May 12, 1936. M. FRÄNKL 2,040,651

ORE SMELTING AND REDUCTION PROCESS

Filed July 19, 1935 2 Sheets-Sheet 1

Fig. 1.

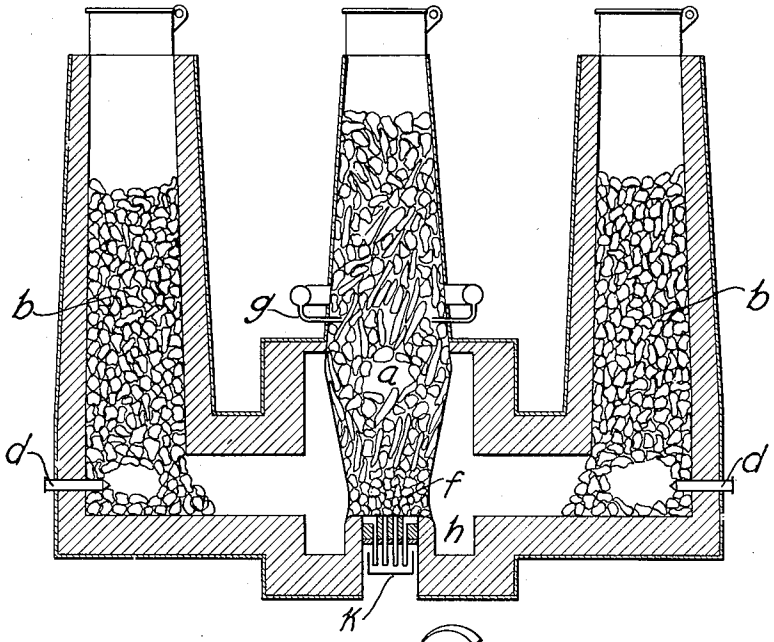
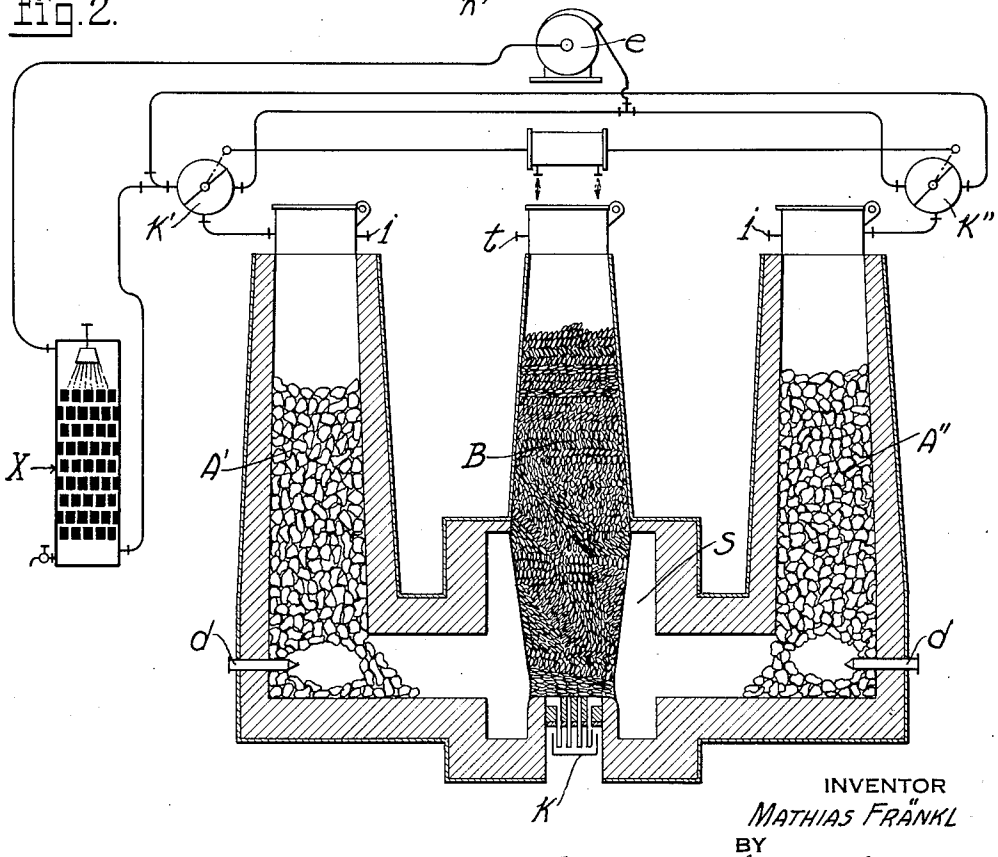


Fig. 2.



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Fig. 3.

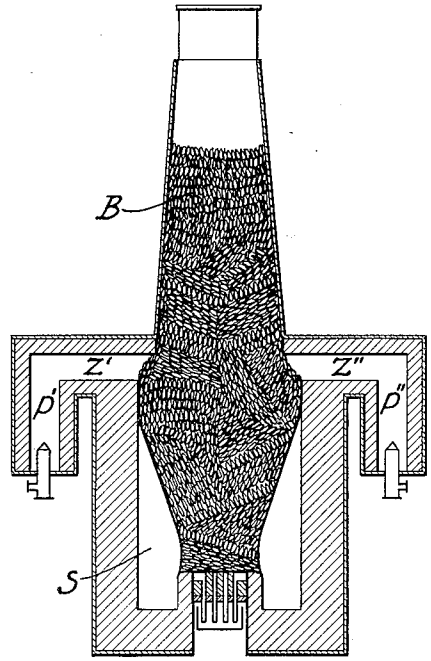
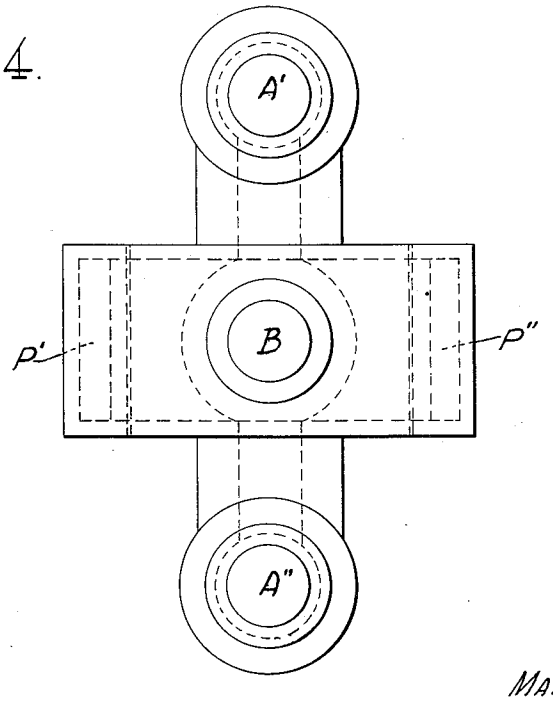


Fig. 4.



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UNITED STATES PATENT OFFICE

2,040,651

ORE SMELTING AND REDUCTION PROCESS

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Application July 19, 1935, Serial No. 32,355
In Germany February 4, 1931

19 Claims. (Cl. 75—92)

The invention relates to a smelting process for the treatment of ores, metals and minerals, as well as to the reduction of ores and to the preparation of compounds of metallic elements. It particularly relates to a process for the manufacture or smelting of steel and includes correlated improvements and discoveries whereby and wherewith such process may be enhanced.

The smelting of steel, for instance steel scrap, is very much hampered by the fact that, with the exception of carbon, no furnace lining will withstand the high temperature and the wear by slag. Further, the use of carbon for the furnace lining is restricted inasmuch as neither oxygen, nor carbon dioxide should contact with it, as these gases rapidly oxidize the lining and destroy it. The carbon lining must also be protected from wear as the charge slides down, as it has very little resistance to mechanical stress.

On the other hand, the consumption of fuel is raised to about treble the amount if coal (or coke) be burned to CO only in order to save the carbon furnace lining from burning.

It is an object of the invention to provide a process in which carbon may be utilized as a furnace lining without danger from mechanical wear, in which a fuel may be burned to carbon dioxide with consequent economy, and in which absorption of carbon by the steel or iron charge may be avoided.

Another object of the invention is to provide a process for smelting and preparation of compounds of metallic elements, wherein the normal gas flow is supplemented or intensified by an augmented gas circulation.

A further object of the invention is to provide a process in which the yield is increased through augmented gas circulation and combustion of carbon with highly concentrated oxygen.

A still further object of the invention is to provide a process in which the gas flow through the smelting space is increased by a regenerative cyclic process without a lessening of the quantity of useful heat in the region requiring high temperature.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others thereof, which will be exemplified in the process hereinafter disclosed, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 illustrates an apparatus in which the process of the invention may be practiced, utilizing a carbon furnace lining and regenerators;

Fig. 2 shows schematically a somewhat modified form of the apparatus of Fig. 1, in which an augmented gas circulation by means of a regenerative cycle is provided;

Fig. 3 depicts schematically a preferred plant arrangement for a treatment of ores in which the mass above the smelting zone is heated only to such a degree that sintering does not take place;

Fig. 4 is a plan view of the plant shown in Fig. 3.

The practice of the invention accordingly involves first, establishing the conditions for carrying out the smelting operation and for the use in the smelting space of a furnace lining, which will not be destroyed by the very high temperature or the slag while permitting, as near as possible, complete combustion of the fuel to CO_2 and H_2O; and second, the output is raised by causing an artificial gas circulation and combustion of carbon with highly concentrated oxygen without exceeding the temperature admissible in the smelting space.

For working the process the stack *a* (Fig. 1) for the charge is connected with two to four fuel stacks *b* which are charged with coke or coal. Through nozzles *d* more or less pure oxygen together with, or without crushed coal, is blown into the stacks *b*.

The fuel then burns only to CO and H_2 as at temperatures above 2000° C. carbon dioxide and steam cannot exist in the presence of carbon. The combustion gases consisting of CO and H_2 flow around the column formed by the charge in the smelting space of the furnace and cause melting along the vertical surface thereof. When it melts to such an extent that it will no longer withstand the weight of the charge, it crumples down and the melting process is repeated.

In order to secure the proper formation of an unsupported column of the charge below the charging stack, that is, in the widened smelting space thereof, it is necessary to operate in such a manner that the charge will be sintered or welded together to such an extent at the lower end of the stack *a* that the column charge on its descent into the widened smelting space will hold together.

The sintering or welding together of the charge whereby a column formation is set up and main-

tained may be initially effected by filling the lower part of the furnace, that is, the smelting space, with coke. The coke is charged so that the entire height of the smelting space is occupied, i. e., the coke filling is continued to the bottom of the shaft. The charge of scrap iron or iron ore is then filled into the shaft and supported by the coke. Air, or air enriched in oxygen, heated to a temperature of about 500° C., may be introduced through the nozzles *d* whereby the coke in the respective regenerator is ignited and burned. The hot combustion gases in conjunction with the circulating gaseous mixture, heated to a high temperature by contact with the fuel filling in the regenerator, is passed to the smelting space, and the coke filling and the charge in the shaft are heated by the hot gases. These gases raise the temperature of the coke, and of the iron in the shaft to a point at which melting takes place. The melted material flows down through the heated coke, and absorbs carbon therefrom. Thereby the coke is gradually consumed and the charge in the shaft gradually descends until the base of the smelting space is reached, and thereafter the reduction or smelting process proceeds in the normal working manner. As the coke gradually recedes, the iron in the shaft passing into the smelting space is welded together, thus forming a supporting column of the type shown in the drawings, of which the outer surface and the base melts and passes to the bottom of the smelting chamber. The consumption of the coke initially charged as a supporting means usually requires about 10 to 12 hours, after which the process proceeds in the manner shown and described. In the continued operation of the process the fuel filling of the regenerator that is burned is either replenished by introduction at the top of the regenerator, or the fuel required for combustion may be blown in through the nozzles *d* in the form of dust, together with the oxygen enriched air.

The accomplishment of this result and also, as far as possible, a complete combustion to CO_2 and H_2O is effected by blowing in secondary air at point *g* (Fig. 1) with which the CO gas passing from the smelting space into the stack *a* is burned to CO_2 either completely or partly, as need be.

The conditions are thus set up under which the smelting space may be fitted with a non-melting carbon lining which will also resist attacks by the slag. This is possible only if the carbon furnace lining is exposed neither to oxidizing influences nor to mechanical wear by the descending charge, since its resistance against mechanical wear is very poor.

There are, however, two more conditions to fulfill to ensure longer life of the furnace lining. First, if in the furnace steel scrap is to be melted, the flowing steel would take up carbon from the carbon furnace lining and thus consume it. This absorption of carbon by the steel must be prevented. Now it is well known that there is a kind of carbon which will not dissolve in steel, namely, graphite. For this reason the receiving trough *h*, in which the liquid steel collects, will be lined with graphite, while for the other parts of the lining in the smelting space and in the combustion zone of the fuel regenerators the considerably cheaper carbon bricks may be used.

The second condition is the provision of an adequate support for the heavy column charge. No fireproof material of any kind is usable for this purpose, as none of them possesses sufficient compression strength at the high temperatures prevailing. For this reason iron is utilized as a support, which by water cooling will be prevented from softening and melting.

The support *k* accordingly consists of a number of thick steel shafts of about 100 mm. diameter, the lower half of which will continually be cooled by water. Into the spaces between the steel shafts graphite is pounded. This water-cooled steel shaft support does not permit the column charge to melt and a so-called "bear" will form, as indicated in the drawings by hatching. At the support there will be a temperature of from 400 to 500° C., at a height of 250 mm. it rises to 800 to 1000° C. and about 500 mm. above the support the smelting temperature will be reached.

A characteristic of this part of the process is the creation of certain conditions for the utilization of an unmeltable and slag-proof, but oxidizable and mechanically easily damaged furnace lining. These conditions consist in measures for keeping all oxidizing combustion gases away from the furnace lining and the avoidance of mechanical wear by not allowing the charge to touch the carbon furnace lining of the smelting space. The process also accomplishes, as far as possible, complete combustion of the carbon to CO_2 and H_2O, in spite of the non-oxidizing condition within the smelting space, by subsidiary combustion in the stack by a secondary supply thereto of air.

The foregoing mode of carrying out the process suffices for the simple smelting of metals and minerals. The pre-heating of the charge to a fusing, or sintering temperature, in the stack requires a fairly large quantity of heat, and this is also the case within the smelting space for effecting the smelting proper. The sensible heat of the hot gases passing from the smelting space, even though it were entirely utilized for pre-heating, would not be sufficient, and therefore this heat must be supplemented by an auxiliary combustion of the CO and H_2 content with secondary air. However, this simple mode of operation has the disadvantage of insufficient flow of gas in the smelting space, because through the separation of a large part of nitrogen from the blast, the temperature thereof is raised very high but the quantity very much lessened.

The condition requisite for a rapid smelting of the column charge is a rapid gas flow, preferably across the vertical column charge.

The second phase of the invention supplements the previously described process by a regenerative cyclic process for increasing gas flow in the smelting space, without lessening the quantity of useful heat in the region of high temperature.

Fig. 2 of the drawings shows schematically a preferred form of a plant for carrying out this process.

It consists of the fuel filled regenerators A' and A'', the stack B which is charged with the charge or the material to be smelted and reduced, and the smelting space S, in which the charge of the stack B is either melted only or, as in the case of the production of carbides or other compounds, also reduced.

Through the nozzles *d* oxygen containing less nitrogen than the air is introduced. A blower *e* serves to cause gas to circulate from one regenerator to the other and across the smelting space in such manner that alternately gas is

withdrawn from one regenerator and blown through the other into the smelting and reducing zone and at the same time removed therefrom by the first regenerator. After a few minutes blowing time the direction of the gas stream is reversed by means of the hinged valves *k'* and *k''* and the gas withdrawn from the regenerator which previously functioned to heat the gas being introduced into the smelting space.

In this manner the gas will be blown constantly across the smelting space (and vertically through the regenerators) a few minutes from left to right and then just as long from right to left.

While streaming from the bottom to the top, the gas gives up its heat to the fuel content of the one regenerator; on the way down it takes it up again. The blower *e* thus withdraws only cooled gas, as the temperature of the coal content of the regenerators drops from bottom to top and remains at the top end at about 20 to 30° C., while at the bottom end it may be as high as the required smelting temperature, that is, from 1300 to 2500° C. Before entering the circulation blower the cycling gas may be cooled, e. g., to the temperature of cooling water, and when this is done the temperature of the regenerators at the top end may be correspondingly raised. This cooling may be effected by conducting gas through a water cooler X, Fig. 2, prior to its passage to the blower *e*.

Since in this process any quantity of gas may be continuously passed through the smelting space, and inasmuch as the combustion of the fuel with almost nitrogen free oxygen gives only a small quantity of highly heated gas, which small quantity of gas at the moment of generation admixes with the three to six times larger quantity of the cycling gas, the temperature of the mixed gas may be kept at any desired height, whereby the heat losses in the smelting space may be reduced to a tolerable extent.

On the way through the smelting space the gas constantly gives up heat to the charge. The entire amount of heat required for the smelting operation is supplied continuously as well as the heat required for preheating the charge in the shaft except for the amount of heat which is furnished by the gas introduced above the smelting zone through the conduits *g*. This is done by burning the coal content of the regenerators to CO by means of oxygen containing only a part of the nitrogen present in the air, which is introduced through nozzles *d*.

Coke is a suitable fuel for the regenerators. However, since coke as a fuel is more expensive than coal, the needed heat is advantageously procured by using mainly burning-dust or fine coal, which is blown in through double nozzles, together with oxygen or separately. A small portion, about 10%, of the coke filling of the regenerators must, however, always be burned also, because otherwise the nozzles would soon be clogged by the dust contained in the cycling gas. The burned portion of the coke filling must then be replaced by putting in a corresponding amount at the top. The regenerators may also be filled with pit-coal or lignite; but in this case the regenerators will have to be hot blasted at the top at a temperature of 300° C., in order to expel the tar by evaporation. The double nozzles are then dispensable.

The portion of gas corresponding to the weight of the coal burned, that is, ⅗ of the total quantity may be withdrawn through the regenerators at point *i* (Fig. 2) or through the valves *k'* and *k''*. This portion of the gas which passes through the regenerators serves to store heat in or to preheat the fuel that is charged to the regenerators and which functions as a heat storing medium.

The other portion of the gas which corresponds to the quantity of oxygen introduced, that is, ⅖, will be withdrawn through the stack which is charged with the charge. The heat content of this quantity of the gas mixture serves to preheat the charge to smelting temperature and this portion of the surplus gas will be withdrawn from the charge stack B at the top, at point *t*. If, in certain cases, the heat content of the ⅖ of the gas from the carbon burned should not suffice to heat the charge to smelting temperature, oxygen is used for combustion which contains correspondingly more nitrogen so that more gas and consequently more heat may be passed through the charge stack.

If additional heat should be needed in the charge stack, preheating the charge to smelting temperature may be effected by means of an oxidizing gas (CO_2) as in the case of smelting steel scrap, which was described in the first part of the description and shown in Fig. 1. The gas which is generated when carbon is burned to CO and part of which is to be withdrawn through the charge stack, is burned in the charge stack to CO_2, if need be with air, and with the heat thereby generated the scrap steel is preheated to a temperature close to smelting temperature. Thus Fig. 2 shows only a regenerative cycling process which supplements the process shown in Fig. 1.

In a large number of metallurgical processes of the high temperature class, however, (ore smelting) and also in the production of compounds of metallic elements (carbides) or of ferro-alloys (ferro-silicon) only a small part of the total amount of heat required is utilized for preheating the charge to reducing temperature; a much larger part is used to attain a temperature which lies above the smelting point of raw iron and slag, that is, about 1300° C. In the production of carbides and ferro-silicon, the limit lies higher still, that is, at 1600 to 2000° C.

If this heat is to be produced by combustion (instead of electro heat), then only that part is utilizable for this purpose which is generated above that temperature, because the heat contained in the flue gas and which is below the reducing and smelting temperature, is lost for the reducing and smelting process.

By burning one kg. carbon to CO only 2430 cal. of heat are liberated. The combustion with air, theoretically, gives a temperature of 1650° C., which is raised to about 2450° if the air supplied is heated to 800° C. Hence the utilizable quantity of heat in the smelting zone of the furnace is 1650—1300=350:1650, or 2450—1300=1150:2450, that is, about one fifth to one half of the heating value of the carbon. To gain more than one fifth the quantity of utilizable heat, the excess above one fifth must be supplied at the cost of air heating.

If, in comparison, nitrogen-free oxygen is used for the combustion, a theoretical combustion temperature is generated of about 8000° C., and the relation of useful heat to waste heat will be 8000—1300=6700:8000, that is, about four fifths.

In certain cases, for instance in ore smelting, contrary to scrap steel smelting, it is not permissible to introduce the entire amount of gas required

for preheating at the high smelting temperature, because by doing so the charge would sinter in the stack and thus become impenetrable to the gas. In such cases, according to the invention, gas is introduced above the smelting zone, which is heated only to such a degree that sintering in the stack cannot occur. Fig. 3 shows, schematically, a preferred form of a plant required for this part of the process.

The additional arrangement comprises two chambers p' and p'' by means of which part of the gas withdrawn from the regenerators at points k' and k'', and from the charge stack at point t, as in Fig. 2, by a cyclic course is passed back into the stack. The gas in these chambers is heated to about 1000° C. by means of an oxygen or air-carbon flame and reintroduced above the smelting zone at points z' and z'' into the charge stack. This gas heated in the chambers p' and p'' mixes with the hotter gas coming from the smelting space and causes the temperature to fall to about 1100° C.

If the ore together with the limestone flux is finely ground and briquetted and thus suitably prepared for thorough indirect reduction, the amount of heat required in the smelting space is limited to that necessary for smelting the charge; for compensating for the heat losses in the smelting space and in the lower part of the furnace where the combustion takes place, and finally, for the residual reduction of the ore where reduction in the stack is not quite complete. Accordingly about 500 to 600 kg. coke and coal dust will be required per ton of iron output, in addition to the burning-dust required by the chambers p' and p'' for the heating and reducing of about 300 to 400 kg. of ore briquettes.

The total required amount of from 800 to 1000 kg. of fuel of 7000 cal. heating value per kg. may thus be composed of from two fifths to four fifths cheap coal dust and from three fifth to one fifth coke, depending upon whether the main firing is effected only with coke, or with coke to which culm has been added.

The coal or the coke in this case will not contact with the iron produced and the iron consequently cannot absorb any carbon. It is thus possible to produce steel directly from ore, and at less cost than raw, i. e., pig iron. If desired, carbon and silicon-bearing material may be charged into the ore stack in the process described.

In Fig. 4 there is presented a plan view of the apparatus depicted in Fig. 3, which is a preferred arrangement of a plant for the treatment of ores. In this arrangement there is in combination a shaft or stack B into which the ore, and if desired other materials undergoing treatment are charged. This shaft or stack is in communication with regenerators A' and A'' which are filled with a heat storing medium, for example, a fuel. As an auxiliary heating means there are provided the channels p' and p'' through which highly heated gases are conducted to the shaft.

The advantageous features of the invention may be thus summarized:

1. The operation of a smelting furnace as hereinbefore described is supplemented by a regenerative cyclic process;

2. A quantity of gas is blown across alternately from left to right and in the reverse direction through a smelting and high temperature zone situated between two regenerators which are filled with a fuel used as a heat storing material, whereby the sensible heat of these gases is alternately taken up by the fuel filling of one of the two regenerators and, at the same time, given up by the other to the circulating gas, so that the blower may be operated within the limits of admissible temperature, and in order to increase gas flow in the smelting space;

3. The high combustion temperature obtained when operating with highly concentrated oxygen is lowered by a circulating gas to an admissible degree, without lowering the total heat in the high temperature zone below that of operation at maximum temperature

4. That by burning the fuel content of the heat storing regenerator in the high temperature zone and renewing the fuel filling at the upper and colder end of the regenerator, the requisite continuous renewal of the heat storing material (regenerator contents) is effected while avoiding clogging by the dust contained in the circulating gas or by slagging.

5. The gas generated by combustion in the high temperature zone, if need be, is preferably withdrawn through the regenerators, while the preheating of the charge of the middle stack is effected by supplementary heating at a lower heating gas temperature, in order to prevent sintering of the charge above the smelting space, proper, that is, in the stack, which sintering might have a detrimental effect on the regular working of furnace

6. The transmission of heat in the high temperature zone is effected by a cross current, while in the preheating and reducing stack it is effected by a counter current flow in a direction opposite to the direction of movement of the charge

7. Only a small amount of the expensive fuel used as filling material for the regenerators need be burned to prevent clogging, and the requisite heat, in the main, is generated by blowing coal dust or small coal into the zone of combustion.

This application is in part a continuation of my copending application Serial No. 568,710, filed October 14, 1931.

Since certain changes may be made in carrying out the above process without departing from the scope of the invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. A process for the operation of shaft smelting furnaces containing a charge of material which comprises introducing a reducing heating gas into the smelting zone, and effecting a sintering of the charged material above the smelting zone by introducing thereinto a less highly heated gas whereby a self-supporting cohesive charge is formed.

2. A process for the operation of shaft smelting furnaces containing a charge of material which comprises producing a gas containing a considerable amount of carbon monoxide and hydrogen by combustion of fuel with an oxygen containing gas at a plurality of places outside the furnace, introducing said carbon monoxide and hydrogen into the smelting zone of the furnace, and effecting a sintering of the charged material above the smelting zone by introducing thereinto a less highly heated gas whereby a self-supporting cohesive charge is formed.

3. A process for the operation of shaft smelting furnaces containing a charge of material which comprises producing a gas containing a considerable amount of carbon monoxide and hydrogen by combustion of fuel with an oxygen containing gas at a plurality of places outside the furnace, introducing said carbon monoxide and hydrogen into the smelting zone of the furnace, effecting a sintering of the charged material above the smelting zone by introducing thereinto a less highly heated gas, whereby a self-supporting cohesive charge is formed, and increasing the heated gas flow through the smelting zone of the furnace by means of forced circulation of the heating gas.

4. A process for the operation of shaft smelting furnaces containing a charge of material which comprises producing a gas containing a considerable amount of carbon monoxide and hydrogen by combustion of fuel with an oxygen containing gas at a plurality of places outside the furnace, introducing said carbon monoxide and hydrogen into the smelting zone of the furnace, effecting a sintering of the charged material above the smelting zone by introducing thereinto a less highly heated gas whereby a self-supporting cohesive charge is formed and conducting a gas in a cyclic course with alternating reversal of direction through a regenerator filled with fuel in which heat has been stored, then through the high temperature smelting zone, and then withdrawing said gas from the smelting zone and through another regenerator filled with fuel, whereby heat is stored therein.

5. A process for the operation of shaft smelting furnaces containing a charge of material which comprises introducing a heating gas containing hot combustion gases into the smelting zone, effecting a sintering of the charged material above the smelting zone by introducing thereinto a less highly heated gas, whereby a self-supporting cohesive charge is formed, and admixing a less highly heated circulating gas with the hot combustion gases, thereby increasing the quantity and decreasing the temperature of the heating gas within the furnace.

6. A process for the operation of shaft smelting furnaces containing a charge of material which comprises lining said furnace with a non-meltable, slag-proof material containing a considerable amount of carbon, introducing a heating gas into the smelting zone, and effecting a sintering of the charged material above the smelting zone by a less highly heated gas introduced thereinto, whereby a self-supporting cohesive charge is formed.

7. A process for the operation of shaft smelting furnaces containing a charge of material which comprises lining said furnace with carbon, introducing a heating gas containing a considerable amount of carbon monoxide and hydrogen produced by burning a fuel with an oxygen containing gas of high oxygen content at a plurality of places outside of the furnace into the smelting zone, effecting a sintering of the charged material by a less highly heated gas introduced thereinto thus forming a cohesive charge which does not rest on the carbon furnace lining, thereby avoiding damage to said furnace lining by oxidizing gases and by mechanical wear during the descent of the charge.

8. In a process for the operation of smelting furnaces containing a charge of material and being in communication with heat-storing regenerators, the improvement which consists in burning a portion of the heat storing fuel filling of the regenerators whereby the high temperature for the smelting zone is attainable, and introducing at the upper and cooler end of the regenerators fuel filling material in quantity corresponding to that burned, whereby a continuous and periodic renewal of heat storing material is attained and clogging by dust and slagging obviated, and conducting the gases produced by burning a portion of the fuel filling in one regenerator through the smelting zone and then through another regenerator.

9. In a process for the operation of smelting furnaces containing a charge of material and being in communication with regenerators, the improvement which consists in drawing heated gases formed by combustion of fuel through a smelting zone and then through a regenerator, and preheating the charged material above the smelting zone by a less highly heated gas mixture containing a part of the combustion gases, whereby sintering of the charge prior to its entry into the smelting zone is avoided.

10. In a process for the operation of smelting furnaces containing a charge of material and being in communication with fuel filled heat-storing regenerators, the improvement which consists in occasioning a burning alternately and periodically of the fuel filling in a regenerator by means of an oxygen containing blast in an amount sufficient only to obviate clogging and producing the principal amount of heat required for treating the charge of material by combusting finely divided coal by blowing the same into the combustion space.

11. In a process for the operation of a smelting furnace containing a charge of material, the improvement which consists in introducing the charge of material upon a support, heating said charge to melting temperature and cooling said support, whereby there is effected the formation of a "bear" at the base of the charged material, said heating being accomplished by burning a portion of a fuel filling in a regenerator with conductance of the gases so produced in said regenerator through a smelting zone of the furnace and then through another regenerator.

12. In a process for the operation of a smelting furnace containing a charge of material, the improvement which consists in introducing the charge of material upon a support consisting preponderatingly of iron, heating said charge to smelting temperature and cooling the iron support by means of water, whereby there is effected the formation of a "bear" at the base of the charged material, said heating being accomplished by burning a portion of a fuel filling in a regenerator with conductance of the gases so produced in said regenerator through a smelting zone of the furnace and then through another regenerator.

13. In a process for the operation of a shaft smelting furnace containing a charge of material, the improvement which consists in producing a gas containing a considerable amount of carbon monoxide and hydrogen by burning coal with an oxygen containing gas having a percentage of oxygen greater than that contained in air outside the smelting zone, introducing said gas into the smelting zone whereby a reducing atmosphere is produced and effecting a preheating of the charge by a further combustion of the gas containing carbon monoxide and hydrogen with secondary air to form carbon dioxide and water.

14. In a process for the operation of a smelting furnace containing a charge of material and in combination with fuel-filled heat-storing regenerators, the improvement which consists in heating the charge of material in the smelting zone by a cross current of circulating gas streaming from a regenerator through the smelting zone to another regenerator, and preheating the material in the stack by a non-cyclic current passing in a direction opposite to the movement of the charge.

15. In a process for the operation of smelting furnaces containing a charge of material and being in communication with fuel filled heat storing regenerators, the improvement which consists in heating a gas by contact with heated fuel filling in a regenerator, burning a portion of the contained fuel filling, conducting hot gases so produced through the smelting zone whereby a high temperature for the smelting zone is obtainable, and conducting hot gases from the smelting zone through another fuel filled regenerator whereby heat is stored therein and the fuel filling preheated.

16. In a process for the operation of smelting furnaces containing a charge of material and being in communication with coke filled heat storing regenerators, the improvement which consists in heating a gas by contact with heated coke in a regenerator, burning a portion of the contained coke, conducting hot gases so produced through a smelting zone whereby a high temperature for the smelting zone is obtainable, conducting hot gases from the smelting zone through another coke filled regenerator whereby heat is stored therein and the coke filling preheated, and alternately and periodically reversing the flow of gases through the regenerators.

17. A process for the operation of smelting furnaces containing a charge of material which comprises producing a highly heated gas containing a considerable amount of carbon monoxide and hydrogen outside of the furnace, introducing said gas into the smelting zone and effecting a circulation thereof by withdrawing, under suction generated by a blower, hot gases through a fuel filled regenerator communicating with the smelting zone whereby the fuel filling is preheated, and then introducing withdrawn gas under blast from said blower into a second regenerator also communicating with the smelting zone and containing highly heated fuel material, burning a portion of the fuel filling and conducting hot gases so obtained together with highly heated circulating gases into the smelting zone, whereby heating of the charged material in the smelting zone is effected, and alternately and periodically reversing the gas flow through the smelting zone and the regenerators.

18. In a process for the operation of a smelting furnace containing a charge of material, the step which consists in heating the charge of material to smelting temperature by burning a portion of a fuel filling in a regenerator with conductance of the gases so produced in said regenerator through a smelting zone of the furnace, and then through another fuel filled regenerator.

19. In a process for the operation of smelting furnaces containing a charge of material and being in communication with fuel filled heat storing regenerators, the step which consists in heating a gas by contact with heated fuel filling in a first regenerator, introducing the highly heated gas so produced into the smelting zone, thereby heating the charge of material, conducting hot gas from the smelting zone through a second fuel filled regenerator whereby heat is stored therein and the fuel filling preheated, and alternately and periodically reversing the gas flow through the smelting zone in the regenerators.

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