OPERATING SMELTING FURNACE

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Fig. 1.

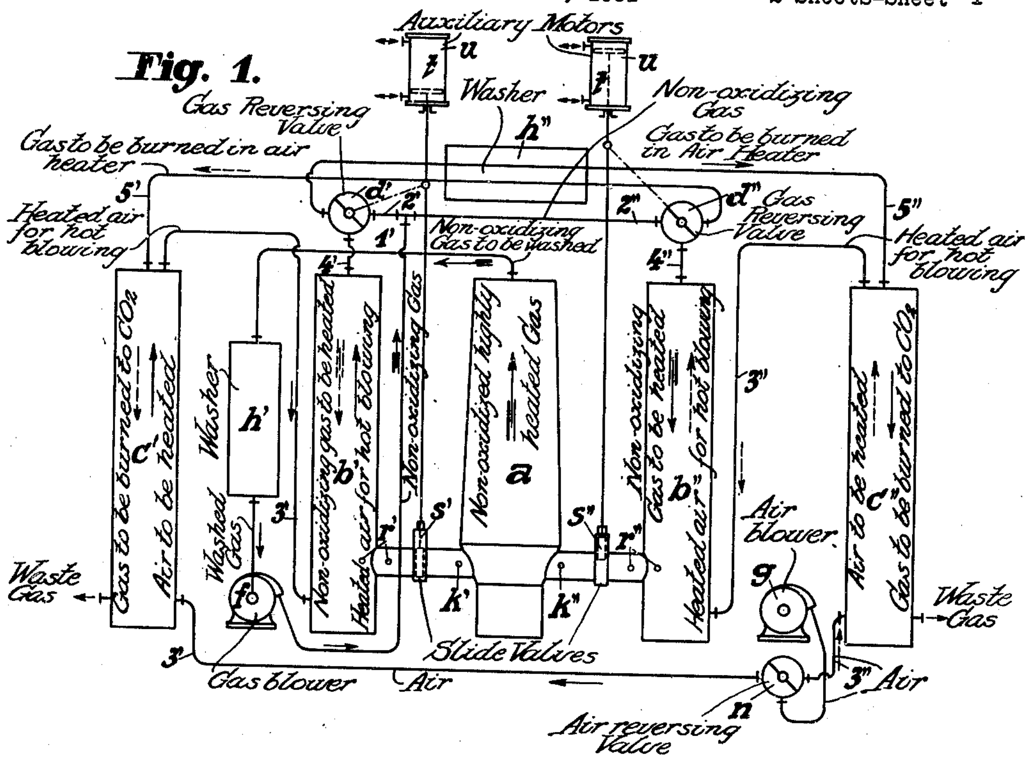

Fig. 2.

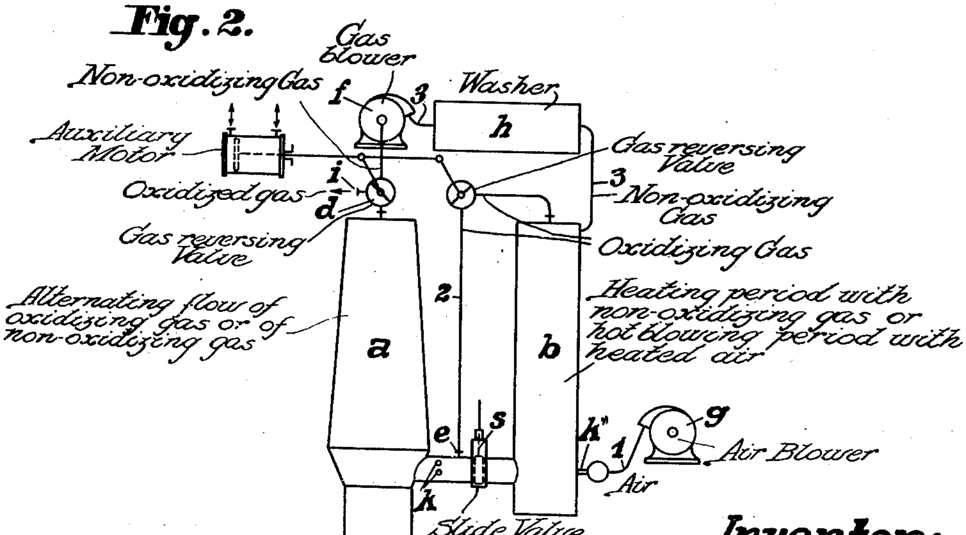

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Fig. 3.

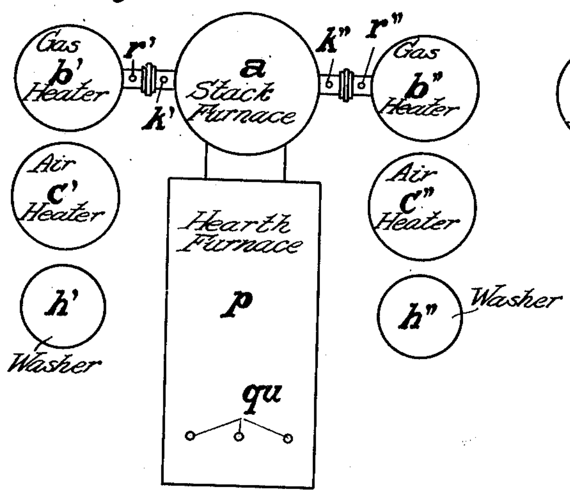


Fig. 4.

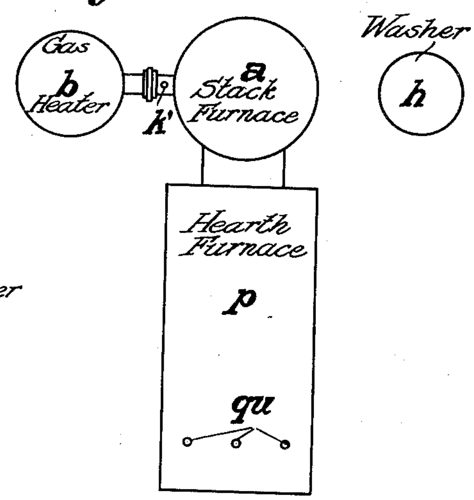


Fig. 5.

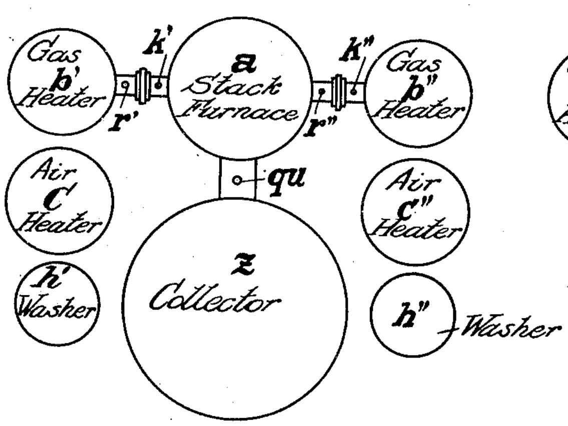
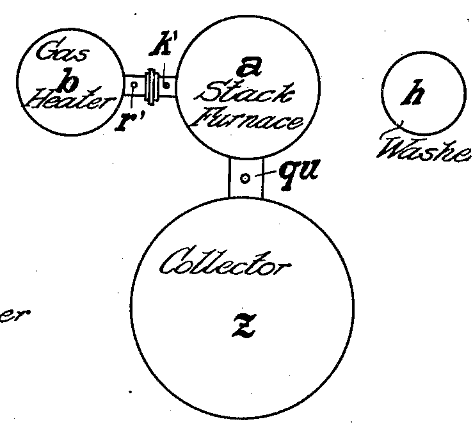


Fig. 6.



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OPERATING SMELTING FURNACES

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16 Claims. (Cl. 75—17)

The smelting of scrap steel, spongy iron, a copper ore, or similar materials that are fusible only at a high temperature, is carried out more advantageously when the combustion temperature due to the firing is as high as possible and the amount of oxidizing gas formed during the combustion is as low as possible. The formation of carbon dioxide is therefore to be avoided so that the coal or coke may be burnt to carbon monoxide only. This however leads to the consumption of large quantities of fuel, as when carbon monoxide is produced only 2450 cal. per kg. of consumed carbon will be liberated, as against 8080 cal. if it is burnt to carbon dioxide.

The object of the invention is to provide a circulatory process for the operation of smelting furnaces using reducing gas (or, an alternation of reducing gas and of oxidizing gas) in order that the coal may be wholly burnt to CO_2.

According to the invention the gas in a stack furnace passes from the bottom to the top of the stack thereby giving up its heat to the contents of the furnace that are to be melted, and is drawn off from the furnace by a blower and forced through a gas heater filled with highly heated coke or other fuel in the direction in which the fuel moves, that is from top to bottom, into the stack again.

In the gas heater, the circulating gas takes up the sensible heat of the fuel and transfers it to the contents of the furnace. After a few minutes of circulation the heat withdrawn from the gas heater is replaced by an alternate hot blasting with air, as in the known watergas process. In consequence the circulating gas and the combustion gas of the hot blasting period stream alternately through the gas heater, the former with, and the latter against the direction of flow of the fuel which is from top to bottom.

The circulating gas consists mainly of CO and therefore has no oxidizing effect on the charge, a circumstance which is of the greatest importance particularly in the case of sponge iron or scrap steel.

Hot blasting the coal within the gas heater but imperfectly burns the carbon to CO_2. The flue gas therefore may still contain up to 20% CO and consequently possesses a certain calorific value. This flue gas may be utilized either to pre-heat, to about 800° C. the air for hot blasting the gas heater (Case I) or, the flue gas may be sent into the smelting furnace there to be burnt—in order to attain a sufficiently high temperature—with nitrogen-free oxygen (Case II). In the first case the flue gas is sent into an air heater there to be burnt entirely to CO_2, whereby complete combustion of the coke or coal is attained, without the charge contacting with the carbon dioxide so produced; in the second case the smelting takes place in a reducing, and an oxidizing atmosphere alternately, inasmuch as initially only CO is passed through the stack furnace and, then, the flue gas to be burnt to CO_2 mixed with oxygen.

When hot blasting with a blast temperature of 800° C. a combustion temperature of about 2000° C. may be reached within the gas heater. However the temperature of the circulating gas can not be raised higher than about 1800° C., since the transfer of heat from the glowing fuel to the gas that is circulating within the smelting furnace and the gas heater requires a certain difference of temperature. A temperature of 1800° C. is in many cases (e. g. scrap steel, sponge iron) not sufficient, because only that part of the heat content is utilizable for the smelting process proper, that lies above 1600° C. For this reason, according to the invention, nitrogen-free oxygen is added to the circulating gas after it is heated to 1800° C. as it passes from the gas heater to the smelting furnace, whereby a partial combustion to CO_2 is effected, or, after hot blasting with hot air, blasting is continued for a short time with oxygen, or, the oxygen is added to the heated hot blast air. If part of the CO is burnt to CO_2, as in the first instance, it suffices to burn about 5% of the circulating gas with the oxygen as then the admixture of CO_2 will not exceed this amount.

Very small quantities of CO_2 are quite innocuous to the smelting process. If, however, in very particular cases no CO_2 at all may be present, the oxygen will not be added to the circulating gas, but after hot blasting, that is during the circulation period, it is blasted into the coal charge of the gas heater or, in addition to oxygen a little coal dust is blasted into the circulating gas between the gas heater and the smelting furnace.

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 shows schematically a preferred form of plant suitable for carrying out the process in the case hereinbefore designated as Case I.

Fig. 2 represents a plant assembly in which the flue gas containing CO is introduced into the smelting furnace wherein it is burned, that is, Case II above mentioned.

Fig. 3 illustrates a plant in which a hearth furnace is combined with the stack furnace wherein the hot blasting air is heated by the calorific value of the flue gas produced during the hot blasting period, that is, Case I.

Fig. 4 depicts a plant assembly as in Fig. 3, in which the flue gas of the hot blasting period is introduced into the smelting furnace to be burned with oxygen, that is, Case II.

Fig. 5 illustrates a combination of a collector with the stack furnace, in the operation of which the molten material flowing from the stack furnace to the collector is fined or refined, by means of an oxidizing gas, as a jet of oxygen continually contacting therewith; the flue gas arising during hot blasting of gas heaters being utilized to heat air heaters, as Case I, and

Fig. 6 is an arrangement similar to that shown in Fig. 5, but in which the flue gas arising during hot blasting is led directly into the smelting furnace.

The plant shown in Fig. 1 comprises in combination a smelting furnace *a*, the gas heaters *b'* and *b''*, the air heaters *c'* and *c''*, the cross over valves *d'* and *d''*, the circulating-gas blower *f*, the air blower *g*, the gas washers *h'* and *h''*, in the connecting conduits between the gas heaters and the smelting furnace, oxygen nozzles *k'* and *k''*, coal dust nozzles *r'* and *r''*, and slide stop valves *s'* and *s''*.

At the start gas heaters *b'* and *b''*, and air heaters *c'* and *c''* are hot blasted by means of the air blower *g*, the air heaters being heated by burning the flue gas containing CO produced in the gas heaters. The temperature which the coal charge of the gas heaters thereby attains is about 2000° C. at the bottom and decreases towards the top end to 100° C. so that the flue gas leaves the gas heaters in a cooled state, passes through the gas washer *h''*, from which it is led into the air heaters and there burned completely. The smelting furnace is charged with the material to be smelted.

The cross over valve *d'* is now set for circulation, which automatically opens slide valve *s'*; gas blower *f* is then put in operation which, through piping 1' and gas washer *h'* draws the gas from the smelting furnace and, through piping 2', forces it from above into the gas heater *b'* where, coming in contact with the coke charge at white heat, it is heated to about 1800° C. At this temperature it leaves the gas heater at the lower end and is then caused to pass through the connecting duct into the smelting furnace. On the way, during the circulation period, it is further heated to about 2200° C. if necessary, by partial combustion with nitrogen-free oxygen (nozzles *k'*), or by the introduction of oxygen or air enriched by oxygen into the firing zone of the gas heaters (nozzles *k''* Fig. 2). In order to prevent the generation of CO_2, coal dust may be blasted into the gas through nozzles *r'* and *r''*, in addition to the oxygen.

In the smelting furnace *a* the circulating gas gives up all its heat to the charge, save a residue of about 200° C. The blower *f* withdraws it from the top end of the furnace through piping 1' and gas washer *h'*, and through piping 2' forces it from above into the gas heater *b'*, thus completing the circuit. After one or two minutes operation the cross over valve *d'* is set for hot blasting and by blower *g* air is blasted into the gas heater *b'* through piping 3' and the air heater *c'* at a temperature of about 800° C., where, by partial combustion of coke it effects the hot blasting of the coke charge of the gas heater. The gas leaves at the top at a temperature of about 150–250° C. and contains about 20% of CO. The blower *g* causes it to flow through piping 4', the gas washer *h''* and, finally, through piping 5'' from above into the air heater *c''*. There air is added to it, and the mixture is ignited and completely burnt in order to heat the fire proof stones filling the air heater.

While gas heater *b'* is being hot blasted and the flue gas generated thereby is heating the air heater *c''*, gas circulates between the smelting furnace *a* and gas heater *b''*, and vice versa, so that in spite of alternate hot blasting, smelting may continue uninterruptedly. During the time a gas heater is hot blasted, its connection with the smelting furnace is barred by a water cooled slide valve *s'* or *s''*. These slide valves are made to open and close simultaneously with the cross over valves *d'* and *d''* by means of pistons *u* which are caused by compressed air, to slide forward and backward within cylinders *t*.

A cross over valve *n* is provided by means of which the blower *g* may send the hot blasting air into the gas heaters *c'* and *c''* alternately.

According to Fig. 2 (Case II) the flue gas containing CO instead of being burnt in the air heater is, alternately with the circulatory operation, introduced into the smelting furnace wherein it is burnt with oxygen which previously has been partially or wholly freed of nitrogen. There are then no air heaters and the combutible flue gas of the hot blasting period is near point *e* introduced into the lower end of the smelting furnace through piping 2, there to be burnt with oxygen. During this period it escapes from the smelting furnace near point *i*, whereas in the next period CO circulates through the smelting furnace and the gas heater. The details of the operation in this case are as follows. Gas heater *b* is hot blasted either with ordinary air, or air enriched with oxygen which blower *g* sends through piping 1. During this period slide valve *s* in the duct connecting the gas heater and smelting furnace is closed.

The flue gas at a temperature of about 250° C. and containing about 20% CO is sent through piping 2 into the smelting furnace *a*, entering it near point *e*; is burnt completely, with oxygen (nozzles *k*) within the connecting duct, and finally allowed to escape at the top through cross over valve *d* near point *i*. Value *d* is then set for circulation and slide valve *s* opened. Blower *f* will now cause the gas contents of smelting furnace *a* and gas heater *b* to circulate by drawing the gas from the top of the smelting furnace, and forcing it through piping 3, and gas washer *h*, from above, into the previously hot blasted gas heater *b*, whence it passes, heated to about 1800° C., into the smelting furnace, from the top of which it is again drawn. While in the smelting furnace or the connecting duct a little oxygen may be added to the gas and a small part of the mixture burnt to CO_2, in order to attain a higher temperature or, during the circulation, oxygen may be blasted into the gas heater. If however the hot blasting is effected with air enriched by oxygen there is no need to supply further oxygen. This mode of working requires only one regenerator, or gas heater because hot blasting may continue during smelting also.

Smelting operations are effected most economically by the use of stack furnaces, because the gas moves in an opposite direction to the charge and consequently gives up most of its heat thereto. In hearth furnaces this is possible only to quite an insufficient degree. On the other hand the hearth furnace offers the advantage that the charge, while in the molten state may, if additional heat be supplied, be subjected to further treatment, that is refined and/or alloyed. Where this is desirable, in front of the stack furnace a smelting hearth may be disposed in which the molten iron may be further heated, refined and subjected to further treatment by means of an oxygen-coal dust flame. The flue gas of the coal dust flame gives up its radiating heat to the molten iron in the hearth before it flows into the adjacent stack furnace. If desirable, the flue gas may, by burning with a fresh supply of oxygen plus coal dust, again be highly heated as it passes from the hearth to the stack furnace.

The position of parts necessary in such case is shown schematically in Figs. 3 and 4. It differs from the one shown in Figs. 1 and 2 only by the additional hearth furnace *p* and a further series of oxygen and coal dust nozzles *qu*. In this manner the advantages of the hearth for further treatment of the molten charge may be combined with that of the much more economically conducted smelting by the stack furnace. It is, for instance, possible to charge the hearth with molten pig iron from the blast furnace, and the annexed stack furnace with scrap steel or solid pig iron. Refining in the hearth furnace may be effected also with ore or rolling mill scale; in this case heat is supplied to the hearth mainly by an oxygen-coal dust flame.

In Figs. 5 and 6 a mode of operation in Case I and Case II is schematically indicated which may be adopted where pig iron and scrap cast iron, or a mixture of pig iron and scrap steel, or of scrap steel and scrap cast iron is to be smelted in a stack furnace and thereupon by a refining process converted into a mild steel. The molten iron while flowing into a collector is refined continually by a jet of oxygen, or the carbon dioxide contained in an oxygen-coal dust flame. Since it is known that the added pig iron or scrap cast iron contains carbon, the smelting operation may be so conducted that the necessary refining effect may take place from the start. To this end a second firing is provided inside the smelting furnace, or in the conduit leading to the collector *z*, or within the collector, in the shape of an oxygen-coal dust flame (nozzles *qu*). Within this flame the carbon burns to carbon dioxide which may serve for refining (oxidizing) molten iron as well as for smelting with an oxidizing effect, inasmuch as the flue gas of the coal dust flame is caused to pass through the stack furnace. If necessary, the refining may be effected by a jet of oxygen without added coal dust, or the addition of only a very small amount of coal dust.

The process according to Figs. 3 and 4 represents a combination of the stack furnace operation, the circulatory process operating with reducing effect and the oxidizing oxygen-coal dust firing of the hearth, while the process according to Figs. 5 and 6 is characterized by the combination of continuous refining by means of oxygen with smelting in a stack furnace operated on the circulatory principle.

In accordance with the proportion of pig iron or of scrap cast iron added to the scrap steel, supplemental firing by the oxygen-coal dust flame must be increased or reduced. Beyond this, the desired exact amount of carbon in the steel produced may be ensured by regulating, that is increasing or reducing the amount of coal dust of the oxygen-coal dust flame.

The principal features of the foregoing procedure for the operation of smelting furnaces may be summarized as follows. A non-oxidizing gas is circulated through a gas heater charged with fuel and a smelting furnace, said gas being heated within the gas heater to about 1500° C., and further heated, if necessary, by introducing thereinto nitrogen-free oxygen or air enriched by oxygen during its passage from the heater to the furnace; the heat exchange between the circulating gas and the furnace charge, and between the hot blasting air of the gas heater and the fuel therein, is effected in accordance with the counter-current principle, whereas the heat exchange between the fuel in the gas heater and the circulating gas is effected on the concurrent principle whereby loss of the sensible heat of the fuel gas arising during the hot blasting period is almost entirely avoided and a high temperature of the circulating gas attained for transfer in the smelting furnace; heating the circulating gas by combustion with oxygen or by an oxygen-coal dust flame while the gas passes from the gas heater to the smelting furnace, or by introducing oxygen or air enriched by oxygen into the firing zone of the gas heater; the use of air heaters for heating the air utilized for the hot blasting of the gas heaters and the heating thereof by secondary combustion of the fuel gas arising in the gas heaters during hot blasting; an alternate heating of the smelting furnace first with circulatory operation by means of a highly heated reducing gas and then by combustion of the fuel gas arising during the hot blasting of the gas heaters with oxygen within the furnace; a combination of a coal dust-fired hearth furnace with the stack furnace operating on the circulatory principle wherein the flue gas from the hearth furnace is passed into the stack furnace with a further heating, if required, prior to its entry by means of an oxygen-coal dust flame; a combination of a fining or refining operation with the stack furnace in which flowing molten iron is subjected to an oxygen flame and the hot gas generated during the fining procedure conducted into the stack furnace.

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 or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A process of smelting in a stack furnace charged with material fusible only at a high temperature, which process comprises circulating a current of non-oxidizing gas containing carbon monoxide through the stack furnace and at least one gas heater charged with fuel and introducing oxygen into the circulating current of non-oxidizing gas whereby a portion of the carbon monoxide is burned and additional heat supplied to the furnace.

2. A process of smelting in a stack furnace charged with material fusible only at a high temperature, which process comprises circulating a current of non-oxidizing gas containing carbon monoxide through the stack furnace and at least one gas heater charged with fuel, said gas streaming within the furnace in a direction opposed to the direction of the movement of the charge and introducing oxygen into the circulating current of non-oxidizing gas whereby a portion of the

carbon monoxide is burned and additional heat supplied to the furnace.

3. A process of smelting in a stack furnace charged with material fusible only at a high temperature, which process comprises circulating a current of non-oxidizing gas containing carbon monoxide through the stack furnace and at least one gas heater charged with fuel, said gas streaming within the furnace in a direction opposed to the direction of the movement of the charge and within the gas heater in the same direction as the fuel movement, and further heating said circulating non-oxidizing gas by introducing oxygen thereinto whereby a portion of the carbon monoxide is burned and additional heat supplied to the furnace.

4. A process of smelting in a stack furnace charged with material fusible only at a high temperature, which process comprises circulating a current of non-oxidizing gas containing carbon monoxide through the stack furnace and at least one gas heater charged wth fuel, said gas streaming within the furnace in a direction opposed to the direction of the movement of the charge and within the gas heater in the same direction as the fuel movement, further heating said circulating non-oxidizing gas by introducing oxygen thereinto whereby a portion of the carbon monoxide is burned and additional heat supplied to the furnace and periodically hot blasting said gas heater by means of air.

5. A process of smelting according to claim 4, which includes circulating a non-oxidizing gas containing carbon monoxide alternatingly through the furnace and a first gas heater and through a second previously heated gas heater and the furnace.

6. A process of smelting according to claim 4, which includes alternately circulating the non-oxidizing gas (1) through the furnace and a first gas heater and (2) through the furnace and a second gas heater, and hot blasting the second gas heater during the first phase of circulation and the first gas heater during the second phase of circulation.

7. A process of smelting according to claim 3, which includes introducing oxygen into the current of non-oxidizing gas during the passage of said current from the gas heater to the furnace whereby a portion of the carbon monoxide is burned and additional heat supplied to the furnace.

8. A process of smelting according to claim 3, which includes introducing oxygen into the current of non-oxidizing gas containing carbon monoxide during the passage of said current through the furnace whereby a portion of the carbon monoxide is burned and additional heat supplied to the furnace.

9. A process of smelting according to claim 3, which includes the introduction of oxygen into the firing zone of the gas heater during the period of circulation whereby a portion of the carbon monoxide is burned and additional heat supplied to the furnace.

10. A process of smelting according to claim 4, which includes hot blasting the gas heater by means of air enriched by oxygen.

11. A process of smelting according to claim 4, which includes preheating the air for the hot blasting of the gas heaters within air heaters previously heated by means of a secondary combustion of the flue gas containing carbon monoxide produced during the hot blasting of the gas heaters.

12. A process of smelting according to claim 1, which includes producing molten iron in the stack furnace, refining said molten iron within a coal dust fired smelting hearth annexed to the stack furnace, directing the flue gas produced during the refining in the smelting hearth into the furnace, and further heating said flue gas during its passage to the furnace by means of an oxygen-coal dust flame.

13. A process of smelting in a stack furnace according to claim 1, which includes producing molten iron in said furnace, continuously refining the molten iron as it flows from said furnace into a collector by means of an oxygen flame, and introducing the hot flue gas produced thereby into the stack furnace.

14. A process for smelting in a stack furnace charged with material, fusible only at a high temperature, which comprises circulating a current of non-oxidizing gas through the stack furnace and at least one gas heater in alternation with a current of flue gas containing carbon monoxide produced during a hot blasting of the gas heater, and burning said flue gas in the stack furnace by means of an oxygen-containing gas.

15. A process for smelting in a stack furnace charged with material, fusible only at a high temperature, which comprises circulating a current of non-oxidizing gas through the stack furnace and at least one gas heater in alternation with a current of flue gas containing carbon monoxide produced during a hot blasting of the gas heater, and burning said flue gas in the stack furnace by means of nitrogen-free oxygen.

16. A process of smelting in a stack furnace charged with material fusible only at a high temperature, which comprises circulating a current of non-oxidizing gas containing carbon monoxide through the charged material, preheating said non-oxidizing gas by passage through a heater containing a heat storing fuel mass, periodically storing heat in such mass by hot blowing, and further heating the non-oxidizing gas by introducing thereinto air enriched with oxygen whereby a portion of the carbon monoxide is burned, said introduction being effected subsequent to the non-oxidizing gas passing through the heat storing fuel mass in the heater.

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