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METHOD OF IMPROVING BLAST FURNACE PERFORMANCE USING RAW PETROLEUM COKE

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It is well known to those skilled in the art that the blast furnace, even in its highest development is by no means the even-going, easily-regulated "monster" the casual observer may take it to be. Although furnace operations are under better control now than ever before, such furnaces are still capable of acting in unpredictable ways.

In general and as illustrated on page 62 of Bray's "Ferrous Process Metallurgy," published in 1954 by John Wiley and Sons, Inc., blast furnaces may be considered as having five parts: (1) the bottom, (2) the hearth, (3) the bosh, (4) the stack, and (5) the furnace top.

The construction and operation of such furnaces are described in many standard reference works on the subject such as the aforecited volume by Bray or the Annual Proceedings published by the American Institute of Mining, Metallurgical and Petroleum Engineers on "Blast Furnace, Coke Oven, and Raw Materials," etc.

Raw materials including the burden are charged through the top of the furnace. The burden or ore to be reduced may consist of raw screened and blended ores, prepared sinter, or agglomerated ore concentrates such as pellets. This burden along with limestone and coke constitutes the charge. Such additional materials as open hearth slag, scrap, and roll scale may be added in minor percentages as available.

In a typical furnace operation the coke is consumed or gasified by means of a preheated blast of air which is forced into the furnace under pressure through tuyeres at the top of the hearth. This gasification of carbon supplies the necessary reducing gases and heat to promote the chemical reactions of reduction and also melt the iron and slag formed. The preheated hot blast may range in temperatures from about 1000° F. to over 1800° F. subject to limitations of heating capacity and refractory linings used. In addition the blast may be modified or enriched with oxygen; steam; and gaseous, liquid, or solid fuels. As the coke of successive charges is consumed the furnace is replenished by adding charges to the top and the finished iron (hot metal) and slag are periodically drained or tapped from the hearth. Thus a charge will require about 8–12 hours to smoothly move to the hearth of a furnace where the coke will be consumed and the hot metal and slag removed.

When a furnace fails to operate smoothly it is said to be hanging during periods when the burden fails to move downward in a normal and smooth manner. This hanging is characterized by rapidly increasing blast pressures and lack of movement of the burden in the upper reaches of the stock column. Initially this hanging may be caused by several conditions, either singly or in combination, such as:

(1) Fused slag may resolidify;

(2) Coke and burden fines may plug the void space and cause both arching of the solid material and resistance to flow of the gases;

(3) Redeposited carbon from the reaction

$$2CO \rightarrow CO_2 + C$$

may fill the voids between particles of ore and thus impede counter current flow of gases and materials;

(4) Alkali vapors may condense in the upper part of the stack and cement the solid material into large impervious masses.

As the coke is gasified and the iron and slag is melted below the area in which the hanging occurs, a large void is created especially when the furnace hangs for any appreciable time. When the unsupported burden eventually breaks loose, the furnace is said to slip. This slip is characterized by an explosive release of high temperature gas along with the sudden movement of the burden. The sudden release of the gas causes a sharp increase in top gas temperature and pressure usually causing the bleeders or safety valves to open. The burden dropping into the bosh causes a marked cooling of the area since this burden has been improperly heated due to the poor gas-solid contact during the period of blockage or hanging.

Recurrent slips of this nature lead to deposits along the periphery of the bosh. These scabs or scaffolds further interfere with normal furnace operation by restricting the flow of the gases and also the countercurrent flow of the burden. Thus scaffolds, once formed, cause irregular operation and promote further encrustation on the furnace walls.

As these scaffolds increase the furnace continually hangs and slips and must be operated at greatly reduced blast volumes and production rates. For example, one blast furnace with a 23 ft. diameter hearth and 28,000 cubic feet working volume, but which had a substantial amount of scaffolding, was producing only 150 tons per day of hot metal as compared to normal production of about 900 tons per day. This furnace had an in wall temperature fifteen feet above the bosh of 900–1000° F., which was about 500–600° F. below normal.

Several different approaches to solving, or minimizing or eliminating such adverse phenomena, and for improving furnace performance have been suggested—or tried—with varying degrees of success. For example, in some cases the quantity of blast has been reduced in order to lower its buoyant effect, with the result that the weight of the material above the scaffolding incrustation is sometimes able to break the incrustation. This is referred to as a bosh slip. Sometimes the incrustation can be removed by the use of quartz—SiO_2 addition which acts on the deposits like rock salt on ice. Sometimes extra metallurgical or foundry coke over the amount normally used has been added and found to be helpful. In extreme cases a number of holes may be drilled at various levels of the furnace to blast or dynamite out the incrustation or bridges, etc. An additional complicating factor in blast furnace operation is that the blast furnace operator must think about 8 to 10 hours "ahead" of the furnace because any burden or charge change will require that time to travel through the furnace and reach the hearth where its effect will be mainly manifested.

It has now been found that a very effective, efficient, and economical way to restore a blast furnace to its normal stock movement, temperature profile, and hot metal output basis, after these have been reduced due to such conditions as "scaffolding" or "bridging" or "hanging," etc., is to charge substantial quantities of raw petroleum coke to the slow moving charge already contained in said furnace. Such raw petroleum coke develops very high and intense temperatures upon burning, resulting in temperatures sufficiently high to weaken the scaffolding by softening or increasing the fluidity of the highly viscous slag. Also, because raw petroleum coke has low ash content (typically about 0.3% as compared to 7–14% ash, for normal furnace coke), upon burning, it contributes very little if any to slag build-up as does normal furnace coke upon burning. Further it permits a limestone burden adjustment which forms a more nearly finished slag in the bosh or primary melting zone.

The high temperature at which petroleum coke burns in relation to metallurgical coke is caused by its structure. Micro photographs show petroleum coke to have very few micro pores compared to metallurgical coke. In the combustion process initially carbon dioxide is formed on the outer surface of the coke (heat release of 169,295 B.t.u. per pound mol of carbon) which then is converted to carbon monoxide in the internal coke surface provided by the micropores (heat consumption of 74,195 B.t.u. per pound mol of carbon). It can therefore be readily seen that a coke with limited micro pores such as petroleum coke will produce higher concentrations of carbon dioxide and therefore the heat release is substantially higher resulting in higher combustion temperature.

The process of this invention is illustrated by the following example.

EXAMPLE 1

A blast furnace having a hearth 23 feet in diameter and a working volume of 28,000 cubic feet was "sick" or "cold" for months, had an in-wall temperature fifteen feet above the bosh of 900°–1000° F., and was producing only about 150 tons of hot metal per day. Thirty-two tons of raw petroleum coke, having a volatile content of 12.5% and a particle size of 100% 4 inch mesh and approximately 50% ¼ inch mesh, was charged through the top of said furnace and added to the normal furnace charge already therein. Within 48 hours the in-wall temperatures 15 feet above the bosh had increased by about 100–400° F. to 1000–1300° F., 1100° F. average. After this 48 hours, thirty-two more tons of the same raw petroleum coke were charged into the furnace in the same manner. (The furnace was charged in a conventional manner during the intervening 48 hours with ore, coke and limestone according to a typical blast furnace charging cycle such as suggested on pages 73 and 74 of the volume by Bray.) Within 24 hours the temperature of the furnace 15 feet above the bosh had risen to 1200°–1400° F., 1300° F. average. Five days later 64 tons of the same raw petroleum coke was added to the furnace and within 24 hours the in-wall temperature 15 feet above the bosh averaged about 1500° F. In other words, furnace temperatures were restored to normal; as was also hot metal output.

As is apparent from the foregoing example, the material employed to effect this restoration to normalcy was utilized in the ore reduction process, the blast furnace was operated continuously while the restoration was taking place—and without the employment of extraordinary labor or blasting, or extraneous additives.

The raw petroleum coke employed in this invention is typically of the type produced from a delayed coker system and generally will have a volatile matter content between about 8 and about 15% with about 12 to 14% being typical. It is preferable also that a substantial proportion of the raw petroleum coke employed be not too large nor too fine. Raw petroleum coke particles which are retained on a ⅛ inch screen and which pass through a 5 inch screen are typical of preferred particle sizes, but this should not be interpreted as precluding the use of minor percentages of raw petroleum coke coarser than 5 inches or finer than ⅛ inch. The ash content of the raw petroleum coke is preferably no higher than about one percent.

The invention, although most applicable to blast furnaces, can be applied to any shaft furnace, such as hot blast basic cupolas, in which incrustation or build-up of viscous material along the in-walls is a problem.

Having thus described the nature of my invention, but being limited only by the appended claims with respect to its scope, I claim:

1. A method of assisting in restoring a shaft furnace to normal operating temperature after the temperature of said furnace has been reduced below said normal operating temperature because of scaffolding, which comprises adding to the shaft furnace as extra coke, raw petroleum coke, having a volatile matter content between about 8% and about 15% and an ash content less than about 1%, in an amount sufficient to increase said reduced operating temperature toward said normal operating temperature.

2. A process according to claim **1** wherein over 50% of the raw petroleum coke possesses a particle size larger than one-eighth inch.

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