United States Patent [19]
Ban

[11] **3,849,115**
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[54] SINTERING PROCESS

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[52] **U.S. Cl.** **75/5**
[51] **Int. Cl.** **C21b 1/10,** C22b 1/16
[58] **Field of Search** 75/5

[56] **References Cited**

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[57] **ABSTRACT**

The present invention provides an improved process for sintering particles composed of iron oxide, e.g., iron ore, combustible carbonaceous material, and water with a flux such as limestone optionally present and combining the principles of recyclng gases exiting from the burden adjacent the feed end back through the burden in a region toward the delivery end of a traveling grate as well as taking gases exiting from the burden adjacent the delivery end and passing them again through the burden near the feed end. Recycling of gases in this manner achieves desirable results such as reduction of the volume of gases handled, conditioning of the gases for removal of entrained particulate material by dust removing apparatus, and removal of entrained or volatilized organic as well as inorganic pollutants from the exhaust gas stream before discharge to the atmosphere. The process combines the advantages of both "hot" recycle and "cold" recycle.

8 Claims, 2 Drawing Figures

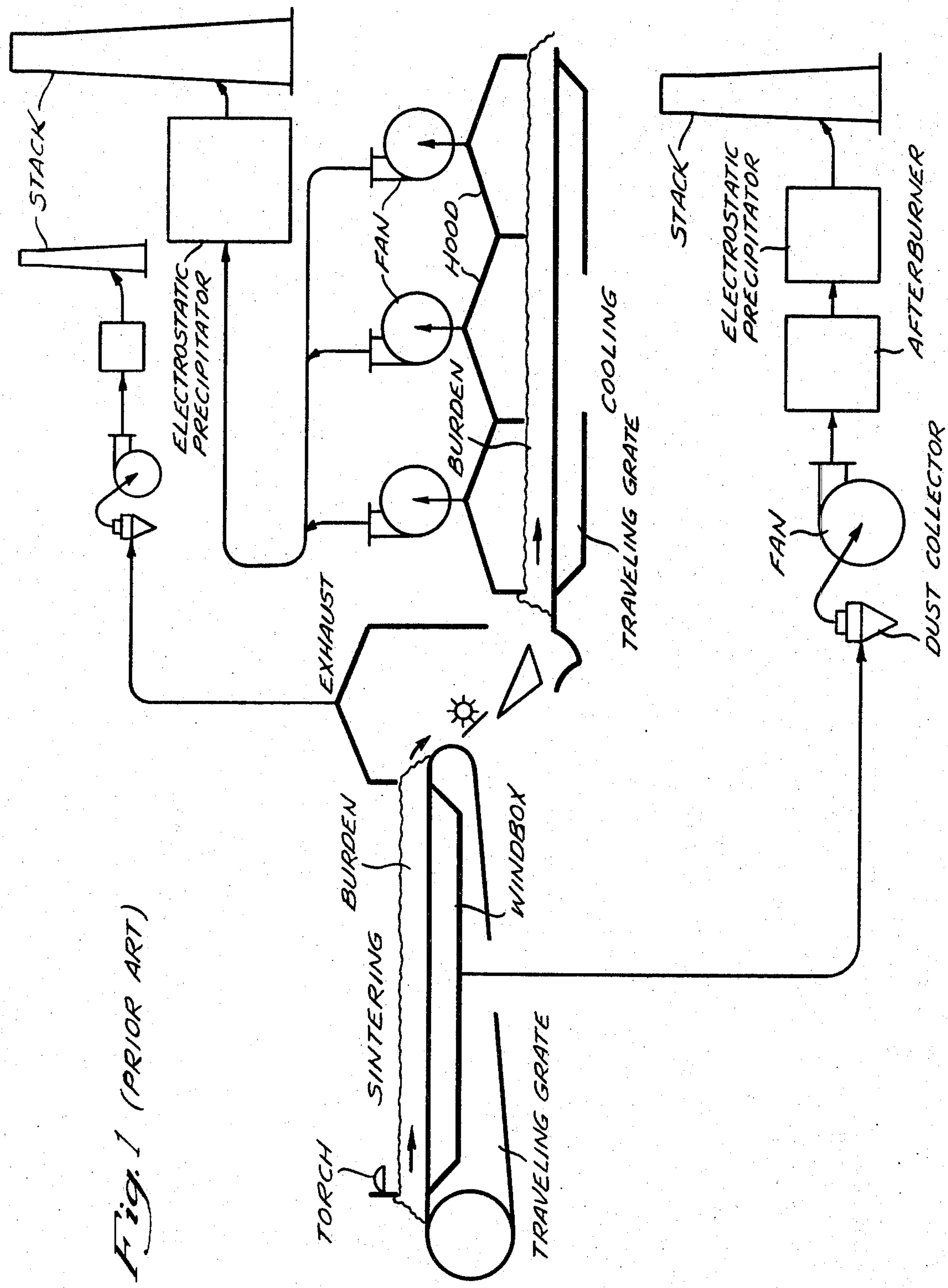

Fig. 1 (PRIOR ART)

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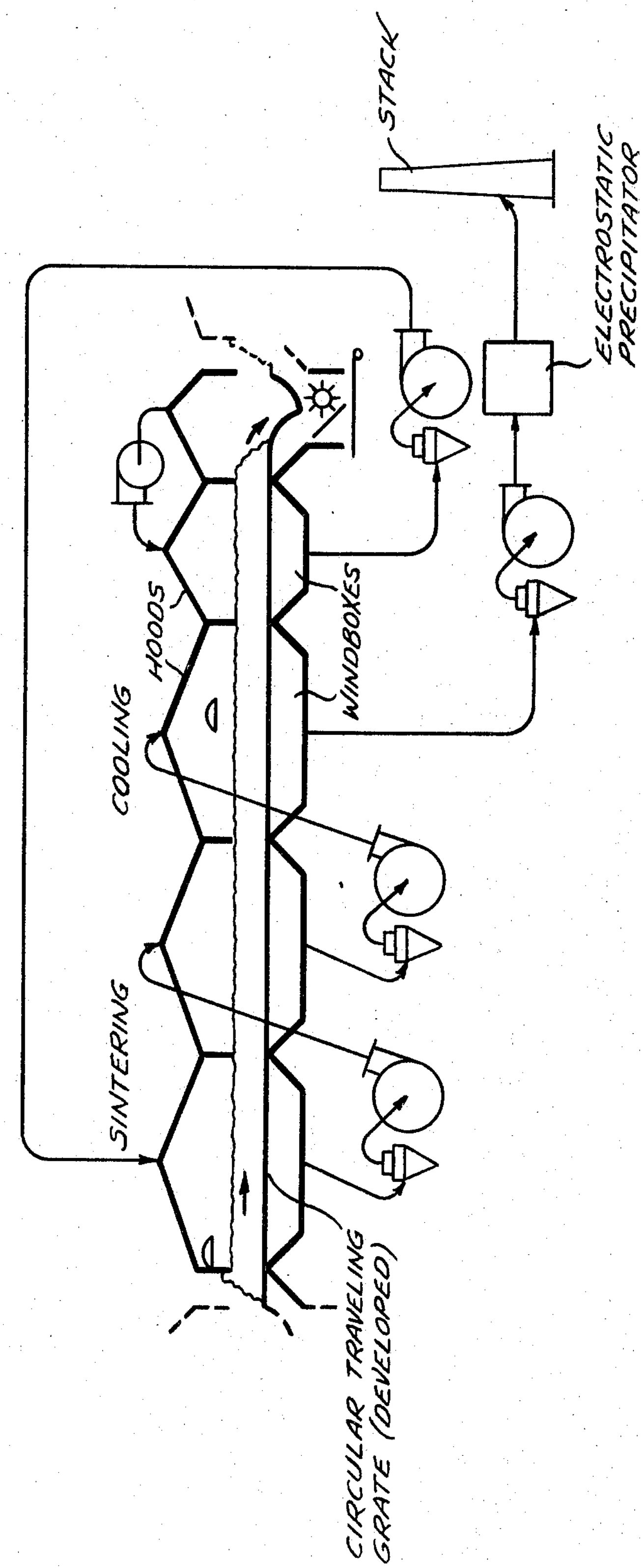

Fig. 2

SINTERING PROCESS

BACKGROUND OF THE INVENTION AND PRIOR ART

Continuous sintering has been known for more than 60 years and was pioneered by Arthur S. Dwight and Richard L. Lloyd. Specifically, their contribution related to the beneficiation of copper ore by desulfurizing and agglomerating the ore for copper blast furnace smelting (U.S. Pat. No. 916,362). Since this early development, the process has been greatly expanded, and current worldwide sintering applications exceed 250 million tons per year for agglomerating ores of lead, manganese, copper, zinc, and iron. The continuous sintering process expanded widely during the 1960's, especially in the production of iron ore and iron oxide sinter products. Sized self-fluxing or highly fluxed sinter has become recognized as a premium blast furnace charge and has enabled, for example, the blast furnaces of Japan to produce upwards of 10,000 tons of metal per day with coke rates of less than 1,000 pounds per ton of metal. This coke requirement is practically 50 percent of the ordinary rates of coke consumption achieved during the early 1950's when peak blast furnace production was less than one-third of the current records of Japan.

Sintering has long been recognized and utilized as a means for reclaiming and upgrading materials such as blast furnace flue dusts, sludges, mill scales, and BOF fume. Small sintering plants have been built for the sole purpose of sintering these reclaimable iron values, and larger plants have accepted these recycle materials as a component of a burden along with various grades of iron ore.

Few processing operations have been required to accept and utilize raw materials of such widely varying characteristics as those utilized in a sinter plant charge. There are, for example, various grades of moist iron ore screenings, warm damp flue dusts, powdery dry BOF fume, wet gummy sludges, thin slurries, hot and cold granular sinter returns, and pugged, unpugged, and semi-pugged recycle sinter dusts. Sinter burden is comprised mainly of ore screenings, a combustible carbonaceous material, e.g., coke, water, and optionally a fluxing material, e.g., limestone. A portion of the composition usually comprises one or more of the foregoing sources of reclaimed iron oxide-containing material. These compositions pose considerable materials handling and blending problems within sinter plants which have been constructed usually with minimum budget, and maximum demands to combine a single material conveying and blending apparatus facility for a very wide range of raw material characteristics.

Not the least of the large problems confronting industries intending to utilize sinter operations are related to environmental control. Sintering involves high temperature processing of relatively finely divided material in high temperature gas-solid reactions. Through the processing cycle and ultimate materials handling, portions of the materials become entrained and enfumed within very high gas volumes required for sustaining the operations. The present invention deals with a new concept for meeting these problems with an improved sintering system. The improved process reduces air pollution and provides a high quality product at lower capital and operating costs. The apparatus which is used is a traveling grate machine of either the linear or circular type, and preferably a liquid sealed circular traveling grate machine such as that described in U.S. Pat. No. 3,302,936. The process is characterized by using recycle draft proceeding in a direction from adjacent the feed end toward the delivery end of the machine as well as from near the delivery end toward the feed end of the machine and utilizing in situ or strand cooling. The combinations of these features leads to very practical and economic benefits most surprisingly in direct contravention of prior expert teaching on the subject.

For example, in a paper entitled "Factors Controlling the Rate of Sinter Production, Special Report No. 53, Symposium on Sinter" by Messrs. Voice, Brooks, Davies, and Robertson published October, 1953, in "Journal of the Iron and Steel Institute," the authors indicated that cooling on the strand or "in situ cooling" requires about the same length of strand or traveling grate as is used for sintering. If the suction is the same as on the rest of the machine, these authors indicated that the horsepower consumption will be almost double that used for sintering because of the high air flow in the cooling zone due to higher permeability. These authors concluded that effective cooling on the strand requires extremely high suctions and immense power or very large grate areas. "A high capital cost or a high running cost are the only alternatives." In April of 1961 at the International Symposium on Agglomeration, Paper No. VIII–34 entitled, "Factors Controlling the Cooling Rate of Sinter," by D. D. Phelps and J. A. Anthes concluded that air cooling on the sintering machine cannot be considered because of the high power consumption and the capital cost of lengthening the strand, the building housing it, and the necessary conveyors. "Both air cooling on the strand and water cooling in any location have proved impractical."

BRIEF STATEMENT OF THE INVENTION

Briefly stated, the present invention is in a process for sintering on a traveling grate which traverses both a sintering zone and a cooling zone on the same strand, the burden comprising iron oxide, combustible carbonaceous material, and water, the process comprising the stages of igniting the burden, such as with a gas torch; passing recycle oxygen-rich exhaust gas from a terminal cooling zone through the burden to effect sintering of the ignited burden as it moves along in the sintering zone and to produce relatively cold sinter exhaust gas; moving the burden from the sintering zone into the cooling zone; recycling at least a portion of the relatively colder sinter exhaust gas through the burden to partially cool the sintered burden; and passing oxygen-rich gas through the burden to further cool said burden in the cooling zone, to increase the temperature of the gas, and to yield an oxygen-rich recycle gas for recycling to the sintering zone.

As used herein the term "oxygen-rich" means above 12 percent by volume O_2. Percentages in reference to gas composition are by volume. Those referring to solid compositions are by weight.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIG. 1 is a simplified diagram of a conventional sintering process.

FIG. 2 is a simplified diagram of the improved sintering process of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

As indicated, FIG. 1 is a simplified diagram of a conventional sintering process illustrating the sequence of sintering, hot crushing, hot screening, and cooling on a separate traveling grate. The relatively large exhaust draft requirements are illustrated by the comparative sizes of fan, dust collector (electrostatic precipitator) and stack. The two boxes identified as afterburner and electrostatic precipitator are shown in the sinter exhaust gas system to denote a series of draft or exhaust gas treatments such as absorption or incineration for removal of combustibles followed by dust removal as in an electrostatic precipitator. Draft emitted from such a sintering process is very high in volume and amounts to an exhaust draft to sinter product weight ratio of about 7.6.

FIG. 2 is a simplified diagram of the improved sintering process which illustrates the combination of sintering and cooling operations in a single rotation of the sealed circular traveling grate machine of the type shown in the above-mentioned U.S. Pat. No. 3,302,936. The burden is generally continuously cast upon the traveling grate as a substantially uniform layer from 5 to 15 inches thick and may desirably be deposited on a hearth layer of sized return material from 1 to 4 inches thick. Relatively cold draft from the initial windboxes of the sintering zone is recycled to the terminal hood or hoods of the sintering zone. In the embodiment shown in FIG. 2, a two-stage sintering operation is shown. The recycle draft from the first phase of sintering to the second phase is warm (200° to 300°F.), slightly humid, and slightly depleted of oxygen. The burden traveling from left to right as shown in the development of the circular traveling grate in FIG. 2 moves from the sintering zone encompassed by the first two hoods into the cooling zone encompassed by the succeeding two hoods. The primary stage of cooling is carried out with recycled draft from the terminal sintering stage. The sinter exhaust draft is high in humidity, somewhat preheated, and provides for "annealing" during the terminal sintering and primary cooling stages. Final cooling is carried out on the same strand with cool draft from the discharge end and crushing operation wherein the dust-laden draft exhausting from the final cooling stage is recycled to the initial stage of sintering in the sintering zone. This recycling operation is known as "hot recycle." It will be observed that relatively ambient air is picked up by the fan above the discharge extremity from beneath the hood over the discharge and crushing operations. Considerable entrained dust exists, and the dust-laden material is pumped downwardly through the burden into the final windbox of the system where the gas temperature is elevated considerably and the gases then recycled through a dust collector, a recycle fan, and into the primary sintering hood. Since little combustion occurs in the terminal cooling stage, the oxygen content of the "hot" recycle gases is essentially the same as the ambient air and contains, therefore, from 20 – 26 percent by volume of oxygen. Dust which is collected in the final hood is arrested to a considerable extent by the hot semi-fused sintering bed and the lower more moist layers of the nodular sinter burden. Exhaust from the final sintering-primary cooling zone is directed to the stack through an electrostatic dust precipitator. This may be of either the wet or the dry type. From the diagram it will be observed that the exhaust draft has been sequentially directed through high temperature firing and cooling zones of the operations and thereby relieved of entrained combustibles and condensible matters. Supplemental heat for the operation, if necessary, may be provided by a torch within the cooling zone, and appropriate water injection may be used within the draft lines for tempering the thermal content thereof.

A most marked comparison between FIGS. 1 and 2 is the relative sizes of emitted exhaust draft volumes as represented by the relative sizes of the stacks. The improved sintering process of the present invention emits a draft exhaust-to-product ratio of about 1.9 or practically one-fouth of that from the conventional sintering process. Adjustment for actual cubic feet per minute of draft flow indicates a draft volume ultimately submitted to treatment for removal of entrained particles which is only 31 percent of that for the conventional process. This significantly lowers capital and operating costs for the sintering process.

The hot crushing and screening operations of conventional practices as shown in FIG. 1 are recognized as one of the highest maintenance and poorly attended areas of the sinter plant. The hot dusty environment thereof contributes to excessive machinery wear and inadequate conditions from a health standpoint for favorable attention. Sinter cake as discharged from the sintering machine ranges from cold brittle surface portions to hot plastic semifused portions. Frequently the discharge characteristic contains unreacted dry and wet portions of the burden which further contribute to maintenance and operating problems on the discharge end. These involve high temperature crush and distortion of materials, caking and blinding of the burden as caused by wet burden and dust fouling of the atmosphere as well as fouling of lubricated portions of the machinery.

The normal forced or induced air draft convection cooling of hot sinter as shown in FIG. 1 presents specific problems inherent with gas/solid segregation brought about by treatment of solid materials having a wide range of particle sizes. Invariably, granular solids segregate through movement by piling, charging, and transferring wherein the larger sized particles orient in locations remote from those occupied by fines. Crushed and screened cooler charge material generally ranges from about 6-inch pieces to residual granular and unaffected micron-sized particles which when bedded on a traveling grate cooler tend to segregate and develop channels or paths for preferential cooling draft flow. Hot finer particles segregated from coarser lump sinter particles are relatively unaffected by the forced cooling draft which takes the path of least resistance and results in nonuniform cooling.

In conventional systems, the sinter exhaust is slightly humid and of relatively low temperature (200° – 300°F.) containing suspended liquid and gaseous hydrocarbons together with solid particulate material which for the most part are normal sinter burden constituents, and new compounds as fumed materials such as volatilized salts, alkalies, and light metal oxides. The discharge end exhaust gases are dry and of moderate temperature (300° – 400°F.). They contain high percentages of fine entrained particles of dry sinter burden. The exhaust from the cooler is dry and relatively moderate in temperature (300° – 400°F.) and contains largely coarser particles of sinter burden and small amounts of unsintered burden. The cooler discharge exhaust (the final hood on the traveling grate in the cooling operation) is dry and of relatively low temperature (100° – 200°F.) and contains small percentages of entrained coarser particles of sinter. The removal of pollutants such as fine liquid and solid particulates and gaseous hydrocarbons requires large equipment which has high capital and operating costs. High efficiency removal of solid particulates may be accomplished with dry electrostatic precipitation apparatus which is useful in dropping out dry materials for recycle or disposal without attendant water pollution problems from soluble particulates. Combustibles in the gaseous or liquid state, and condensibles such as hydrocarbons and volatilized fatty acids, can be removed by combustion in an afterburner by a gaseous incineration operation.

Practical incineration generally requires oxidizing conditions and temperatures of the order of 1,100° to 1,500°F. This temperature can be lowered somewhat by utilizing surface active agents which, however, require periodic regeneration and treatment to prevent fouling. Conversion of large volumes of exhaust draft into the 1,500°F. area obviously favors a high initial draft temperature for the afterburner. The afterburner can be designed as a special reactor chamber with appropriate baffles for mixing, residence time, and surface chemistry reactions. Dry electrostatic precipitation of solid particles is generally favored by hot humid draft conditions with temperatures in the 400° to 600°F. area and by moisture contents on the order of 10 – 20 percent by volume. Such draft conditions enable gaseous adsorption, rapid particulate charge rates and minimum electrical resistance offered by material coated on discharge plates otherwise of low normal electrical conductivity.

The improved sintering process of the present invention is preferably carried out on apparatus which is totally sealed for performing strand sintering and cooling with multipass recycled draft. The use of a liquid sealed circular sintering machine such as described in U.S. Pat. No. 3,302,936 eliminates leakage and draft in filtration between sinter bed, hood, and windboxes. This enables better control and minimization of exhaust draft volumes. This apparatus minimizes the capital investment in operating costs for sintering. Utilization of recycled draft for both sintering and cooling reduces the quantity of exhaust draft for treatment prior to discharge to the atmosphere. The quality of the draft is also conditioned for optimum utilization by electrostatic precipitation apparatus in that it has increased temperature and increased moisture. Entrained organics by reason of being re-introduced through a hot bed undergo oxidation in the body of the bed rather than in any external equipment such as an afterburner. The bed itself may also act as a filter medium to recapture dusts. The use of strand or in situ two-stage cooling eliminates hot crushing, hot recycling, and a separate cooler circuit. There is an improvement of sinter quality by the annealing sintering cooling operation with preheated draft and cold crushing operations. There is an improvement in the sintering capacity by enabling forced firing capacity within the cooling zone.

The diagram of FIG. 2 illustrates the recycling of the draft which results in an improved quality and a diminished quantity of exhaust draft. The draft from the initial windboxes in the sintering zone is warm and humid at a temperature of about 250°F. and contains about 9 percent moisture and 15 percent oxygen. The composition will vary somewhat from case to case, depending upon the amounts of carbonates and hydrates decomposed during the sintering operation. Continuous sintering test data shows that the recycle draft from the terminal portions of the sintering zone does not interfere with sintering practice and has been found to be beneficial.

Up to the present time, relatively high percentages of moisture in sinter drafts are generally disfavored because of the likelihood of condensation in the lower sinter layers and the consequent interference with sinter bed permeability. This has not been found to be a problem when the draft is recycled from the initial ends of sintering toward the terminal ends of sintering where the burden is relatively dry in the lower layers beneath the fire line. The attainment of minimum exhaust draft flow, increased exhaust gas temperature and increased exhaust gas humidity has been realized in the continuous sintering tests. The exhaust from the sintering operation exits at a temperature of approximately 450°F. from the terminal sintering zone windboxes with a moisture content generally more than about 15 percent. These gas conditions are ideal for dry electrostatic precipitation. Additionally, considerable reduction of combustibles such as hydrocarbons in the draft exhaust have been noted. The use of preheated draft for sintering and cooling enables the production of more desirable sinter than that performed by conventional procedures utilizing ambient air. Individual tests have shown that preheated draft assists in the production of higher oxidation rates and a stronger sinter product. It has also been determined that the direction of passage of the draft through the burden, particularly in the cooling zone, may be either updraft or downdraft or a combination of updraft and downdraft.

Although only two passes are illustrated for the recycle drafts of both the sintering zone and the cooling zone, it will be understood that more passes may be considered and that reversal of the recycle, for example from hot recycle to cold recycle, might be used in certain instances.

With respect to the cooling zone illustrated in FIG. 2 and composed of two hoods and associated underlying windboxes, the sinter bed as it enters this zone is highly permeable when sintering is complete because of consolidation of fine particulate matter, solidification of the plastic semifluid firing zone, and reduction of the high temperatures which cause draft expansion. In situ strand cooling with warm recycle drafts though beneficial to sinter quality brings about lower cooling rates than that attained with ambient air. The close interrelation between sinter draft requirements and cooling draft requirements could result in hotter than normal sinter product. Heat balances indicate sinter product at a temperature of 250° to 350°F. instead of the normal 150° – 300°F. The hotter sinter product in these cases can be brought to normal temperatures if desired by direct water quenching. Such practices have shown sinter to be capable of quenching from about 400°F. without noticeable degradation or weakening. Steam from such quenching operations if employed may be gathered within the discharge end draft stream or treated by separate draft scrubbing operation.

It becomes convenient at this point to illustrate the improved sintering process by giving a specific example. Nodular textured material was produced from a granular mixture of ingredients using an inclined revolving balling pan such as that shown and described in U.S. Pat. No. 3,169,269 dated Feb. 16, 1965. Any conventional sinter burden formulation of ingredients may be used in carrying out the process of this invention. Nodular textured material ranges in size from pinhead to about one-fourth inch irregularly shaped. In the present case, sintering was effected upon a linear Dwight-Lloyd traveling grate machine two feet wide by 31.5 feet long active section. The machine included hooded portions for inlet of draft and windbox sections for outlet of draft arranged in a sequence of zones. Part 1 for the sintering zone includes 9 square feet of grate area. Part 2 also for the sintering zone also contains 9 square feet of grate area. The cooling zone comprises Parts 3 and 4, the first including 9 square feet of grate area and the second part, 4½ square feet of grate area. The following tables provide operating data of a typical composition to produce a typical sinter useful in blast furnace operations:

TABLE I

Feed Rates of Raw Material

Materials for Nodulizing		
Iron ore	−⅜″	6600 lbs/hr
Returns	−⅜″	3240 lbs/hr
Limestone	−⅛″	600 lbs/hr
Coke	−⅛″	356 lbs/hr
Hearth layer		
Sized returns	−¾″ +⅜″	1610 lbs/hr

TABLE II

Draft Rates for Sintering

Source	Draft	Temp. °F.
Part		
1 sintering inlet	Recycle from 4 outlet	450
1 sintering outlet	1800 SCFM	250
2 sintering inlet	Recycle from 1 outlet	250
2 sintering outlet	1980 SCFM	500 tempered to 250
3 cooling inlet	Recycle from 2 outlet	250
3 cooling outlet	2440 SCFM	914 tempered to 500
4 cooling inlet	Recycle from discharge	100
4 cooling outlet	1600 SCFM	450

A series of comparative studies was made utilizing a conventional sintering system such as exemplified by FIG. 1 and the improved sintering system as exemplified by FIG. 2. With respect to the improved sintering process of FIG. 2, two types of operation were performed. In the first, the primary cooling stage was performed with recycle draft that was cooled prior to introduction into the first cooling hood to assist the cooling cycle. The second was performed with untempered recycle draft in order to assist with high temperature combustion of entrained hydrocarbons in the first part of the cooling zone. Comparison of both forms of the improved sintering process of FIG. 2 with the conventional system is illustrated in the following Table III:

TABLE III

COMPARISON OF CONVENTIONAL SINTERING SYSTEM WITH TWO SPECIES OF IMPROVED SINTERING SYSTEMS

Fuel level Cooling blast	Conventional Sintering Normal fuel normal blast cooling	Conventional Sintering high fuel normal blast cooling	Improved Sintering normal fuel cold blast cooling	Improved Sintering normal fuel hot blast cooling
Burden Composition				
−⅜″ ore	56.5	55.9	56.5	56.5
Coke breeze	5.4	6.0	5.4	5.4
−⅜″ returns	29.9	29.9	29.9	29.9
Limestone	8.2	8.2	8.2	8.2
Product				
% −⅜″ in grate discharge	47.5	39.6	33.7	34.9
Returns balance −%[1]	38.7% excess	17.1% excess	1.0% deficient	4.0% excess
Remarks	very excessive returns	slightly excessive returns	returns close to balance	returns close to balance

[1]Rated as percentage of original burden requirements for returns. Excessive amounts indicate underfiring or weak product.

From Table III it is apparent that the improved sintering system offers both an improved product and decreased sinter fuel requirements. Sinter tests performed at the same fuel level showed that the conventional sintering system of FIG. 1 generates a greater quantity of −⅜-inch product size (returns) which indicates higher fuel requirements or product quality for conventional sintering. It is also to be noted that the conventional sintering system performed with increased sinter fuel requirements enables an approach to the balanced returns system, thus indicating higher fuel requirements for the same quality of sinter that is produced by the improved sinter system of FIG. 2.

The two different types of operation for the improved process of FIG. 2 are presented in Table III, each of which has a specific feature. Introduction of water to the draft system of the second blower from the left in

FIG. 2 lowers the temperature from about 500°F. to about 200°F. and enables extensive cooling to be performed at the expense of diminished hydrocarbon combustion in the cooling zone. The omission of water from this draft stream enables the 500°F. draft to be admitted to the third zone or first cooling zone, resulting in extensive hydrocarbon combustion at the expense, however, of cooling rates. A burner or torch diagrammatically illustrated in the first part of the cooling zone can further assist the afterburning of the hydrocarbon emissions. In these cases of using hot draft for primary cooling, water quenching of the sinter product is made necessary. It has been determined experimentally, however, that the sinter product for the most part is below about 400°F. and water quenching does not adversely affect the strength of the sinter product. The use of water quenching within the discharge end of the sinter strand results in a higher moisture draft transmitted to the initial portion of the sintering zone. It has been determined experimentally, however, that a draft moisture content on the order of from 1 – 6 percent is not detrimental with respect to the rate of sinter product or to the quality of the sinter product.

What is claimed is:

1. A process for sintering a burden of particles on a traveling grate which traverses a sintering zone and a cooling zone on the same strand, said burden comprising iron oxide, combustible carbonaceous material and water, said process comprising the steps of:

a. igniting the said iron oxide burden containing the water with a flame and moving the ignited burden into the sintering zone;

b. passing recycle oxygen-rich exhaust gas from the cooling zone through the burden to effect sintering of the ignited iron oxide burden in the sintering zone and to produce a relatively cold humid sinter exhaust gas;

c. moving said iron oxide burden from the sintering zone into the cooling zone;

d. recycling at least a portion of said relatively colder sinter exhaust gas through said burden at a downstream point to partially cool the sintered iron oxide; and burden to complete sintering and to relieve the gases of entrained combustible matter;

e. passing oxygen-rich gas through said iron oxide burden to further cool said burden, to increase the temperature of said gas and to yield an oxygen-rich recycle gas for recycling to said sintering zone.

2. A process in accordance with claim **1** wherein the burden comprises iron ore, combustible carbonaceous material, flux and water.

3. A process in accordance with claim **1** wherein the burden comprises nodules of a sinter composition which comprises iron ore, combustible carbonaceous material and water.

4. A process in accordance with claim **1** which additionally includes the step of depositing the burden onto the traveling grate as a continuous bed having a substantially uniform depth of from 5 – 15 inches.

5. A process in accordance with claim **1** which additionally includes the step of depositing a hearth layer onto the traveling grate as a continuous layer having a substantially uniform depth of from 1 to 4 inches prior to deposition of said burden.

6. A process in accordance with claim **5** in which the burden is a continuous bed having a substantially uniform depth of from 5 to 15 inches.

7. A process in accordance with claim **1** wherein the recycle gas in step (b) is passed downwardly through the burden.

8. A process in accordance with claim **1** wherein the gases in steps (b), (d), and (e) are passed downwardly through the burden.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,849,115 Dated November 19, 1974

Inventor(s) THOMAS E. BAN

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, part (d) of Claim 1 should read as follows:

d. recycling at least a portion of said relatively colder sinter exhaust gas through said iron oxide burden at a downstream point to partially cool the sintered burden to complete sintering and to relieve the gases of entrained combustible matter;

Signed and sealed this 11th day of March 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks