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HEAT-TREATING SOLIDS

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This invention relates to improved modes of heat-treating (including drying, decrepitating, roasting, calcining, indurating and similar thermal treatments) inorganic mineral solids such for instance as ores, ore materials, other metallurgical products, non-metallic raw materials such as fireclay, limestone and phosphate rock, and the like, and is particularly concerned with apparatus for carrying out such heat-treatments with improved heat economy.

This application contains subject matter in common with my copending application entitled "Process and Apparatus for Heat-Treating Solids," filed July 3, 1945, Serial No. 602,988.

More specifically, the invention relates to apparatus for and process of indurating a continuously or intermittently moving stream of discrete bodies or particles, particularly pellets, of moist oxidic iron ore fines, at an elevated temperature of the order of 2000° F., while the same flows by gravity through a pair of superposed thermally insulated communicating treating chambers, in which process the stream of ore or ore material is contacted with a treating gas, e. g., air, passed in counter-current heat-exchanging relation through said stream of pellets or particles.

The problem of working up ore fines and other similar finely-divided inorganic solids into objects of such size and structure as would make them economically handleable in a metallurgical furnace such, for instance, as a blast furnace, is very old and has received much consideration. Thus Mason (U. S. Patent No. 307,667), who proposed that iron ore fines and the like be moistened with water (which might or might not contain an added binder substance), formed into molded bricks or unmolded irregularly shaped small masses and heat-treated in a quiescent state, suggested that the small masses be bedded in layers of solid fuel and the latter burned whereby to bake or "burn" the ore fines masses in the intervening layers. Later, briquetting without or with subsequent heat-hardening was proposed, as were sintering and nodulizing. As a variant to nodulizing and sintering, it was proposed that such ore fines be moistened (with or with added binder substance) and formed into shapes or spheres (variously styled "pellets" and "glomerules") which latter were to be dried and more or less baked but without excessive fusion of the mineral constituents of the ore. One suggested method of carrying out this scheme was to feed a stream of the moistened fines into the upper end of a relatively long inclined rotary

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kiln at the lower end of which a high temperature was maintained by the combustion of fuel therein; it was hoped that the moist fines would "ball up" at the initial stage of their travel through the kiln, and that the resulting spherical masses would be dried and eventually heat-hardened during their subsequent travel through the hot end of the kiln. Other investigators, finding that the method just described was unsatisfactory, in that the balls when dried became too fragile to withstand subsequent tumbling and as a result disintegrated badly, proposed that they be supported, in some obscure fashion, in a quiescent state and without being subjected to breaking stresses while undergoing induration; however, the proposals were not accompanied by any readily understood procedure for effecting the desired result.

It has been found that material disintegration of these pellets during the heating step may be avoided by accelerating the rate at which temperature of at least the outer laminae of the "green" or "raw," i. e., untreated, pellets is raised from below 212° F. through drying to that temperature level, e. g., 1650°–2100° F. in the cases of most iron ores, at which a desirable degree of induration of the ore fines occurs, to the end that such outer layers very rapidly are indurated. For effecting this desirable result I cause a supported layer of the "raw" (that is to say, moist and unbaked or untreated) pellets, initially at a temperature below 212° F., to be traversed by a mechanically propelled current of a treating gas initially heated to a predetermined induration temperature for a period of time sufficient not only to heat-harden the peripheral laminae of the pellets in the supported layer, but also to effect thoroughgoing heating of the entire pellet body to indurating temperature, and thereafter I cause the heat resident in the so-indurated pellets very largely to be transferred to the unheated treating gas which I use in the subsequent heating of the raw pellets.

In general, the process of the invention comprises the following steps: a mass of discrete pellets of oxidic iron ore fines, initially substantially unheated and moist, is caused to move by gravity through an upper treating chamber, a restricted conduit and a lower treating chamber, the pellets filling the restricted conduit and also filling the upper and lower treating chambers save for upper and lower open spaces, in each treating chamber, contiguous with upper and lower bounding free surfaces of the mass of particles therein, a current of treating gas (e. g., air), in-

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initially substantially unheated, is forced serially upwardly through the apparatus from the lower open space to the upper open space of the lower of the two treating chambers, from the latter to a communicating combustion chamber or conduit wherein it is thermally enriched by combustion of a fuel introduced therein, from the combustion chamber to the lower open space of the upper treating chamber and thence to the upper open space of the latter and to exhaust. In its travel—counter-current to the pellets—through at least the major portion of the lower treating chamber the initially substantially unheated treating gas is heated by contact with heated pellets descending into the lower treating chamber by way of the aforesaid restricted conduit from the upper treating chamber and the pellets so contacted are cooled to approximately the entrant temperature of said treating gas. During its passage through the combustion chamber the treating gas, at least partially preheated, is further heated to about 2000° F. or the desired gas entrant temperature.

The thermally enriched treating gas, passed from the combustion chamber into the lower open space of the upper treating chamber, at desired treating temperature, is forced through interstices between the pellets substantially filling said treating chamber and transfers heat to said pellets, exhausting into the upper gas-collecting space at substantially the entrant temperature of the pellets fed to the apparatus. The pellets in the lower portion of the upper treating chamber are heated thereby to the desired treating temperature by heat transferred thereto from the treating gas, and the heated pellets flow out of the upper treating chamber through said restricted conduit and into the upper portion of the lower treating chamber in a heated state.

By suitable elongation and restriction of said restricted conduit, the passage of preheated treating gas from the lower to the upper treating chamber through the mass of pellets constantly filling said restricted conduit is reduced to a negligible amount, the treating gas tending to exit from the mass within the lower treating chamber into the upper open space of the latter and thence, by way of the communicating combustion chamber, to and through the lower open space of the upper treating chamber. To expedite this movement of the treating gas, I may partially exhaust gas from the upper open space of the upper treating chamber by any suitable exhaust means, so as to reduce the back pressure on the treating gas passing from the combustion chamber into the lower portion of the upper treating chamber.

In "firing" pelletized iron ore fines, initially containing 10% moisture, at an indurating temperature of 2000° F., the total heat theoretically required to raise a gross ton of the raw (i. e., untreated) briquets or pellets to this temperature is 1,164,000 B. t. u. where about 80% of the heat (930,000 B. t. u.) represents the sensible heat of the 0.9 gross ton of the resultant baked solids and only about 20% is chargeable to evaporating the initially contained moisture. In view of these thermal requirements, the economic necessity to discharge the solids from the apparatus at low temperature is five times as important as the mere drying and indurating of the solids. Accordingly, in carrying out my process, I prefer to discharge the dried and indurated pellets at a reasonably close approach to ambient air temperature, e. g., near the dewpoint of the exhaust gases, and, equally important, to discharge the

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treating gas at a relatively low temperature (ideally, of course, at ambient air temperature).

The invention will be described in greater particularity, with reference to the accompanying drawing, in which the single figure is a schematic sectional elevation, taken on the vertical axes of the two heating chambers, of one operable form of apparatus for carrying out the process or the present invention.

In the drawing, illustrating an apparatus for use in indurating pellets of moist iron ore fines, are shown two similar heating chambers A and B arranged one above the other and connected by an elongated substantially vertical restricted conduit extending from the conical bottom of upper chamber B to and into the upper portion of chamber A and also by a gas-heating means hereinafter to be described more particularly, and their necessary appurtenances.

In each of chambers A and B, 1 represents the substantially tubular side wall, 2 represents the substantially conical roof and 3 represents the substantially conical bottom of the chamber. At least the lower portions of chamber B and at least the upper portions of chamber A are thermally insulated as indicated by the refractory linings at 4' and 4. The bottoms 3, 3' of the chambers are downwardly sloped at an angle greater than the angle of repose of the pellets.

6' represents a pellets-feeding chute positioned substantially at the vertical axis of chamber B and the apex of roof 2'. Chute 6' is projected for some distance into the interior of heating chamber B which projected portion is illustrated at 40'. Chute portion 40' and roof 2' of chamber B are so designed that a bed 7' of pellets fed into B from 6' occupies less than all of the upper interior space of B, there being an upper open space 18' between the free upper surface of bed 7' and roof 2'. 96 represents a substantially vertical elongated restricted conduit extending from the apex of the conical bottom 3' of chamber B to, and projecting for some distance into the interior of, heating chamber A, the projected portion being illustrated at 40: conduit 96 is formed of or lined with refractory material. The lower end 40 of conduit 96 is positioned sufficiently below the roof 2 of chamber A as to insure the maintenance of an upper open space 30, in chamber A, between said roof and the upper free surface of a bed 7 of pellets in chamber A.

51, 51' represent relatively steeply sloping lateral walls depending from side walls 1, 1', respectively, of chambers A and B. These lateral walls serve somewhat to constrict beds 7 and 7' as these latter move downwardly through A and B, the pellets of the beds rolling out beneath 51, 51' after they have passed the latter, to assume their normal angle of repose thereunder leaving beneath 51 an annular lower open space 18 contiguous with lower free surface of bed 7 and under 51' a similar open space 30'.

19 represents a conduit communicating between blower 22 and lower open space 18 of chamber A. 23 represents a conduit communicating between upper open space 18' of chamber B and an exhaust 22' which latter discharges to atmosphere.

Upper open space 30 (chamber A) is in gas communication with lower open space 30' (chamber B) through assemblage C, composed of thermally insulated conduit 86, thermally insulated combustion chamber 70 and thermally insulated conduit 86'. 88 represents a fuel burner let into the end wall of chamber 70 adjacent conduit 86,

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and 26 represents a valved fuel supply pipe feeding fuel to burner 88 from a fuel source not shown.

Means for discharging treated pellets from heating chamber A consists of a substantially vertical discharge chute 8, an adjustable discharge gate 9 and a conveyor band 10.

In operation, "raw" (i. e., moist, initially substantially unheated) pellets of iron ore fines are fed to the stockline of bed 7' of similar but previously heat-treated pellets in chamber B. Restricted conduit 96 is full of pellets, and chamber A likewise is full of pellets save for upper open space 30 and annular lower open space 18; the pellets in at least the lower part of bed 7', in restricted conduit 96 and in the topmost layers of bed 7 are hot, having been heat-treated (indurated) in a prior operation.

Air (the "treating gas" in this case) initially substantially unheated, is forced by blower 22 through conduit 19 and annular lower open space 18 (chamber A) and bed 7 to upper open space 30 (chamber A): in this passage the air becomes preheated by transfer thereto of heat from initially hot pellets resident in the upper portion of bed 7, and these latter are correspondingly cooled.

The preheated air is forced from upper open space 30 (chamber A) through conduit 86 into the space 31 within combustion chamber 70. A gaseous fuel (e. g., blast furnace gas) is simultaneously introduced into space 31 through burner 88 and there mingles with and is burned in the preheated air; the amount of fuel so introduced and burned is adjusted to supply, by its combustion, only that amount of heat necessary to raise the temperature of the air to the predetermined treating temperature (e. g., about 2000° F. in the cases of certain moist iron ore fines pellets).

The so-heated air, containing gaseous combustion products but still "oxidizing" in effect, is passed from space 31 through conduit 86' and into annular lower open space 30' (chamber B) and thence through bed 7' and to upper open space 18' (chamber B). In its intimate contact with the pellets in the lower portion of bed 7' the initially highly heated air gives up heat to said pellets with the net result that the lowermost layers of pellets have been heated substantially to 2000° F. by the time they pass into conduit 96 and the air passes into the layers of pellets in the upper part of bed 7' at a temperature intermediate its initial temperature and the initial temperature of the raw pellets; as it passes through the upper part of bed 7' it further gives up heat in drying and heating the initially moist raw pellets, and correspondingly is cooled, so that it passes out of bed 7' into upper open space 18' at a temperature substantially equal to or not far above the dewpoint of the air. The air is removed from upper open space 18' (chamber B) through conduit 23 by the aid of exhaustor 22' and from the latter is exhausted to atmosphere.

As will be appreciated, the rate at which indurated pellets are discharged from the bottom of bed 7 through gate 9 determines the rate at which raw pellets feed onto the stockline of bed 7' from ever full chute 6'. The selected discharge rate is determined mainly by three considerations, viz., the desired heat economy, the desired power economy and the desired throughput. Where heat economy is all important, the rate of blowing and the rate of discharge of pellets are such as to insure that the heat-treated (indurated) pellets moving out of bed 7 are cooled

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substantially to the entrant temperature of the air in lower open space 12. Where a greater throughput at the expense of heat economy is the more important, the heat-treated pellets can be discharged at a faster rate from bed 7 in which event they may pass out of the apparatus at a temperature more or less elevated as compared with the air entrant temperature, e. g., at 150° F., 200° F., or the like. The rate of blowing preferably is so adjusted that the temperature of the gas exhausted from upper open space 18' (chamber B) is not unduly above the dewpoint thereof.

As was mentioned hereinbefore, the operation may be and usually is so controlled that pellets move as a continuous stream through the apparatus from 6' to 10. However, when the same is desired it is possible to make the operation intermittent and to discharge and charge smaller or larger batches. Thus, the discharge may be arranged to occur at intervals of a few minutes and to amount to a few inches only of bed 7; or, it may be so arranged that a large fractional part of bed 7 is discharged "at one time" and hence that a large fractional part of bed 7' descends and is replaced by raw pellets.

The technical success of this process resides in the fact that a restricted conduit can be built large enough to permit a free flow of particles from the upper to the lower heating chamber without permitting leakage therethrough of any considerable amount of hot gas from lower to upper chamber. Many prior efforts to realize the successful heating and cooling of minerals in succession by causing an initially cool gas to flow through a zone of the heated minerals (whereby to take up heat therefrom) and then to be heated and reintroduced into a bed of unheated particles have been technically unsuccessful because of the failure to provide satisfactory means for removing the gas from the top of the lower column of minerals and, after being heated, for causing it to re-enter the upper chamber.

It is a matter of indifference, from the standpoint of satisfactory heat-treatment of the solids, whether the treating gas be forced thru A, C, and B by means of a blower as at 22, or drawn through A, C and B by means of an exhaustor as at 22', or both simultaneously.

It is to be understood that the apparatus is susceptible to considerable modification without departing from the concepts of the present invention. Thus, assemblage C may be formed as a U-shaped thermally insulated conduit, and one may employ a plurality of burners 88 therein or therealong. Raw pellets may be fed to the stockline of bed 7 of chamber B by other feeding means than a gravity chute; also, they may be fed to the bed by a plurality of chutes (or equivalent feeding means) spaced either over the area of conical roof 2' (so as to provide an irregular stockline comprising a plurality of conical piles of pellets) or about the upper periphery of side wall 1'. The bottom of chamber A being essentially "cold," the lower open space therein may be provided by other means than lateral wall 51; e. g., by a plurality of louver arches formed of structural metal. In fact, instead of lateral wall 51', one may employ other means, e. g., a plurality of louver arches formed of refractory material or even of heat-resistant alloy steel, to provide the necessary lower "open space" for introduction of the heating gas into bed 7' at or adjacent the bottom of the latter. Any of the methods of feeding material into and discharging the same from the treating chambers which are

described in my co-pending application Serial No. 602,988 referred to hereinbefore are adapted to the present process; likewise, the present process is suitable for carrying out the several technical operations therein described.

I claim:

1. Process of indurating in a shaft furnace discrete fluent bodies of moist iron ore fines, which comprises: establishing a gravitationally descending column of previously indurated bodies of oxidic iron ore fines, said column consisting of two gas traversable masses of the bodies disposed one above the other and communicating through an intervening portion of the column of restricted cross-sectional area compared to the cross-sectional areas of said masses and ill-adapted to the flow of gas therethrough; maintaining lower open spaces contiguous to lower free surfaces of each of said masses and gas-collecting spaces of substantial extent above and contiguous with upper free surfaces of said masses; charging a layer of initially substantially unheated raw bodies onto the top surface of the upper mass and discharging a similar volume of indurated bodies from the bottom of the lower mass thereby maintaining said column's height; passing a current of initially substantially unheated air through the lower mass from the lower open space thereof to and through the gas-collecting space thereof and into a combustion space spacially separate from said column thereby effecting heat exchange between the initially substantially unheated air and the bodies constituting said lower mass; thermally enriching the air in said combustion space, by introducing and burning a fluid combustible therein, to an induration temperature below but approaching the incipient fusion temperature of the oxidic iron ore particles constituting said bodies; passing the thermally enriched air from the combustion space to and through the upper mass from the lower open space thereof to the gas-collecting space thereof thereby effecting heat exchange between the initially highly heated air and the bodies constituting said upper mass; so controlling the rate of flow of the air that the same passes into the gas-collecting space above the upper mass at a temperature above but close to its dew point; so controlling the rate of discharge of indurated bodies from the bottom of the lower mass that the bodies are substantially cool as discharged; and so adjusting the amount of fuel introduced into the combustion space with respect to changes in the rate of flow of the air and in the rate of descent of the bodies that the temperature of the air passing into the lower open space of the upper mass is maintained at the aforesaid induration temperature.

2. Process of heat-treating in a shaft furnace discrete fluent bodies of moist mineral solids, which comprises: establishing a gravitationally descending column of previously heat-treated bodies of the mineral solids, said column consisting of two gas traversable masses of the bodies disposed one above the other and com-

municating through an intervening portion of the column of restricted cross-sectional area compared to the cross-sectional areas of said masses and ill-adapted to the flow of gas therethrough; maintaining lower open spaces contiguous to lower free surfaces of each of said masses and gas-collecting spaces of substantial extent above and contiguous with upper free surfaces of said masses; charging a layer of initially substantially unheated raw bodies onto the top surface of the upper mass and discharging a similar volume of heat-treated bodies from the bottom of the lower mass thereby maintaining said column's height; passing a current of initially substantially unheated air through the lower mass from the lower open space thereof to and through the gas-collecting space thereof and into a combustion space spacially separate from said column thereby effecting heat exchange between the initially substantially unheated air and the bodies constituting said lower mass; thermally enriching the air in said combustion space, by introducing and burning a fluid combustible therein, to a predetermined heat-treating temperature; passing the thermally enriched air from the combustion space to and through the upper mass from the lower open space thereof to the gas-collecting space thereof thereby effecting heat exchange between the initially highly heated air and the bodies constituting said upper mass; so controlling the rate of flow of the air that the same passes into the gas-collecting space above the upper mass at a temperature above but close to its dew point; so controlling the rate of discharge of heat-treated bodies from the bottom of the lower mass that the bodies are substantially cool as discharged; and so adjusting the amount of fuel introduced into the combustion space with respect to changes in the rate of flow of the air and in the rate of descent of the bodies that the temperature of the air passing into the lower open space of the upper mass is maintained at the aforesaid heat-treating temperature.

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