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PELLETIZING HIGH-MOISTURE ORE

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1 Claim. (Cl. 75—3)

This invention relates to the beneficiation of ores and ore materials, and is particularly concerned with the provision of a procedure for improving the physical structure, and simultaneously raising the iron content, of certain non-magnetic oxidic iron ores—found in the Mesabi Range and elsewhere—characterized by excessively high moisture contents, high ignition loss, usually a fairly high alumina content, a rather low natural iron content, and a large portion of sticky, clay-like fines. Because of their unattractive iron analyses, and especially because of their very poor physical structure, these "paint rock" and similar high-moisture oxidic iron ores, of which it is estimated approximately 200,000,000 tons are present in the United States, constitute a technological problem in that they are disagreeable to transport (because of their wet, clay-like physical structure) and in that their poor physical structure penalizes their use in burdening the blast furnace. Their high moisture content results in high freight cost in transporting the valueless water from the mine to the steel plant. Up to the present time such high moisture high alumina ores could be made merchantable only by blending them with ores of better physical structure and higher iron contents; or, by selling them at a substantial discount.

Believed to be typical of high-moisture oxidic iron ores are the following examples taken from the upper slaty formation of the Mesabi Range:

TABLE I

Sample No.	Iron	Phos.	Silica	Alumina	Ign. Loss	Moisture	Nat. Iron
1	54.22	.030	7.12	3.36	5.85	15.35	45.90
2	52.38	.095	8.42	4.83	9.47	18.50	42.69
3	57.77	.033	7.55	4.60	4.21	17.80	47.48
4	58.72	.042	7.11	4.18	3.43	17.40	48.50
5	54.38	.052	11.23	3.90	4.70	17.60	44.81

As will be noted, all are high moisture ores. Sample No. 2 consists essentially of yellow limonite and has a much higher ignition loss than have any of the others. The iron contents of samples 1 and 3–5 are largely hematites. There are very few pieces of hard ore in any of the five samples, and most of the large pieces are so soft that they break down when stepped on or tapped lightly with a hammer. Their fines contents are "gummy" or sticky, making it inexpedient to screen such ores at much below one inch.

It heretofore had been proposed—e. g., in "Proceedings of the Blast Furnace and Raw Materials Committee," vol. 4 (1944), pages 46–69, article by Charles V. Firth—to process pulverulent iron ore concentrates for use in the blast furnace by a procedure involving—in broad outline—the steps of (*a*) balling-up the pulverulent material, in moist state, into small balls or pellets and (*b*) indurating the pellets at an elevated temperature of the order of 1050–1150° C. It was the generally accepted theory that in order to ball-up such concentrates the moisture content must be held within narrow limits,

e. g., 8–10%, and the ore material must be "pulverulent" and (see the above "Proceedings" article) must have a certain particle size distribution ranging from only a few (or no) percent plus 100 mesh, Tyler screen down to 60–100% minus 325 mesh, Tyler screen, with about 25% minus 20 microns. It had been propounded that a particle size distribution outside such range would have to be met either by grinding the material to desired particle size or by screening out the undesirably large particles.

Because of the gummy, sticky nature of the above-identified high-moisture ores it is economically unfeasible to grind the material and it is practically impossible to dry-screen it at much below one inch.

However, it has been discovered that such relatively coarse, high-moisture ores, e. g., ores containing upwards from 15% moisture, may be subjected to balling treatment for the balling-up of particles smaller than say three-eighths inch, and that the particles larger than about three-eighths inch pass through the balling-up device without alteration. Were it necessary to screen such ore to three-eighths inch the process would be inoperable because of the practical impossibility of screening such sticky ores to this size.

It has been discovered, further, that the resulting pelletized material (or, mixture of pellets and unpelletized larger pieces) can be fired in an induration furnace without undue formation of dust and without undue decrepitation of the pellets during the firing operation.

According to the present invention, the aforesaid high-moisture oxidic iron ores are significantly improved as to physical structure, and their iron content materially raised, by pelletizing at least the finer portions of the ore and subjecting the pellets to a specific high-temperature induration treatment. In its preferred form, the process of the invention consists essentially in crushing the moist run-of-mine ore to two inches, subjecting the crushed ore in its entirety (i. e., without screening) plus added solid carbonaceous fuel to balling treatment in a balling drum or equivalent balling device, delivering the discharge from the balling device to an appropriate heat-treating apparatus, e. g., to the top of a gravitationally descending column of similar material in a shaft-type indurating furnace, and subjecting the same therein to high-temperature induration treatment by a procedure per se known. Preferably, the high temperature treatment involves the step of counter-currently contacting at least the upper portion of a column of such pellets plus unpelletized pieces of ore with a current of a gaseous mixture of air and combustion products which current is introduced into the column at an elevated temperature of the order of 1800–1900° F. which is well below the desired maximum or "peak" temperature at which it is desired to indurate the material. It has been found that in the aforesaid balling step at least the smaller particled portion of the crushed ore feed rolls into balls or pellets while the largest pieces resist "pelletization" and discharge from the balling device without change; also that the resulting heterogeneous mixture of pieces of ore and balls or pellets of finer ore can be indurated in somewhat the same manner as can a furnace charge consisting exclusively of balls or pellets.

The invention will be further described with reference to the following specific examples.

Example 1

In this experiment the starting material was a mass of the "paint rock merch." ore from which the above sample No. 5 was taken. The same was crushed to minus 2 inches, admixed with anthracite fines in an amount equivalent to approximately 20 pounds of carbon, and the mixture was passed through a balling drum of the general

type disclosed in U. S. Patent No. 2,411,873 to C. V. Firth. Pieces of ore coarser than about ⅜ inch came through the balling drum virtually unchanged, while ore particles smaller than ⅜ inch tended to form nuclei around which the ore fines-coal mixture balled. The balls or pellets thus formed ranged between ⅜ and ½ inch in diameter, and were considerably more resilient than are balls formed from moist magnetite concentrates. When dried at 212° F. they had at least three times the crushing strength of similarly dried magnetic pellets.

The entire product (larger ore pieces plus balled-up pellets) from the balling drum was subjected to furnacing treatment in the following manner:

The furnace was of the vertical shaft, essentially straight-sided type having a cross-sectional area equivalent to that of a circle of 30 inches diameter. The furnace was associated with a spatially seperate combustion chamber which communicated at its top with the interior of the furnace by means of a suitable conduit terminating in a plurality of ports let into the furnace wall. The combustion chamber was provided with a suitable oil burner and with means for delivering metered amounts of fuel oil and combustion air thereto. The furnace was provided with means for introducing a current of cooling air, under pressure, into the lower part of its charge column. The aforesaid ports and conduits from the combustion chamber were intermediate the air-introducing means and the top of the columnar charge.

In this furnacing operation the ore-pellets mixture from the balling drum was fed to the stockline of the charge column at the rate of .85 long ton per hour, and the heat-treated and substantially cooled product was discharged from the bottom of the furnace at the rate of 0.69 long ton per hour, these rates of feed and discharge serving to maintain a charge column of substantially constant height. Cooling air was forced into the bottom of the charge column at the rate of 240 C. F. M., standard conditions. No. 2 fuel oil was fed to the combustion chamber oil burner at the rate of 4.0 gallons per hour (or 4.7 gallons per long ton of raw, i. e., moist, feed), and combustion air was introduced adjacent the burner at the rate of 150 C. F. M., standard conditions, the fuel oil and air amounts being controlled to provide a gaseous mixture of air and combustion products (going to the furnace) at about 1850° F. The average exit top gas temperature was 200° F. and the average temperature of the heat-treated product as discharged from the bottom of the furnace was 250° F. The maximum temperature to which the pellets-ore pieces mixture was subjected, in the upper part of the column, was estimated to have been approximately 2400° F.

Total fuel consumption (coal in the pellets, plus fuel oil to the combustion chamber) was 876,000 B. t. u.'s per long ton of crude, or 1,175,639 B. t. u.'s per long ton of indurated product.

The drop in furnace pressure from the bottom of the furnace to the port openings from the combustion chambers was .3 inch Hg, and from these ports to the top was .65 inch Hg. The total static pressure that the blower had to work against was .95 inch Hg, equivalent to 0.47 lb./sq. in.

The weight loss (moisture plus ignition loss) by reason of the high-temperature treatment of the ore product was 21.48%, indicating that all of the free moisture and all but about 0.22% of the combined water had been removed. Thereby the iron analysis was raised to 57.07% and the silica to 11.78%. The moisture in the pelletized product was reduced to zero.

The indurated product was very markedly improved structurally as contrasted with the crude ore. The stickiness had entirely disappeared. The larger ore particles which had not balled up were much harder than were the natural ore particles, and the indurated pellets were harder than the unballed indurated pieces themselves. The indurated product showed no tendency to absorb water or to become sticky or gummy upon being wetted with water. The material was of a semi-fused structure, and constituted an excellent burden for the blast furnace since it had the favorable characteristics of a pelletized and indurated product. The high-temperature treatment had induced grain growth between the mineral particles as well as inter-particle fusion, thereby conferring a very considerable strength to the fired pellets and ore pieces.

In Table II following are shown the structure analyses before and after subjecting the crushed ore to the treatment described above. The structure analysis of the sticky crude ore was made on a natural basis and hence does not present an accurate "picture," since a wet screen analysis would have shown a much greater proportion of fines.

TABLE II

STRUCTURE ANALYSIS OF CRUDE ORE AND FURNACE PRODUCT

Size	Furnace Test No. 5—Percent Weight	
	Crude Ore	Final Product
+1"	11.15	12.35
+¾"	12.04	15.83
+½"	13.51	23.29
+⅜"	12.91	18.80
+3 Mesh	9.57	9.80
+4 Mesh	6.88	6.33
+6 Mesh	6.10	3.20
+35 Mesh	15.59	5.84
+65 Mesh	5.34	1.10
+100 Mesh	2.17	.51
−100 Mesh	4.74	1.95
Total	100.00	100.00

Crude: 72.16%+6 mesh.
Final Prod.: 90.60%+6 mesh.

To summarize the foregoing data, it is noted that the structural characteristics of the ore were very markedly improved (90.6% plus 6 mesh, as opposed to less than 72.16% plus mesh) and that the natural iron content had been raised from 44.81% to 57.07%. In a commercial plant the pellets would be screened at 6 mesh and the fines retreated, giving a shipping product all coarser than 6 mesh.

Example 2

The process described in Example 1 was repeated, except that the run-of-mine ore (sample No. 3 above) 47.48% iron nat. was not crushed but was screened at 1 inch and only the minus 1 inch portion was balled (with addition of finely divided solid carbonaceous fuel) and furnaced in the manner described in Example 1, above), and the so-indurated product was thereafter mingled with the plus 1 inch material to constitute a final product. The minus 1 inch portion represented approximately 64% of the total.

In this case the coal addition amounted to about 20 pounds per long ton, dry weight, of the ore screenings and (as in Example 1) was mixed with the ore material, prior to the balling operation, without further moisture addition or addition of any other additive. The combustion chamber temperature was maintained at about 1875° F. by the combustion of approximately 4.5 gallons of No. 2 fuel oil per long ton, dry weight, of the raw pellets. The estimated peak temperature was 2425° F. The observed top exit gas temperature and discharged pellets temperature were 185° F. and 325° F., respectively. The amount of cooling air used was 250 C. F. M., and that of the combustion air was 145 C. F. M.

The observed static pressure was about .52 lbs./sq. in.

The indurated pellets analyzed:

	Percent
Iron	60.72
Phos	.033
Silica	7.62
Mn	.44
Alum	4.60
Moisture	0.00
Iron natural	60.72

The indurated pellets were desirably hard and mechanically rugged. The final mixture of indurated pellets and non-indurated plus 1 inch ore analyzed:

	Percent
Iron	59.55
P	.033
Silica	7.78
Mn	.5011
Alum	4.73
Ign loss	1.28
Moist	8.20
Iron natural	54.66

It will be noted that by the above procedure the structure of the ore has been greatly improved and that the percentage of natural iron in the combined product has been increased to 54.66% from the 47.48% in the crude ore.

In repetitions of Example 2 the run-of-mine ore was screened at various sizes between 1 inch and 2 inches, and the undersize material was balled up and indurated with generally similar results.

The indurating step of the present process can be practiced in a shaft-type furnace, and by a furnacing procedure, generally similar to those disclosed in U. S. Patent No. 2,676,095 to Fred De Vaney and Donald Beggs, with some saving in total heat requirements. Such procedure is somewhat less desirable than that disclosed in Example 1 from the standpoint of the somewhat greater dustiness of the present product with attendant probability of slagging the dust carried into the combustion chamber by the stream of preheated air diverted to the latter; however, it is operable in the present relation. It is possible, also, to effect the induration of the pelletized material, or of the above-described mixture of pelletized and unpelletized material, by means of a horizontal grate-type sintering apparatus such as or similar to the well-known Dwight-Lloyd sintering machine: in such

case, substantially more finely divided solid carbonaceous fuel is associated with the ore material in order to insure that all of the charge shall have been sufficiently heat-treated.

While in the foregoing the present process has been described with particular reference to beneficiation of Mesabi high-moisture, high-alumina ores, it will be obvious that the same is not restricted to beneficiation of these particular ores and that the same is applicable to a wide variety of ores, ore materials and earths characterized by poor structure, stickiness, excessively high moisture contents and/or high ignition loss whereby to improve the structure and the handleability and/or to raise the grade thereof.

I claim:

The process for improving the structure and raising the grade of coarse, high-moisture, essentially non-magnetic, iron ores which in run-of-mine conditions are characterized by a moisture content in excess of 15%, a disadvantageously sticky or clay-like structure and a low natural iron content, which consists essentially in the steps of crushing the run-of-mine ore to about minus 2 inches, mixing with the crushed ore in its entirety a small amount, of the order of 1% by weight based on the dry weight of the ore, of a finely divided solid carbonaceous fuel, passing the entire mixture through a pelletizing device under conditions to promote the balling up of particles smaller than about three-eighths inch into pellets while permitting the larger pieces to pass through without change, and subjecting the resulting mixture of pellets and non-pelletized larger pieces of ore to induration treatment in a shaft-type indurating furnace under oxidizing conditions and at a temperature, at least of the order of 2400° F., sufficiently elevated to insure the burning of the solid fuel and the removal of the water content of the pellets and ore pieces and to insure induration of both the pellets and the ore pieces.

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