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BENEFICIATION OF ORES

Filed April 16, 1957

3 Sheets-Sheet 1

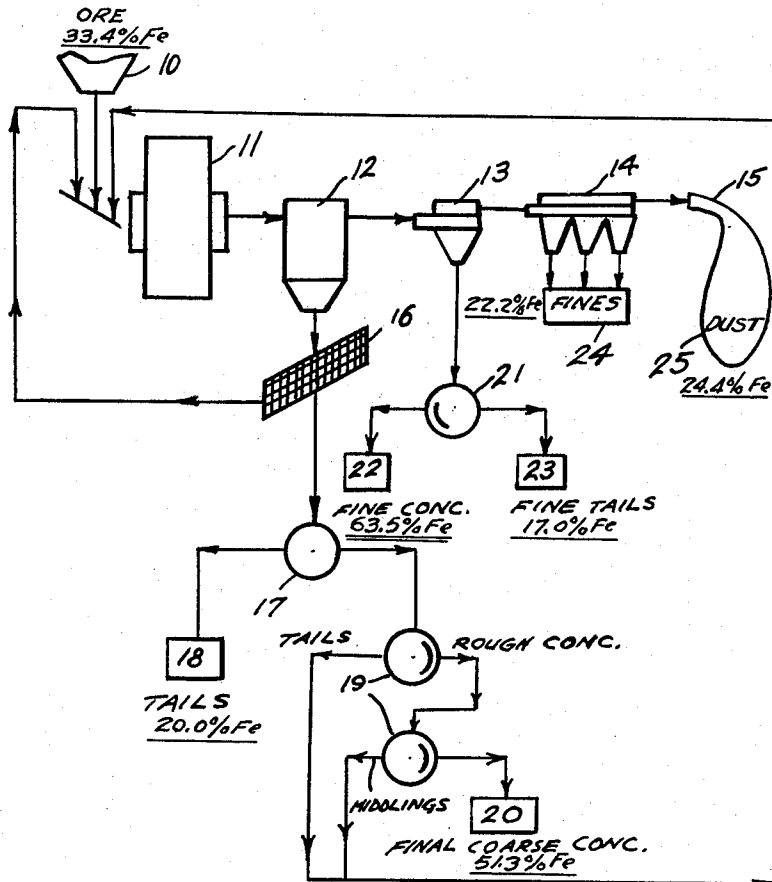


FIG. 1

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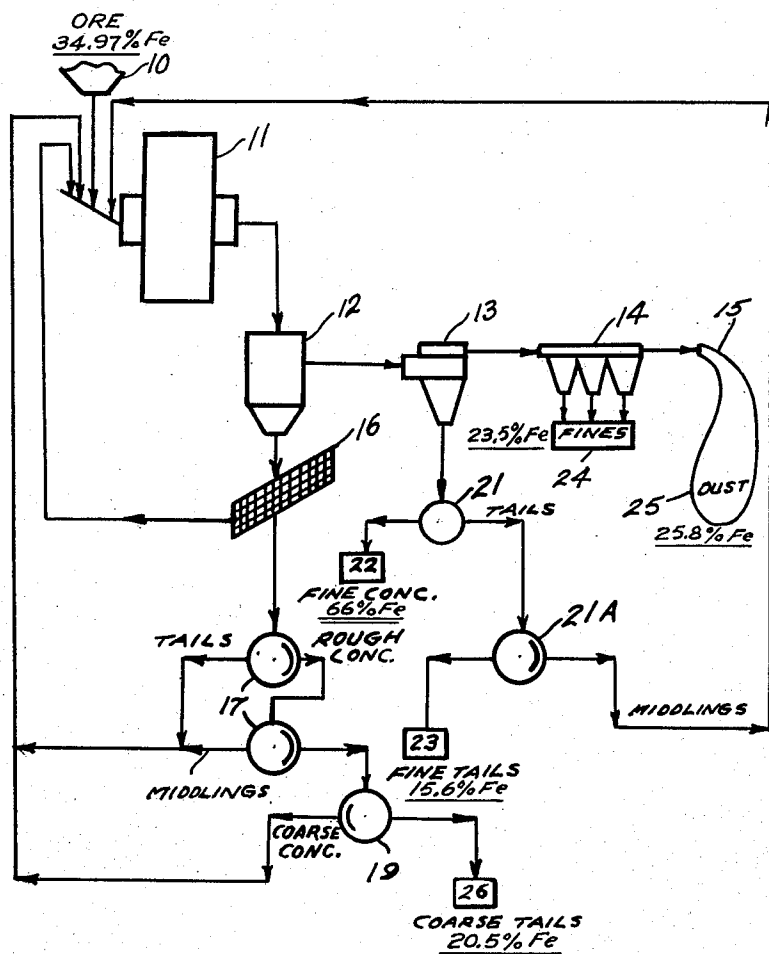


FIG 3

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1

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BENEFICIATION OF ORES

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This invention relates to methods of milling material in dry milling circuits and more particularly to a method of dry milling embodying concentration of values and the production of a beneficiated milling circuit product.

The method of the present invention while it applies particularly to the beneficiation of ores containing components amenable to magnetic separation has broad application to the beneficiation of all ore materials which are amenable to any form of concentration at a stage of reduction at which the values are contained in composite particles, rather than primary crystalline particles.

It has hitherto been the practice with such materials to continue comminution to a point where substantially all of the values have been reduced at least to the primary crystalline grain size (i.e. the particle size wherein the minerals are effectively liberated) and then to concentrate the values from the resulting primarily mechanical mixture of particles of values and gangue. The reduction of the material may be carried out according to these known methods either in a single pass through a series of reduction units or by employing one or more reduction units in which an oversize fraction of the product is recirculated.

I have now found that in the case of many minerals and notably in the case of magnetic iron ores the distribution of values in particles consisting of aggregates of primary crystals is nonuniform in nature so that a substantial percentage of such particles consist for the most of aggregates of crystals of values and a substantial percentage of such particles consist for the most part of aggregates of substantially barren gangue particles. I have further found that in specific cases it is possible to take advantage of this fact to produce a higher grade of concentrate with a concurrent saving in milling costs by removing a substantial proportion of the material from the milling circuit at a size range considerably above that desired in the final product, subjecting the thus removed material to concentration, e.g. magnetic concentration in the case of magnetic iron ores, and then returning the concentrate to the inlet side of the milling circuit along with the normal feed thereto, and in many cases discarding the tailing.

Preferably, according to the present invention, the milling operation is conducted in a combined dry crushing and grinding unit wherein the product is extracted in a stream of air. The mill is so adjusted that a substantial proportion of the material carried away from the mill by the airstream is within a size range coarser than that desired as a final product and a fraction (which may be considered a middlings in relation to the operation being conducted) is removed by air and/or mechanical classification and passed through a dry magnetic concentrator. The concentrate is returned to the inlet side of the mill while the tailing may usually be discarded as a coarse tailing containing only a very small amount of values.

The invention and its operation will be described in some detail as applied to the beneficiation of magnetic iron ores in the following detailed specification in which reference will be had to the accompanying drawings wherein:

2

Figure 1 is a schematic illustration of a typical flow sheet for the beneficiation of magnetic iron ores operating according to previously known principles.

Figure 2 is a schematic illustration of a flow sheet according to one embodiment of the present invention.

Figure 3 is a schematic illustration of an alternative embodiment of the present invention.

Referring now more particularly to the drawings in the conventional method of operation as illustrated in Figure 1 which is given for purposes of comparison, feed 10 is delivered to the combined dry crushing and grinding unit 11 which is an airswept mill discharging into an air classifier 12 which removes the oversize and permits the main product to pass to cyclone 13. After a deposit of the main product in cyclone 13 fines are collected in the multicyclone 14 and dust which is too fine for collection in the multicyclone 14 is collected in the bag filter 15. The air classifier 12 discharges on to the mechanical screen 16 and the oversize from the said screen is returned to the inlet side of the mill. The through product from screen 16 is passed to magnetic separator 17 which produces a final tailing 18 of low metal content (20.0% Fe) and a rough concentrate of higher metal content which is passed to a second magnetic concentrator 19, which latter produces a final coarse concentrate 20 containing 51.3% Fe and a minor proportion of tailings and middlings which are combined and recirculated to the inlet side of the mill 11. The main product from cyclone 13 is passed to a magnetic concentrator 21 which produces a final fine concentrate 22 of 63.5% Fe and fine tails 23 containing 17.0% Fe.

Typical results obtained operating in accordance with the flow sheet of Figure 1 are indicated in the following example.

Example 1.—A 5' by 2' combined dry crushing and grinding unit was brought into operating balance in accordance with the flow sheet illustrated in Figure 1 using as feed a low grade magnetic iron ore obtained from a deposit in Northern Quebec with a feed rate of 0.57 ton per hour and a velocity of air through the mill corresponding to a water gauge reading 1.5" at the mill outlet. The screen 16 was a 20 mesh screen and under balanced conditions the +20 mesh material returned to the mill from the top of screen 16 amounted to 5% by weight of the feed. The combined coarse tails and middlings returned from the magnetic concentrator 19 amounted to 2% of the total feed. The results of this run are illustrated in Table I:

Table I

Final Product	Percent Weight Based on Total Feed	Iron in Product		Soluble iron in product	
		Percent Iron in Product	Percent Weight of Feed	Percent Iron in Product	Percent Weight of Feed
Coarse Tails 18....	25.6	20.0	5.1	7.0 (approx.)	1.8
Coarse Conc. 20....	20.1	51.3	10.3	50.0	10.0
Fine Conc. 22....	17.5	63.3	11.1	62.3	10.95
Multicyclone 24....	4.4	22.2	0.98	14.0	0.62
Fine Tails 23....	26.5	17.0	4.5	9.0	2.38
Dust 25....	5.9	24.4	1.43	17.0	1.0

The same equipment was then operated under balanced conditions in accordance with the method of the present invention, and the results of these runs using the same ore is set forth in Examples 2 and 3.

Example 2 (see Figure 2).—The mill was brought into balance with a feed rate of 0.54 ton per hour with a velocity of air through the mill corresponding to 1.9" water gauge at the outlet side thereof. In this case, the amount of +20 mesh returned to the mill from the top of screen 16 amounted to 4% of the mill feed. In this

case, the magnetic concentrator 17 produces a middlings and a tailings which are combined and returned to the inlet side of the mill 11 and the concentrate from concentrator 17 is cleaned in a second magnetic concentrator 19 which produces a coarse concentrate which is returned to the inlet side of the mill and a final coarse tailing 26 which is discarded. The main product from the cyclone 13 passes to magnetic concentrator 21 which produces a fine concentrate 22 and a fine tailing which is passed to the further magnetic concentrator 21a where it is separated into a final fine tailing 23 and a middling which is recycled to a point just in advance of the cyclone 13.

With conditions in balance the amount of coarse concentrate and middlings recycled to the inlet of mill 11 from the magnetic concentrators 17 and 19 amounted to 50% of the weight of the feed 10. Results of a typical run are shown in Table II.

Table II

Final Product	Percent Weight Based on Total Feed	Iron in Product		Soluble iron in product	
		Percent Iron in Product	Percent Weight of Feed	Percent Iron in Product	Percent Weight of Feed
Coarse Tails 26.....	18.0	23.0	4.15	4.9	0.88
Fine Conc. 22.....	32.5	67.5	22.0	67.3	21.87
Fine Tails 23.....	33.6	15.2	5.9	4.8	1.85
Multicyclone 24.....	8.1	21.2	1.72	16.8	1.26
Dust 25.....	4.5	23.4	1.05	15.5	0.70

It will be noted from Table II with respect to fine concentrate 22 that 32.5% by weight of the product is obtained with an improved iron content of 67.5% by weight as compared to only 17.5% by weight of fine concentrate 22 in Table I with the lower iron content of 63.3% by weight. Thus, almost double the amount of a higher premium concentrate is obtained with the invention. Similar comparisons are indicated as to the soluble iron content.

Example 3.—The same equipment was brought into balance with the same ore in accordance with the method of operation illustrated in Figure 3 which differs from that shown in Figure 2 in that the middlings from magnetic concentrator 21a is returned to the inlet side of the mill rather than to a point in the collection circuit. In this case under balanced conditions the amount of the material returned from the concentrators 17, 19, 21a to the inlet side of the mill amounted to 100% of the feed 10 while the +20 mesh returned to the mill from screen 16 amounted to 4% of the feed 10. Under balanced conditions, the capacity of the mill was 0.54 ton per hour with a velocity of air through the mill corresponding to 2.2" of water at the outlet side thereof.

Results of a typical run operating under the above conditions are given in Table III.

Table III

Final Product	Percent Weight Based on Total Feed	Iron in Product		Soluble iron in product	
		Percent Iron in Product	Percent Weight of Feed	Percent Iron in Product	Percent Weight of Feed
Coarse Tails 26.....	23.4	20.5	4.8	6.2	1.44
Fine Conc. 22.....	34.0	66.0	22.5	65.0	22.0
Fine Tails 23.....	30.8	15.6	4.8	4.8	1.48
Multicyclone 24.....	6.9	23.5	1.61	14.6	1.01
Dust 25.....	4.9	25.8	1.26	17.0	0.83

Once again it will be observed that compared to the method of operation illustrated in Figure 1 the grade of concentrate is higher and the tailing losses lower. Com-

pared to the method illustrated in Figure 2 the result is a slightly lower ratio of concentration, and slightly higher loss in the coarse tailings owing to the higher air velocity used.

Examples 2 and 3 illustrate the advantages which may be gained in increased grade by the return of a coarse concentrate to the inlet side of the milling circuit. Comparable advantage may be achieved in similar manner on ores other than magnetic iron but which are subject to dry concentration when in a state of sub-division larger than their primary grain size. In the foregoing examples, magnetic concentration has been utilized, but it will be appreciated that, where applicable, use may be made of electrostatic concentration or any other form of dry concentration which may suit the particular material being treated.

What I claim as my invention is:

1. A method of beneficiating magnetic iron ores containing aggregates of substantially barren gangue particles and a non-uniform distribution of aggregates of primary crystals of the mineral to be recovered, said method comprising; passing the ore through a dry milling circuit, comprising a combined dry crushing and grinding mill and which is adapted to produce a substantial proportion of product in a size range larger than the primary crystal size of the contained mineral; collecting milling circuit product which is primarily of a particle size larger than the primary crystal size of said ore; subjecting said collected product to magnetic concentration to produce at least a coarse concentrate; and returning the coarse concentrate to the inlet side of said combined dry crushing and grinding mill.

2. A method of beneficiating magnetic iron ore of the type containing aggregates of substantially barren gangue particles and a non-uniform distribution of aggregates of primary crystals of the mineral to be recovered whereby magnetic concentration is effective to produce a discardable tailing when the ore is in a state of sub-division larger than its primary crystal size, said method comprising; passing the ore through a dry milling circuit comprising a combined dry crushing and grinding mill and which is adapted to produce a substantial proportion of product in a size range larger than the primary crystal size of the contained mineral; collecting milling circuit product which is primarily of a particle size larger than the primary crystal size of said ore; subjecting said collected product to magnetic concentration to produce at least a coarse concentrate and a discardable coarse tailing; and returning the coarse concentrate to the inlet side of said combined dry crushing and grinding mill.

3. The method as defined in claim 1 wherein the magnetic concentration stage produces a middlings which is also returned to the inlet side of the milling circuit.

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