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GRINDING AND HINDERED SETTLING CLASSIFICATION OF NATURALLY  
OCCURRING ORES ETC., BY DENSITY INDUCING CONSTITUENTS  
DERIVED FROM THE ORE ITSELF

Filed Feb. 27, 1948

2 Sheets-Sheet 1

Fig. 1.

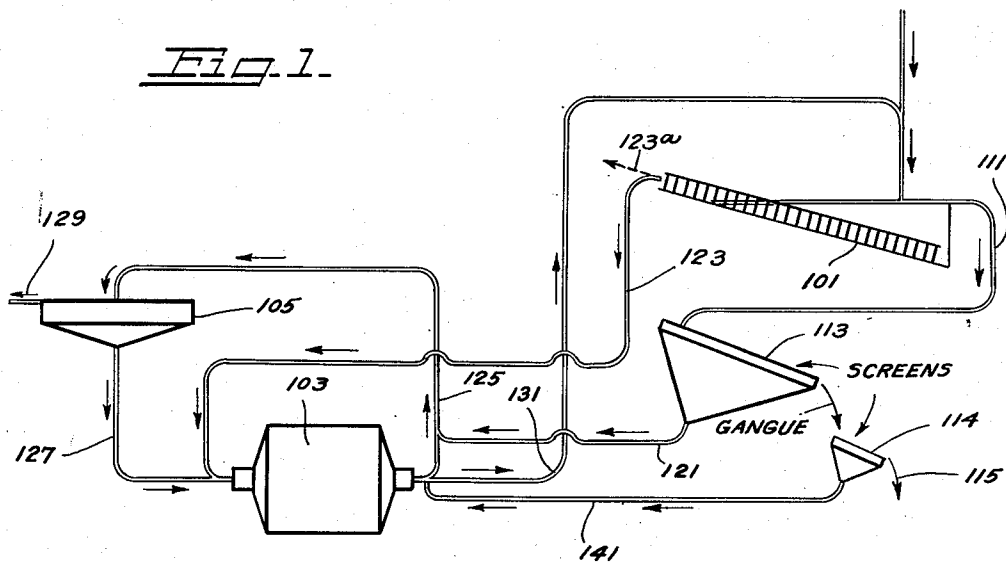
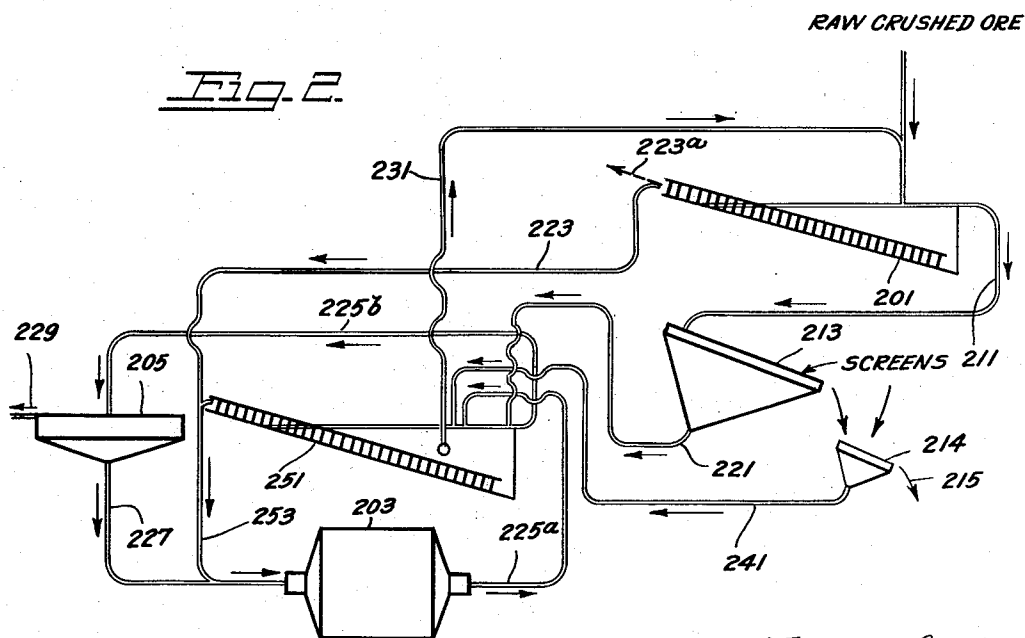


Fig. 2.



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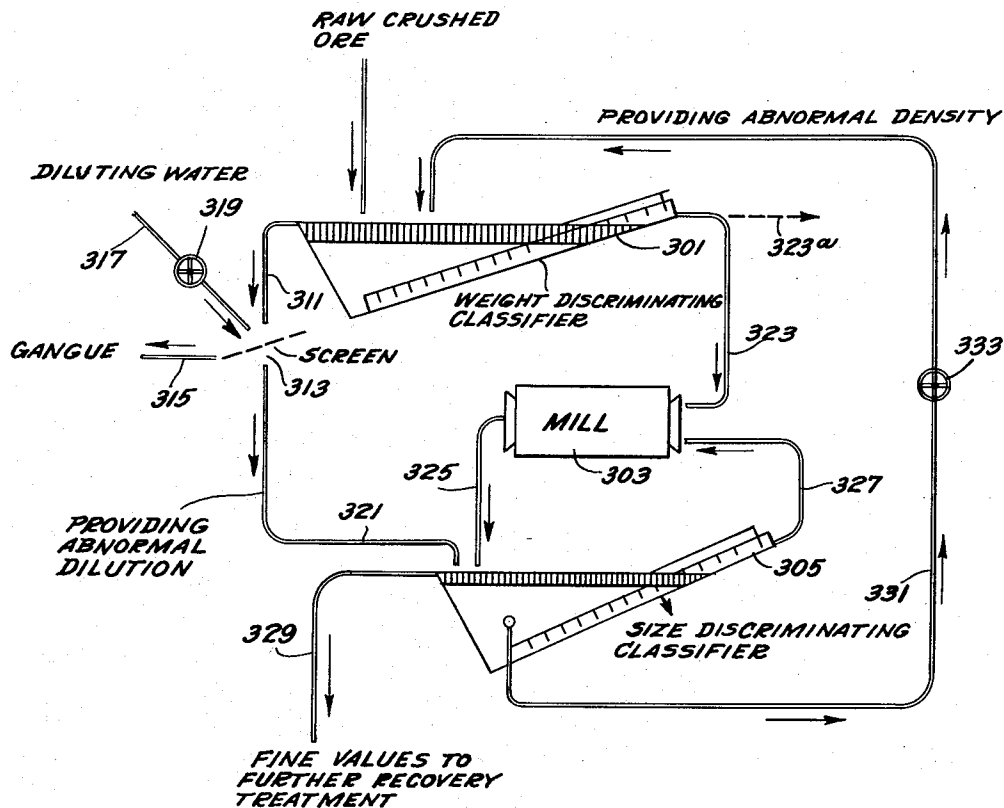
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Fig. 3.



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## UNITED STATES PATENT OFFICE

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## GRINDING AND HINDERED SETTLING CLASSIFICATION OF NATURALLY OCCURRING ORES, ETC., BY DENSITY INDUCING CONSTITUENTS DERIVED FROM THE ORE ITSELF

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Claims priority, application Sweden June 21, 1945

2 Claims. (Cl. 241—20)

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This invention relates to hindered-settling classification methods of fractionating naturally occurring mineral aggregates, or ores, into one fraction containing significantly valuable constituents of the ore, and into another fraction containing significantly gangue, or waste, constituents of the ore. Heretofore, the fractionating bath of suspended ore particles has had its density controlled by the addition thereto of some weighting agent that is extraneous or foreign to the ore, and which accordingly must be washed from the recovered values before final treatment. This invention, therefore, has as one of its main features, the control of the increased density of the weight-discriminating hindered-settling classification bath by density-inducing constituents derived from the ore itself.

The invention proposes the pretreatment of the ore during its beneficiation by subjecting it, prior to its being ground in the usual closed circuit grinding station to gravity-induced fractionation along hindered-settling classification lines, so that one fraction contains relatively light significantly gangue constituents of the ore and another fraction contains relatively heavy significantly metallic values of the ore that may be further treated for their recovery. A feature of novelty of the invention resides in controlling the increased density of the weight-discriminating hindered-settling classification bath by supplying thereto gravity-inducing constituents of the raw ore itself, drawn from any suitable point of the usual closed circuit grinding station including a size-discriminating classifier in which the ore values are being classified predominantly into size groups.

Values fractionated out from the crushed raw ore by the weight-discriminating bath, which have been substantially freed of gangue constituents by passing through that bath, are then supplied to the usual closed circuit grinding station, from which station the beneficiated ore values emerge after treatment in a predominantly size-discriminating or classifying bath so that they are of a particle size small enough to unlock or expose the values to facilitate the usual subsequent values-recovery treatment steps.

A usual closed circuit grinding station comprises a fine-grinding mill that discharges into an agitating classifier having a sloping bottom or deck adapted to hold a predominantly size-discriminating bath of the ore particles in suspension. Agitating rakes rake the settled larger or coarser sized particles usually called sands,

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along the inclined deck to emergence as the rake product or fraction. Overflowing the weir of the classifier, is a fraction of finer or smaller sized particles in suspension, usually called fines. The coarser particles or sands are fed back to the grinding mill for regrinding, while the overflowed fines are passed on to any desired further treatment for the recovery of their values, such as by flotation processes, not forming a part of the present invention.

From the suspension of heavy value-bearing ore particles being classified predominantly according to size in the bath of the classifier in the closed circuit grinding station, there is drawn a quantity of such intermediates in suspension and this is recycled to the weight-discriminating bath in the pretreatment station. Since these intermediates in suspension are gravity-inducing, they are recycled in such quantity and at such a rate in a suspension of such a density as to control the total density or specific gravity of the weight-discriminating bath to the desired value. The weight-discriminating bath has been found to work satisfactorily when maintained at a specific gravity of substantially 2.6 for a pyrite suspension. It will be understood that this value will vary with different minerals undergoing treatment, a normal upper limiting value in any given case corresponding to that for a solids content of approximately 40% by volume, since with a considerably higher solids content the resulting suspensions are generally regarded as too plastic to be used satisfactorily. For example, as just indicated, a pyrite suspension of 40% solids by volume constitutes a pulp having a specific gravity of 2.60; a galena suspension of the same solids content corresponds to a pulp with specific gravity of 3.60; and a sand suspension (for coal separation) of the same solids content corresponds to a pulp with specific gravity of 1.64.

More particularly then, this invention uses the hindered-settling principle to segregate raw ore into a lighter fraction made up significantly of gangue constituents and into a heavier fraction made up significantly of valuable constituents, but the novelty resides principally in that the density of the hindered-settling classification bath in the weight-discriminating classifier is controlled by a fraction derived from the very ore undergoing treatment rather than by the addition of some foreign weighting substance that subsequently must be removed from the ore prior to its final treatment. The novel treatment of this invention is applicable therefore to many

ores in which there is a substantial difference between the specific gravity of the desired mineral and that of the unwanted gangue, but more particularly to massive sulphide ores and to iron ores where the heavy mineral comprises a substantial proportion of the total weight. The improved method is especially applicable to such massive ores where the heavy minerals have a higher grinding resistance than the gangue and thereby cause an accumulation of such a pulp in the closed circuit which is enriched in heavy minerals. The method is also applicable to coal cleaning and to so-called non-metallic ores carrying a relatively heavy mineral such as fluor-spar.

Another feature of this invention relates to the manner of controlling the density of the bath in the size-discriminating classifier (namely, its dilution) thereby determining the particle size above which particles settle and emerge as rake product or sands, and below which the fines pass as overflow. In other words, the line of size division between the two fractions is determined by the dilution of the bath of that classifier. The more dilute the bath the smaller or finer will be the particles of the overflowing fraction, and conversely. The diluting water supplied to that bath, in a closely controllable manner, comprises the water used to flow through the screen or screens that make screened fractions of the overflow (principally gangue material) from the weight-discriminating classifier. Thus, the bath in the weight-discriminating classifier is controllably rendered sufficiently dense while the bath in the size-discriminating classifier is controllably rendered sufficiently dilute—both by the use of constituents present in the cyclic system and not involving the addition of constituents extraneous or foreign to the ore. The said dilution in the size-discriminating classifier gives a high content of heavy finer particle values in the intermediates bled off from the bath of that classifier to be supplied as weighting agents to the bath in the weight-discriminating classifier.

By way of a more detailed explanation of these and other features of my invention, reference is made to the following description taken in conjunction with the accompanying drawings in which:

Figures 1, 2 and 3 are diagrammatic flow sheets of ore concentration plants according to the present invention. In these diagrams three-digit reference numerals are employed for convenience, the first digit indicating the figure number while the last two digits, when identical in the several figures, serve to designate functionally equivalent apparatus elements.

Referring to Figure 1, raw crushed ore is introduced into a weight-discriminating classifier 101 where the lighter gangue constituents are separated and overflow via line 111 while the heavier, and valuable, ore values are removed by means of the rake of the classifier and discharged through line 123. The values leaving via line 123 are introduced into the grinding system of the ore dressing arrangement, which grinding system includes the fine grinding mill 103 and the size-discriminating classifier 105, which may be for example, of the hydro separator type. The values introduced via line 123 are mixed with the larger sized particles removed from the size-discriminating classifier 105 via line 127 and are introduced into the mill 103, where the particles are suitably reduced in size.

Effluent from the grinding mill 103 is intro-

duced via line 125 into the size-discriminating classifier 105, wherein classification predominantly into size groups takes place. The fine values are removed via line 129 for further recovery treatment (not shown) and the relatively coarser particles are returned via line 127 to the grinding mill for further treatment in the grinding circuit.

A portion of the effluent from the mill 103 is introduced via line 131 into the bath of the weight-discriminating classifier 101, where this portion functions as the gravity-inducing constituent imparting the desired density to the bath in order to permit the desired separation of the raw crushed ore in the classifier 101 on the basis of weight or density to take place.

Returning to the gangue which is removed from the weight-discriminating classifier 101 via line 111, this gangue material together with the pulp introduced into the classifier via line 131 and most of the fines possibly present in the new crushed ore supplied, is introduced into one or a plurality of screens 113 and 114 where it is subjected to washing with water (from a source not shown), the final gangue after washing being withdrawn through line 115 and rejected. In order to provide the proper dilution of the bath in the size-discriminating classifier 105, all or a portion of the wash water from screen 113 may be introduced via line 121 into the grinding system together with substantially all the returning pulp and said fines. More particularly, in the embodiment shown this pulp with wash water may be admixed with the material passing via line 125 from grinding mill 103 to the size-discriminating classifier 105.

Meanwhile, and in order to maintain proper density in the bath of the weight-discriminating classifier 101, the gravity-inducing constituents therefor are introduced via line 131 in the form of a suspension in all or a portion of the wash water resulting from the second screening operation. For example the wash water from the washing of the gangue on screen 114 may be introduced via line 141 into the grinding system at a point just ahead of the place from which the gravity-inducing substituents are withdrawn via line 131 for introduction into the bath of the weight-discriminating classifier 101. As in the case of the first screen 113, the second screen 114 is supplied with water from a source not shown.

It will thus be observed that in this ore dressing system the wash water (together with pulp) from one or both of the screens 113 and 114 is used in such manner as to make it possible readily to control the density of the gravity-inducing constituents introduced into the weight-discriminating classifier 101. Furthermore, the introduction into the closed grinding circuit of a portion of the wash water (together with pulp) via line 121 makes it possible readily to control the dilution in the size-discriminating classifier 105, which dilution in turn permits an excellent control over the particle size of the fine values of the ore removed via line 129 to further recovery treatment (not shown).

Figure 2 shows another modification of an ore dressing system which closely resembles that of Figure 1 and in which corresponding reference numerals have been employed, with the exception that here the reference numerals are of the "200" series rather than the "100" series as in Figure 1. The essential difference between the system of Figure 2 and that of Figure 1 is that in the former a separate classifier 251 is inserted in

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the closed grinding system in order to provide a preliminary separation of the coarser of the particles resulting from the grinding operation in grinding mill 203 and thereby to provide a more stable suspension for the weight-discriminating bath.

Thus, in this modification the suspension of ground particles withdrawn from mill 203, instead of being returned directly to the size-discriminating classifier 205 (as in the system of Figure 1), is introduced into the bath of the classifier 251, thereby permitting a smoother operation in that occasional possible variations of the amount of pulp supplied and of the consistency of the mill materials are equalized, as well as further permitting any unduly coarse materials that pass through the mill 203 without being reduced to a suitably fine size to be removed prior to introduction thereof into the size-discriminating classifier 205.

It will be observed that the suspension of materials leaving grinding mill 203 is introduced via line 225a into the bath of the classifier 251. The relatively coarser particles separated in this classifier are returned via line 253 to the mill 203, together with emerged sands of heavier particles from the weight-discriminating classifier 201 that are fed to the grinding system via line 223. Finally, the relatively coarser particles from the size-discriminating classifier 205 are also returned to the mill 203 via line 227 to complete the circuit of materials in the grinding system. The relatively fine particles that are separated in classifier 251 overflow therefrom and are introduced via line 225b into the size-discriminating classifier 205.

In order to adjust to the desired value of the density of the bath in the weight-discriminating classifier 201, a portion corresponding to said desired value of the bath containing gravity-inducing constituents is removed from the classifier 251 and introduced via line 231 into the bath of the weight-discriminating classifier 201. I prefer to remove this portion from a point below and spaced from the level of the bath in the classifier 251.

The relatively light gangue material overflowing from the weight-discriminating classifier 201, and removed via line 211, is washed on screens 213 and 214 with water from a source not shown. All or a portion of the wash water from screen 213 is introduced together with pulp into the classifier 251 via line 221, thus enabling the desired dilution in the size-discriminating classifier 205 ultimately to be obtained. Also additional amounts of wash water from the second screen 214 may be introduced into the bath of the classifier 251 via line 241. The washed gangue material is withdrawn from the screens via line 215 and rejected.

According to Figure 3, the ore treating system includes a weight-discriminating classifier 301 which may, for example, be of the rake type, a suitable grinding mill 303, which may be of the ball mill type, and a size-discriminating classifier 305, which may also be of the rake type. Receiving the overflow from the weight-discriminating classifier 301 via line 311 is a screen 313 that provides screened (and washed) fractions of the overflow from the weight-discriminating classifier 301. The worthless, or relatively worthless, gangue obtained as a result of the screening operation is rejected via line 315. Line 317 provided with a suitable valve 319 serves to introduce wash water to assist in the screening and

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washing operation applied to the gangue derived from the overflow from the weight-discriminating classifier 301. The wash water from this screening operation, which is employed for dilution purposes as described more fully hereinafter, may be introduced together with the pulp returning from the classifier 301 via line 321 to the size-discriminating classifier 305.

Returning to the weight-discriminating classifier 301, the emerged sands or heavy particles separated thereby are introduced via line 323 to grinding mill 303 where they are suitably reduced in size. The ground particles leaving this mill are then introduced via line 325 into the bath of the size-discriminating classifier 305 wherein separation of the ore values predominantly into size groups takes place.

The emerged sands or coarse particles from the size-discriminating classifier 305 are recycled to mill 303 via line 327, while at the same time the fines are removed as overflow via line 329. These fines may then be taken to a further recovery treatment which forms no part of the present invention, e. g., an ore flotation process.

Returning to a consideration of the operation of the size-discriminating classifier 305, a suspension of the heavy values-bearing ore particles undergoing classification predominantly into size groups is withdrawn from the bath therein via line 331 provided with a suitable valve 333, and is introduced into the bath in the pretreatment station, namely, the bath contained in the weight-discriminating classifier 301. By a suitable adjustment of valve 333, either alone or in conjunction with a suitable adjustment of the rate of introduction of wash water which is introduced together with pulp into the bath of the size-discriminating classifier 305 via line 321, the desired density or specific gravity of the bath in the weight-discriminating classifier 301 is obtained.

Summarizing the operation according to Figure 3, the raw crushed ore undergoing treatment is introduced into the weight-discriminating classifier 301, where the coarse particles are separated into light gangue particles and heavy values particles. The former pass over together with fine particles possibly occurring in the raw crushed ore supplied and with pulp into the overflow via line 311, while the latter pass via line 323 to mill 303 where they are suitably reduced in size and then introduced into the size-discriminating classifier 305. The gangue particles are then washed on screen 313 while adding sufficient diluting water via valved line 317 to provide a wash water, which, when introduced into the bath of the size-discriminating classifier 305 via line 321, will provide the desired dilution of the latter bath in order to effect the separation of the heavy ore values into fine particles of the desired size which pass over into the overflow via line 329, while permitting the coarser particles to be removed as rake product and recycled via line 327 to the mill 303.

In the meantime a portion of the bath in the size-discriminating classifier 305 is removed and cycled via valved line 331 to the weight-discriminating classifier 301. By a suitable adjustment of the dilution obtained by means of the wash water introduced via line 321, as well as the rate of cycling of material through line 331, the bath in the weight-discriminating classifier 301 is adjusted to the desired density to effect the desired preliminary separation of light gangue from heavy ore values, all without the introduction of any extraneous or foreign material into any part

of the system—other of course than diluting water via line 317.

By way of summary, it will be observed that the three ore dressing systems that have been described are characterized by the common feature that they permit the ore dressing operations to take place without requiring the addition into the system of weighting or separating agents that are extraneous or foreign to the ore and which ultimately must be removed from the beneficiated ore before final treatment. Thus the weight-discriminating classifiers 101, 201 and 301 of Figures 1, 2 and 3, respectively, are supplied with a suspension of gravity-inducing constituents that are derived from the ore itself introduced to the respective classifiers via lines 131, 231 and 331, respectively. Furthermore, the desired dilution in the size-discriminating classifiers 105, 205 and 305 is brought about by the introduction of wash water obtained during the washing operation and performed upon the gangue material that overflows from the weight-discriminating classifiers 101, 201 and 301, respectively, this wash water being introduced in part at least into the baths of the size-discriminating classifiers via lines 121, 221 and 321, respectively. Moreover, the ore dressing system shown in Figure 3 illustrates more specifically additional features of control whereby a suitable adjustment of the valve 319 in the line 317 to which the diluting water for washing the gangue is introduced into the system, either alone or in conjunction with a suitable adjustment of the valve 333 in the line 331 through which is cycled the gravity-inducing constituents to the bath of the weight-discriminating classifier, provides very close control over all parts of the ore dressing system.

It will be appreciated of course that the optimum rates of supply of wash water to the system and of return of density-inducing constituents from the bath of the size-discriminating classifier to the bath of the weight-discriminating classifier will depend in any given instance upon the nature of the particular ore that is undergoing treatment. Those skilled in the art will be readily enabled to arrive at these optimum values in any such given instance with the aid of the description of the invention set forth herein.

When treating some massive ores, material from the coarse ore separated from gangue in the weight-discriminating classifier 101, 201 or 301 respectively (Fig. 1, 2 or 3 respectively), in line 123, 223 or 323 respectively may be removed as a finished product as shown in the drawings with the dashed lines 123a, 223a or 323a respectively. In this case said material is not supplied to the grinding mill and the closed circuit grinding system will only work with the fine part of the raw crushed ore which has overflowed from the weight-discriminating classifier 101, 201 or 301 respectively and, via line 111, 211 or 311 respectively and line 121, 221 and 321 respectively, past the screens and been introduced into the closed circuit grinding system. In this case the raw crushed ore is divided into one coarse finished ore, one rejected gangue and one intermediate part which after grinding in the mill 103, 203 or 303 respectively is removed for further recovery treatment via lines 129, 229 or 329 respectively.

This application is a continuation-in-part of my copending application Serial No. 676,220, filed June 12, 1946, now abandoned.

While various specific examples of preferred methods embodying the present invention have

been described above, it will be apparent that many changes and modifications may be made in the procedure herein described without departing from the spirit of the invention. It is therefore to be understood that the particular procedures set forth above are intended to be illustrative only and are not intended to limit the scope of the invention as defined in the following claims.

I claim:

1. The process of beneficiating ores by separating them into fractions respectively richer in valuable and in waste constituents of the ore, which comprises supplying the raw crushed ore to a bath containing a dense suspension flowing through the bath, the density of the suspension and its rate of flow being controlled to maintain the density intermediate the densities of the constituents of the ore; removing from said bath a lighter fraction of the ore as finished product; supplying to a closed circuit grinding system the more dense fraction of the ore, said closed circuit grinding system including a grinding zone and a classification zone having predominantly size-discriminating capabilities for yielding one fraction of an overflowed suspension of finer solids and another fraction enriched in larger and heavier solids; recycling said fraction of larger solids to said grinding zone and recovering the fraction of finer solids for further treatment; and recycling to said bath containing the dense suspension a portion of the finer material circulating from the classification zone of the closed circuit grinding system and containing as predominant constituents the said finer enriched fraction, the aforesaid dense suspension flowing through the said bath containing the dense suspension for separating by gravity the coarse material of the ore initially supplied into two fractions of substantially different specific gravities, the density-inducing constituents of the said dense suspension being derived exclusively from the ore undergoing treatment; the lighter fraction from the bath containing said dense suspension being subjected to screening, and the resulting finer ore particles being supplied to the bath of said classification zone having predominantly size-discriminating capabilities.

2. The process of beneficiating ores by separating them into fractions respectively richer in valuable and in waste constituents of the ore, which comprises supplying the raw crushed ore to a bath containing a dense suspension flowing through the bath, the density of the suspension and its rate of flow being controlled to maintain the density intermediate the densities of the constituents of the ore; removing from said bath a lighter fraction of the ore as finished product; supplying to a closed circuit grinding system the more dense fraction of the ore, said closed circuit grinding system including a grinding zone and a classification zone having predominantly size-discriminating capabilities for yielding one fraction of an overflowed suspension of finer solids and another fraction enriched in larger and heavier solids; recycling said fraction of larger solids to said grinding zone and recovering the fraction of finer solids for further treatment; and recycling to said bath containing the dense suspension a portion of the finer material circulating from the classification zone of the closed circuit grinding system and containing as predominant constituents the said finer enriched fraction, the aforesaid dense suspension flowing through the said bath containing the

dense suspension for separating by gravity the coarse material of the ore initially supplied into two fractions of substantially different specific gravities, the density-inducing constituents of the said dense suspension being derived exclusively from the ore undergoing treatment; the bath of the size-discriminating classification zone being supplied with wash water derived by washing the lighter fraction of the waste constituents at a rate such as to dilute said bath to a value such as to effect separation as between fine and coarse ore values having a predetermined size.

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