Feb. 8, 1938. J. J. DENNY ET AL. 2,107,289

CONCENTRATION OF MINERALS

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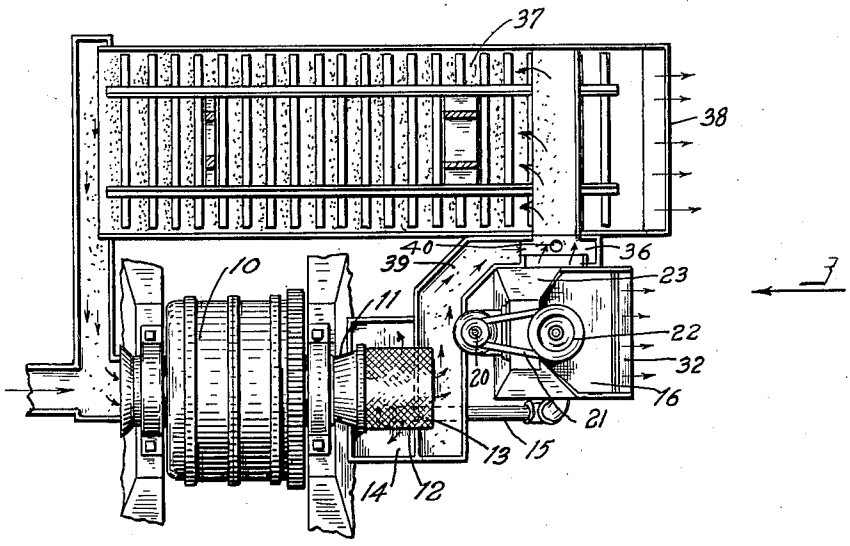


FIG. 1.

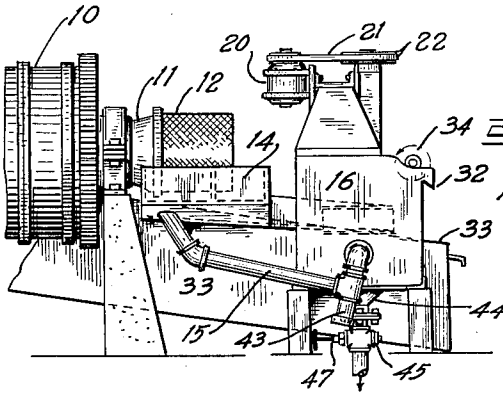


FIG. 2.

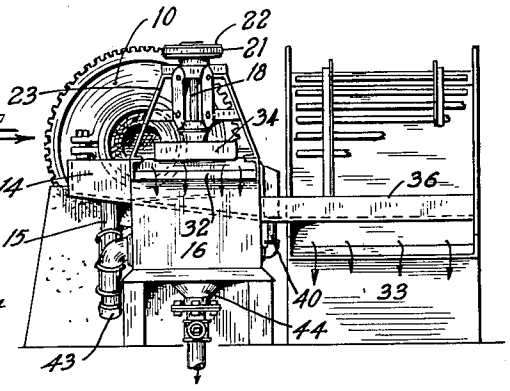


FIG. 3.

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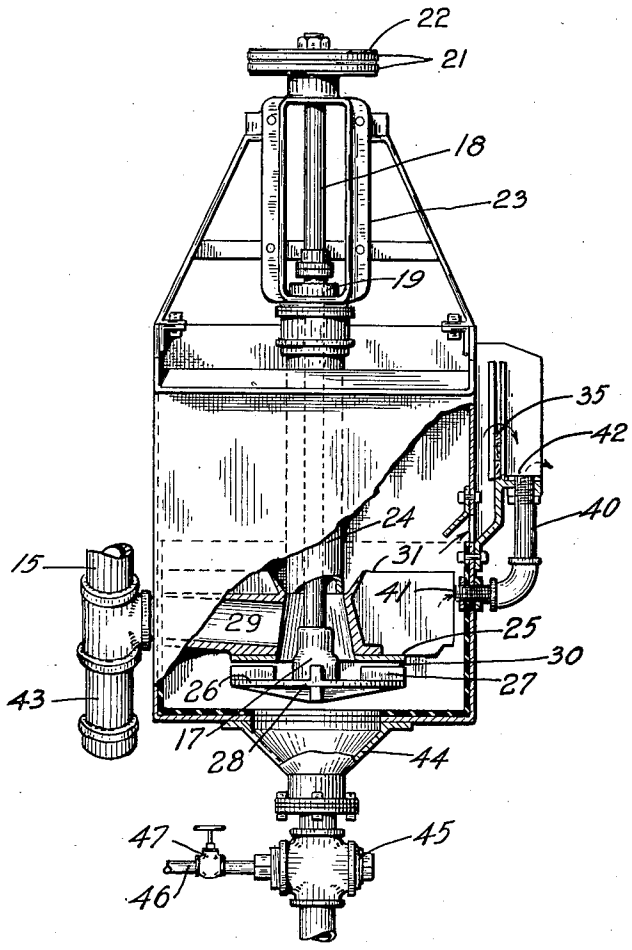


Fig. 4.

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CONCENTRATION OF MINERALS

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10 Claims. (Cl. 209—12)

This invention relates to mineral concentration and aims to improve mineral recovery and reduce concentration costs.

The nature of the invention may be readily understood by reference to one embodiment illustrated in the accompanying drawings.

In said drawings:

Fig. 1 is a plan view showing a grinding mill concentrating unit and classifier in closed circuit, certain conventional apparatus being shown diagrammatically to facilitate illustration;

Fig. 2 is a side elevation of the apparatus as viewed in the direction of the arrow 2 in Fig. 3;

Fig. 3 is an end view of the apparatus in the direction of the arrow 3 in Fig. 1; and

Fig. 4 is an elevation, partly in section, of a flotation cell.

In concentrating minerals according to the present invention, treatment of the ore is undertaken while the mineral is in coarse condition and as soon as a portion of the mineral is freed from the gangue. In other words, the crushing or reduction of the ore is not carried to a point where substantially all of the mineral is free (thereby resulting in an excessive pulverization of most of the mineral) but need be carried to a point where only a relatively small fraction of the mineral is free, before it is delivered to the concentrating unit. This procedure avoids both the expense of unnecessary grinding of the ore and (what is even more important) the production of a high percentage of very fine, unrecoverable mineral (slimes,—which have heretofore been the source of the greatest loss of mineral) which is inevitable with continued grinding and regrinding. In prior practices where the mineral has all been ground to substantially minus three hundred twenty-five mesh, it has been necessary to recirculate the ore through the grinding mill from two to eight times, inevitably resulting in the production of a large percentage of unrecoverable slimes and excessive mineral losses, notwithstanding the fact that about 40% of such mineral may be recovered without further regrinding by an improved concentrating unit. Prior efforts to reduce the loss through slimes have been far from successful.

As here shown, ore is delivered from the ore bins into grinding apparatus here represented by a ball-mill 10 and is there ground until a fraction of the mineral is free, which for purposes of the illustrative process occurs when the ore will pass a one-quarter inch mesh screen. The size of the ore generally varies from three to six mesh depending somewhat upon the specific gravity of the ore and the character of the particles of ore. The percentage of material of coarse mesh will also vary with the character of the ore. It will be understood that even when grinding ore to minus one-quarter inch mesh, a large percentage of it will be much finer. Nevertheless the production of slimes is very substantially limited. A small percentage of material in the form of tramp iron, broken balls, pieces of wood, etc. will exceed the limiting mesh size and for that reason the discharge end 11 of the mill is provided with a screen or trammel 12 having a limiting size mesh screen. The oversize material discharges at the open end 13 of the screen and is returned for regrinding as presently described. Ground mineral of minus one-quarter inch (or whatever the limiting size of the screen be) passes through the screen and into a launder 14 together with such water as is fed into the grinding mill. This amount is relatively small and produces a concentrated pulp which in some instances may not be sufficiently dilute for treatment in the present concentrating unit, in which case additional water may be added at an appropriate point. From the launder the pulp passes by gravity through the feed pipe 15 into the concentrating unit (see particularly Fig. 4).

The concentrating unit is here illustrated in the form of a flotation unit which, as presently explained, may also function in cyanide and amalgamation processes mainly as an agitator in which the froth is either incidental or absent. The illustrative flotation unit is of the subaeration type employing a gravity feed principle which eliminates clogging of the apparatus through accumulation of heavy sands in its bottom. As will presently appear, the settling of heavy sands on the shut-down of the apparatus will not clog the feed and prevent a resumption of operation. In detail the flotation cell comprises a box-like container 16 adjacent the bottom of which is supported a rotary impeller 17 which serves to effect a thorough mixing of the pulp with air (aeration of the pulp). The impeller is in the present case supported from above by a rotary drive shaft 18 provided with appropriate vertically adjusted thrust bearings 19 which carry the weight of the shaft and the impeller and permit appropriate vertical adjustment of the latter when required by ensuing wear. The drive in this instance is from motor 20 through one or more V-belts 21 to pulley 22 on shaft 18. The motor bearings etc. are carried by an appropriate substructure 23 mounted upon the cell. Surrounding shaft 18 and extending from a point

above the froth level to a point just above the impeller, is a sleeve 24 whose internal diameter is substantially larger than that of the shaft to provide a substantial air passage through which air may pass directly to the impeller 17. At the lower end of the sleeve and supported thereby is a horizontally extending plate 25 located just above the impeller and serving as a hood over the impeller to prevent free access thereto of the pulp in the upper portion of the cell and relieving the impeller of the load of such pulp.

The impeller is here shown in the form of a circular plate 26 having on its upper face a plurality of radial vanes 27 (four in the present instance). In the present instance the impeller is also provided on its lower face with a plurality of tapered vanes 28 which gradually taper down toward the edge of the plate. The impeller may advantageously have rubber wearing surfaces since these are much better able to withstand the abrasive action of the pulp than is metal and greatly outlives metal impellers.

The pulp is fed to the impeller through the conduit 29 which leads from the pipe 15 to the sleeve 24 at a point above the impeller and thereby discharges the pulp by gravity upon the impeller where it is intimately mixed with the air and the combined pulp and air thrown outwardly and thence upwardly by the centrifugal action of the impeller. The vanes 27 are preferably adjusted so as to provide a substantial clearance 30 below the hood 25 so as to increase the violence of agitation of pulp and air by causing the pulp to cascade over the successive veins and thereby secure a more efficient incorporation of the air in the pulp. Submerged vertical baffles 31 prevent swirling action of the pulp which might disturb the quiet zone in the upper portion of the cell and the froth layer, without however interfering with the velocity of the rising currents of pulp.

The froth carrying the mineral concentrate discharges the froth lip 32 into launder 33. A rotating paddle wheel 34 is advantageously provided to assist in discharge of froth. The mineral concentrate in launder 33 may be delivered either to storage or to subsequent treatment by cyanidation, amalgamation, etc. If for special reasons the grade of the concentrate may advantageously be improved, it may be reground and refined or cleaned by further flotation. Generally further refinement is undesirable since the concentrate originally recovered is of sufficiently high grade that it cannot economically be further refined by regrinding and reflotation.

The tailings discharge over a vertically adjustable weir 35 (which is below the froth level) into a launder 36 by which they are conducted to the classifier 37 in closed circuit with the grinding mill 10.

The classifier here shown is of a mechanical type such as a conventional Dorr classifier. Its details are well known and need not be described here except to note that its function is to return heavy sands to the grinding mill and allow finely ground gangue and mineral to overflow at the overflow 38 for delivery generally to batteries of flotation machines. The pitch of the bottom of the classifier as well as the speed of the rakes largely determine the fineness of a given ore which passes over the overflow. In this connection it is well to note that the mineral which is generally much heavier than the gangue (such as silica) will not be carried over the classifier overflow until it is much more finely ground than the gangue. This characteristic of classifier operation materially contributes to excessive grinding of free mineral and production of slimes.

While attempts have heretofore been made to minimize regrinding of freed minerals by the interposition of a shaking table (Wilfley table) in closed circuit with a classifier and grinding mill, this has not been entirely successful and its use is not general. The principle of operation of the shaking table does not result in the removal of large particles of mineral which because of their flaky condition or large area (as compared with volume) prevents their discharge with mineral concentrate. Such large mineral particles although readily floatable and recoverable in the present flotation machine, are discharged by a table as middlings or tailings to be unnecessarily reground.

It is evident from the foregoing that the operation of the grinding mill classifier and unit flotation cell in closed circuit results in the removal of the mineral as and when it is free without the necessity of regrinding. The oversize particles of mineral which discharge through the open end 13 of the screen are returned of course through the passage 39 to the classifier. This operation results in a reduction of almost 50% of the amount of finely ground mineral produced in which practically all of the mineral is ground to minus three hundred twenty-five mesh before it is delivered to flotation machines for concentration. The reduction in the production of unrecoverable slimes is of course greater since the production of slimes is a cumulative process which is greatly aggravated by frequent regrinding. The improved results are of course most significant in the reduction by over 50% of mineral lost in waste waters. About 60% of the total mineral delivered to the grinding mill is recovered in the unit flotation cell, the balance carried in the overflow by the classifier is removed on subsequent treatment.

To improve the character of the froth in the flotation apparatus, a sand relief passage is provided directly in line with the impeller discharge to carry off heavy sands which tend to build up in a sand stratum before leaving the flotation cell. A sand stratum of this character occurs in the upper portion of the cell and is made up of the heavier sands carried upwardly but which before being carried away collect in a sand stratum below the froth layer and intend to impair the quality of the froth level. The sand relief passage in the present case is shown in the form of a pipe 40 whose inlet end 41 is opposite the periphery of the impeller where the pulp currents obtain their maximum velocity. The sand relief pipe leads to the tailings launder 36 but terminates at 42 below the level of the overflow weir 35. The difference in liquid level between the overflow weir and the discharge end 42 of the pipe produces a small hydraulic head which contributes to an increased flow through pipe 40. The pipe is of a size sufficient to carry away about one-quarter of the heavy sands, that being sufficient to prevent a concentrated sand stratum in the cell.

In very heavy ores, such for example as gold, large sizes of high grade ore (which therefore have high specific gravity) may be too heavy to be carried by flotation. These may be removed by the use of a collecting pocket 44 at the bottom of the cell which is here shown in the form of a cone in which the heavy mineral may collect and be occasionally removed. The pulsating effect

produced by the ribs on the under face of the impeller (see Fig. 4) aids in separating out heavy and oversize mineral. The cone is closed at its bottom by an appropriate valve here shown in the form of a plug valve 45 which may be opened from time to time to permit the collected ore to fall out. In gold ores, for example, the value of the high grade ore thus collected is substantial.

Since in most instances the pulp feed is not sufficiently dilute for flotation machine operation, water is generally added and if a collecting pocket be used on the cell, the water may be conveniently added at this point so that its upward flow tends to wash the ore and carry up any smaller and lighter particles of ore found trapped with the heavy high grade ore. Such water may be introduced through pipe 46 and its rate of flow controlled by valve 47.

In some installations a jig 43 may advantageously be interposed in the feed line to take out tramp steel and large, heavy pieces of ore which because of a defect in the screen or otherwise, invariably find their way into the feed. The tramp steel is thereby prevented access to the cell and excessive abrasion of the rubber impeller and rubber cell lining is avoided. In the absence of a jig, such heavy material would of course be collected in the pocket 44. The jig is preferably of a conventional hydraulic type and its details are unimportant here.

The effective incorporation of air in the pulp renders the apparatus advantageous also in the cyanide process which requires an aerated pulp for efficient operation. Minerals, such as copper sulphide, which are cyanicides, i. e. have a detrimental effect on the cyanide process, may be concentrated in a froth on the pulp and this removed and prevented from interfering with the cyanidation. In the amalgamation process, coarse gold is removed in the collecting pocket 44 and such froth as may be formed without the usual oil (oil being detrimental in the amalgamation process) is likewise removed.

In connection with the present illustrative construction, it should be noted that the pumping action of the impeller eliminates both the use of auxiliary pumps to reelevate pulp and the loss of head room which would result if the material traveled solely by gravity flow. The loss of head occurring from the grinding mill inlet to the bottom of the flotation cell is more than made up by the action of the impeller which elevates the tailings discharge to a point (i. e. the weir overflow) where the tailings may flow by gravity back into the classifier. In some installations a greater gain in elevation than can be effected by a single cell may be desired. In that case a plurality of cells each higher than the preceding one may be placed in series, each elevating the pulp to the next.

It should be understood of course that the economies above pointed out do not result merely from the use of a concentrating unit at the discharge end of the grinding mill but the operation of the grinding mill so as to deliver a coarse mesh material to the unit and the use of a unit capable of handling heavy coarse mesh material ore. Obviously a unit which could not handle coarse heavy particles would be inappropriate in the system since it would eventually clog up no matter how small the percentage of heavy particles. It should be understood that the present flotation apparatus is capable not only of floating coarse particles but coarse particles of heavy minerals. Obviously the maximum size of the particles (assuming them to be generally of spherical shape and not flaky in character) depends upon the specific gravity of the mineral. The present apparatus makes it possible to float not only coarse particles but coarse particles of heavy minerals such as gold, lead, etc.

Obviously the invention is not limited to the details of the illustrative construction since these may be variously modified. Moreover it is not indispensable that all features of the invention be used conjointly since various features may be used to advantage in different combinations and subcombinations.

Having described our invention, we claim:

1. Apparatus of the character described comprising in combination a pulp cell having adjacent its bottom a rotary impeller carried on a vertical shaft, means for feeding pulp to the cell and discharging it in the cell at a point over the impeller, said impeller having a closed bottom so that all pulp delivered to the impeller must pass through and be acted upon thereby before reaching the body of the pulp in the cell, means for feeding air to the impeller to be incorporated thereby in the pulp, said cell having a pocket in its bottom below and closely adjacent said impeller to receive oversize particles of ore too heavy to be elevated by the pulp currents generated by said impeller, said impeller having vanes on its under surface to develop a pulsating to carry entrapped sands from said pocket.

2. Mineral concentrating apparatus comprising in combination grinding apparatus, a flotation unit and a classifier in closed circuit, the grinder being arranged to feed the ore pulp by gravity into the flotation unit, said unit having a tailings overflow substantially above the classifier and having a rotary impeller which aerates the pulp and creates upward currents of sufficient velocity to carry the tailings over the tailings discharge but without disturbing the froth layer at the top of the unit, a conduit for carrying the tailings from the flotation unit by gravity into the classifier, and a sand relief passage leading upwardly from the impeller to a point above the classifier but below the tailings overflow to provide a hydrostatic head to assist in carrying away sands too heavy to pass over the tailings overflow.

3. Mineral concentrating apparatus comprising in combination ore grinding apparatus adapted to deliver ore ground to minus one-quarter inch mesh, a flotation cell adapted to receive said ground ore from said grinder, said cell having therein a pulp inlet and a tailings overflow, a rotary impeller to agitate the pulp and create upwardly directed currents which elevate the tailings to said tailings overflow, a classifier in closed circuit with said grinder and flotation cell for returning coarse mineral to said grinding apparatus for regrinding and arranged with its lower end below the point of tailings discharge from said cell, a tailings conduit for receiving the tailings from said cell and leading to said classifier whereby said tailings may flow by gravity into said classifier, said flotation cell having an upwardly extending conduit leading directly to the level of the tailings conduit and discharging into said tailings conduit below the level of said tailings overflow so that coarse sands may be returned by gravity to said classifier.

4. Mineral concentrating apparatus comprising in combination ore grinding apparatus adapted to deliver ore ground to minus one-quarter inch mesh, a flotation cell having a pulp inlet, a chute

to receive said ground ore from said grinder and to convey the same to said pulp inlet, a rotary impeller to agitate the pulp and create upwardly directed currents which elevate the tailings to a point substantially above the pulp inlet, a classifier in closed circuit with said grinder and flotation cell and arranged with its lower end below the point of tailings discharge from said cell, a tailings conduit for receiving the tailings from said cell and leading by gravity to said classifier, said classifier having classifying mechanism therein which in its classifying operation elevates the heavy mineral to a point above the level of the inlet into said grinding apparatus, and a conduit for carrying such heavy mineral by gravity from said classifier to said grinding apparatus.

5. Mineral concentrating apparatus comprising in combination ore grinding apparatus adapted to deliver ore ground to minus one-quarter inch mesh, a flotation cell having a pulp inlet, a chute to receive said ground ore from said grinder, and to convey the same to said pulp inlet, a rotary impeller to agitate the pulp and create upwardly directed currents which elevate the tailings to a discharge point substantially above the pulp inlet, a classifier having its inlet and heavy mineral discharge in closed circuit with said flotation cell and grinding apparatus and arranged with its inlet end below the point of tailings discharge from said cell, said classifier being adapted to discharge its fines out of said circuit for subsequent concentration, a tailings conduit leading from said cell to said classifier inlet whereby said tailings may flow by gravity from said cell into said classifier, said classifier being adapted to elevate the heavier and larger particles of ore in separating the same from the fine particles to a point above the inlet to the grinding apparatus, and a conduit for conveying said heavier and larger particles from said classifier and discharging the same into said grinding apparatus.

6. Mineral concentrating apparatus comprising in combination a flotation cell having an inlet and a tailings overflow above the level of said inlet, a rotary impeller in said cell adapted to create upwardly directed currents of pulp of sufficient velocity to carry the tailings over said tailings overflow but without disturbing the froth layer at the top of the cell, a conduit for carrying away the tailings from said tailings overflow, and a sand relief passage leading upwardly from a point adjacent said impeller directly to said conduit and discharging into said conduit at a point below the level of said tailings overflow, thereby to create a hydrostatic head which assists in carrying sands through said sand relief passage which are too heavy to be carried over said tailings overflow.

7. Apparatus of the character described comprising in combination a pulp cell having a pulp inlet, a tailings overflow substantially above the level of the pulp inlet, a rotary impeller adjacent the bottom of said cell adapted to receive pulp from said pulp inlet and to agitate the same to incorporate air therein and to create upwardly travelling currents of pulp of sufficient velocity to carry tailings to said tailings overflow, an air conduit leading to said impeller to supply air for incorporation in said pulp, a launder for carrying away tailings from said tailings overflow, and a sand relief passage opening into said cell in position to receive heavy sands thrown out by said impeller and having an upwardly extending portion discharging directly into said launder at a level lower than said tailings overflow for relieving the cell of sands too heavy to pass over the tailings overflow.

8. Apparatus of the character described comprising in combination a flotation cell, means for feeding pulp to said cell, an impeller in said cell arranged between the pulp feeding means and the body of the cell so as to require all pulp to pass through said impeller before reaching the body of the cell, said impeller being constructed and arranged to develop upwardly directed currents of pulp, means for feeding air to the impeller to be incorporated thereby in the pulp, said cell having a pocket directly below said impeller and arranged to receive oversize particles after they have passed through the impeller and which are too heavy to be elevated by the pulp currents generated by such impeller, said pulp feeding means being arranged relatively to said pocket so as to require the pulp to pass through and be subjected to the action of said impeller before it can gain access to said pocket, and a discharge outlet for said pocket to permit periodic discharge of the oversize particles from said pocket.

9. Apparatus of the character described comprising in combination a pulp cell having a pulp inlet and a tailings overflow, a rotary impeller in said cell adapted to receive pulp from said inlet and to agitate the same to incorporate air therein and to create upwardly travelling currents of pulp of sufficient velocity to carry tailings to said tailings overflow, an air conduit leading to said impeller to supply air for incorporation in said pulp, a launder for carrying away tailings from said tailings overflow, and a sand relief passage opening into said cell opposite the periphery of said impeller and having an upwardly extending portion leading directly into said launder at a level lower than said tailings overflow but above the level of the impeller for directly conducting away sands too heavy to pass over the tailings overflow.

10. Mineral concentrating apparatus comprising in combination ore grinding apparatus adapted to deliver ore ground to minus one-quarter inch mesh and having means for separating and separately discharging oversize particles, a flotation cell having an inlet, a chute to receive said ground ore from said grinder and to convey the same to said inlet, a rotary impeller to agitate the pulp and create upwardly directed currents which elevate the tailings to a point substantially above the pulp inlet, a classifier in closed circuit with said grinder and flotation cell and arranged with its inlet end below the point of tailings discharge from said cell, a tailings conduit for receiving the tailings from said cell and leading to said classifier, said classifier having classifying mechanism therein which in its classifying operation elevates the heavy mineral to a point above the level of the inlet into said grinding apparatus, a conduit for carrying such heavy mineral by gravity from said classifier to said grinding apparatus, the discharge end of said grinding apparatus being above the level of the classifier inlet, and an oversize conduit for carrying said oversize particles by gravity from said grinder to said classifier inlet.

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