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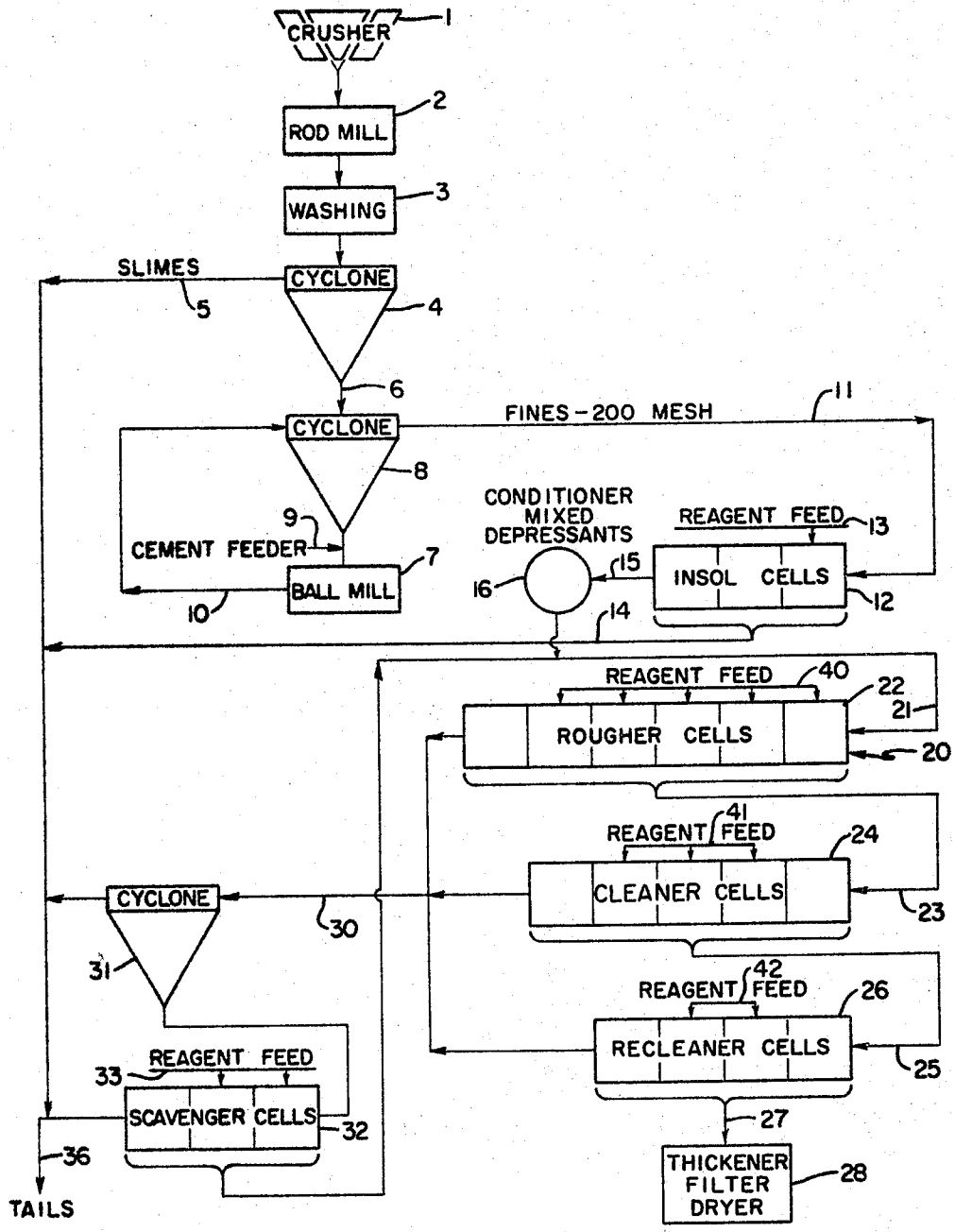

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CONTROLLED REAGENT INTRODUCTION IN A MAGNESITE ORE CONCENTRATION PROCESS

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This invention relates to the beneficiation of magnesite ores, such as the ores mined at Gabbs, Nye County, Nev., in a treatment in which the magnesite content is separated from associated impurities of the ore by froth flotation.

Magnesite ores such as those mined at Gabbs, Nev., will usually contain in addition to magnesium carbonate, other minerals such as dolomite, calcite, tremolite, forsterite, brucite, hydromagnesite, serpentine, talc, pyrophyllite, chlorite, quartz, alumina compounds, clays, graphite and soluble salts, essentially all of which must be eliminated or reduced in quantity to yield a concentrate suitable for use in the production of refractories.

In the practice of the present invention, certain preliminary steps and treatments are utilized to reduce the cost of the flotation separation and to improve its efficiency. The ore taken for treatment is subjected to a preliminary crushing to one-half inch size or smaller, after which it has been found advantageous to remove soluble salts, primary slimes and certain other deleterious substances. Unless a substantial amount of the slimes, particularly clays, are removed before collector reagent introduction into the conditioning stage prior to flotation or directly into the flotation cell, a considerable portion of collector reagent may deposit on or attach to clayey slimes, thereby substantially increasing the quantity of collector reagent required in obtaining optimum magnesite concentration.

The next step in the process is to reduce the ore to a suitable fineness for complete liberation of the different components of the ore. In treating the Gabbs' ores, this is achieved by size reduction to approximately minus 200 mesh utilizing a grinding mill such as a ball mill or rod mill, desliming and circulating partially ground ore in closed circuit with a classifier to discharge a ground product which essentially will pass minus 200 mesh as flotation feed. The ground ore in the flotation size range is then pulped to about 35% solids, conditioned and preferably is introduced into the flotation stage at a temperature over 90° F.

The present invention has as its principal object the retarding of flotation of unwanted materials, such as lime and insolubles which were not removed in the desliming operation, and a novel group or mixture of depressants is provided to prevent such flotation.

Another object of the invention is to reduce the quantity and increase the selectivity of the collector reagent utilized in the froth flotation concentration of magnesite.

A further object of the invention is to provide a premixed reagent combination in a single solution which can be introduced in an optimum quantity for magnesite flotation without excessive operator control.

Other objects reside in novel steps and treatments for improving magnesite ore flotation, all of which will be set forth in the course of the following description.

The present invention utilizes certain discoveries to provide an efficient magnesite flotation separation in which the amount of calcareous and other insoluble impurities is held within desired limits. One discovery is the advantage deriving from forming a selected group of depressant agents for the siliceous and calcareous content of magnesite ore in proper proportions in a single solution which can be added to the pulp through one reagent feeder, thereby simplifying the addition while maintaining a constant control of the uniformity of the composition of the solution regardless of what changes may be made in the rate of its addition. In addition to the uniformity control provided, such mixture provides a more effective depressing of silicates as compared with the results attained when the same agents are introduced separately.

Another discovery is that sodium hexametaphosphate is an efficient depressing agent and is particularly effective when blended with other depressant agents. In experimenting with different blends in producing the premixed solution, I have found that a mixture of a heavy metal salt, sodium silicate solution and sodium hexametaphosphate is required for best results and that these three reagents should always remain in constant proportions. The acid concentration of the solution should be varied according to the composition of the sodium silicate and I have found that if I had to increase the amount of one reagent, the others should be increased proportionately in order to maintain optimum results.

To insure constancy, I attempt to mix the three together and found that a stable solution can be obtained when mixing in a certain manner in an acid solution. For laboratory tests, my depressant is prepared as follows:

(1) To 500 cc. of water add—
Sulfuric acid, of about 93% H_2SO_4 grade__cc__ 6
Sodium silicate solution containing about 38% solids of a grade of about 8.9% Na_2O and 28.7% SiO_2 _____cc__ 40
Sodium hexametaphosphate _____gr__ 10

(2) To 500 cc. of water add—
Aluminum sulphate containing about 17% aluminum oxide preferably having the formula $Al_2(SO_4)_3.14.3H_2O$ _____gr__ 100

(3) Mix (1) and (2) while agitating vigorously.

The same proportions and procedure are used in the plant, and approximately 25 liters of the mixture is used per ton of ore.

Another discovery utilized in the practice of the present invention is the effectiveness of portland cement, stabilized dolomite and hydraulic lime as a depressant to improve magnesite flotation. Due to its availability, I prefer to use portland cement, although for some treatments, use of one of the other materials of the group may be preferred. The cement is introduced into the final grinding stage in established proportions and a thorough dispersion of the cement in the pulp is attained by the intense agitation and circulation provided at the grinding stage. In treating the Gabbs ores, I have found that the cement should be added in an amount between 2 and 10 pounds per ton of ore milled and will be varied within that range according to the composition of the ore. The other depressant agents may be and preferably are premixed into a single solution and the cement carries into the flotation stage with the ore charge. Also, if desired, a conditioning stage may be provided in which the depressant ingredients other than cement will be introduced into the pulp in controlled quantities. For this purpose, I have found the following preparation particularly suitable:

	Percent
Water	86.5
Sulfuric acid	0.5
Sodium silicate solution containing about 38% solids	3.5
Sodium hexametaphosphate	0.8
Heavy metal salt, such as aluminum sulphate	8.7

The collector reagent for the magnesite concentration preferably is oleic acid because it is efficient and is inexpensive. Substitute materials are naphthenic acid, caprylic, acid, fish oil, red oil and tall oils, such as "Liqro" and "Indusoil," all of which are efficient collectors.

In a typical treatment of a low grade magnesite ore, such as the Gabbs, Nev., ore, as represented in the accompanying flow sheet, the mined ore is first subjected to coarse crushing to approximately one-half inch mesh at stage **1**. The crushed ore is ground to about −10 mesh in a rod mill **2** or ball mill and is then subjected to washing or scrubbing at **3**, usually in conjunction with a tumbling movement to loosen and scour clays and other slime constituents until they become separated from the ore particles. The ground ore pulp is then subjected to a desliming treatment as in a cyclone separator **4** or in other types of apparatus, such as a hydroseparator. The removed slimes are conducted from the treatment at **5** in the aqueous carrier vehicle and the deslimed ore oversize passing from the separator at **6** is directed into the final grinding circuit from which the minus 200 mesh undersize ore in discharged as feed to a flotation stage.

Preferably the grinding will be performed in a ball mill **7** or rod mill operating in closed circuit with the cyclone classifier **8** and in the preferred practice the cement will be introduced into the griding stage as indicated at **9** in an established or predetermined quantity. The ground product discharging from the ball mill at **10** contains a significant amount of impurity material which is floatable. I have found it advantageous to remove this material when the ore charge is discharged from the grinding circuit as shown at **11** and for this purpose a flotation reagent mixture of ⅓ frother, ⅓ fuel oil and ⅓ amine is introduced into the pulp in the insoluble flotation cells **12** in an amount not exceeding 0.5 pound per ton of ore milled. Most of the nitrogen fatty acids may be used as the reagent but Aeromine 3035 made by American Cyanamid Company is preferred as the collector at this stage. The frother may be any of the higher straight chain alcohols and Aerofroth 77 made by American Cyanamid Company is preferred.

The product of the classifier **8** which is oversize material is returned to mill **7** for regrinding and the classifier overflow which is essentially a minus 200 mesh product is conducted as feed to the insoluble flotation stage **12**. After discharge of the overflow from classification, excess water is removed or water is added at a suitable point in the line **11** to establish a desired pulp ratio for flotation, such as about 35% solids. Also, as needed, the flotation feed to stage **12** is heated to establish a pulp temperature of 90° F. or slightly higher and heat will be added as required to maintain the flotation temperature substantially uniform. The pulp after reagent introduction into stage **12** as shown at **13** is subjected to a single stage flotation treatment in which the floatable impurities collect in the froth and are removed as a waste product of the treatment at **14** while the flotation underflow **15** passes to a conditioner **16** where mixing or agitation is provided for five minutes or less.

Different procedures may be utilized in the magnesite concentration stage. Preferably the pulp from the classification stage **8** or from line **15** after forming a pulp of about 35% solids is introduced into a froth flotation concentration stage designated generally as **20**. This stage may utilize a series of flotation cells with the entering feed passing through the succession of cells to a final discharge. Also as shown in the flow sheet, the ore feed **21** may be directed into rougher cells **22** and the rougher concentrate is passed as feed **23** into cleaner cells **24**. The cleaner concentrate may be conducted as feed **25** to recleaner cells **26** from which the concentrate **27** passes as product to a dewatering stage **28** including a thickener, filter and dryer.

The underflow from cells **22**, **24** and **26** is delivered into a discharge line **30** feeding a cyclone classifier **31**.

The overflow of classifier **31**, together with the slimes from separator **4** and the waste material from line **14**, are conducted to a final tailings discharge line **36**. The underflow of classifier **31** is taken as feed to a scavenger flotation stage **32** in which the collector reagent is stage-added in starvation amounts as shown at **33**. The concentrate of scavenger cells **32** is conducted to join with the material from conditioner **16** or the line **11** as feed **21** to rougher cells **22**.

Alternatively, a single, elongated flotation cell may be utilized with reagent introduction at successive stages between its inlet and the final discharge outlet. In all said arrangements, the single solution of depressant agents is introduced into the pulp entering the first flotation stage and an oily magnesite collector is stage-added in starvation amounts to each of the flotation stages.

"Starvation amounts" as used in this specification designates a quantity of reagent much less than the minimum required to coat or impregnate the surfaces of magnesite constituents of the pulp sufficiently to promote flotation of all or most of the magnesite content of the pulp. By stage-adding the collector, that part of the magnesite which has insufficient or no collector coating or impregnation at one stage of the progressive flow of pulp through the flotation stage receives a coating or impregnation at another stage in a quantity sufficient to promote flotation of most or all of the magnesite by the time the flow has progressed to the discharge end of the flotation stage.

The stage-addition procedure provides ample contact of the magnesite content by the oily collector during the progressive flow through the flotation stage and due to the action of the depressants and the limited quantity of collector available to contact the siliceous and calcareous fraction of the pulp, a concentrate is collected having a very low tailings content.

In some circuits, it may be preferable to provide a conditioning stage between classification and flotation and this arrangement has been shown in the flow sheet. The depressant agent solution will be introduced into the conditioning stage **16** with heat introduced as required and the pulp at such stage is agitated and circulated sufficiently to provide good contact between the introduced reagents and the siliceous and calcareous fraction of the pulp. After a suitable conditioning time, as for example 5 minutes, the conditioned pulp is then introduced into the first or inlet stage of the froth flotation treatment **20** and the collector reagent is stage-added in starvation amounts at **40**, **41**, **42** and **33** as in the practice previously described. The froth concentrate is removed as the final product of the treatment while the flotation tailings are conducted to waste or may be introduced into a scavenger flotation circuit **32** with additional oily collector introduced therein to separate additional magnesite as the froth concentrate of such flotation. Depending on grade, this magnesite content may be blended with the magnesite concentrate of the first flotation stage or it can be returned through the classification stage as part of the feed to the standard flotation section.

In utilizing the circuiting practices described, a high grade magnesite concentrate is obtained from low grade magnesite ores. The recovery is on the order of 75% and the concentrate contains less than 0.5% SiO_2 and 1.60% CaO. The selection of reagent materials and the controlled introduction thereof provide an efficient flotation separation with low reagent cost. Also, by utilizing the practice of depressant agent introduction in a single solution, operator control is kept at a minimum while providing a close control of the proportioning of the depressant agents introduced into the flotation treatment.

The operating procedure described hereinbefore and represented in the flow sheet is intended as a typical example of the practice of my invention and changes in the steps and in the reagent compositions utilized in the treatment may be availed of within the spirit and scope of the invention as defined in the hereunto appended claims.

I claim:

1. In the froth flotation separation of magnesite from siliceous and calcareous impurities contained in the ore, in which deslimed magnesite ore in a flotation size range is pulped and introduced into a froth flotation concentration stage, the improvement which comprises mixing a selected group of depressant reagents for siliceous and calcareous impurities in predetermined proportions in a liquid carrier, subjecting the magnesite ore pulp to agitation and aeration in the flotation stage, introducing the pre-mixed depressant reagents into the pulp in said stage at a predetermined rate, and stage-adding an oily magnesite collector reagent to the pulp in the flotation stage in starvation amounts at intervals in its progressive flow through the flotation stage so as to promote flotation of portions of the total magnesite content at each introduction stage of said progressive flow.

2. A separation as defined in claim 1, in which the group of depressant reagents comprises portland cement, a heavy metal salt, sodium silicate, sodium hexametaphosphate and sulfuric acid.

3. A separation as defined in claim 1, in which the group of depressant reagents comprises an aqueous solution of sulfuric acid, sodium silicate, sodium hexametaphosphate and aluminum sulphate.

4. A separation as defined in claim 1 in which the oily collector reagent is oleic acid.

5. In a froth flotation treatment of magnesite ores, including grinding crushed magnesite ore to a flotation size range, introducing a pulp of magnesite ore in a flotation size range to a froth flotation separation stage, and introducing collector and depressant reagents into the pulp in the flotation separation stage, the improvement which comprises introducing a depressant reagent into the grinding stage for dispersion in the pulp therein, said reagent being selected from the group consisting of portland cement, stabilized dolomite and hydraulic lime, and conducting the pulp discharge of the grinding stage as feed into the froth flotation stage for concentration of magnesite.

6. A treatment as defined in claim 5 in which an aqueous solution of sulfuric acid, sodium silicate, sodium hexametaphosphate and aluminum sulfate are introduced into the pulp prior to concentration of magnesite in the froth flotation stage.

7. In a froth flotation treatment of magnesite ores, including grinding crushed magnesite ore to a flotation size range, introducing a pulp of magnesite ore in a flotation size range to a froth flotation separation, and introducing collector and depressant reagents into the pulp in the flotation separation stage, the improvement which comprises introducing a depressant reagent into the grinding stage for dispersion in the pulp therein, said reagent being selected from the group consisting of portland cement, stabilized dolomite and hydraulic lime, subjecting the pulp discharge of the grinding stage to a froth flotation action in the presence of a reagent mixture of a frother, fuel oil and an amine collector for removal of flotatable impurities from the pulp in a froth, and then passing the pulp after impurity removal into the froth flotation stage for concentration of magnesite.

8. In a froth flotation separation of magnesite from siliceous and calcareous impurities contained in the ore, in which deslimed magnesite ore is ground to a flotation size range and is pulped and introduced into a froth flotation concentration stage, the improvement which comprises introducing a depressant reagent into the grinding stage for dispersion in the pulp therein, said reagent being selected from the group consisting of portland cement, stabilized dolomite and hydraulic lime, subjecting the pulp containing the depressant reagent to a froth flotation treatment for removal of flotatable insolubles therefrom, introducing a depressant reagent mixture of a heavy metal salt, sodium silicate, sodium hexametaphosphate and sulfuric acid into the flotation pulp after insoluble removal, subjecting said pulp to a froth flotation treatment at a plurality of stages, and stage-adding an oily magnesite collector reagent in starvation amounts at each of said stages so as to promote flotation of portions of the total magnesite content at each flotation stage.

9. A separation as defined in claim 8 in which the depressant reagent mixture is formed as a stable solution.

10. In a froth flotation treatment of magnesite ore, including introducing a pulp of magnesite ore in a flotation size range into a froth flotation separation, and introducing collector and depressant reagents into the pulp of the froth flotation separation, the improvement which comprises introducing a depressant reagent into the pulp of the flotation separation having a plurality of concentration stages, said reagent comprising a mixture of a heavy metal salt, sodium silicate solution and sodium hexametaphosphate, and stage-adding an oily magnesite collector reagent at the plurality of concentration stages so as to promote flotation of portions of the total magnesite content at each said stage.

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