

Sept. 22, 1942.

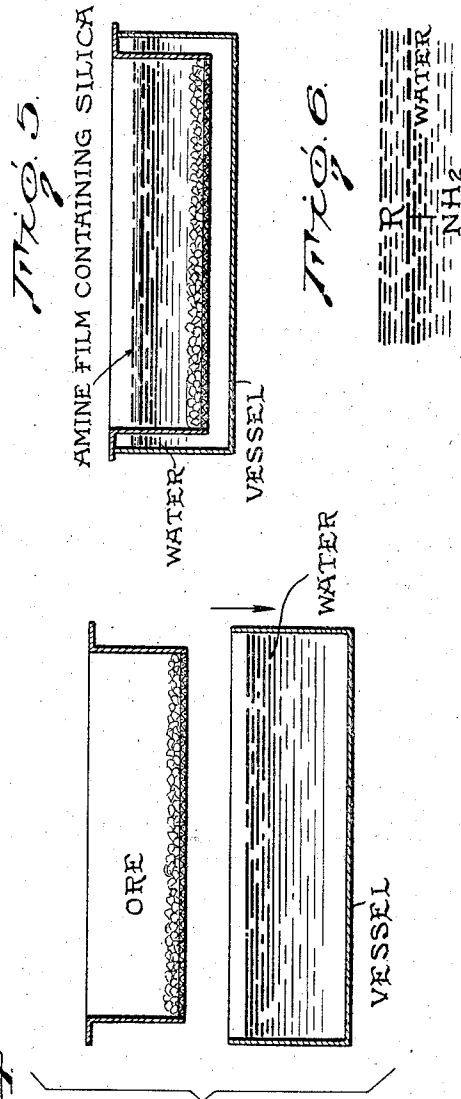
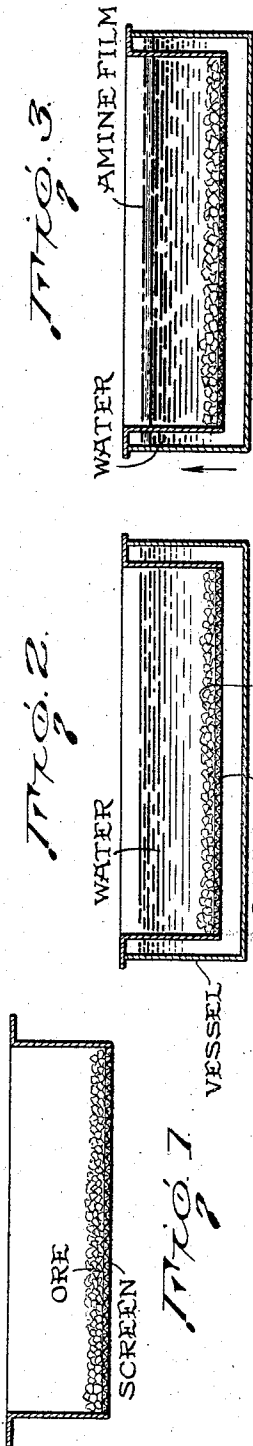
A. W. RALSTON ET AL

2,296,368

PROCESS OF SEPARATING ORES

Filed Nov. 24, 1939

2 Sheets-Sheet 1



Inventors
Anderson W. Ralston
Ervin W. Segebrecht

Fredrick H. Untch

Attorney

Sept. 22, 1942.

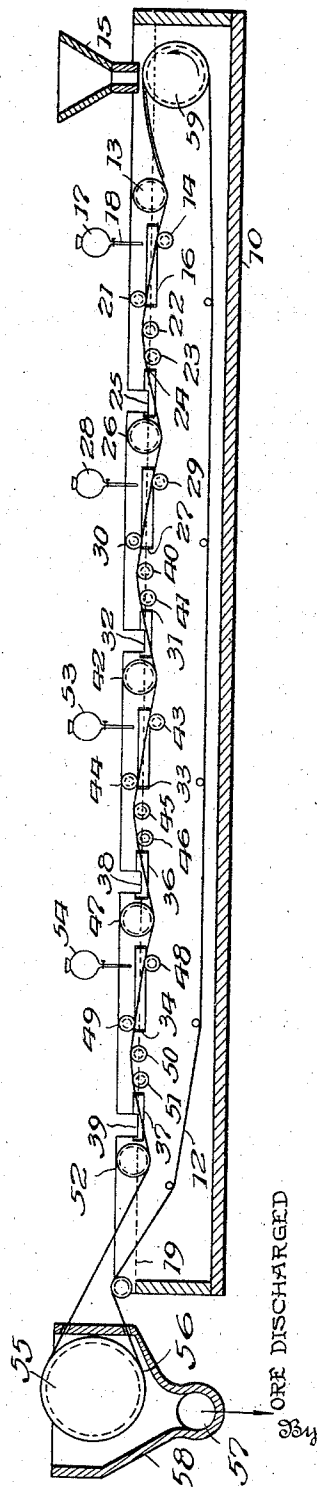
A. W. RALSTON ET AL

2,296,368

PROCESS OF SEPARATING ORES

Filed Nov. 24, 1939

2 Sheets-Sheet 2



Inventors

Anderson W. Ralston
Ervin W. Segebrecht

Frederick H. Unbehel
Attorney

UNITED STATES PATENT OFFICE

2,296,368

PROCESS OF SEPARATING ORES

Anderson W. Ralston and Ervin W. Segebrecht,
Chicago, Ill., assignors to Armour and Com-
pany, Chicago, Ill., a corporation of Illinois

Application November 24, 1939, Serial No. 306,024

12 Claims. (Cl. 209—207)

This invention relates to processes of separating silica from ores containing the same, and it comprises processes wherein a silica-containing ore which is wetted with water is brought into contact with a film of a high molecular weight primary aliphatic amine floating on a water layer, the wetted ore passing from the water layer to and through the amine layer whereby the silica particles in said ore preferentially adsorb the amine, and the amine film then reformed on a water layer whereby the silica particles in the ore are retained by the film and the other ore values passed through the film and under the water surface, thus bringing about a separation of the silica from the other ore particles, and then separately recovering the silica and the other ore particles.

In the froth flotation separation of ores it is customary to place the ore as an aqueous slurry in a flotation cell along with a flotation agent. The slurry is agitated in such a manner that air is drawn under the water surface. The flotation agent is specifically adsorbed by portions of the ore; air bubbles then attach themselves to these portions and they float away from the remainder of the ore. On page 107 of his book entitled "Flotation" Gaudin writes upon froth flotation as follows: "It has already been indicated that froth flotation is essentially a creaming process whereby the light air bubbles with or without attached mineral particles segregate from the heavier pulp. In agitation-type machines the units involved in this creaming are relatively slow-rising, small bubbles heavily loaded with mineral particles. Because of this characteristic mineralization the bubble-mineral aggregates are rigid, and since they reach the top of the pulp at low speed they do not entrain with them much pulp. In pneumatic-type machines the units involved in the creaming are relatively fast-rising, large, lightly loaded bubbles which on account of their abundance entrain in the bubble column a considerable bulk of pulp."

It is evident that in froth flotation the mineral particles are specifically associated with air bubbles so that they are caused to rise and can be separated from the gangue or other ore particles. In general, it may be stated that all froth flotation practices involve this principle for their successful operation. The specific ore value which is floated depends upon the reagent used or upon the presence of so-called promoters or retarders.

Other types of separation have been employed either as adjuncts to a flotation separation or as "per se" means of separating the ore values. Separations depending upon differences in specific gravity of the various ore values are sometimes conveniently employed. At other times the ore is passed over tables and washed with running water in such a manner that certain values

are washed away and collected and others pass over the table and are collected separately. The particular type of separation employed depends quite largely upon the nature of the ore itself; however, froth flotation is the process most generally employed.

In froth flotation the agents used may be either added directly to the cell or mixed with the concentrated pulp and the mixture then added to the cell. As stated before, various agents have been used as collectors depending upon the ore in question. In the flotation separation of phosphate ore soaps, such as sodium oleate, are often used. Gaudin (page 371) gives some typical separations of calcium phosphate from silica by the use of soaps. These examples are as follows: (1) an ore assaying 48.5% B. P. L. (bone phosphate of lime) and containing 37.4% insolubles was treated with 1.6 lbs. per ton of oleic acid, 0.8 lb. per ton of crude pine oil, 0.6 lb. per ton of steam distilled pine oil, 0.25 lb. per ton of sodium silicate and 0.2 lb. per ton of sodium carbonate. The concentrate represented 54.6% of the original and assayed 75.1% B. P. L. and 4.3% acid insolubles. This corresponds to a phosphate recovery of 84.6% and a selectivity index of 9.1. (2) a lower grade ore which assayed 33.5% B. P. L. was treated with the same reagent. This gave a concentrate corresponding to 22.4% of the original and a middling which corresponded to 22.3%. The percentage B. P. L. of the concentrate was 71.8 and of the middling 57.7 and they contained 1.9% acid insolubles respectively. This corresponds to a recovery of 47.9% of the original phosphate in the concentrate and 38.4% in the middling. The tailings which represented 55.3% of the original sample contained 8.3% B. P. L. and 89.2% acid insolubles.

Recently Lenher, U. S. Patent 2,132,002, has described a series of flotation agents containing positively charged ions. These agents are useful for the froth flotation of certain ores. The salts of high molecular weight amines such as dodecyl or octadecyl amine acetates or hydrochlorides fall in this class. In the Ralston and Pool application, Serial No. 221,008, it has been shown that the unionized amine molecule is superior to an amine ion for the froth flotation of ores. The flotation processes in this case are not dependent upon the presence of positively charged ions, but are due to the specific adsorption of the unionized amine molecule by certain portions of the ore.

As above stated, fatty acids and their soaps are now extensively used for the froth flotation of certain ores, particularly phosphate ores. In these cases the calcium phosphate is floated away from the siliceous gangue. With the amines the reverse is true and the silica is floated leaving the calcium phosphate behind as the tailing.

Quite excellent separations are possible by the use of the latter reagents, but from an economic standpoint it is necessary that such separations be decidedly superior either as regards the separations obtained or the amount of reagent required before their large scale use is indicated. This is due to the fact that the amines or amine salts are and probably always will be somewhat more expensive than the acids because the acids are the starting materials for the preparation of the amines. We have realized this phase of the problem and, consequently, have set ourselves to devise a process by which substantially smaller amounts of the amines can be used to effect a satisfactory separation. As a consequence of this study we have devised a process of separation which operates effectively with from one to ten percent of the amount of reagent required for a froth flotation.

We have discovered that if a layer of finely ground ore is passed up through a film of a high molecular weight amine forming a film on a water surface in such a manner that the film is disrupted and if this process is repeated by passing the ore layer down through the water surface the film is reformed and the silica present in the ore is retained in the film and the other ore values pass through the film and under the water surface. This process can be repeated the desired number of times until an essentially complete separation of one ore value from another is obtained. We have found that by this process ores containing silica as one of the components can be separated by the use of astonishingly small amounts of amines. In some cases the amount required is only one percent of that necessary to bring about the equivalent separation by a froth flotation or by other methods. In the practice of this invention it is necessary to first either elevate the ore layer through the amine film, or lower the water surface carrying the film in such a manner that the ore first comes in contact with the hydrophilic portion of the amine. Agitation of the water or the film is not desirable since if agitated the ability of the film to hold up the silica particles is materially reduced.

In order to operate this procedure we have devised and operated methods by which this process can be accomplished mechanically. These will be described in some of the later examples.

One of the simplest procedures is to spread the ore over a fine meshed screen and, after immersing the screen under water, form a film of amine upon the water surface and then bring the screen containing the ore layer up through this film and then reverse the process. This procedure involves all of the principles necessary in a mechanical process and has been used by us as an experimental means of determining the amounts of reagents necessary and the separations which can be obtained.

On the appended sheets of drawings we have illustrated the general mechanical method employed in the present process, together with one suitable form of apparatus by which the process can be practiced continuously.

In the drawings,

Figures 1 to 6 are a schematic showing of the new principles used in the present invention.

Figure 7 is a cross-sectional view of one type of apparatus for practicing the present process continuously.

In order that the general procedure may be clearly understood, reference is directed to Figures 1 to 6. In Figure 1 we show a 100 mesh

screen on which there is a relatively thin layer of the silica-containing ore to be separated. This screen is then immersed beneath the surface of a layer of water maintained in a vessel as shown in Figure 2. By this procedure all of the ore particles are contacted with water. Then a few drops of a high molecular weight primary amine suitably dissolved in alcohol are placed on the water surface. The amine immediately spreads to form a thin film not more than a few molecules thick. In Figure 3, the depth of the film has been greatly exaggerated. The screen containing the ore is then passed upwardly (in the direction of the arrow, Fig. 3) through the water and through the amine film as shown in Figure 4. Finally, the screen is then lowered into the water again, care being taken to avoid agitation so that the amine film will reform on the upper surface of the water. This amine film now contains silica, the other ore values remaining on the screen. As a last step, the silica film is scraped from the surface of the water. The process can be repeated at this stage by reforming a fresh amine film and repeating the raising and lowering of the screen any desired number of times. Figure 5 shows the screen after it has been lowered with the amine film containing the silica floating on the surface of the water. In Figure 6 we have endeavored to illustrate our conception of how the present invention operates theoretically. In this figure we illustrate a water surface carrying a film of a primary aliphatic amine of high molecular weight. The hydrophilic portion of the amine, namely the amino group, extends into the surface of the water and the alkyl portion of the amine, not being hydrophilic, remains on the surface of the water. In many respects this conception is analogous to what is believed to happen when oleic acid is filmed on a water layer. The carboxyl group of the oleic acid is thought to extend downwardly into the water and the alkyl portion of the acid is thought to remain on the surface of the water.

For the successful practice of the present invention it is essential that the ore be passed from a water phase to and through an amine film in such a manner that the ore particles first meet the amine at the interface between the film and the water, in this way insuring that the ore particles first contact the hydrophilic groups in the amine. The process is not operative if the amine is added haphazardly to an aqueous slurry of the ore. No film holding the silica can be obtained thereafter. It is essential, as stated, that the procedural steps which we have broadly outlined in the above description be followed.

We shall now give a number of examples illustrating the present invention and comparing its results with previous procedures.

Example 1

33.739 grams of a phosphate ore were spread evenly upon an eight inch, one hundred mesh sieve. The area of the sieve was 34.27 square inches. The phosphate ore used had the following analysis: 15.25% P_2O_5 , 20.96% CaO , and 60.25% SiO_2 . The sieve was then immersed under the water surface and a film of dodecyl amine formed upon the water surface. The film was formed by placing a drop of an alcoholic solution of dodecyl amine upon the surface of the water. The amount of amine used was the equivalent of 0.011 lb. per ton of ore present. The screen was then brought up through the film and then immersed. The film which was disrupted by bring-

ing the ore through it reformed upon the second operation and solid particles were retained in the film. This film was then skimmed from the surface and the solids dried and weighed. These solids weighed 14.774 grams which corresponds to 43.78% of the original sample. The analysis was as follows: SiO_2 85.45%, CaO 7.10%, and P_2O_5 5.34%. It is evident that the film had selectively retained the silica.

This process was repeated using 0.011 lb. of amine per ton of ore and 7.848 gm. retained in the film. This corresponds to 23.28% of the original sample. The composition was as follows: SiO_2 66.35%, CaO 16.90%, and P_2O_5 12.80%. The process was repeated a third time and 2.756 gm. retained in the film. This corresponds to 8.16% of the original sample and had the following compositions: SiO_2 33.09%, CaO 34.40%, and P_2O_5 25.80%.

8.361 grams remained upon the screen which corresponds to 24.78% of the original sample. This had the following analysis: SiO_2 4.46%, CaO 51.00%, and P_2O_5 37.30%.

Based upon these results the distributions were as follows: SiO_2 66.04% in the first concentrate, 27.23% in the second, 4.77% in the third, and 1.96% in the residue. CaO 12.21% in the first concentrate, 17.91% in the second, 12.73% in the third, and 57.15% in the residue. P_2O_5 14.03% in the first concentrate, 17.85% in the second, 12.67% in the third, and 55.45% in the residue. This means that the residue contained 55.45% of the original bone phosphate, or in other words, a 55.45% recovery of phosphate as an 81.46% B. P. L. product. If the residue is combined with the last fraction removed the analysis of the product is as follows: SiO_2 11.57%, CaO 46.89%, and P_2O_5 34.45%. This gives a phosphate recovery of 68.12% as a 75.24% B. P. L. product. It can be seen that these results are outstanding when the recovery and percent B. P. L. are compared. The amount of amine necessary by this method to obtain a 68.12% recovery as a 75.24% B. P. L. product is only 0.022 lb. per ton of sample and the amount necessary to obtain a 55.45% recovery as an 81.46% B. P. L. product is only 0.033 lb. per ton of ore.

In order to compare these results with the usual froth flotation separation a sample of the ore was separated in a Denver type froth flotation cell. 38.655 grams were placed in a flotation cell and the equivalent of one pound per ton of dodecyl amine reagent added. This resulted in a concentrate which weighed 22.606 grams and analyzed as follows: SiO_2 88.75%, CaO 6.00%, and P_2O_5 4.34%. The tailings weighed 16.055 grams and analyzed as follows: SiO_2 14.45%, CaO 44.60%, and P_2O_5 32.81%. This corresponds to a separation of 86.25% of the silica in the concentrate and 80.43% of the phosphorus in the tailings. The phosphate recovery is, therefore, 80.43% of a product which contained 71.65% B. P. L.

It will be noted that this separation is not as selective as the former although they are comparable. Approximately fifty times as much amine was required for the froth flotation as in the process of the present invention.

In order to further show the effectiveness of this method as compared to the usual flotation practice a sample of ore was treated in the Denver type cell with the equivalent of 0.033 lb. per ton of dodecyl amine which is the amount used by us to obtain the separation of Example 1.

This amount proved insufficient to produce any separation by froth flotation.

Example 2

A 43.143 gram sample of the same ore used in Example 1 was treated by the procedure used in Example 1 using 0.033 gram of octadecyl amine per ton of ore. This resulted in the retardation in the film of 18.892 grams (50.89% of the original) which analyzed as follows: SiO_2 87.21%, CaO 6.20%, and P_2O_5 4.65%. An amount of amine equivalent to 0.011 lb. per ton was then added and 4.878 grams (13.07% of the original) was retained. This analyzed as follows: SiO_2 64.84%, CaO 18.80%, and P_2O_5 14.11%. The residue weighed 13.373 grams and had the following analysis: SiO_2 9.75%, CaO 48.58%, and P_2O_5 35.57%. The distribution of the ore values was, therefore, as follows: SiO_2 78.67% in the first concentrate, 15.10% in the second, and 6.23% in the residue. CaO 13.62% in the first concentrate, 10.65% in the second, and 75.73% in the residue. P_2O_5 12.32% in the first concentrate, 11.08% in the second, and 76.60% in the residue. This corresponds to a phosphate recovery of 76.60% as a product containing 77.68% B. P. L. The total amount of reagent used was 0.044 lb. per ton which is about one twenty-fifth of the amount necessary by froth flotation processes.

Example 3

Using another sample of the ore described under Example 1 and a similar procedure the addition of an amount of dodecyl amine equivalent to 0.0030 lb. per ton of ore produced 54.28% of a residue which analyzed as follows: SiO_2 31.34%, CaO 37.65%, and P_2O_5 27.70%. The concentrate analyzed as follows: SiO_2 89.45%, CaO 5.55%, and P_2O_5 4.24%. The amount of reagent used in this case is approximately one three-hundredth of the amount required in froth flotation.

Example 4

33.106 grams of the phosphate ore described in Example 1 was treated with a total of 0.036 lb. per ton of dodecyl amine acetate in four portions using 0.009 lb. per ton of amine in each treatment. This resulted in a concentrate which weighed 16.215 grams and had the following analysis: SiO_2 93.36%, CaO 3.62%, and P_2O_5 2.81%. The residue weighed 16.891 grams and analyzed as follows: SiO_2 24.77%, CaO 41.60%, and P_2O_5 30.00%.

Example 5

48.901 grams of an ore which analyzed 76.72% CaCO_3 and 15.07% SiO_2 was spread out upon the screen and treated with 0.009 gram of dodecyl amine as described under Example 1. This resulted in a concentrate which weighed 10.121 grams and analyzed as follows: SiO_2 62.01% and CaCO_3 34.27%. The residue weighed 38.780 grams and contained 87.79% CaCO_3 , and 3.34% SiO_2 . The distribution of the silica and calcium carbonate is, therefore, as follows: 82.91% of the silica is present in the concentrate and 17.09% is in the residue, 90.73% of the calcium carbonate is in the residue and 9.27% in the concentrate.

For comparative purposes a sample of the same ore was separated in a Denver type flotation cell using dodecyl amine as the flotation agent. 49.781 grams were placed in the flotation cell and the equivalent of one pound per ton of dodecyl amine added. This resulted in a concentrate which weighed 13.370 grams and had the following analysis: SiO_2 53.76% and CaCO_3

41.51%. The tailings weighed 36.411 grams and contained 5.36% silica and 85.15% calcium carbonate. The distribution of the ore values was, therefore, as follows: silica 26.02% in the tailing and 73.98% in the concentrate, calcium carbonate 82.52% in the tailing and 17.48% in the concentrate.

It will be noted that the froth flotation requires over one hundred times as much reagent as that required in the process of the present invention.

Example 6

A 47.082 gram sample of fluor spar containing 76.82% calcium fluoride and 18.01% silica was placed in the screen and treated successively with two portions of octadecyl amine each of which was equivalent to 0.009 gram per ton of ore. The treatment was similar to that described under Example 1. The ore was first spread upon the screen, the screen immersed in water, and a film of amine spread over the water surface. The ore surface was then brought up through the film and then lowered again into the water. The film containing the suspended solid particles was then collected and the process repeated. The solids in the film weighed 13.012 grams and containing 60.23% silica and 31.02% calcium fluoride. The residue weighed 34.070 grams and contained 1.89% silica and 94.31% calcium fluoride. The distribution was, therefore, as follows: CaF_2 88.84% in the residue and 11.16% in the concentrate, SiO_2 7.57% in the residue and 92.43% in the concentrate.

A similar sample was separated in the Denver type flotation cell using octadecyl amine as the flotation agent. Using the equivalent of 1.75 lbs. per ton of reagent 72.01% of the fluorite was recovered from the concentrate and 81.73% of the silica was present in the tailings.

It will be noted that the froth flotation was not as selective as the present process. The amount of reagent required presents a decided contrast, 0.018 lb. per ton in the case of the proposed process and 1.75 lbs. per ton for the froth flotation. It is quite interesting to note that in the case of the froth flotation using octadecyl amine as the flotation agent the calcium fluoride floated away from the silica while in the present process the silica was retained in the film and the calcium fluoride was formed in the residue. The present process differs from the usual processes employed not only in that it requires only a small percentage of the reagent formerly required but also reverses the flotation phenomena as regard the ore values floated. This is a fundamental difference between the two processes. In all cases observed using this process the silica has been retained by the film and the other ore values pass through it.

Example 7

51.734 grams of a sample of galena containing silica as the gangue mineral was placed in the Denver type flotation cell and dodecyl amine added as the flotation agent. The amount of amine necessary was the equivalent of 0.25 lb. per ton of ore. This resulted in a concentrate which weighed 24.398 grams and which contained 82.2% lead and 4.24% silica. The tailings weighed 27.336 grams and contained 12.7% lead and 83.0% silica. This corresponds to a separation of 85.19% of the lead in the concentrate and 95.64% of the silica in the tailings.

A sample of the same ore was placed in a

screen and immersed in water. A film of dodecyl amine was then formed on the surface and the ore passed up through this film and then down again below the water surface. The amount of amine present corresponded to 0.01 lb. per ton of ore. The film, containing the entrapped solids, was then removed and the process repeated using a similar amount of dodecyl amine. The total amount of amine used was, therefore, the equivalent of 0.02 lb. per ton of ore. 93.21% of the silica originally present was removed by the film and 83.22% of the lead was present in the residue.

These results are significant in view of the fact that in a flotation cell or by other processes galena is easily floated from silica and as a rule the separation does not require a large amount of reagent. In this example the silica is retained by the film and the galena rejected. The amount of reagent necessary is only a small proportion of that required by other process.

Example 8

17.801 grams of a barite ore were spread evenly over the surface of a two hundred mesh screen. The ore contained 46.82% barium sulfate (calculated as barium oxide) and 22.91% silica. This was then passed up through a film of dodecyl amine in water. The amount of dodecyl amine present in the film corresponded to 0.033 lb. per ton of ore present. This resulted in a suspension which weighed 6.602 grams and had the following composition: BaO 31.60% and SiO_2 48.90%. The process was repeated using an additional amount of amine equivalent to 0.011 lb. per ton of ore. This resulted in a second suspension which weighed 2.341 grams and analyzed 44.25% barium oxide and 28.44% silica. The residue weighed 8.858 grams and contained 61.00% barium sulfate (calculated as barium oxide) and 5.38% silica.

The distribution of the ore values is, therefore, as follows: BaO 22.76% in the first suspension, 12.43% in the second suspension, and 64.81% in the residue, SiO_2 71.98% in the first suspension, 16.33% in the second suspension, and 11.69% in the residue.

These results are economically striking since a satisfactory separation has been obtained with the use of a total amount of dodecyl amine equivalent to 0.044 lb. per ton of ore. Comparative results using the Denver type flotation cell required 1.5 lbs. per ton of ore to effect a separation. In the case of the froth flotation procedure it is the barium sulfate which is preferentially floated.

In Figure 7 we have illustrated in a schematic way suitable apparatus for practicing the principles of the present process continuously.

In this figure, a long, narrow trough 10 contains water through which a belt 12 is drawn over a series of idlers and pulleys. The ore to be separated is charged in hopper 15 from which it feeds onto the belt 12 continuously moving in the direction of the arrow. This belt carrying the ore is then caused to pass under the pulley 13 over idler 14 and up through a segregated zone of the water surface which has been supplied with the amine. A bottomless boxlike, rectangular barrier 16 is arranged in the water to close off a rectangular area thereof and at the surface of the water. By means of container 17 and discharge nozzle 18 the primary amine is supplied to the water surface and remains as a film of restricted area maintained within the

confines of the barrier. The water surface is indicated by the dotted line 19 and the film is maintained on this surface. In consequence, as the ore on the belt passes over and under the idlers 14 and 21 adjacent barrier 16, the ore is first wetted with water and then passed upwardly through the amine film. The belt is then caused to pass over the next set of idler pulleys, 22 and 23, to the left of barrier 16 and then downwardly through a barrier arrangement 24 where the film of amine is reformed on the surface of the water from which it can be skimmed off in any convenient manner at point 25. This represents a complete cycle of the separation, and the cycle can be repeated any number of times. In Figure 7 we have shown three repetitions of the cycle. Thus, as shown in the drawings, the belt continues its travel under pulley 26 through another barrier 27 supplied with amine from container 28 over and under idler pulleys 29 and 30 where the film is disrupted and coats the ore particles, thence to barrier arrangement 31 where the film is reformed and the film skimmed off at 32 and so on through the films maintained in barriers 33 and 34, and the films containing solid particles reformed in barriers 36 and 37 from which the film is skimmed off at 38 and 39. Pulleys and idlers for guiding the belt through barriers 31, 33, 34, 36 and 37 are shown at 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51 and 52. Discharge containers for the amine are shown at 53 and 54. Finally, the belt passes over drum 55 and the ore remaining thereon scraped off by scraper 56 from whence it falls to the discharge opening 57 in the housing 58. Drums 55 and 59 over which the belt passes can be driven by any suitable means, not shown.

Thus the process can be rendered continuous by continuously charging ore to be separated on the belt, passing the belt through layers of amine film, then reforming the film, skimming off the film for the recovery of silica therein, and finally recovering the ore remaining on the belt. It is understood that Figure 7 and the description thereof is not intended to be a description of all of the necessary mechanical parts for the operation of the belt conveyor but is simply intended to illustrate an alternative method by which we can practice the principles of the present invention.

In the preceding examples we have shown that ores may be separated by passing them up through an adsorbed film, which process serves to rupture the film, and that the film can be reformed by passing the ore under the water surface. This second process serves to reform the film. We have shown that certain ore values are retained by the film and others pass through the film and under the water surface. All the primary amines we use are insoluble, or substantially insoluble, in water. Thus we are limited to primary amines having at least six carbon atoms and these range from hexyl amine to octadecyl amine and the unsaturated primary amines of like number of carbon atoms.

Films of mineral oils, etc., are rather difficult to form and our experimental work has shown them to be of no value whatever for this purpose. Likewise, films of oleic acid are not at all suited to the present process. Although oleic

acid will suspend and collect a small amount of silica from calcium phosphate ores, the very small amount of gangue retained in the film is such that the process is not satisfactory commercially.

In our process it is not necessary to deslime or otherwise treat the ore before it is subjected to our type of separation. Our results indicate that the separation is as satisfactory with an undeslimed as with a completely deslimed ore and that no greater amount of reagent in the film is required in the former case. This is, of course, quite advantageous from a commercial standpoint since the process of desliming is quite often costly in itself and often leads to substantial losses of desirable ore values.

Having thus described our invention, what we claim is:

1. The process of separating silica from ores containing the same which includes providing a film of a substantially water-insoluble primary aliphatic amine on a layer of water beneath which the ore to be separated is disposed, passing the ore to and through the film, and then submerging the ore beneath the water surface to reform the film on the water surface whereby silica in the ore is preferentially retained in the reformed film.

2. The process of separating silica from ores containing the same which includes passing the ore beneath the surface of a pool of water, forming a film of a substantially water-insoluble primary aliphatic amine on the water surface, passing the ore to and through the amine film, and then submerging the ore beneath the water surface to reform the film on the water whereby the silica in the ore is preferentially retained in the reformed film.

3. The process of separating silica from ores containing the same which includes charging the ore on a continuously moving belt, passing the ore on the belt into a trough of water, passing the wetted ore on the belt upwardly through a film of a substantially water-insoluble primary aliphatic amine of restricted area maintained on said trough of water, passing the ore on said belt downwardly through another portion of said water trough to reform said film, the film containing silica, and removing the film from the water surface.

4. The process as in claim 1 wherein the ore is a phosphate ore.

5. The process as in claim 2 wherein the ore is a phosphate ore.

6. The process as in claim 4 wherein the ore is a phosphate ore.

7. The process as in claim 1 wherein the amine is dodecyl.

8. The process as in claim 2 wherein the amine is dodecyl.

9. The process as in claim 3 wherein the amine is dodecyl.

10. The process as in claim 1 wherein the ore is a phosphate ore and the amine is dodecyl.

11. The process as in claim 2 wherein the ore is phosphate ore and the amine is dodecyl.

12. The process as in claim 3 wherein the ore is a phosphate ore and the amine is dodecyl.

ANDERSON W. RALSTON.
ERVIN W. SEGEBRECHT.