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FROTH FLOTATION PROCESS EMPLOYING POLYMERIC FLOCCULANTS

Robert G. Woolery, Monroe, N.Y., assignor to Union Carbide Corporation, a corporation of New York
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The present invention relates to an improved froth flotation process. More specifically, the present invention relates to a novel use of flocculants in froth flotation circuits to facilitate increased recovery of ore values in more selective circuits at high concentration ratios.

Froth flotation has been widely used over a period of years to beneficiate sulfide and oxide ores. The process is capable of treating high volumes of low grade material to produce highly concentrated fractions of ore-values having a much higher assay than the starting mother ore.

Typical froth flotation processes employ an ore pulp prepared by adding comminuted mother ore to an aqueous liquid. The pulp is conditioned by various chemicals and agitated in a flotation machine which introduces dispersed air in the form of fine bubbles throughout the pulp. The chemicals enhance the tendency of ore values to selectively adhere to the fine bubbles and float to the surface to form a froth loaded with the ore-values. The froth is removed as a concentrate with the gangue remaining in the pulp as a tailing product. In some instances the gangue is floated with the ore-values being concentrated in the pulp.

The chemicals added to froth flotation pulps to aid in selective concentration of the ore values are generally classified as follows:

(a) Frothers are heteropolar organic compounds consisting of one or more hydrocarbon groups attached to one polar group. The function of the froth is to act as a mechanism for transporting the ore-values selectively from the pulp to the froth column as a concentrate having a high assay in ore-values.

(b) Promoters or, as they are more commonly termed, collectors selectively alter the surfaces of minerals in the mother ore so as to cause selective adherence to froth bubbles thus promoting flotation of the ore-values in preference to gangue and collecting them in a froth as a concentrate.

(c) Modifiers change the surface of minerals so as to modify their amenability to froth flotation in a given promoter-frother combination. These agents may be termed activators, depressants, inhibitors, pH regulators, and the like.

Proper combination of the above-noted reagents enables an artisan to perform selective or differential flotation of predetermined fractions of minerals and/or gangue in a given mother ore by maintaining the proper chemical condition on the surface of the ore-values so as to allow selective removal of the same from the pulp by adherence to fine bubbles.

The success of a flotation process is measured by several effects including the following:

(a) The recovery which denotes the amount of the total ore values in the mother ore which are passed to the concentrate.

(b) The grade or assay of the concentrate.

(c) The concentration ratio which is a measure of the extent to which the mother ore is fractionated into the ore-values and gangue.

The aim in flotation processes is to obtain a high grade concentrate in a single float while maintaining a high recovery of the total amount of ore-values in the mother ore at a high concentration ratio. It is readily seen, therefore, that selectivity in a particular flotation setup is very important.

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The optimum combination of the above chemical reagents aids in realizing high selectivity and consequently a high concentration ratio with a high grade concentrate and high recovery.

Several factors other than the use of proper chemical reagents influence the degree of success realized in froth flotation. They include:

(a) pulp density—the weight ratio of the ore to the ore plus water,

(b) conditioning time—the time which the reagents are allowed to be mixed in the pulp prior to flotation,

(c) pulp temperature—the temperature of the pulp may or may not be significant,

(d) particle size of ore.

Ores which have a tendency to slime when comminuted present formidable flotation problems. Ores which tend to form fine particles such as uranium, vanadium, and some of the manganese ores are notorious slime formers. The presence of slimes in flotation pulps causes excess consumption of chemical reagents, less selectivity in removing ore-values preferentially from gangue materials, loss in recovery of ore values, lower concentration ratios and lower grade concentrates.

It should be noted that uranium and vanadium have never been beneficiated by froth flotation to any extent because the low recovery caused by high sliming tendencies renders the process uneconomical. Where attempts have been made to float uranium and vanadium, maximum recoveries average less than 50 percent. The value of uranium and vanadium has allowed artisans to resort to more expensive recovery processes such as acid leachings and organic solvent extraction.

Fine particles are invariably present in every comminuted ore. Some ores, such as uranium, vanadium, and manganese ores, readily break into a large fraction of fine particles. The optimum ore-value particle size in froth flotation is generally about 400 mesh or about 38 microns. Seven microns up to about 150 mesh or about 104 microns are generally considered the broadly operable range of particle size without detrimental effect on the flotation process. Particles below about 7 microns are especially detrimental to froth flotation because of their tendency to form slimes. To preclude the possibility of slime formation in flotation pulp, it is often necessary to remove the fine particles in an effort to stop the detrimental effect of slimes. Even with classification, the pulp contains some amount of slimes.

Another alternative which is commonly employed in many instances to reduce the detrimental effect of slimes in froth flotation is to add dispersing or deflocculating agents.

It is an object to provide an improved froth flotation process capable of efficiently and effectively treating slime-forming materials.

It is another object to provide a forth flotation process for effectively producing a high grade concentrate of uranium, vanadium, and manganese ore with a high concentration ratio and high recovery of the ore values.

It is a further object to provide a method of controlling grade of concentrate and recovery in froth flotation processes while treating slime-forming mother ores.

The process accomplishing the above-mentioned objects comprises the addition of an amount of flocculating reagent to pulps utilized in froth flotation in an amount sufficient to cause formation and maintenance of a floc of the slimes in the froth flotation pulp during flotation.

It is contemplated that the present improvement is amenable for use in the pulp of any froth flotation process irrespective of the type and amount of standard known flotation reagents utilized in the pulp such as, for example, frothers, promoters or collectors and modifiers.

For the purpose of the present invention, flocculating

agents are defined as materials which cause conglomeration of slime particles in aqueous solutions. They include starches, glues, certain polysaccharides, such as locust bean gum, gar gum and cactus extract and polyacrylamides and other flocculating agents well known to skilled artisans.

The flocculating agent causes the formation of a floc of the slime materials in the pulp. This leads to a decrease in reagent consumption, especially the consumption of collectors or promoters and modifiers. In addition, the use of flocculating agents enables an artisan to realize increased recovery of ore-values in a high grade concentrate with a high concentration ratio.

It is contemplated that any flocculating agent can be utilized in the present process. High molecular weight polyacrylamide flocculants are especially amenable for use in the present process and are indeed preferred.

The following examples show embodiments of the present process as adapted to the treatment of uranium and vanadium ores. This fact is not to be construed as restrictive of the scope of the present process, but rather the use of the present process enhances the effectiveness and efficiency of froth flotation processes in general which processes encounter the problems resulting from the presence of slimes in flotation pulps.

Uranium ore from various deposits has been utilized in the following examples. Oxidic uranium ores are notoriously slime forming. This fact has undoubtedly hindered the application of froth flotation to the beneficiation of uranium ores and at present little application of froth flotation to uranium ores has been accomplished because the presence of slimes decreases the extent of recovery of the uranium ore values. As stated above, the high economic value of uranium justifies the use of more expensive and unique recovery methods, such as acid leaching coupled with organic-solvent extraction. Accordingly, the following examples illustrate the ability of the present process to effectively upgrade uranium ore which previously has been commercially treatable only by more complicated and expensive extraction processes.

The following examples were conducted in a Fagergren flotation cell. The pulps in the following examples were prepared by standard procedures. The reagents utilized are noted in each example along with the results as noted by: (1) percent weight which denotes the weight percent of the total feed of the concentrate and the tailing. This determines the concentration ratio; (2) percent U_3O_8 (assay) indicating the grade of the feed, concentrate and tails; and (3) the distribution which denotes the percent of the total ore-values in each fraction.

The reagents are referred to by trademarks. The composition of each correlated with the respective trademark is shown in the table below:

Sold under the trademark:	Reagent
Aero promoter 710--	The sodium soap of a fatty acid of vegetable origin.
Aero promoter 712--	A water soluble, saponified fatty acid promoter.
Aero promoter 765--	A highly refined fatty acid consisting essentially of oleic and linoleic acids.
Aerofloc 3000-----	A high molecular weight polyacrylamide.
Superfloc 16-----	A polyacrylamide, but of higher molecular weight than Aerofloc 3000.
Separan 2610-----	Polyacrylamide type flocculant.

In all the examples the amount of flocculant noted is that amount added to cause flocculation of the slimes during the flotation itself.

Example 1

Maybell uranium ore comprising uranium bearing minerals in a sandstone was pulped with water to a pulp

density of 25% with the following reagents added in the amounts shown below:

Reagents	Purpose	Lb./Ton
Fuel oil-----	Promoter-----	3.2
Copper Sulfate-----	Activator-----	1.0
Sodium Carbonate-----	Adjust pH-----	5.0
Aero Promoter 710-----	Collector-----	4.8
Aerofloc 3000-----	Flocculant-----	0.5

The results were as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed-----	100.00	0.103	100.00
Flotation Conc. (Product)-----	19.12	0.474	88.2
Flotation Tails-----	80.88	0.015	11.8

Example 2

Another sample of the same ore as utilized in Example 1 was submitted to froth flotation utilizing the same type and amount of reagent as noted in Example 1 except no fuel oil or copper sulfate was utilized. The results were as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed-----	100	0.076	100.00
Flotation Conc. (Product)-----	17.1	0.37	83.6
Flotation Tails-----	82.9	0.015	16.4

It is readily apparent that the fuel oil promoter and the copper sulphate activator were not the cause of the high recovery shown in Example 1 above, since Example 2 showed recoveries well in excess of 80.0% of the U_3O_8 .

Example 3

The same ore as utilized in Example 1 was pulped with 40 lbs./ton of fuel oil and 1.5 lbs./ton of Aero Promoter 710 as a collector. No flocculating agent was utilized. The results are illustrated as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed-----	100	0.079	100.0
Flotation Conc. (Product)-----	1.6	0.51	10.4
Flotation Tails-----	98.4	0.072	89.6

It is readily seen from Examples 1, 2, and 3 that the presence of sufficient flocculating agent to cause formation of a floc during flotation results in approximately an eight fold increase in the recovery of uranium ore values. Note that the absence of a flocculating agent in Example 3 shows a drastic decrease in recovery from above 80.0% to about 10%.

Examples 4, 5, 6, and 7 were conducted on low-grade Maybell uranium ore comprising uranium bearing minerals contained in a sandstone. Example 4 is a standard. Examples 5, 6, and 7 were conducted without various reagents to show that the flocculant reagent has the most pronounced influence on the success of the float.

Example 4

Maybell low-grade ore was pulped to a pulp density of 25% with water and the following reagents were added:

Reagent:	Lb./ton
Sodium Carbonate-----	5.0
Aero Promoter 710-----	6.3
No. 2 Fuel Oil-----	2.0
Copper Sulphate-----	1.0
Aerofloc 3000-----	0.7

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The pulp with reagents were charged into a Fagergren flotation machine and a float was conducted. The results of the float are as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.00	0.085	100.0
Flotation Conc. (Product).....	15.88	0.44	82.2
Flotation Tails.....	84.12	0.018	17.8

Note that the use of a flocculating agent (Aerofloc 3000) again enables recoveries of greater than 80.0%, even in low-grade uranium ores.

Example 5

Maybell low grade ore was pulped to a pulp density of 25% with water and the same reagents in the same amount as listed in Example 4 were utilized with the exception of the copper sulfate activator which was not used. The results of the float are as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.00	0.069	100.0
Flotation Conc. (Product).....	14.78	0.40	85.2
Flotation Tails.....	85.22	0.012	14.8

In this example the absence of an activator caused a significant increase in recovery of U_3O_8 of about 3.0%.

Example 6

Maybell low grade ore was pulped to a pulp density of 25% with water and the same reagents in the same amount as listed in Example 4 were utilized with the exception of the sodium carbonate pH adjuster which was not used. The results of the float are as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.00	0.077	100.0
Flotation Conc. (Product).....	10.30	0.44	59.1
Flotation Tails.....	89.70	0.035	40.9

The absence of a pH adjuster in this float caused a decrease in recovery, yet the actual recovery of 59.1% of the uranium values as U_3O_8 is still well above the recoveries normally obtained in uranium flotation processes.

The above example should be viewed in light of the fact that pH adjustment is normally considered a critical factor in virtually all flotation processes and the failure to control pH in normal flotation processes generally leads to virtually complete loss of selectivity and recovery of values yet utilization of the present invention enables artisans to achieve about 60.0% recovery without pH control in uranium flotation, whereas known processes generally are limited to below 50.0% recovery with pH adjustment in the absence of the present invention.

Example 7

Maybell low grade ore was pulped to a pulp density of 25% with water and the same reagents in the same amount as listed in Example 4 were utilized with the exception of the fuel oil promoter which was not used. The results of the float are as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.00	0.075	100.0
Flotation Conc. (Product).....	17.66	0.35	82.4
Flotation Tails.....	82.34	0.016	17.6

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Note that the absence of fuel oil causes an increase in recovery when the present invention is utilized.

The following Example 8 was conducted to show the effect of Separan 2610, a different polyacrylamide flocculating reagent.

Example 8

Maybell uranium ore comprising uranium bearing minerals contained in sandstone was pulped with water to a pulp density of 25% solids. The following reagents were added to the pulp and the pulp was charged into a Fagergren flotation machine:

Reagent:	Lb./ton
Fuel Oil.....	2.0
Copper Sulfate.....	1.0
Sodium Carbonate.....	5.0
Aero Promoter 710.....	6.3
Separan 2610.....	0.7

The results of the float are:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.00	0.081	100.0
Flotation Conc. (Product).....	13.19	0.44	71.2
Flotation Tails.....	86.81	0.027	28.8

Example 8 shows that the use of another type polyacrylamide flocculant enables an artisan to recover a high percentage of uranium values.

Examples 9 and 10 show the amenability of the present process for the treatment of still other uranium ores.

Example 9

Gas Hills, Wyoming uranium ore comprising uranium bearing minerals in sandstone was pulped with water to a density of 25% solids. The following reagents were added to the pulp and the pulp was charged into a Fagergren flotation machine and a float was conducted:

Reagent:	Lb./ton
Aero Promoter 710 (soap).....	2.7
Aero Promoter 712 (fatty acid).....	1.2
Superfloc 16.....	0.1

The results of the float are as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.0	0.091	100.0
Flotation Conc. (Product).....	26.2	0.294	84.6
Flotation Tails.....	73.8	0.019	15.4

Note that a pH adjuster was not even utilized.

A second run was made on the same ore using 3.9 lb./ton of Aero Promoter 710 (soap), 2.0 lb./ton of sodium carbonate pH adjuster and 0.9 lb./ton of Superfloc 16. The results showed 89.1% U_3O_8 recovery in 25% of the weight of the feed. Here the addition of a pH adjuster, normally required to successfully float most ores, simply increased recovery from 84.6 to 89.1%.

Gas Hills, Wyoming uranium ore was further submitted to flotation in a Fagergren flotation cell without the use of a flocculant. The following reagents were utilized in each run in the noted varying amounts:

Reagent:	Lb./ton
Kerosene.....	9-45
Aero Promoter 710 (soap).....	1.5-4.5
Copper Sulphate.....	0.5

The results of three of the floats are as follows:

Percent U_3O_8 in Feed:	Percent U_3O_8 in Concentrate
0.086.....	23.2
0.095.....	38.7
0.074.....	37.4

It is readily apparent that the absence of a flocculating agent causes a drastic decrease in recovery. The above recoveries approximate those commonly attained by standard flotation process for uranium beneficiation.

Example 10

Uranium ore from the Brown's Park Formation near Baggs, Wyoming comprising uranium bearing minerals in a sandstone was pulped with water to a density of 25% solids. The following reagents were added and the pulp was charged into a Fagergren flotation machine.

Reagent:	Lb./ton
Superfloc 16.....	0.10
Aero Promoter 765.....	3.3
Slaked Lime.....	to pH 9.2

The results of the float are as follows:

	Percent Weight	Percent U_3O_8 (Assay)	Percent U_3O_8 Distribution
Feed.....	100.00	0.11	100.0
Flotation Conc. (Product).....	17.33	0.62	79.6
Flotation Tails.....	82.67	0.028	20.4

Again the recovery of U_3O_8 is approximately double that achieved in standard processes.

Examples 11 and 12 show the amenability of the present process for utilization in the upgrading and recovery of uranium-vanadium ores of various types.

Example 11

Green River vanadium-uranium ore comprised of a combination of various ores was pulped with water to a pulp density of 25% solids. The following reagents were added to the pulp and the pulp was charged with a Fagergren flotation machine.

Reagent:	Lb./ton
Aero Promoter 710.....	2.4
Aero Promoter 712.....	1.5
Superfloc 16.....	0.085

The results of the float are as follows:

	Percent Weight	Percent Assay		Percent Distribution	
		U_3O_8	V_2O_5	U_3O_8	V_2O_5
Feed.....	100.0	0.234	1.15	100.0	100.0
Flotation Conc. (Product).....	20.7	0.69	3.28	60.8	59.2
Flotation Tails.....	79.3	0.116	0.59	39.2	40.8

Uranium and vanadium recovery is much higher than normally achieved by standard froth flotation processes.

Example 12

Slick Rock vanadium-uranium ore comprised of various ores was pulped with water to a density of 25% solids. The following reagents were added to the pulp and the pulp was charged into a Fagergren flotation cell.

Reagents:	Lb./ton
Aero Promoter 710.....	3.0
Superfloc 16.....	0.08
Slaked Lime.....	to pH 10.0

The results of the float are as follows:

	Percent Weight	Percent Assay		Percent Distribution	
		U_3O_8	V_2O_5	U_3O_8	V_2O_5
Feed.....	100.0	0.136	1.21	100.0	100.0
Flotation Conc. (Product).....	13.69	0.66	4.61	48.9	52.2
Flotation Tails.....	86.31	0.11	0.67	51.1	47.8

Recovery of both uranium and vanadium is well above 50.0%.

Example 13 illustrates that the present process can be utilized to successfully recover vanadium values from the tailings resulting from acid leaching.

Example 13

Acid leached tailings resulting from the leaching of UraVan ore that has been reduced to 75.4% minus 65 mesh were pulped with water to a density of 25% solids. The following reagents were added to the pulp and the pulp was charged into a Fagergren flotation machine:

Reagents:	Lb./ton
Aero Promoter 710.....	3.0
Aero Promoter 765.....	0.6
Superfloc 16.....	0.11
Slaked Lime.....	to pH 9.3

The results of the flotation are as follows:

	Percent Weight	Percent Assay V_2O_5	Percent Distribution V_2O_5
Feed.....	100.00	0.82	100.0
Flotation Conc. (Product).....	20.59	2.61	65.3
Flotation Tails.....	79.41	0.39	34.7

From the above examples it is readily apparent that uranium and vanadium ores can be successfully treated by the present invention to effectively upgrade and concentrate the ore-values and even to treat tailings from acid leaching processes.

The above examples show that the use of sufficient flocculating agent in froth flotation processes greatly increases the efficiency of flotation in slime-containing circuits. The amount of flocculating agent added may vary quite widely, depending on the inherent strength of the flocculating agent. Accordingly, the only restriction on the amount of flocculating agent employed is that a flocculating agent in sufficient amounts must be employed to cause formation and maintenance of a floc of the slimes in the ore pulp itself during flotation.

Note that as the pulp is agitated or if pulp agitation is increased, a corresponding greater amount of flocculating agent may be required to form and maintain a floc of the slimes. In addition, if flotation time is extended or several successive floats are performed on the same pulp, a corresponding greater amount or a supplementary addition of flocculating agent may be required.

It should also be noted that the use of many of the standard chemicals now employed in standard froth flotation circuits can be dispensed. The use of the present invention allows much higher recoveries even in the absence of standard flotation reagents such as activators.

What is claimed is:

1. In froth flotation processes for fractionating pulps containing slime forming metallic ore values into concentrates and tailings wherein at least one agent having collector properties is utilized, the improvement comprising adding to said pulp at least one polymeric flocculating agent selected from the group consisting of flocculating polysaccharides, polyacrylamides and flocculating glues in an amount sufficient to cause formation and maintenance of a floc of the metallic ore value slimes in said pulp during flotation treatment of said pulp and recovering said floc from the froth as a concentrate.

2. A process in accordance with claim 1 wherein said metallic ore is selected from the group consisting of uranium ore, vanadium ore and manganese ore.

3. A process in accordance with claim 1 wherein said pulp has a pH value greater than about 7.

4. In froth flotation processes for fractionating uranium ore pulps into uranium concentrates and tailings wherein at least one collector is utilized, the improvement comprising adding a polyacrylamide flocculating

agent to said pulp in an amount sufficient to cause formation and maintenance of a floc of the uranium ore slimes in said uranium pulp during flotation treatment of said uranium ore pulp and recovering said floc from the froth as a concentrate.

5. In froth flotation processes for fractionating vanadium ore pulps into vanadium ore concentrates and tailings, wherein at least one collector is utilized, the improvement comprising adding a polyacrylamide flocculating agent to said pulp in an amount sufficient to cause formation and maintenance of a floc of the vanadium ore slimes in said vanadium pulp during flotation treatment of said vanadium ore pulp, and recovering said floc from the froth as a concentrate.

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