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BENEFICIATION OF IRON ORE

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This invention relates to the froth flotation of oxidized iron ores and more particularly to processes using sulfonated organic carboxylic acid reagents.

The beneficiation of oxidized iron ore by froth flotation has presented a peculiarly difficult practical problem. It is a comparatively simple matter to concentrate certain oxidized iron ores by froth flotation with a large series of promoters, such as for example oleic acid; however, the economics of iron ore utilization are such that it is necessary to obtain both good iron recovery and a relatively high grade in order to make the process economical because of the low price for which iron ore concentrates sell.

According to the present invention oxidized iron ore is floated using a sulfonated talloel reagent, preferably in the presence of an unsulfonated oil, and for best results it is necessary to treat the iron ore feeds with an acid substance the anion of which is capable of forming an acid having a dissociation constant greater than 10^{-7}. Commercial results are not obtainable without the acid treatment except when very highly sulfonated talloel is used, in which case the promoter itself is probably sufficiently acid or gives off sufficient acid to effect the necessary change on the surface of the iron ore particles.

Throughout the specification and claims the term "sulfonated talloel" will be used in its usual commercial sense to cover the products obtainable by reacting talloel with strong sulfuric acid. It is quite possible that both sulfonation and sulfation take place, and it is not intended that the term "sulfonated talloel" shall be restricted to a compound in which all ordinary sulfur is present in the form of the sulfonic acid groups.

It is an advantage of the present invention that reasonably satisfactory results may be obtained with talloel having various degrees of sulfonation from about 10–20% sulfuric acid based on the weight of the talloel up to such highly sulfonated products as those obtained by treating talloel with equal quantities of sulfuric acid. It is a further advantage of the present invention that it is not necessary to use any particular grade of talloel. Thus, it is possible to use crude talloel obtained by acid treatment of black liquor soap containing not only unsaturated fatty acids and resin acids but also lignins and other products, or refined talloel which has been freed of lignin may be used; and it is, of course, possible to use highly purified talloel obtained by distillation and similar processes for refining talloel. For practical operation we prefer to use sulfonated refined talloel as the results are slightly better than with the sulfonated crude product, and no material improvement is obtained when sulfonated distilled talloel is used, so that the higher cost of the latter product is normally not justified in commercial operation. This flexibility with regard to the constitution of the reagent is of considerable importance because talloel is not a rigidly standardized chemical compound. On the contrary, the exact composition of talloels will vary depending on the particular wood used in the sulfate paper process from which the black liquor soap is obtained, the part of the country in which the trees occur, and other factors. In our experience any of the widely distributed commercial refined talloels may be sulfonated to produce a reagent which will give satisfactory results in practical operation. While comparable results may be obtained with sulfonated refined or semi-refined talloel and with sulfonated distilled talloel, it should be noted that the amount of sulfonation is not necessarily the

same. For example, treating distilled talloel with a smaller amount of sulfuric acid will produce a product which behaves in a manner similar to a sulfonated product obtained from refined or semi-refined talloel which has been treated with a larger amount of sulfuric acid. For example, distilled talloel treated with 30% by weight of sulfuric acid gives a product, the behaviour of which in the process of the present invention closely approximates that of ordinary refined talloel which has been treated with 50% of sulfuric acid.

It is not necessary to isolate the sulfonated talloel. On the contrary, the reaction mixture itself may be used or it may be partially or wholly neutralized with alkali. No material difference in flotation efficiency is to be noted, and we believe that the impurities produced in the sulfonation reaction do not exert any deleterious effect on the flotation. The possibility of using crude sulfonation mixtures which are, of course, cheaper is a valuable advantage of the present invention. Any economy in reagent cost is of considerable importance in iron ore flotation by reason of the low sales price of the final product.

It is a further advantage of the present invention that it is not limited to sulfonated talloels produced by any particular sulfonation procedure and any of the ordinary sulfonation processes may be used.

The sulfonated talloel reagent of the present invention is rather different in its characteristics from sulfonated petroleum hydrocarbons which are claimed in our copending applications, Serial No. 481,906, filed April 5, 1943, and Serial No. 491,384, filed June 18, 1943. While the present invention shares with these other applications the possibility of producing a commercially useful grade of iron ore concentrate from practically any iron ore which is available, the behavior toward acid neutralization and other factors is rather different. Sulfonated petroleum hydrocarbons in general do not give useable results unless the iron ore is pre-treated with a fairly strong acid. Sulfonated talloel may, however, be used alone or with additional unsulfonated oils without pre-treatment with acid where highly sulfonated material is employed. On the other hand low sulfonated talloel will not give useful results with acid treated ore alone in the absence of unsulfonated oils, and in fact with very low degrees of sulfonation the acid treatment may actually inhibit practical flotation. It is clear that the froth flotation of iron ore using sulfonated reagents with acid pre-treatment of the ore must involve a number of factors, the full extent of which has not yet been determined. Without desiring to limit the present invention to any unproven theories we believe that one reason for the anomalous results with talloel of low degree of sulfonation may lie in the fact that in such cases the major portion of the promoter is in the form of an unsulfonated fatty acid or resin acid, and one of the drastic distinctions between sulfonated reagents and carboxylic acid reagents is that acid pre-treatment of the ore often-times inhibits flotation with the latter.

Another distinguishing feature between sulfonated talloel and sulfonated hydrocarbons is that many of the latter give satisfactory results on acid pre-treated iron ore even though the flotation circuit may be brought to neutrality or even slight alkalinity with ordinary alkali such as soda ash. With sulfonated talloel, however, commercial results have not been obtained unless the flotation circuit itself remains acid.

It is an advantage of the present invention that the particular acid used does not appear to be critical, although results of practical utility are not obtained with weaker acids than those having a dissociation constant of 10^{-7}. It is, of course, necessary that the acid anion should not have a known depressive effect on the iron ore. Sulfuric acid gives as good results as any, and because of its great cheapness constitutes the preferred acid for practical operation. It is, however, not superior to other strong acids in the quality of the results obtained and its choice is, therefore, dictated primarily by economic costs rather than operative efficiency.

It is an advantage of the present invention that satisfactory results are obtainable with sulfonated talloel alone when the ore has been properly pre-treated with acid. However, the sulfonated talloel may, of course, also be mixed with other sulfonated reagents such as sulfonated petroleum hydrocarbons and under some circumstances these mixed reagents possess some economical advantages. It is also possible to combine an anionic float using sulfonated talloel with a silica float of the concentrate using known cationic froth flotation procedures. With ordinary iron ores this double float does not give improved results and, therefore, its additional cost is not justified. It is, however, available for the treatment of certain particularly refractory ores.

The froth flotation process of the present invention behaves normally with respect to slime, that is to say in common with many anionic flotations a small amount of slime can be tolerated, but larger amounts of slime decrease grade of concentrate and increase reagent consumption. It is, therefore, desirable to deslime fairly thoroughly, although the extreme degree of desliming which is essential with many cationic flotations is not necessary. Ordinary good desliming practice may, therefore, be followed, and it is an advantage of the present invention that the process is not critical in this respect.

The process of the present invention gives excellent results with the more common oxidized iron minerals such as hematite and magnetite. It is, however, an advantage of the present invention that other iron minerals commonly present in iron ores, such as martite, limonite, siderite, goethite, and the like, may also be successfully floated by the procedure of the present invention.

The invention will be described in greater detail in conjunction with the following specific examples which deal with the treatment of typical iron ores. In some cases low grade iron ores are used which present a more difficult problem in obtaining high grades with good recoveries. The parts are by weight.

Example 1

A low grade refractory Minnesota iron ore forming a reject from iron beneficiation operations and containing about 15% Fe as hematite with some limonite mixed with a quartz gangue was deslimed, conditioned at 60–65% solids with various sulfonated talloels with and without sulfuric acid and unsulfonated oils, diluted to 22% solids, floated in a standard Fagergren flotation machine and the concentrate cleaned once. The talloel used was ordinary refined talloel substantially free from lignin.

The metallurgical results are given in the following table, the sulfuric acid used being 95% strength and the amount of sulfonated reagent 1.62 lbs. per ton:

Promoter used sulfonated talloel		Sulfonated talloel alone				With 1.62 lbs./ton sulfuric acid				With 3.23 lbs./ton fuel oil				With 1.62 lbs./ton sulfuric acid and 3.23 lbs./ton fuel oil			
		Concentrate percent Fe		Rgh. tailing		Concentrate percent Fe		Rgh. tailing		Concentrate percent Fe		Rgh. tailing		Concentrate percent Fe		Rgh. tailing	
Parts talloel	Parts sulfuric acid	Assay	Distrib.	Assay percent Fe	pH	Assay	Distrib.	Assay percent Fe	pH	Assay	Distrib.	Assay percent Fe	pH	Assay	Distrib.	Assay percent Fe	pH
100	None	31.47	80.25	3.46	7.1	No promotion				28.48	54.23	6.81	7.1	No promotion			
100	10	39.33	52.77	5.50	6.7	No useful float				51.71	45.89	7.06	6.7	No useful float			
100	20	19.94	89.56	2.75	6.7	56.37	61.34	4.90	2.8	42.75	90.52	1.71	6.7	56.67	70.84	4.18	2.8
100	30	29.38	90.35	1.79	6.5	49.56	71.09	3.82	2.8	44.42	92.81	1.01	6.5	50.39	88.15	1.91	2.8
100	40	30.93	87.38	2.15	6.4	48.36	61.28	5.07	2.6	35.83	92.62	1.43	5.8	55.23	90.67	1.19	2.7
100	50	37.38	83.85	2.39	6.2	56.61	72.90	3.76	2.8	43.95	91.70	1.49	4.6	52.66	89.72	1.31	2.6
100	60	35.23	91.87	1.31	5.3	43.71	80.14	2.45	2.6	53.92	94.76	0.72	4.3	56.48	94.39	0.83	2.6
100	70	54.93	81.27	2.87	4.0	53.98	68.85	3.40	2.6	52.18	92.75	0.95	4.0	56.19	96.86	0.42	2.6
100	80	41.06	83.71	2.15	3.8	52.42	63.79	4.06	2.7	55.77	93.09	0.89	3.8	57.50	92.85	1.07	2.6
100	90	53.50	65.66	4.18	3.7	52.00	66.69	3.28	2.7	57.74	86.62	1.79	3.8	57.56	89.06	1.55	2.6
100	100	60.07	38.33	7.40	3.5	59.59	36.16	7.76	2.6	58.46	69.01	3.70	3.55	59.11	86.27	1.73	2.6

Certain anomalous results will be noted where sulfonated talloel was used alone or with ore treated with sulfuric acid but without any unsulfonated oil. The 80% sulfonated talloel gave poorer grade than the 70% and in conjunction with sulfuric acid the 60% was poorer than even the 20%. These grade results are not significant where they fall unusually low, because in the absence of unsulfonated oil the froth was very intense and an unusually low grade merely means that there was gangue carried along mechanically. The adverse effect of sulfuric acid in the case of unsulfonated talloel or 10% sulfonated talloel has been discussed above, and we believe is due to the fact that in these cases the normal effect of acid with carboxylic acid promoters predominated.

Example 2

A somewhat higher grade Minnesota iron ore washer tailing, containing about 25% Fe mainly as hematite associated with a quartz gangue, was conditioned with 30% sulfonated distilled talloel with and without added fuel oil, sulfuric acid and both. The amount of sulfonated reagent was 2 lbs. per ton. The results appear in the following table:

Promoter used sulfonated talloel		Sulfonated talloel alone				With 2.00 lbs./ton sulfuric acid				With 5.00 lbs./ton fuel oil				With 2.00 lbs./ton sulfuric acid and 5.00 lbs./ton fuel oil			
		Concentrate percent Fe		Rgh. tailing		Concentrate percent Fe		Rgh. tailing		Concentrate percent Fe		Rgh. tailing		Concentrate percent Fe		Rgh. tailing	
Parts talloel	Parts sulfuric acid	Assay	Distrib.	Assay percent Fe	pH	Assay	Distrib.	Assay percent Fe	pH	Assay	Distrib.	Assay percent Fe	pH	Assay	Distrib.	Assay percent Fe	pH
100	30	24.12	92.96	3.94	6.5	38.09	80.14	5.37	2.8	43.59	96.45	0.95	6.4	58.69	91.90	2.15	2.8
100	20	22.10	88.62	8.80	6.7									61.16	80.57	4.37	2.8
100	10	38.12	86.44	4.49	6.8									No useful float			
100	None	39.17	79.87	6.89	7.1									No promotion			

It will be noted that when fuel oil and sulfuric acid are used together with the reagent good commercial results are obtainable even with 30% sulfonated talloel.

Example 3

The ore of Example 1 was used to test sulfonation of different talloels. The conditioning and flotation procedure was the same as in Example 1. The amount of sulfonated reagent used was 1.62 lbs. per ton, except in the case of test 3, where it was 1.08, and test 7, where it was 1.35. In each case attempts were made to operate under optimum conditions for the particular talloel.

Promoter used—type of talloel	Percentage sulfonication		Lbs./ton		Concentrate per cent Fe		Rougher tailing	
	Parts talloel	Sulfuric acid	Fuel oil	Sulfuric acid	Assay	Distrib.	Assay per cent Fe	pH
A crude talloel containing lignin	100	40	3.23	1.62	52.66	90.88	1.01	2.7
Distilled talloel—about 30% rosin acids	100	30	3.23	1.62	54.75	90.83	1.19	2.6
Distilled talloel	100	50	2.28	1.62	52.30	86.86	1.67	2.7
Partially refined Canadian talloel high in nonsaponifiable material	100	50	3.23	1.62	59.41	50.06	5.91	2.6
A refined blown talloel	100	30	3.23	1.62	53.74	93.30	0.83	2.6
Partially refined talloel containing some precipitated rosin	100	29	3.23	1.62	57.77	99.19	1.38	2.6
Do	100	50	3.23	1.62	60.46	89.55	1.36	2.6
Talloel—diluted with 10% secondary butanol	100	50	3.05	1.62	56.54	88.55	1.55	2.7
Distilled talloel about 30% rosin acids	100	30 (as 86% acid)	3.66	1.62	55.35	85.84	1.61	2.6
Do	100	30 (oleum)	3.23	1.62	55.65	83.34	1.91	2.7
Refined talloel—after sulfonation neutralized to methyl orange with caustic soda	100	25 (as 98% acid)	1.21	1.62	60.68	78.87	2.57	
Distilled talloel—after sulfonation neutralized to methyl orange with caustic soda	100	11 (as 98% acid)	1.21	1.62	60.80	70.99	2.57	

It will be noted that some crude talloels gave excellent results and that distilled talloels, except in one case, did not give quite as good results as sulfonated ordinary refined talloel. However, all of the talloels gave results which may be considered satisfactory.

Example 4

The ore of Example 2 was used with various amounts of different unsulfonated oils. The talloel was 50% sulfonated in the first two tests and 30% sulfonated in the remainder. The amount was 2 lbs. per ton for the sulfonated talloel and 2 lbs. per ton of sulfuric acid except in the case of saponified talloel, where 4 lbs. of sulfuric acid were used. Conditioning procedure and flotation procedure were identical with those of the two preceding examples. The metallurgical results appear in the following table:

Addition reagent		Concentrate percent Fe		Rougher tailing	
Type	Lbs./ton	Assay	Distribution	Assay percent Fe	pH
Talloel	4.58	58.40	92.53	1.25	2.8
Oleic acid	4.47	59.23	91.00	1.91	------
Crude oil	5.13	56.48	95.21	0.83	2.8
Chlorinated kerosene	3.88	60.66	83.93	3.28	------
Coconut oil	3.24	60.07	92.14	1.37	------
Cottonseed oil	3.03	59.47	86.12	2.15	------
Naphthenic acids	4.11	56.25	85.35	2.45	------
n-Heptaldehyde	4.20	54.57	82.70	2.81	------
Methyl ester of talloel	4.47	59.59	84.23	2.89	------
Lauryl mercaptan	3.56	59.83	83.68	3.22	2.8
Saponified talloel	4.00	55.89	90.54	1.91	2.6
22° Bé, fuel oil	5.02	58.69	91.90	2.15	2.8

It will be apparent that good results are obtainable with all of the unsulfonated oils and are commercial with the possible exception of n-heptaldehyde where the concentrate was a little below usual commercial grade. Excellent results are obtained with talloel and coconut oil as the unsulfonated modifying agents. Good results are also obtainable with ordinary fuel oil, and the choice will be determined largely by economic considerations, primarily the relative costs of the materials. The wide choice of cheap unsulfonated modifying agents represents an advantage because of the greater flexibility of the operation. It is of course, possible to use mixtures of unsulfonated oils where such mixtures may be desirable for economic reasons.

Example 5

The procedure of Example 1 was followed using the ore of Example 2 and determining the effect of various acids on the iron ore. In each case the sulfonated talloel was 30% sulfonated distilled talloel and the amounts used were 1.62 lbs. per ton except in the fourth test where 2.7 lbs. were used and the eleventh test where 2.16 lbs. were used. In the third test 3.48 lbs. per ton of talloel (unsulfonated) were used instead of the fuel oil used in all other tests. The results appear in the following table:

Acid used		Fuel oil, lbs./ton	Concentrate per cent Fe		Rgh. tailing	
Type	Lbs./ton		Assay	Distrib.	Assay per cent Fe	pH
Sulfuric	1.62	4.07	58.69	91.90	2.15	2.8
Nitric	1.62	3.80	56.37	96.51	0.83	2.9
Hydrochloric	2.16	[1] 3.48	58.87	91.12	1.67	2.4
Phosphoric	2.48	5.60	59.71	73.55	6.45	3.0
Acetic	3.24	3.83	53.14	96.31	0.83	3.9
Sulfurous	3.96	3.80	57.56	94.24	1.19	4.0
p-Toluene sulfonic	2.16	3.80	56.37	96.20	0.83	3.6
Carbonic	([2])	4.06	54.57	96.16	0.96	6.1
Boric	5.41	3.54	42.77	96.66	1.07	6.5
Oxalic	3.25	3.54	59.83	77.00	4.90	2.9
Citric	3.25	4.07	57.92	91.72	1.31	3.3
Sulfamic	3.25	3.80	58.51	95.72	1.07	2.7
None	None	4.07	43.59	96.45	0.96	6.4

[1] Unsulfonated talloel used in place of fuel oil.
[2] Saturated.

It will be apparent that acceptable results are obtainable with practically any strong acid. Carbonic acid which has a dissociation constant of barely over 3×10^{-7} began to show a slight falling off and boric acid, which has a dissociation constant below 10^{-7}, is definitely inferior. As sulfuric acid gives as good results as any other it is preferred because of its cheapness. The figures for acid and fuel oil are based on ore rather than deslimed feed which basis was used in the table following Example 2.

Example 6

The flotation procedure of Examples 1 and 2 was followed using the ore of Example 2. In each case a 30% sulfonated refined talloel was used, the first and third tests employing 3.34 lbs. per ton and the second test 4 lbs. per ton. Typical acid salts were used in place of acids and the metallurgical results appear in the following table:

Acid salt used		Fuel oil, lbs./ton	Concentrate percent Fe		Rgh. tailing	
Type	Lbs./ton		Assay	Distrib.	Assay percent Fe	pH
Sodium chlorosulfonate	8.00	5.96	59.23	90.72	2.34	2.4
Potassium bisulfate	13.3	6.91	59.35	90.00	2.75	2.3
Sodium silicofluoride	4.40	5.65	56.72	94.52	0.83	3.45

It will be noted that strong acid salts such as sodium chlorsulfonate or potassium bisulfate give substantially the same results as sulfuric acid, but require larger quantities. Smaller quantities of sodium silico-fluoride may be used with some sacrifice of grade. In each case an amount of acid salt was used which was felt to give good results.

Example 7

The ore and flotation procedure of Example 1 was followed using a 30% sulfonated distilled talloel as promoter, together with sulfuric acid. Part of the ore was thoroughly deslimed in accordance with good ore dressing practice, part was partially deslimed, and part was not deslimed at all. The results appear in the following table:

Product	Per cent weight	Assay		Per cent Fe distrib.	Lbs./ton used		
		Per cent Fe	Per cent insol.		Promoter	H_2SO_4	Fuel oil
Essentially completely deslimed:							
Calc. head	100.00	14.33		100.00			
Slime	5.84	36.78		14.99			
Clean. conc	19.54	57.20	9.74	78.01	1.50	1.50	3.76
Clean. tail	7.10	3.94		1.95			
Rgh. tail	67.52	1.07		5.05			
Partially deslimed:							
Calc. head	100.00	14.16		100.00			
Slime	5.36	26.57		10.10			
Clean. conc	17.04	53.30	17.28	64.39	1.50	1.50	5.17
Clean. tail	4.47	6.23		1.97			
Rgh. tail	73.13	4.54		23.54			
Not deslimed:							
Calc. head	100.00	14.21		100.00			
Clean. conc	12.42	52.60	17.80	45.96	2.50	2.50	9.40
Clean. tail	2.85	10.33		2.07			
Rgh. tail	84.73	8.72		51.97			

It will be apparent that while desliming is desirable it need not be carried to an extreme degree. In each case the amount of reagent employed was that which gives optimum results, and it will be apparent that when the ore is undeslimed inferior grade is obtained, even though a considerably increased amount of reagent is used.

Example 8

The ore of Example 1 was used, but part of the ore was conditioned at 65% solids and part at 22% solids. The reagents used were 1.62 lbs. per ton of 30% sulfonated distilled talloel, 1.62 lbs. per ton sulfuric acid and 3.05 lbs. per ton fuel oil. The results appear in the following table:

Concentrate per cent Fe		Tailing		Pulp density per cent solids	
Assay	Distrib.	Assay percent Fe	pH	Conditioning	Flotation
54.75	90.43	1.19	2.6	65	22
40.36	71.29	4.89	2.6	22	22

It will be apparent that conditioning at high solids appears to be necessary in order to get maximum results. This is in line with our experience with sulfonated hydrocarbons as promoter reagents and in this respect the present invention does not depart from optimum conditions set out in our two copending applications referred to above.

Example 9

The ore of Example 1 was deslimed at 25% solids, then scrubbed by agitation in a Fagergren flotation machine with the air shut off at 25% solids, again deslimed, thickened and conditioned at 65% solids with 0.81 lbs. per ton 30% sulfonated distilled talloel, 1.62 lbs. per ton sulfuric acid and 2.03 lbs. per ton 22° Bé. fuel oil. The conditioned ore was then diluted to 22% solids and floated in a Fagergren flotation machine. The results appear in the following table:

Product	Percent weight	Assay		Percent distrib. of Fe
		Percent Fe	Percent Insol.	
Calc. head	100.00	14.28		100.00
Prim. slime	6.19	34.39		14.91
Sec. slime	3.51	34.87		8.57
Clean. conc	16.73	59.59	7.08	69.82
Clean. tail	4.12	5.19		1.50
Rgh. tail	69.45	1.07		5.20

It will be apparent that with a soft iron ore considerable secondary slime is formed by scrubbing. However, in many cases it is desirable to remove this slime as it will be noted that an excellent recovery was made, the 69.82% actually amounting to over 90% of the iron in the flotation feed, some 23% of the iron in the original sample being rejected as slime. The desirability of scrubbing to remove secondary slimes is largely dependent on the nature of the surface of the ore particles and is desirable with some ores and not with others. By comparing the results of Example 9 with those obtained in Example 7 on essentially completely deslimed ore, it will be apparent that considerable saving in reagents was obtained by the use of the scrubbing procedure.

Example 10

The procedure of Example 1 was followed but the various sulfonated talloels were used in three portions, immediately after preparation, one hour after preparation, and 24 hours after preparation. The sulfonated talloel for the first series of three tests was 30% sulfonated distilled talloel, while that used for the second and third series was 50% sulfonated refined talloel. In the third series the sulfonated talloel was diluted as soon as made and was allowed to stand in the form of a 7.5% aqueous solution. The reagent amounts in the case of the first two series were 1.62 lbs. per ton and in the last series 3.24 lbs. per ton. Results appear in the following table:

When used	Lbs./ton		Concentrate percent Fe		Rgh. tailing	
	H_2SO_4	Fuel oil	Assay	Distrib.	Assay percent Fe	pH
Immediately after preparation	1.62	4.07	57.20	91.77	1.07	2.65
1 hour after preparation	1.62	4.07	59.59	90.57	1.31	2.7
24 hours after preparation	1.62	4.07	60.43	46.77	6.69	2.6
Immediately after preparation	1.62	5.07	57.54	93.83	0.83	2.6
1 hour after preparation	1.62	5.07	58.40	92.93	0.95	2.65
24 hours after preparation	1.62	5.07	42.99	38.16	9.25	2.7
Immediately after preparation	1.62	5.07	53.92	91.46	0.95	2.5
24 hours after preparation	1.62	5.07	52.66	89.07	1.07	2.6

It will be apparent that the sulfonated talloel keeps for a sufficient time to permit satisfactory feeding in commercial operations, but does not keep for a day. However, if it is desired to keep the talloel for longer periods this may be effected

by dissolving the sulfonated talloel in water as soon as it is prepared.

The above results were obtained with sulfonated talloels which had not been neutralized, and these remarks are not completely applicable to neutralized or partially neutralized talloels.

Example 11

Various iron ores were floated using the procedure of Example 1. The sulfonated talloel in the case of the first 4 tests was 30% sulfonated distilled talloel and in the case of the last 4 tests 50% sulfonated refined talloel. In every case the amounts chosen were those to give optimum conditions. The amount of cleaning differed, C–1 referring to a single cleaning, and C–2 to double cleaning.

Promoter used, lbs./ton	Lbs./ton		Source of ore	Feed assay per cent Fe	Concentrate per cent Fe		
	H_2SO_4	Fuel oil			Assay	Distrib.	
3.48	2.64	4.96	Minnesota—a washer tailing, containing principally hematite and quartz	43.28	68.67	89.85	C–2
2.11	2.11	3.72	Minnesota—a taconite ore, containing principally hematite and quartz	22.76	[1] 54.45	96.29	C–2
3.17	4.22	5.46	New Jersey—a magnetic iron concentrate	64.22	68.43	96.81	C–1
2.50	2.50	3.52	New Jersey—a magnetite-martite table concentrate	67.47	70.32	76.41	C–1
2.64	2.64	4.96	Minnesota—a taconite ore, containing hematite and quartz	37.88	55.89	94.58	C–2
2.64	2.11	4.9	Minnesota—a washer reject from a hematite ore	30.28	59.83	89.77	C–1
2.11	2.11	4.46	Minnesota—a washer tailing, containing hematite	18.38	[1] 54.69	92.97	C–1
1.50	1.50	3.29	New Jersey—an ore containing martite and quartz	22.75	67.09	91.61	C–2

[1] Refractory due to locking of Fe and SiO_2 in fine sizes.

It will be apparent that acceptable results are obtained with various iron ores, the less refractory ores giving commercial grade products and even the highly refractory ores giving products which can be utilized.

While the best results are obtained when sulfonated talloels are used in conjunction with other acid substances such as sulfuric acid, fair results are obtainable with some sulfonated talloels particularly when associated with unsulfonated oils without additional acid. It is difficult to determine whether the action may be due in part to some of the sulfonated talloel acting as an acid agent and some as a promoter. However, the invention is not limited in its broadest aspects to the use of an added acid substance although this constitutes the preferred procedure and in most cases gives the best commercial results.

Throughout the specification and claims natural talloel has been described, that is to say the mixture of resin and unsaturated fatty acids which is obtained by acidification of black liquor soap from the sulfate paper pulp process. In certain localities where talloel is not readily available synthetic mixtures have been made up of resin acids and unsaturated fatty acids which behave in the same manner as natural talloel and which are referred to in the art as synthetic talloel. The term as used in the present specification and claims is intended to cover the mixture of resin and unsaturated fatty acids regardless of the method by which this mixture is produced and, therefore, is intended to cover synthetic talloels as well as natural talloels. From the standpoint of froth flotation there is no discernible difference between natural and synthetic talloels of the same composition.

The expression "oxidized iron ores" is used herein in its commonly accepted meaning to include not only iron oxide ores such as those containing magnetite, hematite, etc., but also hydroxides, carbonate, etc.

We claim:

1. A method of beneficiating oxidized iron ores by froth flotation which comprises subjecting the ore to froth flotation in the presence of an effective amount of a collector containing as its essential collecting constituent sulfonated talloel including an effective amount of an acid substance the anion of which is a constituent of an acid having a dissociation constant of at least 10^{-7} and which does not adversely effect flotation whereby a concentrate is obtained relatively rich in iron mineral and a tailing relatively poor in iron.

2. A method of beneficiating oxidized iron ores by froth flotation which comprises conditioning the ore at high solids with a reagent containing sulfonated talloel as its essential collecting constituent including an effective amount of an acid substance the anion of which is a constituent of an acid having a dissociation constant of at least 10^{-7} and which does not adversely effect flotation, diluting the conditioned ore to flotation density and subjecting it to froth flotation to produce a concentrate relatively rich in iron mineral and a tailing relatively poor in iron.

3. A method of beneficiating oxidized iron ores by froth flotation which comprises conditioning the ore at high solids with a reagent containing sulfonated talloel as its essential collecting constituent and an effective amount of sulfuric acid, diluting the conditioned ore to flotation density and subjecting it to froth flotation to produce a concentrate relatively rich in iron mineral and a tailing relatively poor in iron.

4. A method according to claim 1 in which the reagent is associated with an unsulfonated oil.

5. A method according to claim 2 in which the reagent is associated with an unsulfonated oil.

6. A method according to claim 3 in which the reagent is associated with an unsulfonated oil.

7. A method according to claim 1 in which the reagent is associated with unsulfonated talloel.

8. A method according to claim 2 in which the reagent is associated with unsulfonated talloel.

9. A method according to claim 3 in which the reagent is associated with unsulfonated talloel.

10. A method according to claim 1 in which the reagent is associated with an unsulfonated glyceride oil.

11. A method according to claim 2 in which the reagent is associated with an unsulfonated glyceride oil.

12. A method according to claim 3 in which the reagent is associated with an unsulfonated glyceride oil.

13. A method according to claim 1 in which the reagent is associated with an unsulfonated hydrocarbon oil.

14. A method according to claim 2 in which the reagent is associated with an unsulfonated hydrocarbon oil.

15. A method according to claim 3 in which the reagent is associated with an unsulfonated hydrocarbon oil.

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