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BENEFICIATION OF COAL BY FLOTATION

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This invention relates to the purification of coal and more particularly to the separation of siliceous impurities from coal contaminated therewith.

The fines obtained in the grading of coal are generally of lower grade because of contaminating impurities such as sand and clay. The fines from strip mining operations are particularly low grade for this reason. Thus fines which accumulate from washing operations from strip mining and the fines salvaged from waste wash water and coal residues are of poor quality because of the high ash content. Although it has been known to separate coal from impurities by floating the coal from the impurities, such flotation processes have not been practical where the impurities have constituted a minor proportion of the crude coal. Moreover, such flotation processes have required crushing the coal to increase the fines so as to make it floatable.

Now in accordance with the present invention, it has been found that coal containing siliceous material such as fine sand and clay is upgraded by subjecting the coal to froth flotation in the presence of a depressant for the coal and a rosin amine in the form of its water-dispersible salt whereby the siliceous material is floated away from the coal.

By this process, coal of random sizes may be reduced in siliceous ash without pulverizing the coal. Moreover, the coal may be purified with or without prior classification as to size. Thus coarse coal containing fines and siliceous material may be purified directly by the present flotation process or the coal may first be classified by any of the well-known processes such as screening, gravity separation, water washing, and the like, and the fraction containing fine coal and siliceous fines may be subjected to the flotation with the rosin amine in the form of its water-soluble salt in accordance with this invention to float the siliceous material from the coal.

The method of carrying out the process of this invention is illustrated by the following examples wherein parts are parts by weight.

Example 1

Coal screenings having a particle size smaller than about 28 mesh (standard sieve) including dust particles smaller than 200 mesh and containing siliceous material of about the same particle size, including clay dispersible in the wet state to the colloidal state, were washed with water on a 200-mesh sieve to remove dispersible clay which passed through the sieve. A sample of this coal amounting to 400 parts dry weight

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and having an ash content of 20.9%, which was chiefly siliceous ash, was subjected to flotation in a standard flotation machine in water of about pH 8 containing

	Pounds per ton coal
Starch	4.3
Pine oil	0.14
Kerosene	0.19
Dehydrogenated rosin amine acetate	0.57

At the end of the first float, the floated material amounting to 20.6% by weight of the feed contained 38.6% ash and the tailings amounting to 79.4% by weight of the feed contained 16.2% ash.

Example 2

A sample of 400 parts of anthracite coal (dry basis) having 23.2% ash having a particle size distribution between 28- and 200-mesh screens was subjected to flotation in a standard flotation machine using water at pH 8–8.2 containing

	Pounds per ton coal
Starch	2.0
Dehydrogenated rosin amine acetate	0.78

At the end of one treatment, the floated material amounting to 13.8% of the coal contained 56.1% ash and the tailings amounting to 86.2% of the coal contained 18.0% ash.

Example 3

A sample of 400 parts coal (dry basis) having 22.9% ash and having a particle size distribution between 28- and 200-mesh screen was subjected to flotation in a standard flotation machine using water at pH 8.1–8.3 containing

	Pounds per ton coal
Starch	2.0
Kerosene	0.18
Dehydrogenated rosin amine acetate	0.54

The floated material amounting to 15% of the weight of the coal contained 50.0% ash and the tailings amounting to 85% of the coal contained 18.0% ash.

Example 4

A sample of 400 parts coal (dry basis) having 24.0% ash and having a particle size distribution between 28- and 200-mesh screen was subjected to flotation in a standard flotation machine using water at pH 7.9–8.2 containing

	Pounds per ton coal
Starch	2.0
Pine oil	0.18
Dehydrogenated rosin amine actate	0.77

At the end of one treatment the floated material amounting to 13.1% of the coal contained 58.1% ash.

As a result of a second flotation treatment of the tailings, 3.8% was floated with 45.3% ash and the tailings amounting to 83.1% had an ash content of 17.8%.

Examples 5 and 6

A sample of 400 parts of coal (dry basis) having 22.9–23.5% ash and a particle size distribution between 28- and 200-mesh screen was subjected to flotation in a standard flotation machine using water at pH 8.0–8.2 in one instance and 3.8–5.7 (H_2SO_4 added) in another. The water used in the flotation contained in each instance

	Pounds per ton coal
Starch	2.0
Kerosene	0.18
Dehydrogenated rosin amine acetate	0.54

The results were as follows:

Example	pH	Float		Tailings	
		Percent	Ash, Percent	Percent	Ash, Percent
5	8.0–8.2	15.0	50.0	85.0	18.1
6	3.8–5.7	11.0	43.0	89.0	21.1

Examples 7–10

Using water at pH 7.5–8.5 in the standard flotation machine and 400 parts coal (dry basis) having particle size distribution between 28- and 200-mesh, the following data were obtained in the use of dextrin, egg albumen, casein, and gelatin as depressants in the flotation process using rosin amine.

Example	7	8	9	10
Dehydrogenated Rosin Amine Acetate	0.49	0.74	0.47	0.47
Pine Oil	0.12	0.12	0.12	0.12
Kerosene	0.16	0.16	0.16	0.16
Dextrin	3.7	------	------	------
Egg Albumen	------	3.7	------	------
Casein	------	------	1.2	------
Gelatin	------	------	------	2.4
Float:				
Weight	18.0	20.9	14.9	15.6
Percent Ash	51.5	41.5	32.8	40.9
Tail:				
Weight	82.0	79.1	85.1	84.4
Percent Ash	20.9	17.7	26.1	22.1

By carrying out a second float still more ash is removable and the resulting tailings are of still lower ash content.

The flotation process as shown in the examples may be carried out repeatedly, in combination with intermediate screenings, if desired, to get much lower ash content in the tailings. The flotation may also be carried out on coal containing particles larger than 28 mesh in apparatus so designed or the coal may be washed on a screen so as to get the smaller particle size separated for flotation. The material floated in this process will be less than 28 mesh in size and ash of larger size will normally require separation by known supplementary processes.

While the process may be carried out using a rosin amine in the form of its water-dispersible salt and depressants for the flotation of the coal without other flotation aids, the efficiency is improved by addition of an alcohol having 4 to 10 carbon atoms, cyclic or acyclic, e. g., butanol, pentanols, hexanols, heptanols, octanols, lauryl alcohol, pine oil, terpineols, cyclohexanols, cresols, xylenols, and the like. The alcohol may also be advantageously mixed with a liquid hydrocarbon oil, preferably in the range of 10 to 25 carbon atoms, such as light lubricating oil, kerosene, naphtha, terpenes, terpene polymers, etc. The amount of the alcohol used will be within the range of about 0 to aobut 0.25 pound per ton of coal and the hydrocarbon may be used in the range of about 0 to about 0.75 pound per ton, but the total of alcohol and hydrocarbon will not be used in excess of about 1.0 pound per ton of coal.

Materials which depress the flotation of the coal are particularly useful in reducing the tendency of coal of fine particle size to float and are necessary in the present process because of the ease with which coal fines are floated. Examples of such materials are high molecular weight carbohydrates having hydrophilic properties such as starch, particularly soluble starch, caramel, dextrin, molasses residues, proteins such as glue, gelatin, albumen, edestin, collagen, blood proteins, blood, tannins, and glucosides such as saponins. These materials are often referred to as protective colloids. The amount of depressant will be sufficient to depress the flotation of the coal but not sufficient to depress also the flotation of the siliceous material. In general, the amount of depressant will vary with the particular depressant used and the coal under treatment. However, not more than about 0.25 part (water-free weight) per 100 parts dry solids will be used.

The rosin amines which may be used in the form of their salts in the process of this invention are the rosin amines prepared by replacing the —COOH group of the rosin acids of wood or gum rosin, dehydrogenated rosin and hydrogenated rosin by a $—CH_2NH_2$ group. The rosin amines so prepared are well known in the art as rosin amine, dehydrogenated rosin amine and hydrogenated rosin amine, respectively. Their method of preparation is well known in the art.

The effectiveness of the process of this invention does not appear to be dependent upon what particular salt is used as long as it is water-dispersible to a sufficient degree that it is in contact with the mineral particles in the flotation system. Salts which may be used are the formate, acetate, chloroacetate, propionate, butyrate, citrate, hydrochloride, sulfate, hydrobromide, etc. The salts may also be formed from the salts normally in the flotation water being used if the water contains free acids in sufficient amount to promote the solubility. The rosin amine may also be added to water which has previously been acidified and mixtures of acids may be used, if desired, just as a mixture of salts may be used. In acidic water the rosin amine may be dispersed with a hydrocarbon solvent, e. g., the liquid hydrocarbon oil used in the flotation or it may be added to the pine oil or a pine oil-hydrocarbon mixture. Usually, however, the rosin amine is used directly in the form of a commercially available salt such as the acetate. The amount of rosin amine in the form of its salt will be within the range of about 0.2 to 1.50 pounds per ton based on the dry feed. Since all of these salts are at least partially soluble in this concentration range, the term "dispersed" is used broadly to include "dissolved" within its scope.

The process of flotation of this invention is of value not only in making it possible to recover low ash coal from coal residues, strip-mined coal, and the like, but also in clarifying wash water so as to avoid contamination of streams with fine coal and dust carried off in wash water. While ap-

plicable to both anthracite and bituminous coal, it is particularly suitable for use with anthracite.

What I claim and desire to protect by Letters Patent is:

1. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and a rosin amine in the form of a water-dispersible salt thereof, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

2. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and rosin amine in the form of a water-dispersible salt thereof, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

3. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and dehydrogenated rosin amine in the form of a water-dispersible salt thereof, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

4. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and hydrogenated rosin amine in the form of a water-dispersible salt thereof, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

5. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and rosin amine in the form of its acetate, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

6. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and dehydrogenated rosin amine in the form of its acetate, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

7. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and hydrogenated rosin amine in the form of its acetate, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

8. A method of reducing the ash content of anthracite coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and a rosin amine in the form of a water-dispersible salt thereof, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

9. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing starch as a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis and a rosin amine in the form of a water-dispersible salt thereof.

10. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis, a rosin amine in the form of a water-dispersible salt thereof, a monohydric alcohol containing 4 to 9 carbon atoms, and a liquid hydrocarbon containing 10 to 25 carbon atoms, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

11. A method of reducing the ash content of coal containing siliceous impurities which comprises subjecting said coal to froth flotation in an aqueous flotation system containing a depressant for the coal in an amount up to about 0.25 weight per cent on the dry coal basis, a rosin amine in the form of a water-dispersible salt thereof, pine oil, and kerosene, said depressant being selected from the group consisting of high molecular weight carbohydrates having hydrophilic properties, proteins, tannins, and glucosides.

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