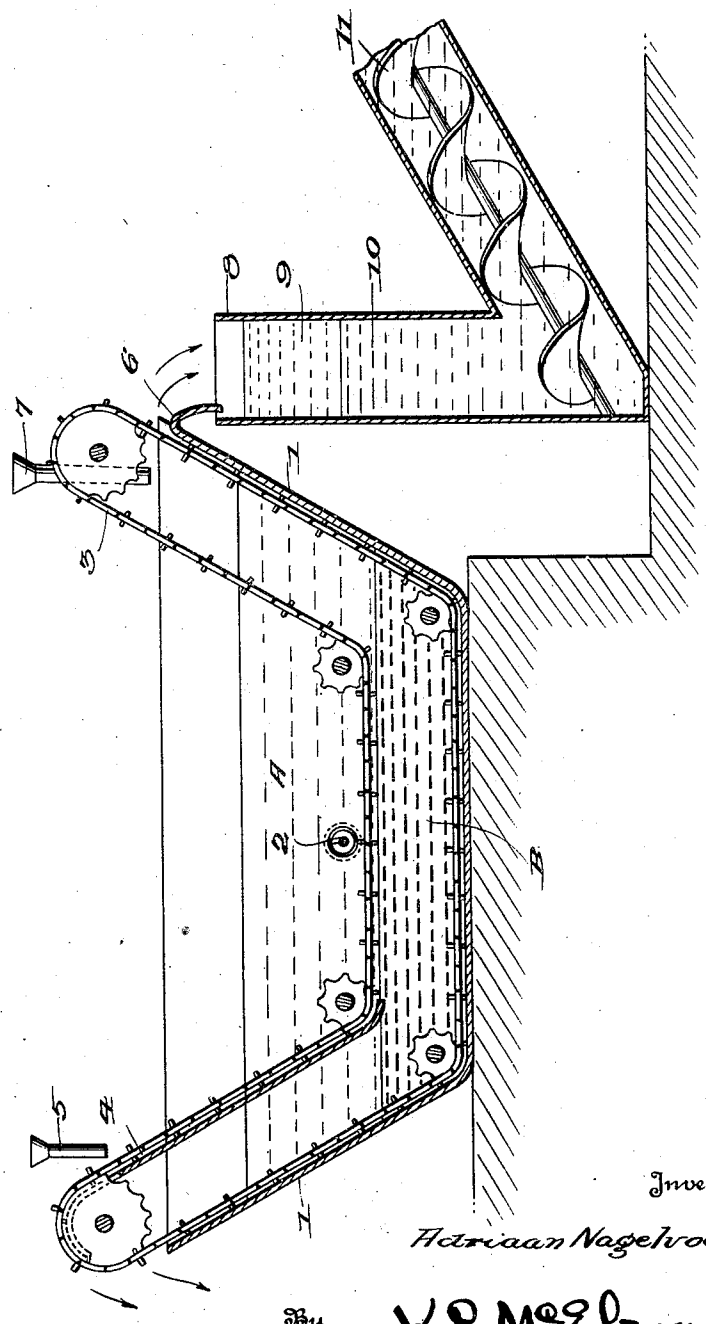
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SEPARATION OF MINERALS

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SEPARATION OF MINERALS

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This invention relates to the separation of minerals; and it comprises an improvement in the separation of fragmentary minerals of different specific gravity by means of heavy liquids wherein prior to separation sized particles of such minerals are wetted with a liquid immiscible with, and non-reactive with, such heavy liquid and of less specific gravity, thereby preventing actual contact of said wetted sized particles with said heavy liquid and also adjusting their specific gravity as a whole, the wetting liquid being generally water where the heavy liquid is of organic nature and being a hydrocarbon such as kerosene where the heavy liquid is an aqueous solution and the heavy liquid having a density intermediate the apparent specific gravity of the lighter wet particles and the heavier wet particles; all as more fully hereinafter set forth and as claimed.

Minerals have true specific gravities from, perhaps 2.0 in the case of certain silicates up to 8 or 9 in the case of some heavy metal ores. It is an old laboratory expedient to separate minerals of different specific gravities by means of a liquid of intermediate specific gravity in which one mineral will sink and another float. In the laboratory, saturated aqueous solutions of various heavy salts are used. In the art this method of separating minerals is used to some extent. The separation is usually a classification; several components of an ore floating and several sinking; and the first classification is often followed by others under different conditions to obtain a particular ore mineral. In part, the liquids used are heavy aqueous solutions, like the Thoulet solutions used in the laboratory; and in part, they are heavy organic liquids; mostly substitution products containing bromin, iodin or chlorin. In using either class of heavy liquid, one disadvantage is that of removing and recovering the heavy liquid from the mineral particles after the separation is effected. The mineral particles are wet by the heavy liquid and the wetting film of heavy liquid must afterwards be removed; a matter of some inconvenience and expense. All these heavy liquids are relatively costly. With either class of liquid, densities around a specific gravity of 3 are not difficult to secure; and these often serve well enough in separating the usual gangue minerals from heavy metal ores. But for separating ore minerals from each other liquids of densities materially above 3 are required; and these are by no means so readily available or so practicable for use. Densities above 3.50 and under 4 can be secured with solutions of certain costly materials like barium-mercury iodid, cadmium borotungstate or thallium formate or with a solution of iodin in carbon tetrabromid; but these liquids, apart from their cost, are sensitive to the action of many substances occurring in ores; and in any event are not applicable where specific gravities above 3.5 or 4 are in question.

It is the purpose of the present invention to provide a method for separating minerals of differing specific gravity by heavy liquids in which losses of heavy liquid are reduced, special recovery methods obviated and the whole operation cheapened; and a method moreover by which liquids with a density around 3 can be used in separating from each other minerals whose densities are greater than 3.

The present method may be employed with any available heavy liquid of either class. Among heavy aqueous solutions which can be used are those of sodium metatungstate (density 3.02), of sodium silicotungstate (3.05), of potassium mercuric iodide (3.196), of cadmium borotungstate (3.55), of barium mercuric iodide (3.55) or a saturated water solution of thallium formate, etc.

Among the heavy organic liquids which can be employed in the present process are methylene iodide with a specific gravity of 3.19–3.35, bromoform (2.88), acetylene tetrabromid (3.01), carbon tetrabromid (3.3 when melted), etc. These liquids can be given increased density, when this is wanted, by various expedients. For example carbon tetrabromid can be dissolved in acetylene tetrabromid. Iodin can be dissolved in carbon tetrabromid. When, as is more commonly the case, these liquids are required of a somewhat lessened density, this result can be

cheaply and economically secured by an admixture of hydrocarbon oils. I ordinarily use heavy organic liquids of adjusted gravity in the present process. For reasons later appearing, a variety of densities may be necessary in separating different sizes of the same ore; and it is convenient to obtain these as different dilutions of the same liquid.

In the present invention, sized fragments or particles of minerals to be separated by a heavy liquid are first thoroughly wet with a lighter liquid immiscible with such heavy liquid. In separation, the wet mineral does not come into actual contact with the heavy liquid; the floating light fraction and the sinking heavy fraction can both be withdrawn without carrying any substantial amount of heavy liquid with them. This obviates much of the expense and inconvenience of prior art methods.

In using heavy aqueous solutions, the wetting liquid employed is generally a hydrocarbon, such as kerosene. Other available hydrocarbons such as benzol, gasoline, lubricating oil, etc. may be used. These hydrocarbons are immiscible with aqueous solutions and prevent an actual contact of a mineral particle wet therewith with the heavy liquid. After separation of the two classes of mineral, the kerosene or other hydrocarbon adhering to the separated mineral may be removed and recovered by appropriate methods. In using heavy liquids of organic character, I generally employ water as the wetting liquid. Water is immiscible with most of the halogen-substituted hydrocarbons and such bodies can be secured of sufficient density for the present purposes. As a matter of fact the density of a number of the available liquids is greater than is necessary in many separations under the present invention and it is desirable to lighten them somewhat by dilution with hydrocarbon oils. As these oils are cheap, this dilution gives a saving in cost.

The presence of the wetting film of light liquid lessens the apparent specific gravity of the mineral fragments. By "apparent specific gravity" is meant the averaged specific gravity of the mineral particle with its wetting film. The film being of substantially constant thickness, the smaller the fragment, the greater the diminution in specific gravity and vice versa. With fine material, the diminution is quite considerable, enabling the present invention to be applied to the separation of quite dense ore minerals; minerals of an actual specific gravity higher than that of the available heavy liquids. For example, limonite of an actual specific gravity of 3.4 can be separated from pyrolusite of specific gravity 3.8 by means of acetylene tetrabromid of 3.01. When wetted with water fragments of limonite of about 1/8th inch diameter will float in acetylene tetrabromid while wet fragments of pyrolusite of similar size will sink. Without uniformity of fragment size, the separation of minerals of small density difference is usually incomplete and unsatisfactory.

The lessening of specific gravity is greater with light minerals than with heavy minerals; i. e., natural differences in specific gravity are increased which enables separations to be made by the present method which are impracticable by former methods.

Whatever the ore or mineral to be separated or classified by the present method, it is advantageous to have all the particles of about the same size, so as to make the change in specific gravity uniform. With crushed minerals it is therefore advantageous to size the crushed material rather closely, using the sized fractions separately. Sometimes this means that a different heavy liquid must be employed for each sized fraction or for groups of sized fractions. However, there is no particular difficulty in providing such a different heavy liquid since commonly it simply means that in using heavy organic liquids, the organic liquid is somewhat diluted with hydrocarbon; the dilution being different with each size fraction.

By sizing the particles before applying the coating liquid the change in apparent specific gravity of the particles treated is substantially the same for all particles; while without sizing the coarse particles of a given mineral receive less of the coating liquid relatively to their masses than do finer sizes and the consequent change in apparent specific gravity is less in the coarse particles than in the finer particles. The more uniform the particle size the sharper the separation becomes between particles of different materials of small differences in true specific gravity.

In the performance of the described process any convenient type of apparatus can be used which will permit a preliminary thorough wetting of the mineral particles and the subsequent separation of the floating and sinking minerals in a bath of heavy liquid. The usual mechanical accessories, such as conveyors, may be employed.

In using the present invention the lighter liquid is also used as a cover for the heavy liquid, sealing it from contact with air. The heavy aqueous solutions are all hygroscopic, tending to take up moisture from the air and become diluted and lightened. A sealing layer of kerosene prevents this. The heavy organic liquids are mostly somewhat volatile and a sealing layer of water restrains evaporation.

In the accompanying illustration, I have shown diagrammatically a simple form of apparatus available in practicing the described process; the view being in longitudinal section.

As shown, the apparatus comprises an

open-topped tank having sloping end walls 1. In using this apparatus with organic heavy liquids of the type of carbon tetrabromid, it is not necessary to close the top against the air. In working with heavy aqueous solutions and using kerosene as a sealing layer, for obvious reasons it is better to provide a top for the tank. For simplicity of illustration this top is here omitted. Within the tank are shown two layers of liquid A and B, the former being the light liquid and the latter the heavy liquid. In using carbon tetrabromid and other organic heavy immiscible liquids, layer A is water. As shown ore or other material in sized fragments of say an eighth of an inch diameter is delivered into the tank by a screw conveyor 2 at a point near the boundary line between the heavy liquid layer and the light liquid layer. The mineral is wetted with water by means not shown in its forwarding by the screw conveyor 2. From the mixture of mineral and water sent into the tank by 2 the excess water separates and joins the water in layer A. The mineral fragments carrying a wetting layer of water sink to the boundary line between the two liquids and the heavier mineral goes to the bottom of heavy layer B. The remaining lighter mineral floats on layer B whence it is removed and sent to the left by bladed conveyor 3. At the left the conveyor passes upward over a sloping apron 4 and it finally discharges to the left. It is a useful expedient to direct a slight flow of water into the mineral passing over dry portion of apron 4. This may be done from a water jet 5. This carries back any entangled drops of heavy liquid. The return flight of the conveyor passes along the bottom of the tank and carries forward to the right the heavier mineral. This heavy mineral is carried upward over the sloping end of the tank and discharges over flange 6. A stream of water is sent over the upwardly moving mineral from water pipe 7. If there is much fine material in the ore drops of heavy liquid may escape washing back by this stream of water. I therefore advantageously pass the heavy mineral next into a vertical casing 8 having a layer of benzol or the like 9 floating on the surface of a body of water 10. In passing through the benzol the fragmentary minerals are stripped of any carbon tetrabromid which they may carry. Ordinarily this layer of benzol may be used for a considerable time before it picks up enough carbon tetrabromid to make it as heavy as water. When this happens the layer of benzol is removed and the dissolved organic heavy liquid recovered. The benzol layer may be used until it shows a tendency to sink when it is replaced by fresh benzol. The heavy mineral accumulating at the bottom of the casing 8 is removed by angularly disposed conveyor 11. A similar trap system (not illustrated) may be advantageously used at the other end of the apparatus for catching any of the tetrabromid which may go forward with the separated light mineral.

In using the apparatus shown, with some ores simple passage of the ore fragments through the upper lighter liquid layer A gives a sufficient wetting for my purposes, but with other ores a special preliminary wetting operation is necessary. With minutely porous ores sometimes the use of vacuum or other drastic treatment to get rid of "air bound" pores is required. Sand and silicates are usually quite easily wetted by water, but sometimes it is expedient to use soap or other like agents in the water where the surfaces are greasy. Kerosene and hydrocarbons do not wet silica or silicates readily if moisture is present and where they are used as the light wetting liquid thorough drying of the mineral is expedient.

In a specific embodiment of the present invention separating limonite (sp. g. 3.6) from gangue carrying silica and silicates carbon tetrabromid in an undiluted state was used with fragmentary ore sized to give granules of about one inch diameter. The sand and silica with an actual specific gravity of 2.2–2.6 would have floated in any event but in this particular ore there were certain silicates whose specific gravity closely approached that of carbon tetrabromid. By the wetting these silicates were given an apparent specific gravity considerably below 3 and were floated with great certainty. The wet limonite itself sank.

In another specific embodiment of the present invention certain Virginia ores were utilized in the production of pure MnO_2 in a state of sufficient purity for use in battery cells of the Leclanche type; such as those used in B batteries. This ore carried in addition to pyrolusite (MnO_2) substantial amounts of limonite as well as sand and silicates. Acetylene tetrabromid in an undiluted state was used as a separating liquid. The ore in 1/8th inch fragments was wetted with water in a conveyor provided with spray means and sent into an apparatus of the type of that shown; being delivered into the layer of light liquid A at a point immediately above the surface of the heavy liquid B. By the wetting the apparent specific gravity of the silica present became approximately 1.8. The limonite (sp. g. 3.4) was given an apparent specific gravity of 2.8. The apparent specific gravity of the pyrolusite (3.8) became 3.2. Pure pyrolusite sank and limonite, sand and silicates floated. In a subsequent operation the limonite itself was recovered in a similar way.

The present method is applicable to a wide variety of ores and minerals. In the case of oxidized ores of lead and zinc it enables separations which can not be effected by the ordinary oil flotation processes.

In the present method it will be noted that the apparent specific gravity of the minerals is adjusted by adjusting the size of the fragments. And, as already pointed out, the specific gravity of the heavy liquid can be adjusted up or down. The specific gravity of the heavy liquid must always be intermediate the apparent specific gravity of the fragments to be separated by it so that one class of fragments will float and another class will sink.

It is desirable that the layer of heavy liquid be quite shallow, partly for economy and partly to lessen the chance of detachment of the protective film of light liquid from the mineral fragment in sinking.

What I claim is:—

1. In the separation of mineral constituents of an ore by wetting the ore with a light liquid and immersing the wetted ore in a heavy liquid, the process which comprises classifying the ore before wetting in fragments of substantially uniform volume and diluting the heavy liquid to a density corresponding with the fragment size and the resulting apparent specific gravity of the heavier mineral constituent so as to float lighter minerals in the diluted heavy liquid and to sink minerals of slightly greater true specific gravity.

2. In the separation of minerals of differing specific gravity by flotation in a relatively heavy liquid of mineral particles wetted by a light immiscible liquid to obtain a reduction of specific gravity of said particles, the improvement which comprises first crushing and sizing the mixed minerals to obtain particles of substantially uniform size, then wetting said sized particles with the light liquid to obtain mineral particles of a less specific gravity than that of the heavy liquid and other mineral particles of a greater specific gravity than that of the heavy liquid and then separating the two kinds of particles by respective flotation in and sinking through the heavy liquid.

3. In the separation of minerals of differing specific gravity by flotation upon a relatively heavy liquid immiscible with water of mineral particles wetted by water to obtain a reduction of specific gravity of said particles, the improvement which comprises first crushing and sizing the mixed minerals to obtain particles of substantially uniform size, then wetting said sized particles with water to obtain mineral particles of a less specific gravity than that of the heavy liquid and other mineral particles of a greater specific gravity than that of the heavy liquid and then separating the two kinds of particles by respective flotation in and sinking through the heavy liquid.

4. In the separation of minerals of differing specific gravity by flotation upon a relatively heavy liquid immiscible with water of mineral particles wetted by water to obtain a reduction of specific gravity of said particles, the improvement which comprises first crushing and sizing the mixed minerals to obtain particles of substantially uniform size, then wetting said sized particles with water to obtain mineral particles of a less specific gravity than that of the heavy liquid and other mineral particles of a greater specific gravity than that of the heavy liquid, separating the two kinds of particles by respective flotation in and sinking through the heavy liquid, and passing the separated heavy mineral particles through water and through a light hydrocarbon liquid to recover adherent heavy liquid.

5. In the separation of minerals of differing specific gravity by flotation upon a relatively heavy liquid immiscible with water of mineral particles wetted by water to obtain a reduction of specific gravity of said particles, the improvement which comprises first crushing and sizing the mixed minerals to obtain particles of substantially uniform size, then wetting the sized particles with water to obtain mineral particles of a less specific gravity than that of the heavy liquid and other mineral particles of a greater specific gravity than that of the heavy liquid, passing the wetted sized particles into a layer of the heavy liquid with a supernatant layer of water, separately removing the floating lighter particles and the sinking heavier particles and passing the heavier particles first through the supernatant layer of water and then through a bath of liquid immiscible with water and a solvent for the heavy liquid.

6. In the separation of minerals of differing specific gravity by flotation upon a relatively heavy liquid of mineral particles wetted by a light immiscible liquid to obtain a reduction of specific gravity of said particles, the improvement which comprises first crushing and sizing the mixed minerals to obtain particles of substantially uniform size, then wetting said sized particles with the light liquid, diluting the heavy liquid to a specific gravity between that of the wetted heavier mineral particles and that of the wetted lighter particles and separating said lighter from said heavier particles by flotation in said diluted liquid.

In testimony whereof, I have hereunto affixed my signature.

ADRIAAN NAGELVOORT