July 21, 1936. W. E. BEATTY 2,048,316

METAL SEPARATION

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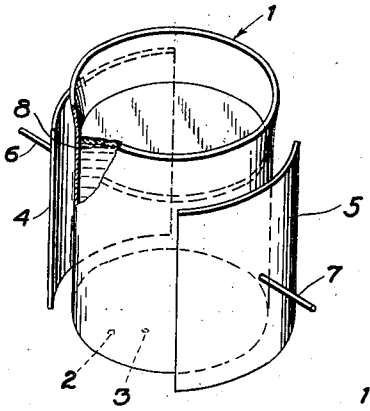


FIG. 1.

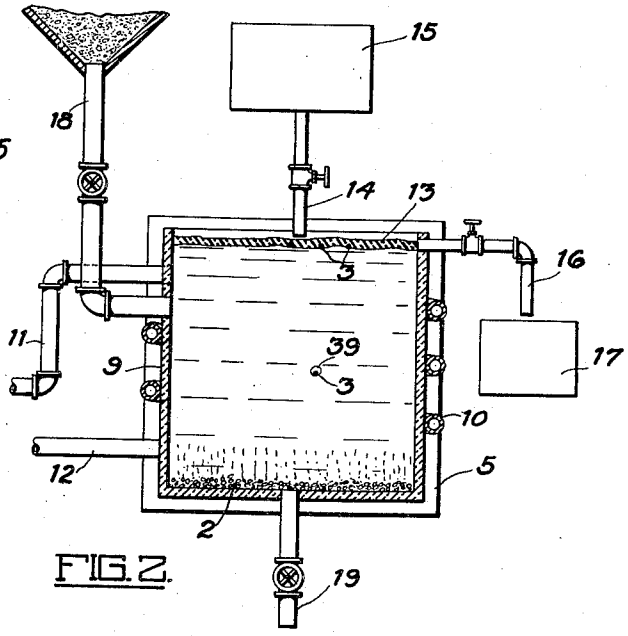
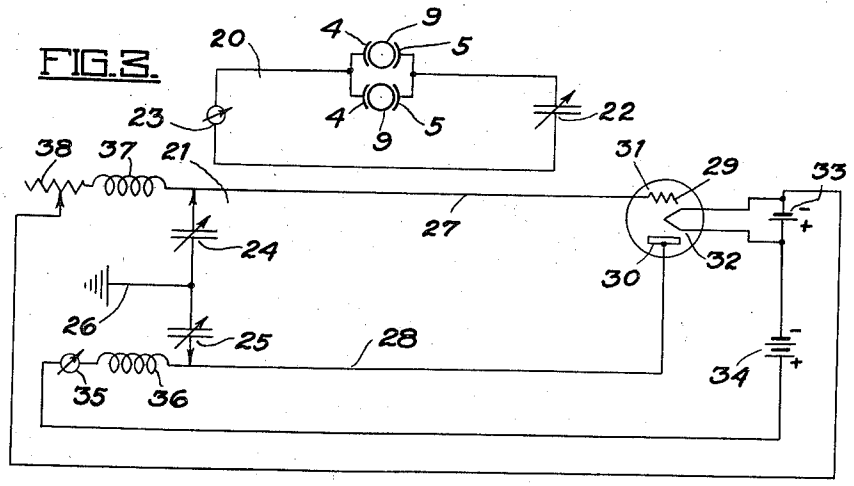


FIG. 2.

FIG. 3.



W. E. Beatty.

INVENTOR

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METAL SEPARATION

William E. Beatty, Los Angeles, Calif.

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13 Claims. (Cl. 209—164)

The invention relates to metal separation, that is to method and means for separating metal, such as gold, silver, copper, or the like, whether in the metallic state or chemically combined with other substances (as zinc blend, argentite, etc.) from gangue material, in a finely divided state as is customary in milling practice and when suspended in water or other liquid.

While the flotation process has been extensively used, it has some limitations due to the fact that the separation depends on the difference in surface tension on metallic and non-metallic particles, there being no such difference if the metallic particle is coated with a thin layer of earthy matter or the like. Also, while the Wilfley table has been extensively used, this also has its limitations due to the fact that separation depends, in part at least, upon the difference in specific gravity of metallic and non-metallic particles, there being no difference in the total weight of two such particles which differ in size in proportion to their specific gravities. The same defect is also present in certain hydraulic and other types of separation which depend for their operation on the difference in specific gravity of metallic and non-metallic particles.

Also, in separating gold from sand or gravel or other gangue material by amalgamation, difficulty is frequently experienced in effecting amalgamation of the gold particles and the mercury, due to a film of extraneous matter such as earthy substance or iron oxide which coats the gold flakes or particles thereby preventing intimate contact of the gold and mercury necessary for amalgamation, and with the result that such gold particles pass into the tailings.

According to the present invention, the above defects are overcome by method and means which depend upon the difference in electrical conductivity of metallic and non-metallic particles to electric current as distinguished from electrostatic charges, the current preferably being induced whereby it makes no difference whether the metallic particles are coated with foreign matter or not. This selective action of metallic and non-metallic bodies to electrical current is employed to effect relative movement therebetween, whereby the metal particles are separated from the non-metallic particles.

In a preferred embodiment of the invention, the differential effect to electric current in the two kinds of particles is produced by subjecting a mixture of metallic particles and gangue material to the influence of a rapidly alternating electric field, while such particles are suspended in water or other liquid.

The non-metallic particles are passive to such electric fields while metallic particles, such as gold, have induced therein a current of sufficient intensity to heat the metallic particles so that they will generate a small bubble of vapor or steam which lifts the metallic particles to the surface of the liquid, thereby separating the metallic from the non-metallic particles.

Suitable method and means are provided for removing the metallic particles so raised and for operating on a continuous basis.

In the above description a line has been drawn between electrical current, that is electricity in motion or electrokinetics on the one hand, and electrostatic charges on the other. The Cottrell precipitation process is well known and provides for the removal and collection of finely divided solid or liquid particles carried in suspension in air or other gases by the application of a high potential uni-directional electrical current to such gases to effect an electrostatic charge on such particles and on a collecting electrode. This process is not intended to and does not sharply differentiate between metallic and non-metallic particles for the reason that an insulating body, i. e. a non-metallic particle, will take up an electric charge as well as a metallic body, as can be seen by reference to any standard textbook on physics. (A description of the Cottrell process appears on page 523 of Pender's Handbook for Electrical Engineers, Second Edition.)

As shown on pages 948 and 949 of Taggart's Handbook of Ore Dressing, published 1927, it has been proposed to effect electrostatic concentration by employing the difference in electrical conductivity of minerals to electrostatic charges thereon. While Taggart comments unfavorably on certain of the machines operating on this principle, he does not offer an explanation of the physical reasons therefor. In order to further differentiate the present invention from concentration methods employing electrostatic charges, it is suggested that the reason it may not be possible to effect a clean separation of metallic and non-metallic particles due to electrostatic charges thereon may be that through the conduction of the air or capacity of neighboring bodies, an electrostatic charge will leak off from an insulating body and it seems clear that the higher the charging potential, that is the greater the amount of charge on the particle, the greater is the tendency for such leakage currents, which serves as a serious limitation to any

differentiation between separation of metallic and non-metallic particles by reason of electrostatic charges thereon.

The present invention is not concerned with such electrostatic processes and instead depends upon electrokinetics according to which electrical current is caused to flow through the metallic particle, being unable to flow through an insulating particle, and method and means are provided for translating this current flow into a relative movement of the two kinds of particles.

For further details of the invention reference may be made to the drawing, wherein:

Fig. 1 is a perspective view of electric field inducing elements capacitatively associated with a container of sludge, i. e. metallic particles and gangue material in a liquid.

Fig. 2 is a sectional view of an improved form of the container in Fig. 1 with provisions for continuous operation.

Fig. 3 illustrates a circuit arrangement for generating high frequency oscillations and for thereby producing a rapidly changing electrical field to which the sludge is subjected.

The invention may be described in a simple form by referring to Fig. 1 wherein a glass beaker or other non-metallic container 1 is partially filled with water or the like which is liquid at ordinary temperatures and in which is one or more discreet solid particles 2 of sand or other gangue material and one or more discreet solid particles 3 of metallic material, such as gold. In capacitative relation to the container 1 are the arcuate condenser plates 4 and 5 which are connected by means of the terminals 6 and 7 respectively to a source of high frequency current, the wave length or frequency of which is such as to induce eddy currents in the particles 3 of sufficient intensity to form a bubble of vapor or steam at or adjoining this particle for raising it to the surface of the water where it encounters a film 8 of oil which seizes and holds the metallic particle 3. The high frequency electrostatic field has no effect on the particle 2 as it is non-metallic and does not conduct any appreciable amount of current. The non-metallic particle 2 remains at the bottom of the vessel 1, thereby resulting in separation of the metallic from the non-metallic particles.

The condenser plates 4 and 5 serve as a source of rapidly varying electrical waves and the reason for using plates instead of an induction coil is because with the particular oscillating circuit shown in Fig. 3 and hereinafter described for energizing these plates, the wave length is so low, in this case being about two meters, that if an induction coil were employed it would not be practical to obtain a frequency of this short wave length. If desired, however, a wave length sufficiently large may be used so that it will be practical to employ an induction coil as a source of electromagnetic waves and in this case the Colpitts, Hartley, or any other standard type of vacuum tube oscillating circuit may be employed, the induction coil surrounding the material under treatment as shown by any one of the following patents which illustrate the use of such coils for induction furnaces: French #361,627, United States #1,083,677, United States #1,374,679, United States #1,565,857.

It follows therefore that I contemplate the use of frequencies within the ranges described in the aforementioned patents.

Referring to Fig. 2, 9 illustrates a non-metallic container corresponding to 1 in Fig. 1. One of the plates 5 is shown in this figure and the other plate 4 does not appear herein due to the line on which the section was taken. The arrangement of the plates 4 and 5 in Fig. 2 is the same as in Fig. 1, the shape of the plates conforming to the shape of the container.

Between these plates and the container 9 is arranged a cooling coil 10 having an inlet at 11 and an outlet at 12, or vice-versa. The purpose of this cooling coil is to prevent undue heating of the water in the container 9 either by a current induced therein by the electrical field from plates 4 and 5, or by conduction from the heated metallic particles 3. This cooling coil is preferably non-metallic.

At the surface of the water in the container 9 is a film 13 of oil which catches and holds the particles 3 which have risen to this film of oil for the reason explained in connection with Fig. 1. One such particle 3 with a bubble of steam 39 produced by the eddy currents in that particle, is illustrated. Collapse of the bubble 39 is prevented while particle 3 is passing through the water as the eddy currents are maintained while the particle is in the electrical field. The boiling point of the oil is so much higher than that of water that the steam bubble collapses when the particle 3 rises to the oil.

Fresh oil from time to time may be added by means of a pipe 14 leading from an oil supply tank 15. The oil with metallic particles entrained therein may be drawn off from time to time by pipe 16 mounted in the top of container 9 and which discharges into a tank 17. The metallic particles may be separated from the oil in any suitable manner as by filtering. Fresh sludge, that is sand, gravel, tailings or finely ground ore with metallic particles, such as gold, or other mineral therein and admixed with water may be sluiced into the supply pipe 18 which discharges into vessel 9 at a point below the level of the oil film 13. From time to time the gangue, from which the metal particles have been caused to rise to the oil film 13, may be discharged from the bottom of the container 9 by means of the pipe 19. The various inlet and outlet pipes associated with the container 9 are illustrated as having conventional valves and it is obvious that these valves may be set so that the process operates on a continuous basis.

The invention is not restricted to any particular type of oscillator for supplying high frequency current. The circuit shown in Fig. 3 has given good results, and in this case the work circuit 20 is inductively coupled to the oscillating circuit 21 by reason of the inductive relation of the parallel sides of these circuits as illustrated. The work circuit 20 comprises one or more pairs of plates 4—5, each pair inclosing the container 9 and its associated parts as illustrated in Fig. 2. In order to tune the circuit 20 a variable condenser 22 is provided and the meter 23 is also useful. The natural period of the circuit 20 is determined largely by the condenser 22 and the capacity between the plates 4—5, together with the inductance between the parallel line sides of the circuits 20 and 21.

The frequency delivered by the circuit 21 to the circuit 20 is determined largely by the two condensers 24 and 25, the mid point of which is grounded at 26 and which are slidable (to vary the inductance) along the two wires 27 and 28 connected to the grid 29 and plate 30 respectively of the vacuum tube oscillator 31. The cathode 32 of the vacuum tube is energized by

the battery 33 and the plate circuit is energized from the battery 34 which supplies current through a meter 35 and a high frequency choke coil 36. The grid 29 is connected through wire 27, high frequency choke coil 37, variable grid leak resistance 38 to the cathode 32. The condensers 24 and 25 are each of about 0.01 m. f.

It has been found preferable to employ direct current for heating the filament 32 instead of alternating current for the reason that alternating current of say 60 cycles will modulate the high frequency generated and thereby periodically reduce the amplitude of these high frequency oscillations.

The amount of the heating effect may therefore be readily controlled by purposely modulating the high frequency oscillations with a lower frequency, such as 60 cycles, as is well understood in radio practice, the amount of the 60 cycle modulation being varied from zero to any desired finite value. Either grid circuit modulation as in Van der Bijl, #1,350,752, may be used or plate circuit modulation as in Heising, #1,442,147. The potentiometer of the former constitutes the means for varying the intensity of the modulating current, the microphone 15 being energized in this case by a suitable source of sound waves, such as 60 cycles. Or instead, the vacuum tube oscillator may be self-modulating. This is well understood in radio practice.

The frequency of the electrical field to be used depends upon the size of the metallic particle to be treated and is determined from the following considerations:

The voltage induced in a metallic particle is a function of the length L of that particle and the product of flux intensity and time rate of flux change therethrough (that is, the frequency of the field). Consequently, in order to obtain a given induced voltage in the metallic particle, it is necessary to increase product of flux intensity and the time rate of flux change as L decreases. In other words, the smaller the metallic particle to be treated the higher the product of flux strength and the frequency of the field should be. It will also be apparent that doubling the frequency serves to double the induced voltage, which doubles the current and increases the heating effect four times, as the latter is proportional to the second power of the current. Therefore, the current in the metallic particle can be varied both by sizing the particles and by choosing the frequency. In other words, assuming a given flux intensity, by choosing the frequency high enough, as herein illustrated, it is not necessary to grind the ore as fine as required for other methods of metal separation. Tests indicate that a particular ore may be ground to ten mesh or coarser and still effect separation with frequencies lower than the value corresponding to a wave length of two meters. I contemplate that frequencies used in induction furnace practice as before stated, and frequencies from the order of 20,000 cycles to wave lengths of the order of 2 meters may be used.

The frequency generated may be varied by varying the inductance and capacity of the circuit 24—25—27—28. The amount of energy transferred to the circuit 20 may be varied by varying the separation of this circuit from circuit 21, or by varying the condenser 22. In case the oscillator delivers its energy to an induction coil, as above described, the amount of energy delivered to this coil and the frequency of the currents may be varied, as is well understood in the radio art.

The arrangement shown in Fig. 3 and described above has been successfully used to separate fine particles of metal from sand or the like, and this separation has been effected in about five seconds or less from the time that high frequency energy was imparted to the container.

The above arrangement may also be used as a classifier for the reason that the amount of induced voltage is proportional not only to the resistance of the particles, but also to the length thereof, whereas the heating effect of the eddy currents is proportional to the square of the current. Therefore, a mixture of different kinds of metallic particles having different resistances or sizes will be brought to the film of oil at different times and may be selectively removed.

It will be understood that some or all of the cooling effect may be derived from the incoming sludge in the feed pipe 18 and that various modifications in the arrangements above described may be made without departing from the spirit of the invention; for example, the gold or other mineral bearing ore, in a finely divided state (say ground to 10 mesh or finer) may be delivered in a dry state from a chute or by hand into vessel 9 instead of introducing sludge through pipe 18. Thus a small quantity of water will serve for a large quantity of ore. Also, the film of oil may be dispensed with and the metallic particles which have risen to the top of the water may be carried off by a stream of water which flows into the pipe 18 as sludge and out of pipe 16. The use of the oil film is preferable, however. Also a suitable insulating support not shown is provided for condenser plates 4 and 5 such as a block of insulating material at the base of each plate. These plates 4 and 5 may be flat and parallel to the sides of the condenser, but in this case the electrical field has a dead space at the periphery of the plates so the container should be smaller than the plates. The circular form is preferred. Each plate may be made in sections connected in any suitable series, parallel or series-parallel fashion. Other modifications will suggest themselves.

The term "electrical field" is used herein as generic to a magnetic field and an electrostatic field, taken singly or in combination.

Having thus described the invention, what is claimed as new and desired to secure by Letters Patent is:

I claim:

1. The method of mineral separation which comprises generating a high frequency electrical field, suspending metallic and non-metallic particles in a substance liquid at ordinary temperatures, and subjecting said suspended particles to said field, whereby eddy currents are induced in said metallic particles of sufficient intensity to produce a bubble for lifting said metallic particles, whereby separation is effected.

2. The method of mineral separation which comprises generating a high frequency electrical field, subjecting a liquid suspension of solid metallic and non-metallic particles thereto, whereby eddy currents are induced in said metallic particles of sufficient intensity to produce a bubble for lifting said metallic particles, whereby separation is effected and in removing the metallic particles so lifted and separated.

3. The method of mineral separation which comprises generating a high frequency electrical field, subjecting a liquid suspension of metallic

and non-metallic particles thereto, whereby eddy currents are induced in said metallic particles of sufficient intensity to produce a bubble for lifting said metallic particles, whereby separation is effected, and in entraining the lifted metallic particles in a liquid having a higher boiling point than said first-mentioned liquid.

4. The method of mineral separation which comprises generating a high frequency electrical field, subjecting a liquid suspension of metallic and non-metallic particles thereto, whereby eddy currents are induced in said metallic particles of sufficient intensity to produce a bubble for lifting said metallic particles, whereby separation is effected, cooling said liquid, and entraining the lifted metallic particles in a film of oil.

5. Metal separation apparatus comprising means for producing a stationary high frequency electrical field, a non-metallic container for a liquid suspension of discrete solid metallic and non-metallic particles in said field, said means being arranged at opposite sides of said container and means for separately discharging said discreet solid metallic and non-metallic particles from said container.

6. Metal separation apparatus comprising a vacuum tube generator of an electrical field having a wave length of the order of 2 meters and a non-metallic container for sludge associated therewith, said sludge containing discrete solid metallic particles, means in circuit with said generator for inducing in said metallic particles eddy currents of sufficient intensity to produce bubbles for lifting said metallic particles, and means for removing the lifted particles.

7. Metal separation apparatus comprising plates, a non-metallic container for sludge therebetween, said sludge containing solid metallic particles, and a high frequency generator connected to said plates, the field between said plates inducing in said metallic particles eddy currents of sufficient intensity to produce bubbles for lifting said metallic particles, and means for removing the lifted particles.

8. The method of mineral separation which comprises inducing, in discrete metallic particles in a sludge, eddy currents of sufficient intensity to produce bubbles for lifting said metallic particles and separating from said sludge the metallic particles so lifted.

9. Electrical heating apparatus comprising means for supplying a fluid containing particles having different degrees of conductivity to electric current, means for removing certain of said particles, a non-metallic conduit between said supplying means and said removing means, separated plates at opposite sides of said conduit, and a source of short electrical waves connected to said plates.

10. The method of separating metallic from non-metallic particles suspended in a fluid liquid at ordinary temperatures and which fluid is insufficient to chemically react with the metallic particles to produce bubbles for lifting the metallic particles, which method comprises radiating electrical energy through said particles to heat the same and thereby generating at the loci of the metallic particles respectively bubbles for lifting said metallic particles.

11. Metal separation apparatus comprising a non-metallic container for a suspension of metallic and non-metallic particles in water, means for producing an alternating field through said container to selectively heat said metallic particles whereby said metallic particles are lifted by bubbles, and a heat transferring device associated with said water.

12. Metal separation apparatus comprising a non-metallic container for a suspension of metallic and non-metallic particles in water, means for producing an alternating field through said container to selectively heat said metallic particles whereby said metallic particles are lifted by bubbles, a heat transferring device associated with said water, and means for admitting a fresh supply of cool liquid material with particles therein to be treated to said container to lower the temperature of the liquid material in said container and to furnish to said container a fresh supply of particles to be treated.

13. Electrical heating apparatus comprising means for supplying a fluid containing particles having different degrees of conductivity to electric current, means for removing certain of said particles, a non-metallic conduit between said supplying means and said removing means, electric field producing means adjacent said conduit, and a source of electrical waves of high frequency connected to said electric field producing means for selectively heating said particles of greater conductivity more than particles of lesser conductivity.

WILLIAM E. BEATTY.