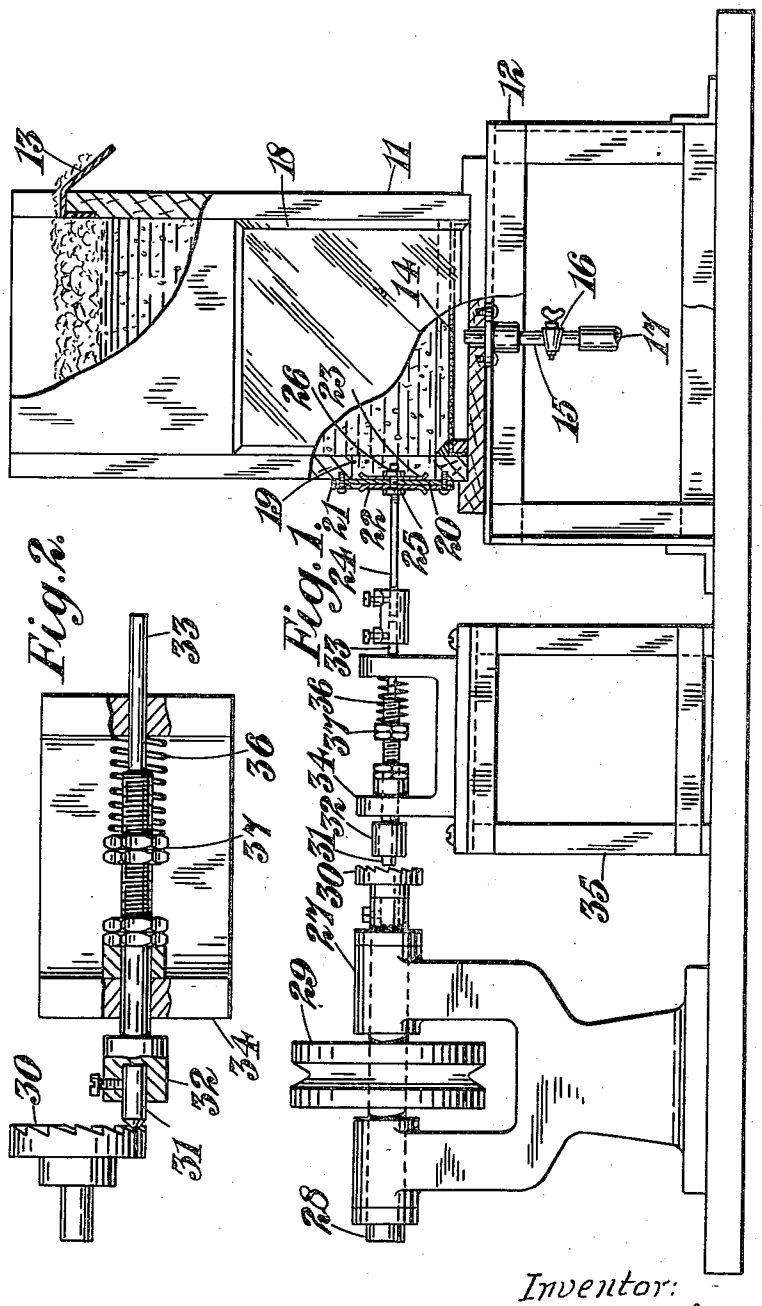
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FROTH FLOTATION CONCENTRATION PROCESS

Filed Nov. 22, 1934 2 Sheets-Sheet 1



Inventor:
Thomas James Taplin,
By
Byrnes, Stebbins & Blenko,
attys.

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Fig. 3.

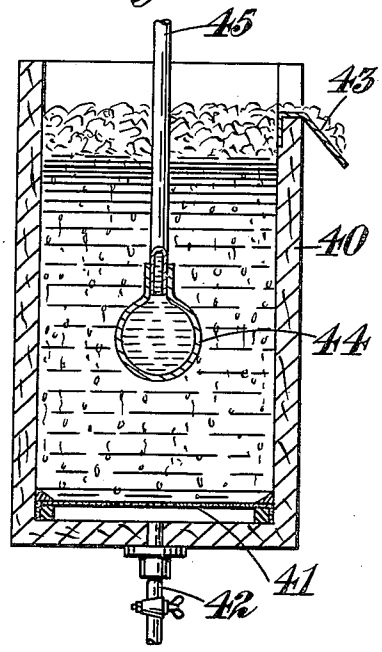
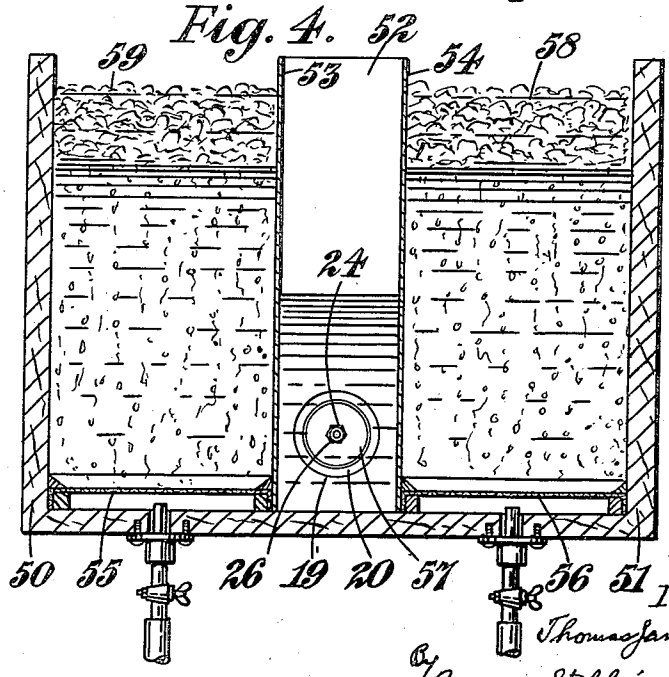


Fig. 4.



Inventor:
Thomas James Taplin,
By Byrnes, Stebbins & Blenko,
Attys.

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FROTH FLOTATION CONCENTRATION PROCESS

Thomas James Taplin, Strawberry Hill, Middlesex, England

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This invention comprises improvements in or relating to froth flotation concentration processes. In the well known froth flotation process for the concentration of ores a mixture of the material from which values are to be concentrated and of water containing various agents is agitated and air is introduced in such manner that a froth which contains the concentrates is formed on the surface of the liquid. The effectiveness of this process depends upon every available particle being brought into effective contact with an air bubble so as to become attached thereto and the main purpose of the agitation is to bring the air bubbles and the particles of the material under treatment into contact with one another. The agitation may be mechanically effected or brought about by the action of the air bubbles themselves. It is commonly found that the finest particles tend to float more slowly than those of medium size. This may be attributed partly to the fact that the liquid, the air bubbles and the solid particles in the mixture all tend to flow at any given place in the liquid in the same direction as one another. Although their flow is not strictly a streamline flow the directions of movement are more or less parallel and thus particles and bubbles may move for considerable distances without making contact, and the smaller particles will be less likely to receive contact with the air bubbles than the larger ones because they present, so to speak, a smaller target.

It is an object of the present invention to increase the probability of contact between the solid and gaseous particles in the liquid, and thus to reduce the time or expenditure of power which is necessary to effect a given degree of concentration. To this end it is proposed to take advantage of the highly diverse specific gravities (and consequent inertia) and diverse elastic properties of the constituents of the mixture, namely the liquid, the mineral, the gangue and the gas bubbles.

The present invention is characterized by the superposition upon the usual agitation of the pulp (whether produced mechanically or by air bubbles), of vibration of the pulp. Vibration may be of sonic or even super-sonic frequencies. Preferably it is applied in a direction transverse to the general direction of movement of the pulp or of the gaseous bubbles therein. It is the intention of the present invention to produce a decided differential movement between the mineral particles and the bubbles in the pulp.

It is found that by the employment of vibration in accordance with the present invention it is possible very greatly to reduce the quantity of air employed for producing the concentrate or the time of concentration, or both these factors, while obtaining equal results in the process.

The invention includes apparatus for the concentration of materials by froth flotation comprising in combination an agitation or froth-forming vessel, a movable wall in contact with the liquid in said vessel and means for vibrating said movable wall. The movable wall may be constituted by a portion of the walls of the vessel which may be flexibly linked to the remainder of the vessel and means outside the vessel are provided for vibrating said movable wall. The means for vibrating the movable wall may either comprise a cam mechanism or it may be operated by an intermittently energized electromagnet or otherwise.

According to another feature of the present invention a means of imparting vibration to a flotation pulp is provided comprising a vibration-transmitting partition in contact on one side with the flotation pulp, a liquid container bounded by the said partition so that liquid therein is in contact with the other side of the partition and means for imparting vibration to the liquid in the container. The liquid in the container will not be submitted to aeration and consequently will retain its natural low compressibility. Therefore it will serve to impart vibrations to the whole area of the vibration-transmitting wall without material loss. This is an advantage since the flotation pulp itself, as it is highly aerated, is capable of compression and expansion, and in order to transmit vibrations through it, it may sometimes be desirable to apply the vibrations over a considerable area of pulp and to reduce as far as possible the distance through which they are required to travel in the aerated pulp.

The wall between the aerated and non-aerated liquids may completely enclose the non-aerated liquid so that it constitutes a vessel immersed in the aerated pulp if desired, connected to a source of vibration, for example by a liquid-filled pipe. The liquid in such a vessel may be under a super-atmospheric pressure.

In another form of apparatus according to the present invention there is interposed, between two flotation cells, a liquid container separated from each of the cells by a vibration-transmitting wall and non-aerated liquid is filled into the container, which container is provided with means for vibrating the liquid therein, for example a diaphragm in one of the walls other than those adjacent to the flotation cells, and means for

vibrating the diaphragm. If the liquid used is water, it is preferably de-aerated before use, since dissolved air may be objectionable.

If desired, the vibration-transmitting container may be closed at the top and the liquid therein placed under superatmospheric pressure. By sealing the container and having a water head of, say, twenty to thirty feet it becomes possible to vibrate the liquid therein more violently than would be the case if it were under atmospheric pressure without risk of breaking up the water surface or of leading to cavitation between the water and the vibrating diaphragm. Cavitation may occur through loss of contact between a liquid (water) and a vibrating diaphragm if the vibrations are of such amplitude or frequency that the water is not able to follow the movements of the diaphragm fully, and especially is it liable to occur if the liquid contains much dissolved gas.

According to a further feature of this invention an alternative or additional means of counteracting cavitation troubles consists in periodically interrupting the application of the vibrations to the liquid. This may be effected either by an automatic periodic interruption of the vibrator or by employing some form of vibrator the power supply to which is easily measured; for example an electromagnetic vibrator may be used. A relay device is then provided whereby when the electrical input required to operate the vibrator suddenly falls due to cavitation, the action of the vibrator is interrupted momentarily and then restored. This gives the opportunity for the cavitation to be eliminated as soon as it begins.

The following is a description by way of example of certain forms of apparatus in accordance with the invention and of tests of the process carried out therein.

Referring to the drawings:—

Figure 1 is an elevation with parts broken away to show the internal construction of one form of the apparatus in accordance with the invention.

Figure 2 is a plan of the cam mechanism shown in Figure 1.

Figure 3 is a diagram of a modified form of apparatus.

Figure 4 is a diagram of a further modification.

Referring to Figure 1, **11** represents a square-sided flotation cell upon a raised stand **12**. The cell **11** is provided with an overflow lip **13** and has a porous false bottom **14** below which is an air admission pipe **15**, the quantity of air admitted being controlled by a cock **16**, and the air supply under a suitable slight superatmospheric pressure being admitted through a pipe **17**. The vessel **11** has a glass wall **18** to permit observation of the condition of its contents. This glass wall is only necessary for experimental investigations and could be omitted in practical work.

Near the bottom of the vessel, just above the porous false bottom **14**, there is an aperture **19** in the side wall which is closed by a rubber diaphragm **20** held in place by a clamping ring **21**. The centre of the diaphragm **20** is held between two washers **22**, **23** and the washers are clamped to the diaphragm by a central threaded vibration-transmitting rod **24** which passes through the diaphragm and is secured by two clamping nuts **25**, **26**. At about the same level as the vibration-transmitting rod **24** but somewhat out of line therewith, as viewed in plan, there is a bearing bracket **27** for a spindle **28** which carries a driving pulley **29** and a cam **30**. The cam **30** has a serrated face, and it bears endwise upon a cam follower **31** made of very hard steel which is held in a socket **32** on a push rod **33**. The push rod **33** can slide endwise in a bearing bracket **34** supported on a frame **35** and it is pushed towards the cam **30** by means of a strong spring **36**, the strength of which can be adjusted by means of a nut **37** screwed on the push rod **33**. The push rod **33** is united to the vibration-transmitting rod **24** by a coupling **38**.

In the operation of this apparatus the bulk of ore suspended in water which is to be separated is poured into the separation vessel **11**, air is admitted at a suitable rate through the cock **16** and the porous bottom **14**, while the pulley **29** is rotated at such a speed as will vibrate the diaphragm **20** at a frequency of about 300 cycles per second. Suitable reagents are added to the ore pulp either before or after its introduction into the flotation vessel in accordance with the usual practice in the flotation process and a froth is caused to overflow at the lip **13**.

In contradistinction to the froth usually produced by means of air admitted through a porous diaphragm at the bottom of a cell, the froth produced is not voluminous and readily broken down but is dense, heavily mineralized and stable. The rate of admission of air may be slower than that normally required for producing a concentrate in apparatus of the pneumatic type and the time during which the concentrate is collected may also be reduced. The time may be in certain instances as little as one-half to one-third of the time required in the absence of vibration, and the total amount of air may be as little as one-quarter to one-sixth. In certain instances the economy of the reagents, or the degree of concentration, or the recovery may be also improved.

Referring to Figure 3, this shows a froth-forming vessel **40** having a porous bottom **41**, an air inlet **42** and an overflow lip **43**. Within the vessel is a rubber bag **44** on the end of a pipe **45** depending into the liquid from above. The rubber bag and the pipe **45** are filled with a liquid from which air is excluded and vibration is applied to the liquid at the end of the pipe **45** by any suitable means, not shown in the drawings. By this means the vibration is carried into the centre of the body of the pulp and a device of this kind can readily be added to existing flotation apparatus. If the vertical height of the pipe **45** is made sufficient the liquid within the bag **44** may be maintained under superatmospheric pressure so that any risk of cavitation may be prevented. Alternatively, it may be kept under superatmospheric pressure by some form of pump or by other means.

Referring to Figure 4, two froth forming vessels **50**, **51** are located side by side with a third compartment **52** between them. The partitions **53**, **54** between the compartments are made thin enough to transmit vibrations and the central compartment **52** is partly filled with water as shown, without applying any aeration to it, while the froth forming compartments have porous bottoms **55**, **56** through which air is admitted. A flexible diaphragm **57** is provided in the central compartment **52** and vibrated as already described for Figure 1. Consequently vibration is transmitted by the water in **52** through the walls **53**, **54** to the pulp in the froth forming compartments over the whole area of the water in contact with the walls **53**, **54**. This area can be

varied by regulating the amount of water in the compartment 52. Froth overflows at the lips 58, 59.

The following examples are the results of tests carried out in apparatus illustrated in Figures 1 and 2:—

Example I

The ore employed was a copper sulphide ore obtained from a Rhodesian mine and assayed 4.74% of copper. About 500 grams of the ore were ground with 250 cubic centimetres of water in the presence of a quantity of lime at the rate of 3¾ lbs. per ton, pine oil at the rate of 0.16 lb. per ton and cresol at the rate of 0.194 lb. per ton. In addition about 0.4 lb. per ton of potassium xanthate was added. The charge was ground for about half an hour until it would pass a screen having about 200 meshes to the lineal inch and thereafter a portion of the charge containing about 80 grams of ore was made up to 300 ccs. with water and introduced into the vessel 11.

In one case where the vibrator was not operated, a first concentrate was collected in four minutes using 0.7 cubic foot of air which assayed 17.2% of copper and contained 90.4% of the copper in the ore. Further agitation for another 2¼ minutes yielded a second concentrate assaying 1.75% of copper which contained a further 2.3% of the copper in the ore, giving a total recovery of 92.7% of copper. The expenditure of air in obtaining the second concentrate amounted to 0.64 cubic foot. The total time for the two concentrates was 6¼ minutes and the total air expended 1.34 cubic feet.

In a second test on part of the same charge of ore pulp under parallel conditions but using the mechanical vibrator the froth comprised smaller and more stable bubbles, more heavily mineralized more like the froth produced by an agitation froth machine. The first concentrate was collected in one minute with an expenditure of 0.1 cubic foot of air. It assayed 17.2% of copper and contained 87.4% of copper in the ore. The second concentrate was obtained in 1½ minutes with an expenditure of 0.175 cubic foot of air. It assayed 2.4% of copper and contained a further 4.29% of copper in the ore, giving a total recovery of 91.69% of copper. It will be observed that the total time occupied was 2½ minutes as against 6¼ minutes, and the total air expended 0.275 cubic foot as against 1.34 cubic feet, while the recovery and grade of the two concentrates taken together was approximately the same. In this case therefore the time occupied was about 40% and the air expended about one-fifth of that required when no vibrator was employed.

Example II

In this case another sample of the same ore as before was employed but assayed 5.06% of copper. The conditions were the same with the exception that the height of the sides of the machine was increased to accommodate a charge of 240 grams of ore in about 700 ccs. of water and the amount of pine oil employed was reduced to 0.08 lb. per ton. Using no vibration the first concentrate was obtained in 2½ minutes with the expenditure of 0.425 cubic foot of air. This concentrate assayed 37.9% of copper and contained 84.3% of the copper in the ore. After a further 3½ minutes, using 0.9 cubic foot of air a second concentrate was obtained which assayed 2.6% of copper and contained 5.9% of the copper in the ore, making with the first concentrate a total recovery of 90.2% of copper.

Using the vibrator on a second sample of the same ore the quantities of reagents being the same and the method of grinding similar to that previously described, a first concentric was obtained in one minute, with an expenditure of 0.1 cubic foot of air, which assayed 36.7% of copper and showed a recovery of 86.4% of the copper in the ore. A second concentrate was obtained in two minutes with an expenditure of 0.25 cubic foot of air. This assayed 4.3% of copper and contained a further 4.32% of copper, giving a total recovery of 90.72%. It will be observed that in this case the total quantity of air was reduced to about one-quarter and the total time to about one-half of that when no vibrator was employed along with a slightly increased recovery of copper and a better grade of concentrate. It should be observed that as in this example the depth of pulp was increased as compared with Example I, it would appear that it is advantageous to have the vibration in the lower part of the vessel and relative quiet in the upper part where the froth collects.

It will be understood that in any particular case the exact conditions as to the frequency, amplitude, and point of application of the vibrations may require to be the subject of simple experimental determination to get the best results.

It will be observed that the mechanical vibrator illustrated tends to give a non-symmetrical wave-form to the movements of the diaphragm, that is to say a wave-form rich in harmonics of the prime frequency and this may be advantageous. If an electromagnetic vibrator is employed a similar result can be obtained by applying electric currents of mixed frequencies to it suitably co-related the one to the other. Preferably means may be provided to vary both the periodicity and amplitude of the vibration or vibrations employed.

Although the invention has been specially described in its application to a pneumatic flotation cell it is to be understood that it is within the scope of the invention to apply similar vibration to agitation-froth or any other type of flotation machine.

I claim:—

1. A froth flotation process for the concentration of minerals comprising the steps of agitating a pulp of the mineral in the presence of flotation reagents by air introduced through a submerged distributor and superimposing vibration upon said agitation by imposing vibrations of high frequencies upon a deformable wall in contact with the pulp, said vibrations being applied in a direction transverse to the rising movement of the bubbles and above the point at which the air is introduced.

2. A froth flotation process for the concentration of minerals comprising the steps of agitating and aerating a mineral-bearing pulp in the presence of a flotation reagent and applying high frequency vibrations thereto in a direction transverse to the general direction of movement of gaseous bubbles in the pulp.

3. A froth flotation process comprising agitating a mineral pulp in the presence of flotation reagents, passing air bubbles through the pulp and imposing vibration of sonic frequency in a direction substantially transverse to the general primary path of flow of said bubbles.

4. A froth flotation process for the concentration of minerals, comprising the steps of agitating a body of pulp of the mineral in the presence of flotation reagents by gas introduced through a submerged distributor, and independently superimposing vibrations of sonic frequency upon the body of the pulp.

5. In a froth flotation process for minerals, the method which comprises introducing a multiplicity of gas bubbles into a portion of a pulp body, allowing the bubbles to rise through the pulp body, and subdividing the bubbles by subjecting them to independently produced vibrations of sonic frequency.

6. In a froth flotation process for minerals, the method which comprises introducing a multiplicity of gas bubbles into a portion of a pulp body, allowing the bubbles to rise through the pulp body, and subjecting the pulp body to independently produced vibrations of high frequency and low amplitude.

7. A froth flotation process for the concentration of minerals comprising the steps of agitating a pulp of the mineral in the presence of flotation reagents by air introduced through a submerged distributor and superimposing vibration upon said agitation by imposing vibration of high frequency upon a deformable wall having only one surface in contact with the pulp, said vibrations being applied to the rising movement of the bubbles and above the point at which the air is introduced.

8. A froth flotation process for the concentration of minerals, which comprises the steps of agitating a liquid medium with gas, characterized by imparting to the liquid medium independently produced vibrations of an amplitude sufficiently low to prevent surging of the medium and of a frequency in or above the sonic range.

THOMAS JAMES TAPLIN.