United States Patent

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[54] SONIC METHOD AND APPARATUS FOR PROCESSING SLURRIES FOR TRANSPORTATION

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[52] **U.S. Cl.**.....**302/14,** 302/66
[51] **Int. Cl.**.....**B65g 53/30**
[58] **Field of Search** 302/14, 15, 16, 66; 222/196

[56] **References Cited**

UNITED STATES PATENTS

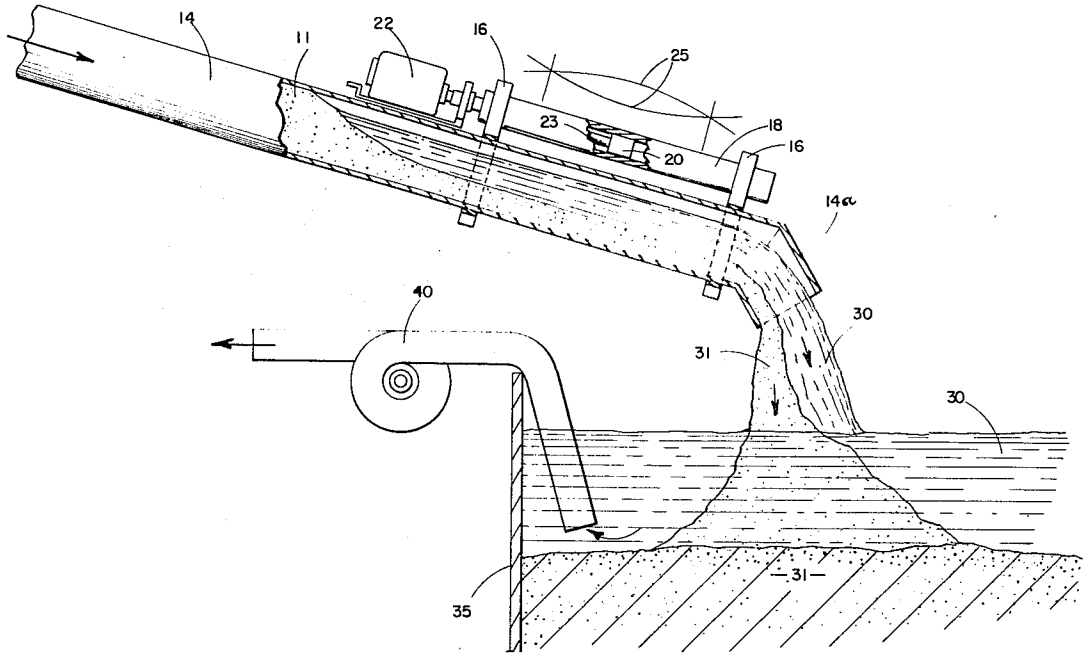
2,766,881	10/1956	Westervelt et al.	302/14 X
3,168,350	2/1965	Phinney et al.	302/14
2,718,717	9/1955	Collins	302/14 X

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[57] **ABSTRACT**

A slurry formed from particulate material and water, to facilitate handling of such material, is fed from the nozzle of a conduit into a storage compartment of a vehicle. Sonic energy generated by means of an orbiting mass oscillator is coupled to the conduit in the region of the nozzle where the velocity of flow tends to decrease with the spreading flow out of the nozzle. Sonic energy which is delivered from a resonant vibration system causes the water and particulate material to separate from each other so that they are divided in the compartment with the heavier particulate material on the bottom. The water then is pumped out of the compartment so that it is eliminated from the transportation load. The nozzle may be placed into the slurry material after most of the water has been removed to further continue the separation process so that substantially all of the water is removed. In unloading the vessel the process may be reversed with water being added to the particulate material while sonic energy is imparted thereto to re-form the slurry so that it may be readily removed from the transportation compartment.

6 Claims, 3 Drawing Figures



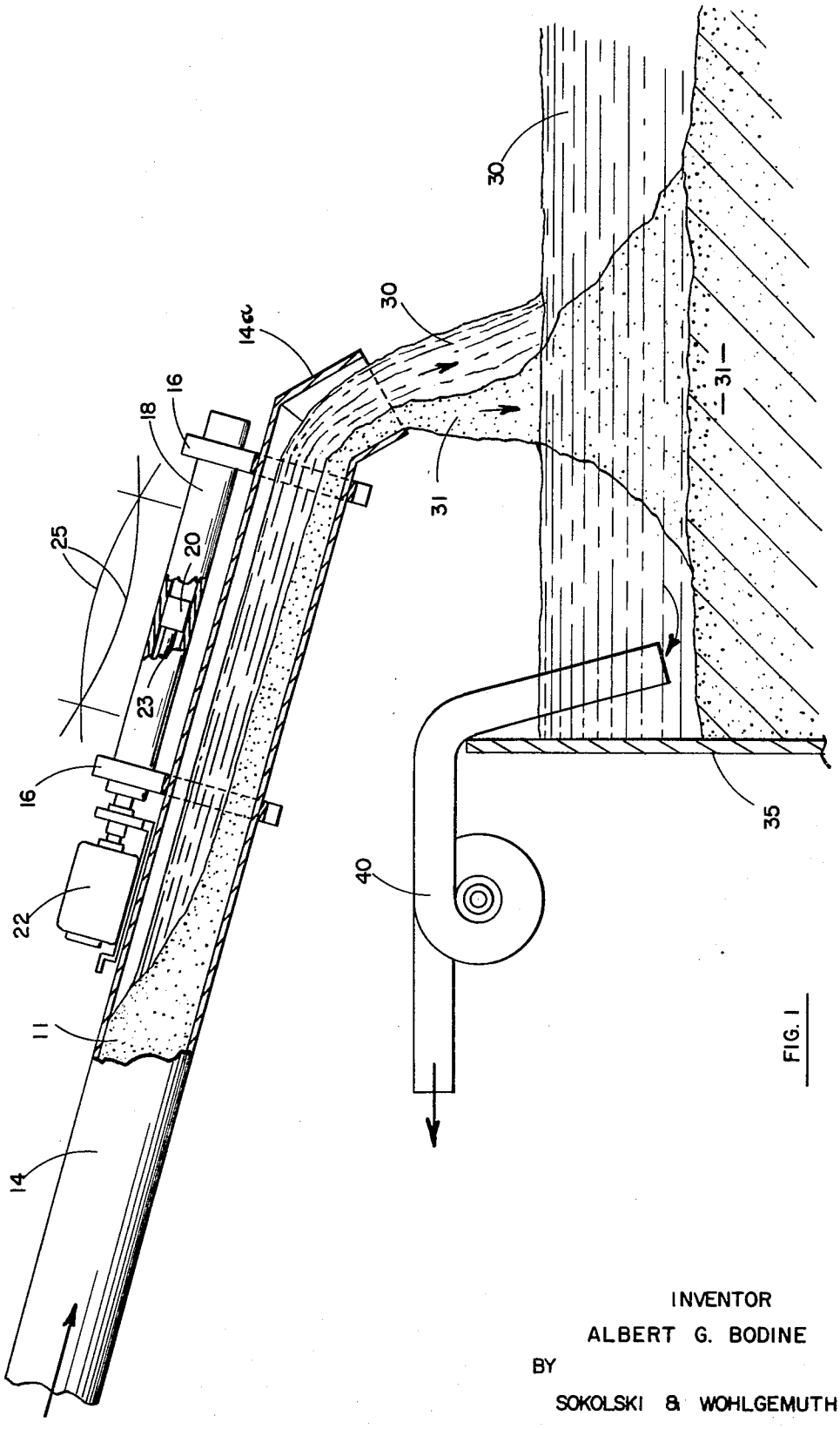


FIG. 1

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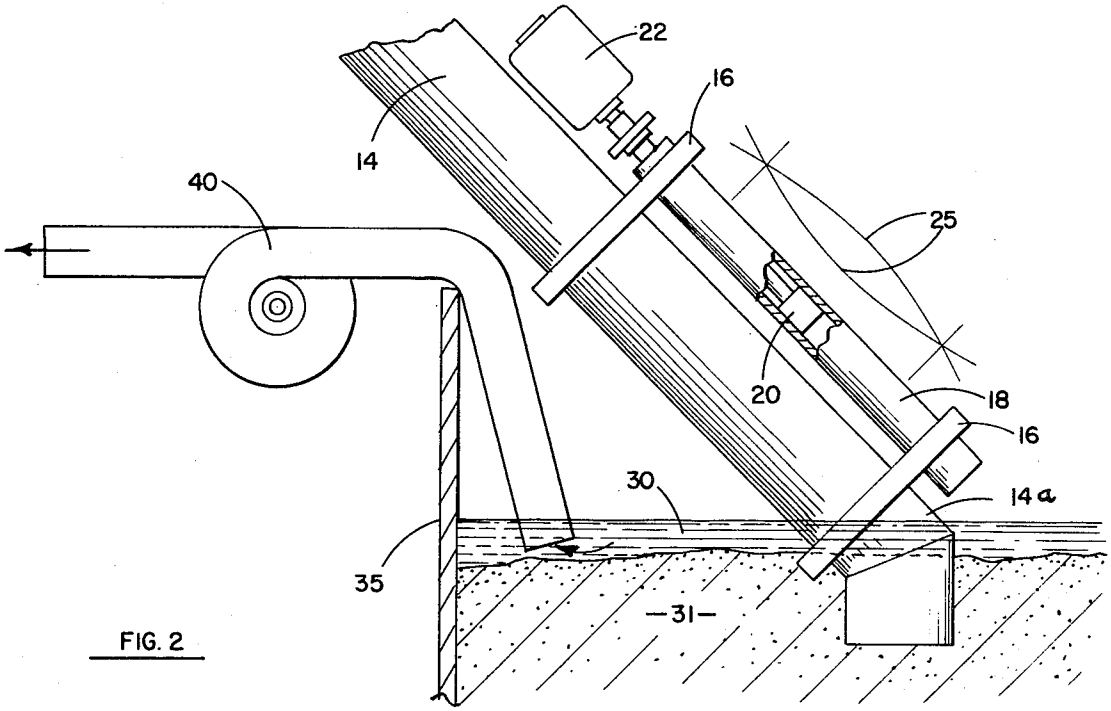


FIG. 2

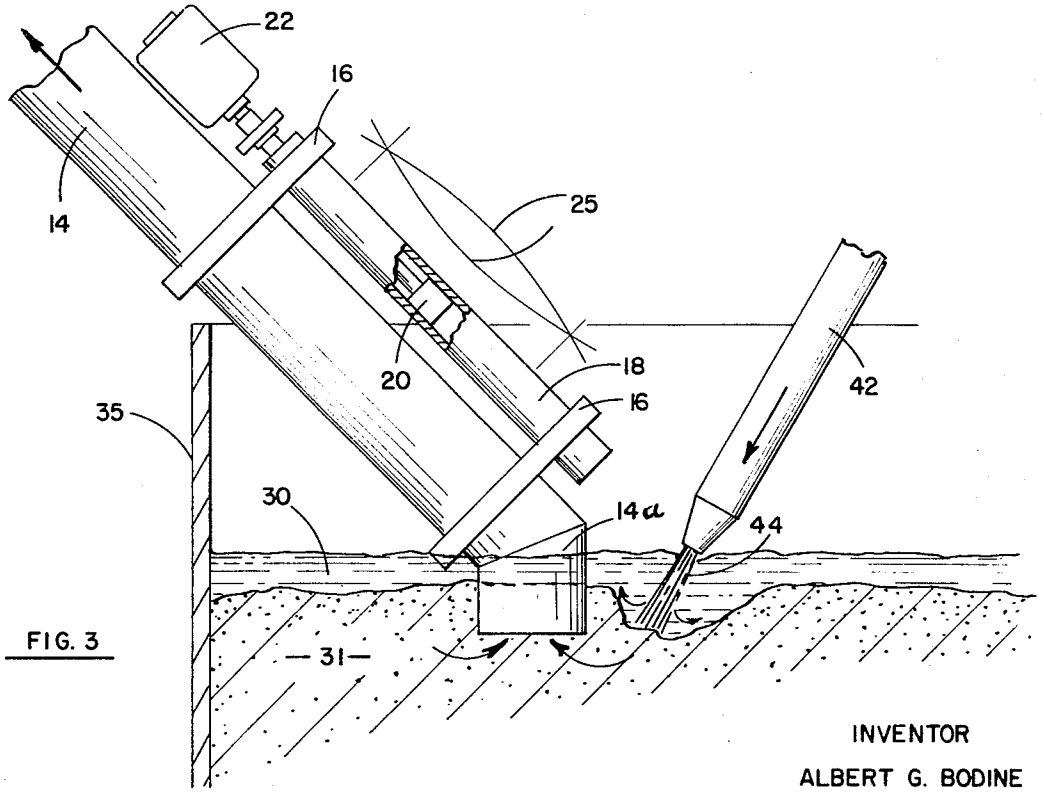


FIG. 3

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SONIC METHOD AND APPARATUS FOR PROCESSING SLURRIES FOR TRANSPORTATION

This invention relates to the handling of particulate material for transportation, and more particularly to the utilization of sonic energy applied to a slurry to separate particulate material from a liquid carrier and subsequently recombining such material to re-form the slurry.

In handling particulate material for transportation such as in loading such material onto a vehicle such as a ship and then at the ultimate destination removing such material, the material is often combined with water to form a slurry. While this greatly facilitates the loading and unloading, it has several shortcomings. Firstly, the water adds considerably to the load, thus utilizing a considerable portion of the vehicle's handling capacity in an unproductive matter. Further, the water tends to gradually separate from the particulate material during the voyage, coming to the top of the compartment. Such a fluid load, especially in the higher portions of a ship contributes to instability, creating a hazard which becomes especially dangerous in rough weather.

This invention provides a technique and apparatus by which particulate material may be loaded and unloaded in a slurry, with the water being efficiently removed at the time of loading, and added when unloading is being accomplished, thereby affording the advantages of handling particulate material as a slurry while obviating the disadvantages of transporting the material in this form.

It is therefore an object of this invention to provide an improved technique and apparatus for handling particulate material for transportation.

It is another object of this invention to enable the loading and unloading of particulate material in slurry form while efficiently removing the water from such material for transportation of the material.

Other objects of this invention will become apparent from the following description taken in connection with the accompanying drawings, of which:

FIG. 1 is a side elevational view of one embodiment of the invention as being utilized in loading the compartment of a vehicle,

FIG. 2 is a side elevational view illustrating the apparatus of FIG. 1 being utilized to remove the last bit of water from the particulate material to be transported, and

FIG. 3 is a side elevational view of the embodiment of FIG. 1 being utilized to remove material from a vehicle compartment.

Briefly described, the apparatus and technique of this invention involves the utilization of a resonant vibration system which is vibrated at a resonant frequency by means of an orbiting mass oscillator. This vibration system may be coupled to a conduit near the discharge nozzle thereof. Particulate material combined with water to form a slurry to facilitate the handling thereof is passed through the conduit and out the discharge nozzle into a compartment of a vehicle, such as the hold of a ship, wherein it is to be transported. As the slurry passes through conduit portions near the discharge nozzle, it is subjected to high level sonic energy coupled to the conduit from the resonant vibration system. The resonant energy causes the liquid and particulate material to effectively separate from each other as they are passed into the vehicle compartment,

the heavier particulate material moving to the bottom of the compartment with the liquid on top. The liquid is then pumped out. The last portion of liquid may be removed from the particulate material by placing the nozzle into the particulate material so that the vibrational energy is directly coupled thereto. In removing the particulate material, the process is reversed, the nozzle being utilized to impart sonic energy to the particulate material while water is actively added thereto, thereby engendering a mixing of the water and material to re-form the slurry for removal. The water velocity here is substantially greater than that where separation is accomplished as above described.

It has been found most helpful in analyzing this invention to analogize the acoustically vibrating circuit utilized to an equivalent electrical circuit. This sort of approach to analysis is well known to those skilled in the art and is described, for example, in Chapter 2 of "-Sonics" by Hueter and Bolt, published in 1955 by John Wiley and Sons. In making such an analogy, force F is equated with electrical voltage E, velocity of vibration u is equated with electrical current a, mechanical compliance C_m is equated with electrical capacitance C_e, mass M is equated with electrical inductance L, mechanical resistance (friction) R_m is equated with electrical resistance R and mechanical impedance Z_m is equated with electrical impedance Z_e.

Thus, it can be shown that if a member is elastically vibrated by means of an acoustical sinusoidal force $F_o \sin \omega t$ (ω being equal to 2π times the frequency of vibration), that

$$Z_m = R_m + j\left(\omega M - \frac{1}{\omega C_m}\right) = \frac{F_o \sin \omega t}{u} \qquad (1)$$

where ωM is equal to $1/\omega C_m$, a resonant condition exists, and the effective mechanical impedance Z_m is equal to the mechanical resistance R_m, the reactive impedance components ωM and $1/\omega C_m$ cancelling each other out. Under such a resonant condition, velocity of vibration u is at a maximum, power factor is unity, and energy is more efficiently delivered to a load to which the resonant system may be coupled.

It is important to note the significance of the attainment of high acoustical "Q" in the resonant system being driven, to increase the efficiency of the vibration thereof and to provide a maximum amount of power. As for an equivalent electrical circuit, the "Q" of an acoustically vibrating system is defined as the sharpness of resonance thereof and is indicative of the ratio of the energy stored in each vibration cycle to the energy used in each such cycle. "Q" is mathematically equated to the ratio between ωM and R_m. Thus, the effective "Q" of the vibrating system can be maximized to make for highly efficient, high-amplitude vibration by minimizing the effect of friction in the system and/or maximizing the effect of mass in such system.

In considering the significance of the parameters described in connection with equation (1), it should be kept in mind that the total effective resistance, mass, and compliance in the acoustically vibrating system are represented in the equation and that these parameters may be distributed throughout the system rather than being lumped in any one component or portion thereof.

It is also to be noted that orbiting-mass oscillators are utilized in the implementation of the invention that au-

tomatically adjust their output frequency and phase to maintain resonance with changes in the characteristics of the load. Thus, in the face of changes in the effective mass and compliance presented by the load with changes in the conditions of the material as it is sonically excited, the system automatically is maintained in optimum resonant operation by virtue of the "lock-in" characteristic of applicant's unique orbiting mass oscillators. Furthermore in this connection the orbiting mass oscillator automatically changes not only its frequency but its phase angle and therefore its power factor with changes in the resistive impedance load, to assure optimum efficiency of operation at all times. The vibrational output from such orbiting mass oscillators also tends to be constrained by the resonator to be generated along a controlled predetermined coherent path to provide maximum output along a desired axis.

Referring now to FIG. 1, one embodiment of the apparatus of the invention as being utilized in the loading of particulate material is illustrated. A slurry **11** which includes particulate material to be transported, such as metal ore or the like, is fed down conduit **14** to the nozzle portion **14***a* thereof. Coupled to conduit **14** near nozzle portion **14***a* at points therealong for optimum impedance coupling of the sonic energy thereto by means of clamps **16** is a resonator tube **18**. Resonator tube **18** has an orbiting mass oscillator **20** mounted therein, such oscillator including an eccentric rotor member which is rotatably driven by means of motor **22** which is coupled to the oscillator through shaft **23**. Oscillator **20** may be of the type described in connection with FIG. **21** of my U.S. Pat. No. 2,960,314.

The oscillator is driven at a speed such as to cause resonant standing wave vibration of resonator member **18** so as to cause a standing wave vibration pattern to be set up therein as indicated by graph lines **25**. Resonator **18** is coupled to conduit **14** at point or points therealong which is experimentally determined for impedance matching of the resonator to the load so as to afford optimum coupling of energy thereto. It is also to be noted that the slurry **11** should have a relatively low velocity in the region of the nozzle portion so as to prevent re-mixing and to enable efficient separation of the liquid from the particulate material by the resonant energy.

The sonic energy which is coupled to the slurry material causes a random vibration of the particles of the particulate material which causes the liquid to separate therefrom. This may be explained by virtue of the fact that in view of the different impedances presented by the liquid and the particulate material, these two media tend to vibrate at different amplitudes and phases and thus tend to separate out from each other in the low velocity environment, with the generally heavier particulate material falling to the bottom of the conduit. In other words, this fluidizes the material and aids the gravity migration of water. Thus, by the time the material exits from the nozzle it is effectively separated into two parts, water **30** and particulate material **31**, with the heavier particulate material dropping to the bottom of vehicle compartment **35**. The water **30** can then readily be pumped from the top portion of the compartment by means of pump **40**, this all being accomplished almost simultaneously.

Referring now to FIG. **2**, when substantially all of the surface water has been removed and the loading of the material from the conduit has been completed, as described in connection with FIG. **1**, nozzle portion **14***a* is placed down into particulate material **31** while resonator **18** is being resonantly vibrated. The nozzle **14***a* is drawn back and forth through the body of the particulate material to cover all portions thereof as a sonic probe. This sonic activation of the otherwise quiescent particulate material causes further water separation, this remaining water **30** rising to the top where it can readily be extracted by means of pump **40**. Thus, substantially all of the water is removed from particulate material **31** both while it is being loaded and after the loading has been completed.

Referring now to FIG. **3** the use of the apparatus of the invention in the re-forming of the slurry for removal of the particulate material is illustrated. When the vehicle arrives at its destination and the particulate material is to be removed, nozzle **14***a* is placed in particulate material **31** and sonic oscillator **20** rotatably driven so as to cause resonant vibration of resonator **18**. Thus, the particulate material is randomly vibrated and fluidized by the high level sonic energy, which again causes mobility and aids water migration, this time in response to pressure ingress. Simultaneously, a high velocity water stream **44** is introduced by means of nozzle **42**, this water stream acting to stir up and carry the particulate material. The combined sonic action and that of the high velocity water stream readily reforms the slurry to that it may readily be pumped out of compartment **35** through conduit **14** by means of a pump connected to the conduit (not shown).

Thus, the technique and apparatus of this invention provides highly effective means for removing water from particulate material while and immediately subsequent to loading for transportation and for re-forming the slurry to facilitate the unloading of such material when it arrives at its destination.

I claim:

1. A method for loading particulate material on a vehicle for transportation comprising the steps of:

combining the material with liquid to form a slurry,

feeding the slurry through a conduit and from a discharge nozzle of the conduit into a compartment of the vehicle,

while the slurry is being so fed, applying high level sonic energy to the conduit in the vicinity of the nozzle so as to separate the liquid from the particulate material whereby the liquid and particulate material are separated from each other in the compartment, and

removing the liquid from the compartment.

2. The process of claim **1** wherein the slurry is fed at a low velocity in the portion of the conduit where it is being subjected to sonic energy.

3. The method of claim **1** and additionally including the final step, after all of the material has been passed from the nozzle into the compartment, of placing the nozzle in the particulate material while simultaneously applying resonant vibrational energy thereto so as to cause liquid to further separate from the particulate material, and removing said liquid from the compartment.

4. The method of claim 1 wherein the vibrational energy is generated by means of an orbiting mass oscillator which is coupled to a resonant vibration system, the oscillator being driven at a speed such as to cause resonant vibration of said system, said vibration system being coupled to the conduit.

5. A method for combining water with particulate material to form a slurry for removal from a vehicle compartment, comprising the steps of:

placing a sonic agitator member in said particulate material,

applying high level sonic energy to said agitator member from a resonant vibration system driven by an orbiting mass oscillator,

simultaneously applying a high velocity stream of liquid to said particulate material so as to stir up such material

whereby the combined vibratory action of said agitator member and the stirring action of said high velocity liquid stream cause a combining of the liquid and the particulate material to form a slurry, and

drawing the slurry so formed out through a conduit.

6. Apparatus for use in separating particulate material from water in a slurry while loading said slurry into a compartment comprising:

a conduit member, said conduit member having a discharge nozzle,

a resonator member,

an orbiting mass oscillator coupled to said resonator member,

means for driving said orbiting mass oscillator at a frequency such as to cause resonant vibration of said resonator member, said resonator member being coupled to said conduit member at a predetermined optimum coupling region thereof near said nozzle,

said slurry being passed through the coupling region of said conduit at a relatively low velocity while being subjected to high level resonant vibration so as to cause separation of the liquid from the particulate material forming the slurry, and

means for removing the separated liquid from the compartment.

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