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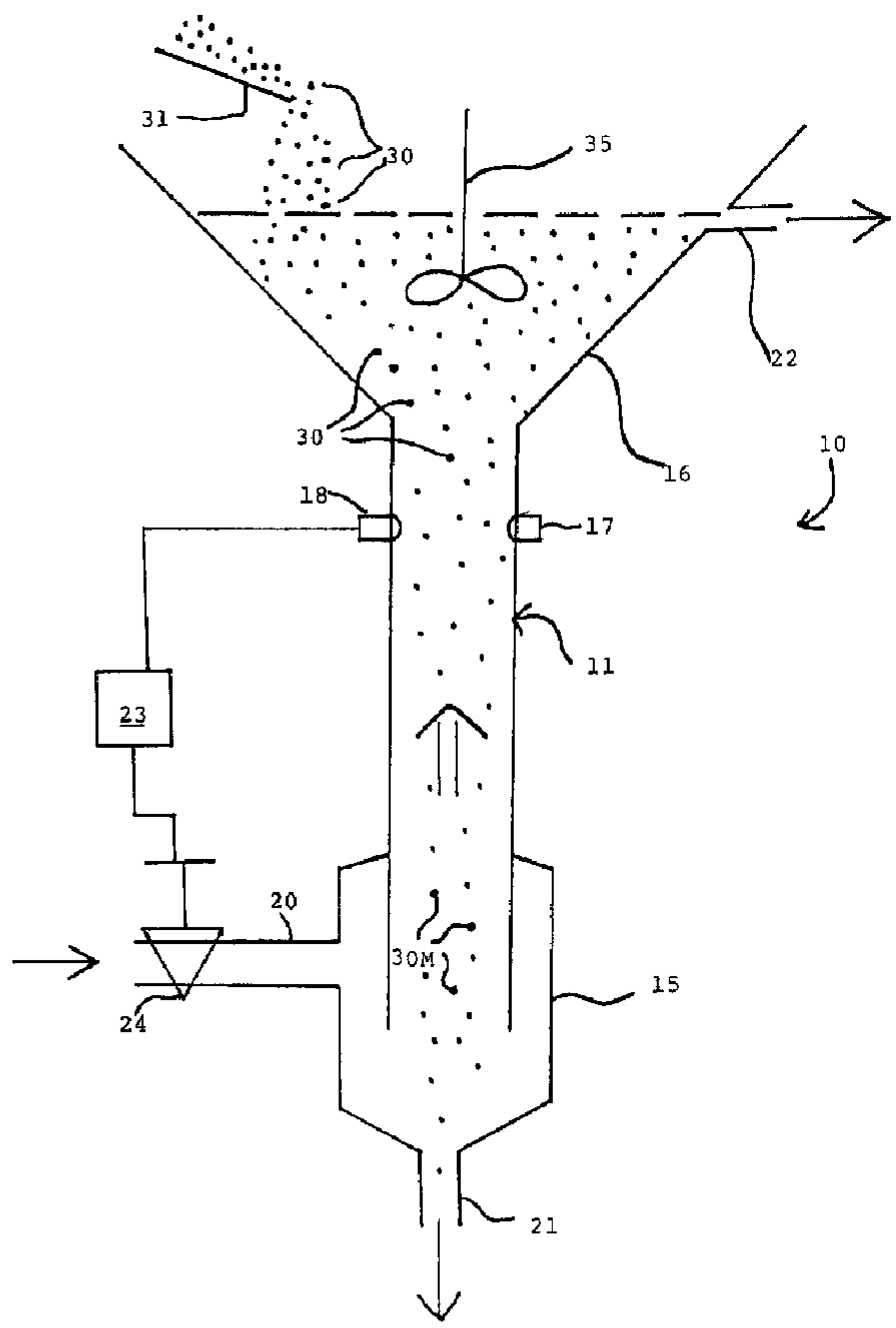

(57) Abrégé/Abstract:
A hydraulic mineral separator is provided for the separation of materials based on differences in particle density in a vertical flowing stream of a liquid, wherein the liquid flow rate is adjusted in accordance with signals received from a particle sensor in the vertical tube. The apparatus allows for the automation of the mineral separator, and for better control of the process conditions within the separator.

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Abstract

Hydraulic Mineral Separator

A hydraulic mineral separator is provided for the separation of materials based on differences in particle density in a vertical flowing stream of a liquid, wherein the liquid flow rate is adjusted in accordance with signals received from a particle sensor in the vertical tube. The apparatus allows for the automation of the mineral separator, and for better control of the process conditions within the separator.

Hydraulic Mineral Separator

Field of the Invention

This invention relates to a hydraulic mineral separator apparatus.

Description of the Related Art

In the mining industry, it is known that soil particles containing precious metals, such as gold, can be separated from other particles of comminuted ores, by use of a hydraulic mineral separator. This type of device uses a upward flow of a liquid, which is typically water, through an essentially vertical tube, to separate those particles having a higher density from those particles with a low density. In a typical hydraulic mineral separator, the liquid stream enters the vertical tube at or near the bottom of the tube and flows upwardly until it exits the tube at or near the top of the tube. Soil particles of a preferably constant size (by volume) are fed into the top of the tube so that they are exposed to the upward flow of liquid. The rate of liquid flow is controlled so that only the heavier particles will settle and/or sink through the upwardly flowing liquid stream. The lighter particles are unable to sink through the upwardly flowing liquid stream and remain at, or near the top of the vertical tube. Thus, the lower density particles can be removed from the top of the mineral separator while the higher density particles are removed from the lower section.

These types of hydraulic mineral separators have been known for a number of years and have been described by, for example Miller in U.S. Patent No. 1,483,371 (issued Feb. 12, 1924), McDaniel et al. in U.S. Patent No. 3,642,129 (issued Feb. 15, 1972), Turbitt et al. in U.S. Patent No.

4,554,066 (issued Nov. 19, 1985), and Kuryluk in U.S. Patent No. 4,789,464 (issued Dec. 6, 1988).

While these devices have been known for several years, their primary use has been limited to the classification of ore samples for mining operations or as a guide to the amount of heavy metals present in an ore sample.

An operational modification of the standard technique for use of a mineral separator is the practise of manually causing an intermittent reduction in the flow of water into the apparatus, or causing an intermittent reduction in the flow of liquid at a regular time interval. This reduction causes particles currently in the lower parts of the vertical tube to fall more rapidly out of the bottom of the tube. While this technique provides a method to improve the rapidity of ore classification, it would be desirable to improve this technique further.

Summary of the Invention

The present invention is thus directed to an apparatus which facilitates use of the technique wherein the rate of upward flow of liquid through the vertical tube of the mineral separator is adjusted through the use of a particle sensing means.

Accordingly, the present invention provides a hydraulic mineral separator comprising:

a substantially vertical tube having a liquid inlet at or near the bottom of said tube;

a liquid outlet at or near the top of said tube so that liquid flows upwardly through said tube from said liquid inlet to said liquid outlet;

a particle sensor located within said vertical tube; and,

a liquid flow regulator, operatively connected to said particle sensor, which regulator adjusts the flow rate of liquid within said vertical tube when a particle, or particles, is or are, detected by said particle sensor.

The basic components of the hydraulic separator may be any of the known mineral separators described in the prior art. Generally, the vertical tube is of sufficient length to allow the particles to separate in response to the liquid flow selected. The liquid flow rate may be adjusted to effect separation of the higher density particles from the lower density particles for the given sample parameters (size, density and the like) and for the vertical tube length selected.

The separator may be used to separate a wide variety of materials which are capable of being classified by density. This can include the separation of solids of different densities, separation of solids from liquids, and even separating two liquids of different density.

Throughout this document reference is made to high density and low density "particles". In this document, the term "particles" is used to designate solid materials, but can also include droplets of high density liquid, such as for example, droplets of mercury which can be separated from soils, and the like, in the apparatus of the present invention.

The preferred liquid of use in the hydraulic separator is water. However, any other liquid may be used depending on the nature of the materials to be separated. In accordance with standard mineral separator technology, the liquid is added to the mineral separator at the lower portion of the separator so that the liquid will flow upward through the vertical tube. The liquid exits the tube and enters a mixing zone wherein it mixes with the subject sample which is typically added to the mixing zone. After the liquid has mixed with the sample, the higher density particles fall through the vertical tube against the upward flow of the liquid. The remaining lower density particles are eventually removed from the mixing zone of separator together with liquid present in the zone. The liquid may be removed from the lower density particles and preferably is recycled to the mineral separator.

The higher density particles fall through the vertical tube and are removed from the bottom of the mineral separator through an outlet opening. This opening may be open at all times - provided that the flow rate from the outlet is not greater than the flow rate of liquid added to the mineral separator - or may be opened intermittently in order to drain any collected high density particles.

The particle sensor used in the mineral separator of the present invention may be any device which is capable of detecting particles in the liquid stream. Depending on the properties of the particle (which can include a liquid droplet) and the properties of the liquid used in the separator, a wide variety of sensors may be utilized. These sensors may act based on a number of physical property differences including conductivity, capacitance, magnetism and the like. For a non-transparent particle, the sensor is preferably a light sensor which can include sensors operating on any suitable electromagnetic radiation frequency such as infrared or ultraviolet, but most preferably, is one which operates in the visible light spectrum.

The sensor may be located anywhere within the vertical tube so long as it is above the liquid inlet. Preferably, however, the particle sensing means is located in the upper half of the vertical tube so that adjustment of the liquid flow can occur while the sample particle is still within the vertical tube.

The liquid flow regulator may operate by increasing or decreasing the flow rate of liquid to the separator, or by adjusting the flow rate of liquid to the vertical tube by releasing liquid from the separator prior to entering the vertical tube. The flow regulator may operate to turn the liquid flow on and off, or may operate to adjust the flow rate of liquid while maintaining a constant, positive (i.e. non-zero) base flow rate.

The liquid flow regulator is preferably a valve which will open or close in accordance with desired parameters based on signals received from the particle sensor. The particle sensor and the liquid flow regulator are preferably connected through a controller which has been programmed to operate the liquid flow regulator in a pre-determined fashion once a particle has been detected by the particle sensor.

In one preferred embodiment, the particle sensor is located in the upper half of the vertical tube. Once a particle is detected, the liquid flow rate is immediately increased for a set period of time. Preferred time periods range from 0.1 to 10 seconds, and more preferably from 1 to 6 seconds, and most preferably from 1 to 3 seconds. After the set time period, the liquid flow rate is returned to its base flow rate. This base flow rate may be a low flow rate, or may even be a no flow rate (ie the liquid flow is turned off). However, the base flow rate should be low enough so that particles will be able to enter the vertical tube, and, the flow rate during the set time period should be high enough so that only the particles above the desired particle density are able to pass through the vertical tube.

The liquid flow regulator may also function by releasing, or by preventing the release of liquid from the bottom section of the mineral separator. By increasing or decreasing the amount of liquid exiting the mineral separator, the flow rate of liquid flowing upward through the vertical tube is adjusted if the liquid addition rate is kept constant. A combination of control of liquid addition rate and liquid outlet rate may also be used.

The controller is preferably an electronic, and preferably, programmable device adapted to receive inputs from the particle sensor and utilize this information to control the liquid flow regulator.

In another preferred embodiment, the particle sensor is utilized to adjust the flow rate in the vertical tube so as to establish an essentially constant heavy particle collection rate for a given set of operating conditions. In this embodiment, the flow rate is adjusted by the liquid flow regulator so that a steady state condition is achieved wherein a steady amount of higher density particles passes through the tube. If the rate at which particles pass through the tube varies, the liquid flow regulator will adjust the flow rate so as to return the heavy particle collection rate to the pre-established rate. Similarly, the flow rate can be decreased should the heavy particle collection rate fall below the pre-established rate.

In this embodiment, the hydraulic mineral separator will automatically adjust to variations in the composition of the particles added to the separator, and thus will be able to avoid situations wherein all particles are rejected as being too light for entry into the vertical tube, or situations where an excessive number of particles enter the tube.

In a further preferred embodiment, the mineral separator comprises a high density particle level sensor which can detect the level of high density particles which have collected at the bottom of the separator. When the level of high density particles has achieved a certain level, the level sensor will cause an drain outlet to open to remove the high level particles from the separator.

Accordingly, the present invention also provides a fully automated hydraulic mineral separator comprising the hydraulic mineral separator described hereinabove with reference to the present invention and which additionally comprises a high density particle level sensor at the bottom of, or below the bottom end of the vertical tube, and an outlet valve operatively connected to said high density particle level sensor, wherein said outlet valve is opened or closed in accordance with signals received from said high density particle level sensor.

The high density particle level sensor may be any of the level sensors described hereinabove with respect to the particle sensor. Selection of an appropriate high density particle level sensor will be dependent on the nature of the high density particles, but can be, for example, a light sensor.

The outlet valve may be partially open at all times, with increased flow on receiving an appropriate signal from the high density particle level sensor, or may be normally closed and opening only when the high density particle level sensor detects a level of particles which is higher than a set value. The outlet valve may remain open for a set time period, once initiated, or the separator may comprise a second high density particle level sensor wherein the first and second sensor are used to establish a high and low setting for the level of high density particles in the separator.

Through appropriate use of the release of high density particles from the separator the amount of liquid released from the separator (as a "contaminant" with the high density particles) can be minimized.

Other features may additionally be utilized in the apparatus of the present invention. These include: (i) relatively small water inlets near the surface of the particle sensor(s) in order to maintain a clean surface near the face of each sensor; (ii) a water inlet valve near the top end of the vertical tube in order to ensure that this area is not blocked by a large inflow of particles added to the mixer; (iii) a stirring motor in the particle mixer in order to keep particles in the mixer in a free-flowing, non-agglomerated state; (iv) a controller connected to the stirring motor which controller adjusts the rate of particle addition to the mixer based on changes in the power requirement of the mixer, and thus ensures that the number of particles in the mixer is essentially constant, or an stirring motor power indicator which allows an operator to manually adjust the particle addition rate to obtain a constant level of particles in the mixer; and (v) a mixing device within the vertical tube area, such as an ultrasonic mixer, to either prevent agglomeration of some type of particles, such as solid materials, or to assist in agglomeration of other types of particles, such as heavy liquids - for example, mercury.

Brief Description of the Drawings

The apparatus of the present invention will now be described, by way of example only, by reference to the attached figures wherein:

Figure 1 is a cross-section representation of a hydraulic mineral separator in accordance with the prior art;

Figure 2 is a hydraulic mineral separator in accordance with the present invention;

Figure 3 is a modified hydraulic mineral separator wherein an outlet valve is added; and

Figure 4 is an alternative embodiment of the apparatus of the present invention.

In Figure 1 hydraulic mineral separator 10 comprises an upright central tube 11 which extends from a water inlet chamber 15 to funnel opening 16. Water inlet 20 is attached to water inlet chamber 15, and discharge outlets 21 and 22 are attached to water inlet chamber 15 and funnel opening 16, respectively.

In the apparatus shown in Figure 2, water is fed to separator 10 through water inlet 20. The water enters water inlet chamber 15 and then flows upward through central tube 11 into funnel opening 16. A portion of the water exits separator 10 through discharge opening 21, and the remaining water exits separator 10 through discharge opening 22. Discharge opening 21 is smaller than water inlet 20 so as to ensure that water is forced to flow upward through tube 11 as indicated by the arrow in tube 11. The flow of water into separator 10 is controlled so that the flow of water upward through tube 11 is essentially constant.

Sample particles 30, having an essentially constant particle size are added from hopper 31 to funnel opening 16. There, they are mixed into the water in funnel 16 by stirrer 35. While in funnel opening 16, sample particles 30 enter the upper opening of tube 11. Only those particles which have a higher density are able to settle through the upwardly flowing water stream in tube 11. These dense sample particles, designated as 30M are able to settle through tube 11 and fall into water inlet chamber 15.

Water inlet chamber 15 has a cross sectional area greater than that of tube 11 so that the water velocity in chamber 15 is less than in tube 11. Accordingly, once particles 30M have reached chamber 15, they quickly settle to the bottom of chamber 15, and are removed through discharge opening 21. Particles 30M can be separated from the water stream exiting discharge opening 21, and the water returned to the system through inlet 20.

Lower density particles 30 which are not sufficiently dense to settle through tube 11 are eventually discharged from discharge opening 22. These particles may also be separated from the water, and the water recycled to the system through inlet 20.

Stirrer 35 is optional, particularly if funnel opening 16 is designed so as to promote mixing of sludge particles 30 in the water from tube 11. This mixing minimizes the possibility that higher density particles may prematurely exit separator 10 through discharge opening 22.

In Figure 2, a modified hydraulic mineral separator in accordance with the present invention is shown which additionally comprises a light source 17 and a light sensor 18, both of which are to tube 11. Light sensor 18 is also operatively connected to water inlet valve 24 through a water valve controller 23.

In the operation of the apparatus shown in Figure 2, water valve 24 is normally closed so as to prevent water from entering inlet water chamber 15. As particles 30 and

30M settle through tube 11, they pass in front of light source 17 and break the light signal to light sensor 18. In this manner, light sensor 18 is able to detect the presence of particles 30 and 30M in the sample tube. The presence of particles is relayed to controller 23 which opens water inlet valve 24 for 4 seconds (or any other set period of time). Valve 24 is set so as to allow a sufficient flow of water into tube 11 so as to cause particles 30 to flow upwards back into funnel 16. However, the flow rate is not sufficient to significantly raise particles 30M which settle through tube 11. After the set period of time, controller 23 closes valve 24 so as to stop the flow of water into tube 11. This allows additional particles 30 and 30M to enter tube 11 where again, they are detected by light sensor 18.

In a modification of the shown apparatus, water valve 24 can be set so as to provide a low water flow rate (a base rate) which flow rate is low enough to allow particles 30 and 30M to pass in front of light sensor 18 so as to be detected. When detected, controller 23 causes water inlet valve 24 to open further so as to allow additional water into water inlet chamber 15 and thus increase the water flow rate through tube 11. The increased flow rate is in accordance with the flow rate described hereinabove with respect to Figure 2. After a set period of time, controller 23 causes valve 24 to close so as to provide, once again, the base flow rate.

This second approach can also be accomplished by providing a second water inlet (not shown) which allows water to flow into the bottom of tube 11 at the base flow rate.

In Figure 3, a further modification of the separator of the present invention is shown which additionally comprises an additional light source 41, an additional light sensor 43, an additional controller 45, and an outlet valve 46. In this apparatus, outlet valve 46 is normally closed so that particles 30M collect at the bottom of water inlet chamber 15. If particles 30M are essentially insoluble in water (such as, for example, mercury droplets), the particles collect into a near homogeneous, water free mass 30T at the bottom of chamber 15. When sufficient particles have collected, mass 30T continuously interferes with the transmission of light from light source 41 to light sensor 43. This continuous interruption of the light beam causes controller 45 to open valve 46 for a set period of time. Mass 30T is allow to drain through outlet 21 when valve 46 is open. Valve 46 is preferably open for a period of time sufficient to remove a substantial portion of mass 30T without allowing any water to exit outlet 21.

The flow rate of mass 30T through outlet 21 can also be adjusted so as to have a minimal effect on the flow rate of water through tube 11.

Other means can be utilized so as to cause mass 30T to drain from the apparatus. These means can include a high and low mass 30T level detectors which opens valve 46 when the high level is reached, and closes valve 46 when a low level is reached.

In Figure 4, a further modification of the apparatus of the present invention is shown wherein water inlet chamber 15 has been eliminated. In this embodiment, water inlet 20 is directly connected to tube 11 so that water directly enters the tube. Further, outlet 21 is located at the bottom of tube 11. Mass 30T is allowed to collect at the bottom of tube 11. Particle sensor 18 has been replaced by a combined light source/light sensor 18A, and light source 17 has been replaced by a mirror 47 which acts as a reflective surface. Light from the source/sensor 18A is reflected off of mirror 47 back to source/sensor 18A. Any particles breaking the light beam between the source and sensor as the light travels to and from mirror 47, will be detected by the sensor 18A.

In order to minimize disruption of mass 30T, water inlet 20 is preferably located above light sensor 43 so that mass 30T is below the water inlet location.

Having described specific embodiments of the present invention, it will be understood that modifications thereof may be suggested to those skilled in the art, and it is intended to cover all such modifications as fall within the scope of the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A hydraulic mineral separator comprising:

a substantially vertical tube having a liquid inlet at or near the bottom of said tube;

a liquid outlet at or near the top of said tube so that liquid flows upwardly through said tube from said liquid inlet to said liquid outlet;

a particle sensor located within said vertical tube; and,

a liquid flow regulator, operatively connected to said particle sensor, which regulator adjusts the flow rate of liquid within said vertical tube when a particle, or particles, is or are detected by said particle sensor.

2. A hydraulic mineral separator as claimed in Claim 1 wherein said liquid is water.

3. A hydraulic mineral separator as claimed in Claim 1 wherein said separator is utilized to separate a solid from a sample liquid.

4. A hydraulic mineral separator as claimed in Claim 3 wherein said sample liquid is mercury.

5. A hydraulic mineral separator as claimed in Claim 1 wherein said particle sensor acts based on a physical property difference between said particle and said liquid.

6. A hydraulic mineral separator as claimed in Claim 5 wherein said physical property is conductivity, capacitance, magnetism, or transparency to electromagnetic radiation.

7. A hydraulic mineral separator as claimed in Claim 6 wherein said particle sensor is a light sensor.

8. A hydraulic mineral separator as claimed in Claim 7 wherein said light sensor operates in the visible spectrum.

9. A hydraulic mineral separator as claimed in Claim 1 wherein said particle sensor is located in the upper half of the vertical tube.

10. A hydraulic mineral separator as claimed in Claim 1 wherein said liquid flow regulator operates by increasing or decreasing the flow rate of liquid to the separator.

11. A hydraulic mineral separator as claimed in Claim 10 wherein said liquid flow regulator operates by adjusting the liquid flow rate while maintaining a constant, positive base flow rate.

12. A hydraulic mineral separator as claimed in Claim 1 wherein said liquid flow regulator is a valve which will open or close in accordance with desired parameters based on signals received from the particle sensor.

13. A hydraulic mineral separator as claimed in Claim 1 wherein said particle sensor and the liquid flow regulator are connected through an electronic, programable controller which has been programmed to operate the liquid flow regulator in a pre-determined fashion once a particle has been detected by the particle sensor.

14. A hydraulic mineral separator as claimed in Claim 13 wherein said particle sensor is located in the upper half of the vertical tube.

15. A hydraulic mineral separator as claimed in Claim 13 having a base flow rate of liquid through said vertical tube, and an increased flow rate, and wherein said flow rate is adjusted from said base flow rate to said increased flow rate for a set period of time when said particle sensor detects a particle.

16. A hydraulic mineral separator as claimed in Claim 15 wherein said set period of time is from 0.1 to 10 seconds.

17. A hydraulic mineral separator as claimed in Claim 15 wherein said set period of time is from 1 to 3 seconds.

18. A hydraulic mineral separator as claimed in Claim 1 having a pre-established heavy particle collection rate, wherein said flow rate through said vertical tube is increased or decreased as necessary in order to achieve said collection rate.

19. A hydraulic mineral separator as claimed in Claim 1 which additionally comprises a high density particle level sensor at the bottom of, or below the bottom end of the vertical tube, and an outlet valve operatively connected to said high density particle level sensor, wherein said outlet valve is opened or closed in accordance with signals received from said high density particle level sensor.

20. A hydraulic mineral separator as claimed in Claim 1 additionally comprising:
(i) water inlets near the surface of the particle sensor(s) in order to maintain a clean surface near the face of each sensor;
(ii) a water inlet valve near the top end of the vertical tube in order to ensure that the top end of the vertical tube is not blocked by a large inflow of particles added to the mixer;

(iii) a stirring motor connected to a stirrer located in a particle mixer at the top of said tube, in order to keep particles in the particle mixer in a free-flowing, non-agglomerated state;

(iv) a controller connected to the stirring motor which controller adjusts the rate of particle addition to the particle mixer based on changes in the power requirement of the particle mixer, thus ensuring that the number of particles in the particle mixer is essentially constant; or

(v) a mixing device within the vertical tube area.

21. A hydraulic mineral separator as claimed in Claim 20 wherein said mixing device within the vertical tube area is an ultrasonic mixer.

22. A process for the separation of higher density materials from lower density materials in a material sample comprising treating said sample in a hydraulic mineral separator as claimed in any one Claims 1 to 21.

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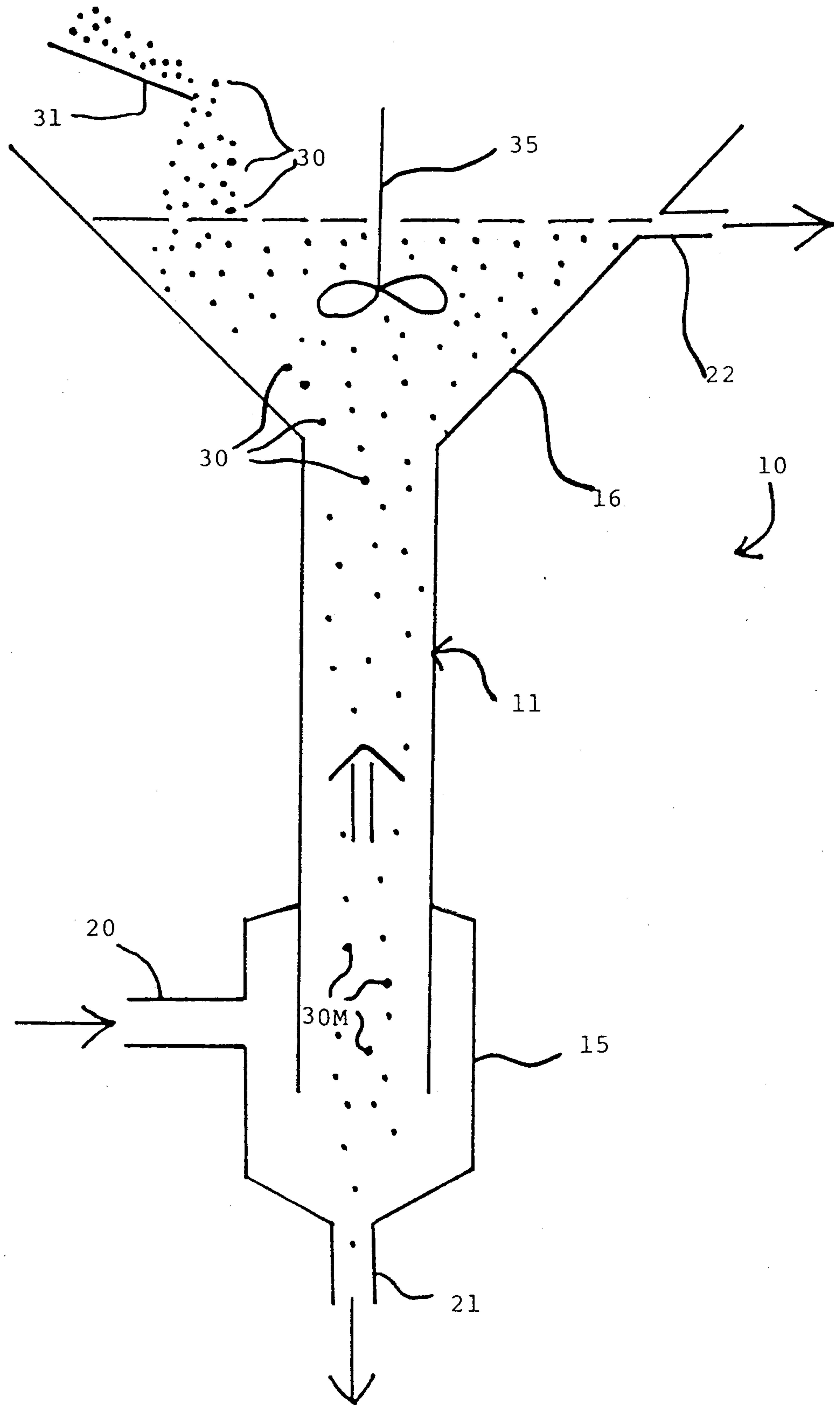


FIGURE 1 (prior art)

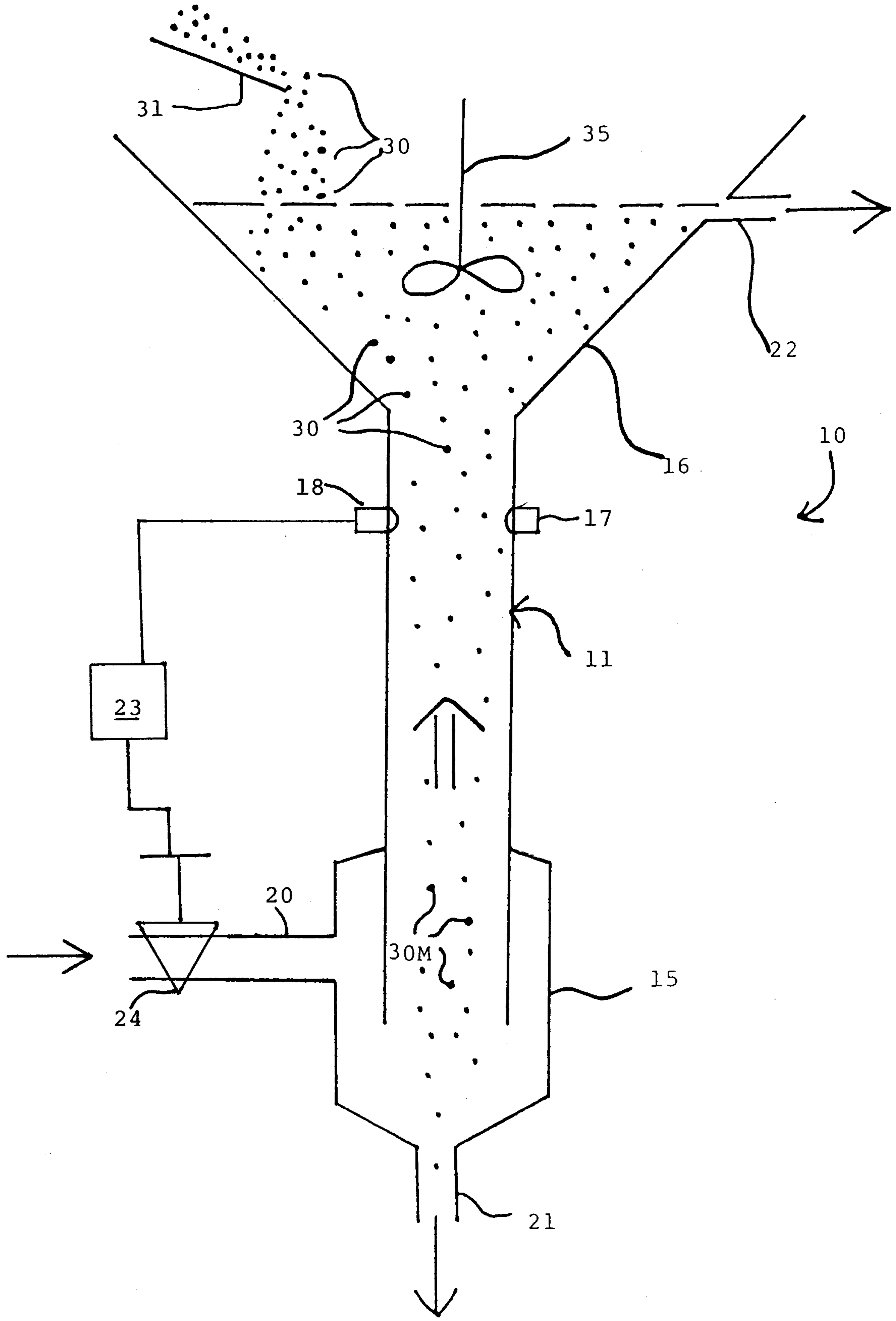


FIGURE 2

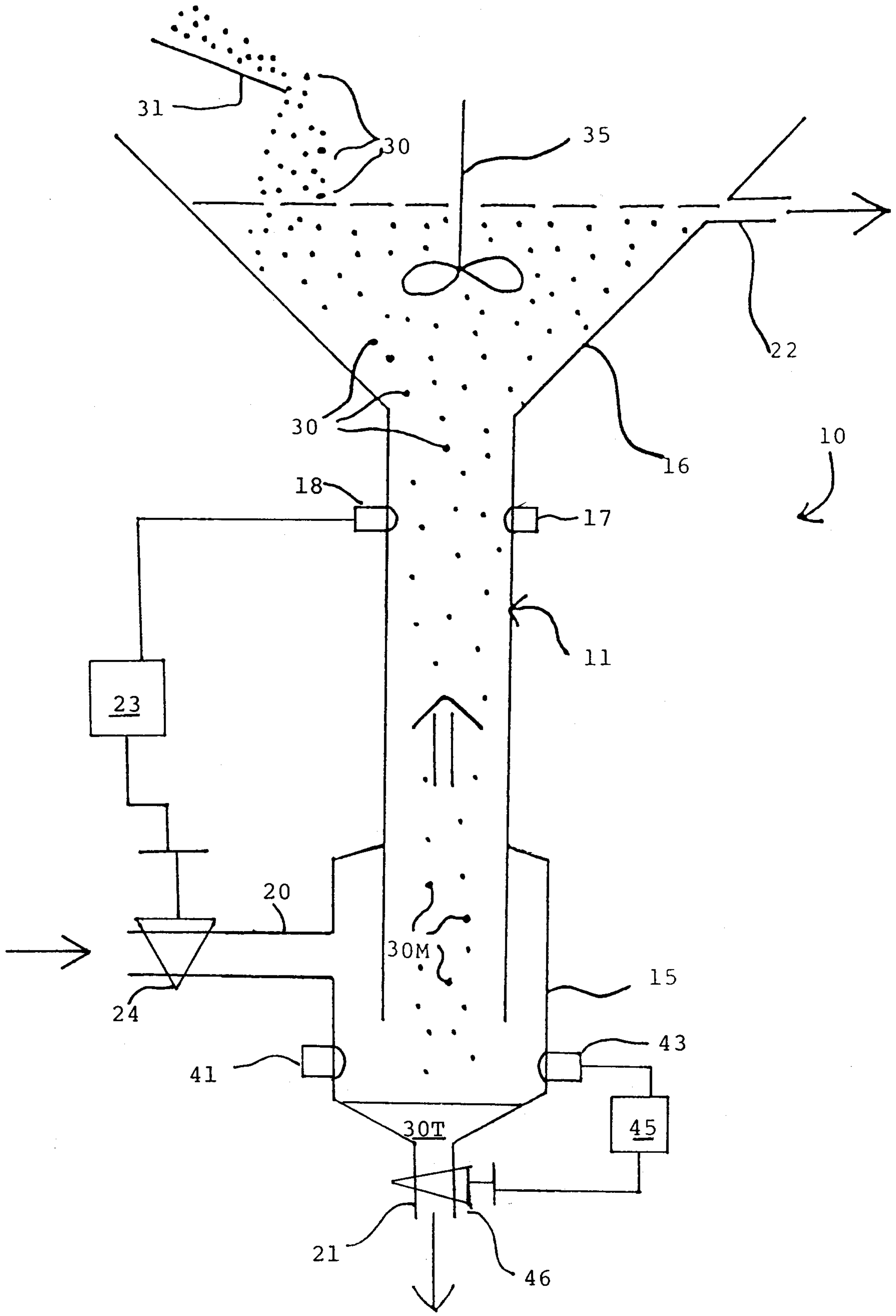


FIGURE 3

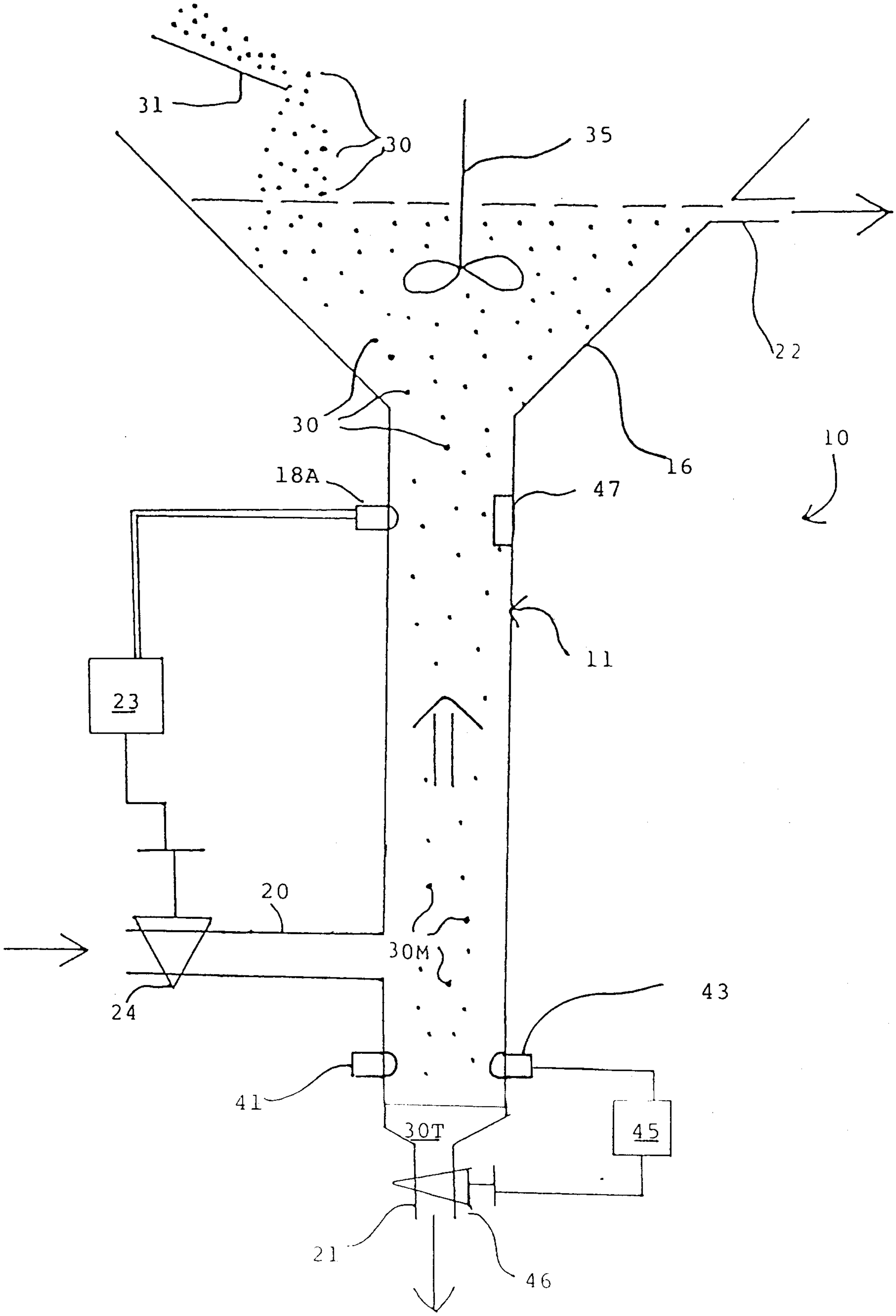
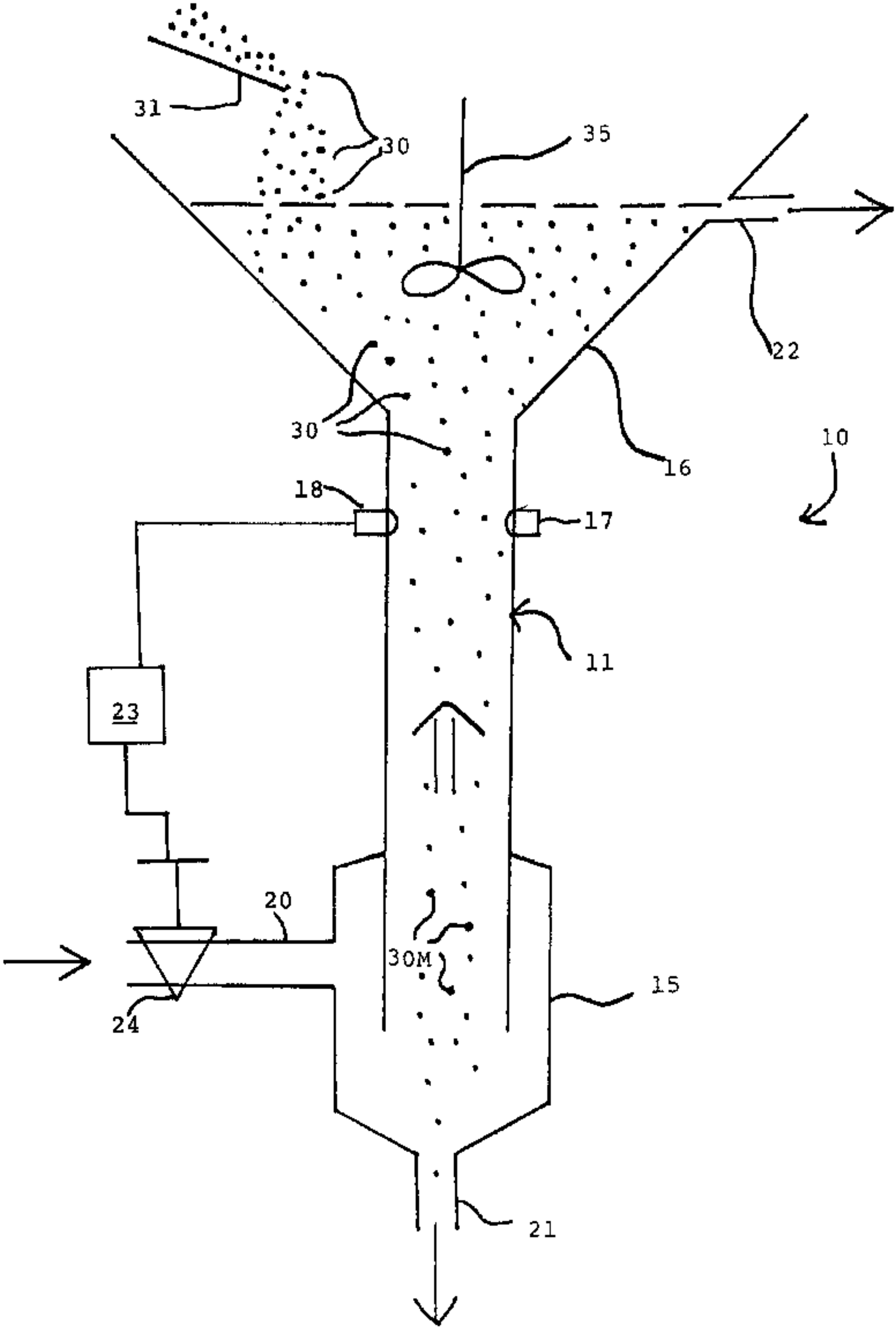


FIGURE 4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