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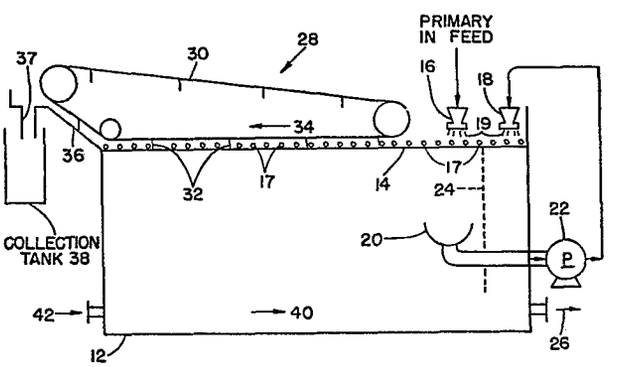
(54) Apparatus and method for froth flotation separation.

(57) A method and apparatus for froth flotation separation of the components of a slurry, having particular utility for the beneficiation of coal by the flotation separation of coal particles from impurities associated therewith such as ash and sulfur. A spray nozzle (16) is positioned above a flotation tank (12) having a liquid bath therein, and sprays an input slurry throuph an aeration zone (19) into the surface (14) of the liquid. The spraying operation creates a froth (17) on the liquid surface (14) in which a substantial quantity of particulate matter is floating, while other components of the slurry sink into the liquid. A skimming arrangement (28) preferably skims the froth (17) from the surface (14) as a cleaned or beneficiated product. Moreover, a reycling operation may be provided wherein particulate materials which do not float after being sprayed through the input spray nozzle (18) to provide a second opportunity for recovery of the recycled particles.



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Apparatus and Method for Froth Flotation Separation

The present invention relates to apparatus for use in froth flotation separation of components of a slurry having particulate matter therein, the apparatus comprising a flotation tank for containing a liquid and means for creating a froth phase on the surface of said liquid, and further relates to a method for froth flotation separation of components of a slurry having particulate matter therein, in which method then is created a froth phase in which a quantity of particulate matter is floating on a liquid surface and the froth is removed from the surface.

The described method and apparatus may be usefully applied for beneficiating coal, ground coal particles being separated from impurities associated therewith such as ash and sulfur.

Coal is an extremely valuable natural resource in the United States, as well as the remainder of the world, because of its relative abundance. It has been estimated that the United States alone has more energy available in the form of coal than in the combined natural resources of petroleum, natural gas, oil shale, and tar sands. Recent energy shortages, together with the availability of abundant coal reserves and the continuing uncertainties regarding the availability of crude oil, have made it imperative that methods for converting coal into a more useful energy source be developed.

Known prior art processes for froth flotation separation of a slurry of particulate matter are based on constructions wherein air is introduced into the liquid slurry of the particulate matter as, e.g. through a porous cell bottom or a hollow impeller shaft, thereby producing a

surface froth. These prior art methods are relatively inefficient approaches especially when large concentrations of particulate matter are being processed.

Generally, these techniques are inefficient in providing sufficient contact area between the particulate matter and frothing air. As a result large amounts of energy can be expended in frothing. In addition, froth flotation techniques which permit bubbles to rise in the slurry can tend to trap and carry impurities, such as ash in the froth slurry, and accordingly the resultant beneficiated particulate product can have more impurities therein than necessary.

Methods have been suggested and are being explored in the beneficiation of coal, i.e., the cleaning of coal of impurities such as ash and sulfur, either prior to burning the coal or after its combustion. In one recently developed technique for beneficiation, termed herein chemical surface treating, raw coal is pulverized to a fine mesh size and is then chemically treated. According to this technique the treated coal is then separated from ash and sulfur, and a beneficiated or cleaned coal product is recovered therefrom.

In further detail, in the heretofore mentioned chemical surface treating process coal is first cleaned of rock and the like, and is then pulverized to a fine size of about 48 to 300 mesh. The extended surfaces of the ground coal particles are then rendered hydrophobic and oleophilic by a polymerization reaction. The sulfur and mineral ash impurities present in the coal remain hydrophilic and are separated from the treated coal product in a water washing step. This step utilizes oil and water separation techniques, and the coal particles made hydrophobic can float in recovery on a water phase

which contains hydrophilic impurities.

An object of the invention is to provide a method and apparatus for use in forth flotation separation of components of a slurry having particulate matter therein which method and apparatus are relatively efficient.

The apparatus according to the invention is characterized in that said means for creating a froth phase comprises at least one input spray nozzle positioned to spray input slurry containing particulate matter through an aeration zone into the surface of said liquid to create said froth in which floats a quantity of said particulate matter.

The method according to the invention is characterized in that the froth is created by spraying an input slurry having particulate matter therein from at least one input spray nozzle through an aeration zone into the liquid surface.

The apparatus may further comprise: a collector means positioned in said tank below said at least one input spray nozzle for collecting sinking materials; and at least one recycle spray nozzle positioned above said surface for spraying through an aeration zone into the surface the materials collected by said collector means.

The or each spray nozzle may, in use of the apparatus, be spaced from said surface of liquid in said tank.

Expediently, at least one of said spray nozzles includes a hollow jet member spraying a hollow cone pattern into the liquid surface of the tank.

Preferably, the apparatus includes means for supplying

said at least one input spray nozzle with slurry in a pressure range of from 5 to 40 psi.

Preferably, the apparatus further includes a skimmer means, adapted to operate along the top of said tank, for skimming froth from the liquid surface.

Means may be provided for removing materials settling towards the bottom of the tank.

The method may include the further steps of: collecting sinking materials from the spray of the or each input spray nozzle; and utilizing at least one recycle spray nozzle to respray through an aeration zone into the liquid surface the collected materials, whereby particulate matter therein is recycled and a portion of the recycled material floats as a froth on the liquid surface and is recovered therefrom.

In one embodiment, said step of utilizing a recycle spray nozzle is carried out in proximity to said step of utilizing an input spray nozzle, and further including the step of providing a vertical baffle plate in the liquid between the positions at which the steps of utilizing a recycle spray nozzle and utilizing an input spray nozzle are performed, to provide separation for the sinking materials from both steps.

As will be apparent, the spraying operation creates a froth on the surface of the liquid in which a quantity of the particulate matter is floating, such that the froth containing the particulate matter can be removed from the water surface as a separated product. Other components of the slurry and a minor quantity of particulater matter sind in the liquid bath.

Thus, in one embodiment of the present invention, a collector trough is positioned in the tank below the input spray nozzle(s) for collecting the sinking materials. The collected materials are then recycled to at least one recycle spray nozzle positioned above the tank which resprays them through an aeration zone into the liquid surface. Therefore, in this embodiment, the present invention operates in an efficient manner by providing a recycling operation wherein particles which do not float after being sprayed through a primary spray nozzle are recycled to a further spray nozzle to provide a second opportunity for recovery. In a further embodiment, the recycle spray nozzle(s) is positioned in proximity to the primary spray nozzle(s), and a vertical baffle plate is positioned in the tank between the primary and recycle nozzles to provide separation for materials sinking from the sprays of the respective nozzles.

In accordance with further embodiments of the present invention, the or each spray nozzle utilized herein is preferably a hollow jet cone nozzle defining an approximately 30° spray pattern. Further, the slurry is preferably supplied to the nozzle in a pressure range of from 5 to 40 psi, and more preferably in the range of from 15 to 20 psi. Also, the present invention has particular utility to a coal benefication operation for froth flotation separation of a slurry of coal particles and associated impurities.

The present invention can operate in a manner which is more efficient than prior art arrangements because of the manner of froth generation in which the slurry is sprayed through an aeration zone. Moreover, further efficiency is preferably provided by more effective cleaning of particulate matter such as coal and higher product recoveries by providing that those particles

which do not initially float are resprayed into the water surface to promote and provide a high probability of secondary recovery of the product from waste materials.

In accordance with further details of another embodiment of the present invention, a skimmer arrangement having a plurality of spaced skimmer plates depending from a conveyer is arranged along the top of the tank to skim the resultant froth therefrom. An upwardly inclined surface extends from the water surface in the tank to a collection tank arranged at one side of the flotation tank, and the skimmer plates skim the froth from the water surface up the inclined surface and into the collection tank. Moreover, in one embodiment, the input and recycle spray nozzles are inclined from the vertical in the direction in which the skimmer arrangement operates to direct the flow of froth in that direction along the water surface. Settling impurities can be removed from the flotation tank by a circulating arrangement operating near the bottom of the collection tank to remove both water and settling impurities.

The present invention will be more readily understood by one skilled in the art with reference to the following detailed description of several preferred embodiments thereof, taken in conjunction with the accompanying drawings wherein like elements are designated by identical reference numerals throughout the several drawings, and in which

Figure 1 is an elevational view of a schematic exemplary embodiment of a flotation arrangement constructed according to the present invention;

Figure 2 illustrates an elevational view of another

flotation tank utilizing the invention;

Figure 3 is a partially sectional elevational view of one type of spray nozzle which can be utilized in the embodiments of Figures 1, 2 and 4; and

Figure 4 illustrates an elevational view of a more detailed embodiment of a flotation tank constructed according to the invention.

The apparatus and method of the present invention are adapted to the separation of a wide variety of solid-fluid streams by the creation of a solids-containing froth phase, and are suitable for the separation of many types of particulate matter. U.S. Patent No. 4,304,573 may be referred to for further details on the chemical processes which are particularly useful in conjunction with the subject invention.

The present invention is described herein with reference to a coal beneficiating operation as disclosed, for example, in detail in the aforementioned U.S.Patent. Thus, referring to the drawings herein in greater detail, Fig. 1 illustrates a first embodiment 10 having a flotation tank 12 filled with water to level 14. In operation, a slurry of finely ground coal particles, associated impurities, and if desired additional additives, such as monomeric chemical initiators, chemical catalysts and fluid hydrocarbons is sprayed through at least one primary spray nozzle 16 positioned at a spaced apart distance above the water level in tank 12. In alternative embodiments, two or more nozzles can be used to spray slurry and/or any other desired ingredients into the tank.

The stream of treated coal is pumped under pressure through a manifold to the spray nozzle 16 wherein the resultant shearing forces spray the coal flocculent slurry as fine droplets such that they are forcefully jetting into the mass of a continuous water bath in tank 12 to form a froth 17. High shearing forces are created in nozzle 16, and the dispersed particles forcefully enter the surface of the water and break up the coal-oil-water flocs thereby water-wetting and releasing ash from the interstices between the coal flocs and breaking up the coal flocs so that exposed ash surfaces introduced into the water are separated from the floating coal particles and sink into the water bath. The surfaces of the finely divided coal particles now contain air sorbed in the atomized particles, much of which is entrapped by spraying the slurry through an aeration zone 19 such that air is sorbed in the sprayed slurry. The combinded effects on the treated coal cause the flocculated coal to decrease in apparent density and to float as a froth 17 on the surface of the water bath. The hydrophilic ash remains in the bulk water phase, and tends to settle downwardly in tank 12 under the influence of gravity. Tank 12 in Fig. 1, 2 and 4 may be a conventional froth flotation tank commercially available from KOM-LINE-Sanderson Engineering Co., Peapack, N.Y. modified as set forth below. The flotation tank can also include standard equipment which is not illustrated in the drawings such as a liquid level sensor and control system and a temperature sensing and control system.

The apparatus operates on a froth generation principle in which the slurry is sprayed through an aeration zone such that substantial quantities of air are sorbed by the sprayed fine droplets of the slurry. Accordingly, air is introduced into the slurry to generate the resultant froth. The advantages of this manner of froth

generation make the apparatus and method herein particularly applicable to froth flotation separation of slurries which have a substantial proportion of particulate matter therein.

The coal particles in the floating froth 17 created by nozzle 16 can be removed from the water surface by, e.g., a skimming arrangement 28 in which an endless conveyor belt 30 carries a plurality of spaced skimmer plates 32 depending therefrom. The skimmer plates are pivotally attached to the conveyor belt to pivot in two directions relative to the belt, and the bottom run of the belt is positioned above and parallel to the water surface in the tank. The plates 32 skim the resultant froth on the water surface in a first direction 34 toward a surface 36, preferably upwardly inclined, extending from the water surface to a collection tank 38 arranged at one side of the flotation tank, such that the skimmer plates 32 skim the froth from the water surface up the surface 36 and into the collection tank 38.

In the arrangement of the disclosed embodiment, the waste disposal at the bottom of the tank operates in a direction 40 flowing from an influent stream 42 to the effluent stream 26, while the skimmer arrangement at the top of the tank operates in direction 34, counter to that of the waste disposal arrangement. Although the illustrated embodiment shows a counterflow arrangement, alternative embodiments are contemplated within the scope of the present invention having, e.g., cross and concurrent flows therein.

Fig. 3 is a partially sectional view of one type of commercially available spray nozzle 64 which may be used in conjuntion with the systems shown in Fig. 1, 2 and 4. A recessed threaded coupling 66 is provided to attach

the nozzle to a primary or recycle manifold supplying the nozzle with slurry under pressure. The slurry encounters a frustoconical venturi section 68 which accelerates the flow velocity thereof according to the well known venturi effect. The slurry then flows through the nozzle aperture having a nominal diameter 70, which in combination with a diverging section 72 defines a hollow cone spray pattern 74 having an encompassing spray angle 76. In one preferred embodiment of the present invention, angle 76 is approximately thirty degrees, although other angles which provide the herein contemplated results are included within the scope of this invention.

Spray nozzle 64 may be a hollow jet nozzle as is commercially available from Spraying Systems Co., Wheaton, Illinois. Of course, it is contemplated herein that other types of nozzles, which function to provide the desired results as hereinbefore described, may also be used. The nozzles are preferably constructed of stainless steel, ceramic or other suitable hard metal to avoid erosion by the various particles in the slurry being pumped therethrough. The nozzles are preferably supplied with slurry in the supply manifolds at a pressure in the range of 5 to 40 psi, and more preferably in a pressure range of 15 to 20 psi.

Each nozzle 16 may bei tilted at an angle θ with respect to a vertical, (i.e., the position of the nozzle relative to the liquid surface level), as shown in Fig. 4, such that it functions to direct the flow of froth in a direction towards the skimmer arrangement 28. However, the angle of incidence θ does not appear to be critical, and the vertical positioning shown in Fig. 1 may be preferred to create a condition most conducive to agitation and froth generation at the water surface. It appears to be

significant that the agitation created by the nozzle sprays define a zone of turbulence extending a limited distance beneath the water surface level. Too much turbulence may actually reduce the amount of frothing produced at the water surface. Among other means, the depth of the turbulence zone may be adjusted by varying the supply pressure of the slurry in the supply manifolds and also the distance of the nozzles above the water surface. In one operative embodiment, a zone of turbulence extending two to four inches beneath the water surface produces very good agitation and froth generation, although the distance is dependent on many variables such as the tank size, the medium in the tank, etc. and accordingly may vary considerably in other embodiments.

In one embodiment as shown in Fig. 2, a recycling technique is employed to further improve the efficency relative to prior art arrangements. In the recycling technique, coal particles which do not float after being sprayed through a spray nozzle 16, designated a primary spray nozzle in context with this embodiment, are recycled to a further recycle spray nozzle 18 to provide the coal particles with a second opportunity for recovery. In this arrangement a collector trough 20, preferably in the form of an open hemispherical pipe, is positioned in tank 12 beneath the primary spray nozzle(s) 16 for collecting the sinking materials. A pump 22 is coupled to trough 20 and functions to draw settling materials into the trough from which it is pumped under pressure to the recycle spray nozzle(s). At least one recycle spray nozzle 18, which may be the same type of nozzle as primary spray nozzle 16, is provided above the tank for respraying into the surface of the water bath the materials collected by the trough such that coal particles collected therein are recycled and a portion of the recycled coal floats as a froth on the water surface

an additional time and is recovered. The recycled spray nozzle(s) 18 is positioned in proximity to the primary spray nozzle(s) 16, and a vertical baffle plate 24 is positioned in the tank 12 between primary and recycle nozzles to provide separation for materials sinking from the sprays of the respective nozzles. In alternative embodiments, further stages of recycling may be provided by adding additional troughs and recycle nozzles in the tank.Thus there may be provided an additional collector means positioned in said tank below said at least one recycle spray nozzle 19 for collecting the sinking materials from its spray, and a further recycle spray nozzle positioned above said tank for spraying through an aeration zone into the liquid surface the materials collected by said additional collector means, whereby two or more stages of recycling are provided.

This arrangement results in an efficient operation, providing more effective cleaning of the coal and higher product recoveries by providing that coal particles which do not initially float have a high probability of being resprayed onto the water surface to promote secondary recovery of the product from waste materials.

After the recycling operation, the materials which sink from the recycle spray tend to settle downwardly in tank 12 under the influence of gravity, and are withdrawn in an ash-water stream 26 from the base of the vessel.

Fig. 4 illustrates an elevational view of a more detailed illustration of another embodiment of a flotation arrangement 46 pursuant to the teachings herein. Tank 12 may be a conventional froth flotation tank commercially avalilable from KOM-LINE-Sanderson Engineering Col, Peapack, N.J. modified as set forth below. The base of the tank can be supported in a conventional manner by channel

and flanged structural members, as illustrated. The flotation tank can also include somewhat standard equipment which is not illustrated in the drawings such as a liquid level sensor and control system and a temperature sensing and control system.

The conveyor system in this embodiment includes a drive roller 48 at one end, driven by a chain or equivalent linkage from a skimmer drive 50 mounted on the tank. The other end of the conveyor is defined by an idler roller 52 which in combination with a second idler roller 54 defines a horizontal run for the conveyor along the top of the flotation tank. The conveyor belt in this design is defined by two strands of two inch, double pitch chain with each strand having ninety-six pitches. Twelve skimmer plates are carried by the two chains, with each plate being eight pitches apart on the two conveyor chains. The bottom run of the conveyor arrangement is positioned approximately ten inches above the water surface, and each plate depends downwardly from the conveyor chains approximately ten inches to the water surface. The skimmer plates carry the coal bearing froth up an inclined surface 36 to a chute 37 through which the froth is directed to a collection tank.

Trough 20 is in the form of an open hemispherical pipe positioned below the area at which the spray from the primary spray nozzle 16 impinges on the water, and is coupled by lengths of vertical and horizontal conduits 60 and 62 to pump 22, not shown in Fig. 4, which in turn supplies recycle manifold 58 with a slurry at a preferred feed pressure.

While several embodiments and variations of a method and apparatus for froth flotation separation of the components of a slurry have been described in detail

herein, it should be apparent that the teachings and disclosure of the present specification will suggest many other embodiments and variations to those skilled in this art.

Although the froth flotation system has been described in detail herein in the context of a coal beneficiating operation, it is apparent that the disclosure herein has direct applicability to other applications of froth flotation separation technology. For instance, the froth flotation separation techniques disclosed herein can be utilized in conjunction with particulate matter such as carbonaceous particles, noncarbonaceous particles, or mixture of both, mine tailings, oil shale, residuals, waste particulates, mineral dressings, graphite, mineral ores, fines, etc.

Claims:

1. Apparatus for use in froth flotation separation of components of a slurry having particulate matter therein, the apparatus comprising: a flotation tank (12) for containing a liquid; and means for creating a froth phase (17) on the surface (14) of said liquid, characterized in that said means for creating a froth phase (17) comprises at least one input spray nozzle (16) positioned to spray input slurry containing particulate matter through an aeration zone (19) into the surface (14) of said liquid to create said froth (17) in which floats a quantity of said particulate matter.

2. Apparatus as claimed in claim 1, further characterized by: a collector means (20) positioned in said tank (12) below said at least one input spray nozzle (16) for collecting sinking materials; and at least one recycle spray nozzle (18) positioned above said surface (14) for spraying through an aeration zone (19) into the surface (14), the materials collected by said collector means.

3. Apparatus as claimed in claim 1 or 2 wherein the or each spray nozzle (16, 18) is in use of the apparatus, spaced from said surface (14) of liquid in said tank (12).

4. Apparatus as claimed in any one of claims 1 to 3 wherein at least one of said spray nozzles includes a hollow jet member (64) spraying a hollow cone pattern (76) into the liquid surface (14) of the tank (12).

5. Apparatus as claimed in any one of the preceding claims including means for supplying said at least one input spray nozzle with slurry in a pressure range of grom 5 to 40 psi.

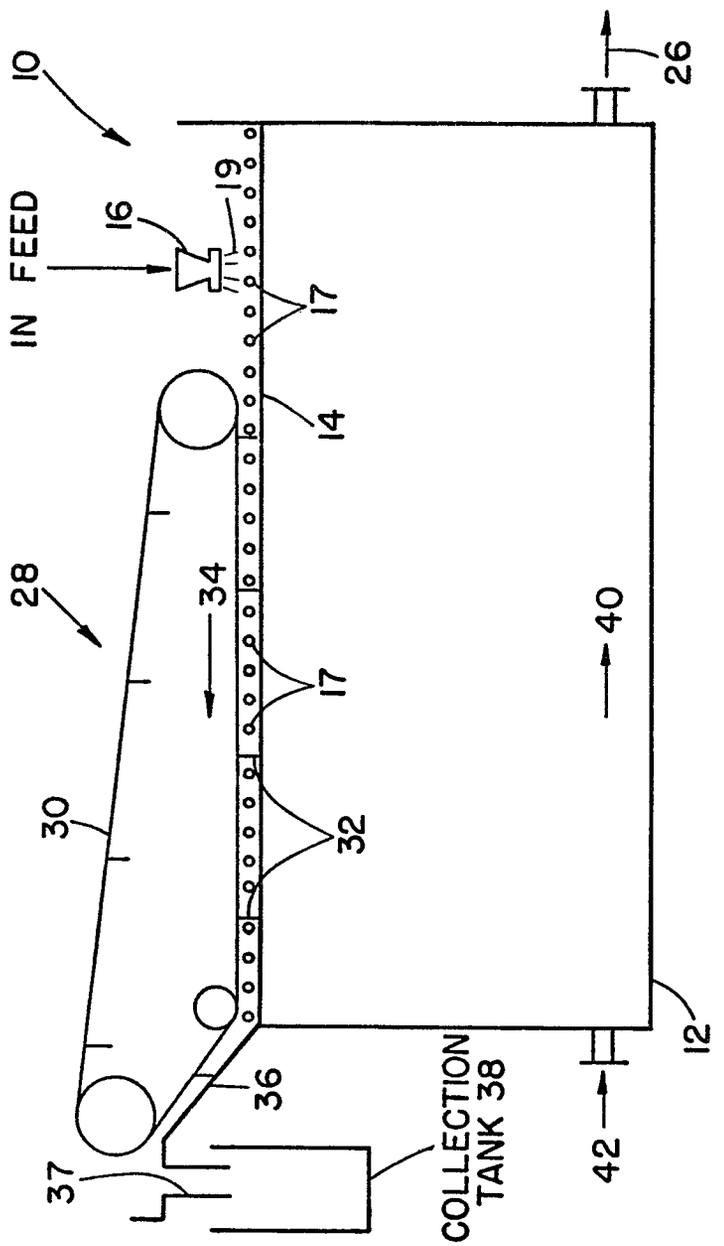
6. Apparatus as claimed in any one of the preceding claims further including a skimmer means (28), adapted to operate along the top of said tank,for skimming froth from the liquid surface (14).

7. Apparatus for froth flotation separation of the components of a slurry as claimed in claim 2, including means for removing materials settling towards the bottom of said tank.Thus there may be provided an additional collector means positioned in said tank below said at least one recycle spray nozzle (19) for collecting the sinking materials from its spray, and a further recycle spray nozzle positioned above said tank for spraying through an aeration zone into the liquid surface the materials collected by said additional collector means, whereby two or more stages of recycling are provided.

8. A method for froth flotation separation of components of a slurry having particulate matter therein, in which method: there is created a froth phase (17) in which a quantity of particulate matter is floating on a liquid surface (14); and the froth (17) is removed from the surface, characterized in that the froth (17) is created by spraying an input slurry having particulate matter therein from at least one input spray nozzle (16) through an aeration zone (19) into the liquid surface (14).

9. A method as claimed in claim 8 further characterized by the steps of: collecting sinking materials from the spray of the or each input spray nozzle (16); and utilizing at least one recycle spray nozzle (18) to respray through an aeration zone (19) into the liquid surface the collected materials, whereby particulate matter therein is recycled and a portion of the recycled material floats as a froth on the liquid surface and is recovered therefrom.

10. A method as claimed in claim 9 wherein said step of utilizing a recycle spray nozzle is carried out in proximity to said step of utilizing an input spray nozzle, and further including the step of providing a vertical baffle plate (24) in the liquid between the positions at which the steps of utilizing a recycle spray nozzle and utilizing an input spray nozzle are performed, to provide separation for the sinking materials from both steps.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IN FEED
16
19
17
14
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17
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12
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COLLECTION TANK 38
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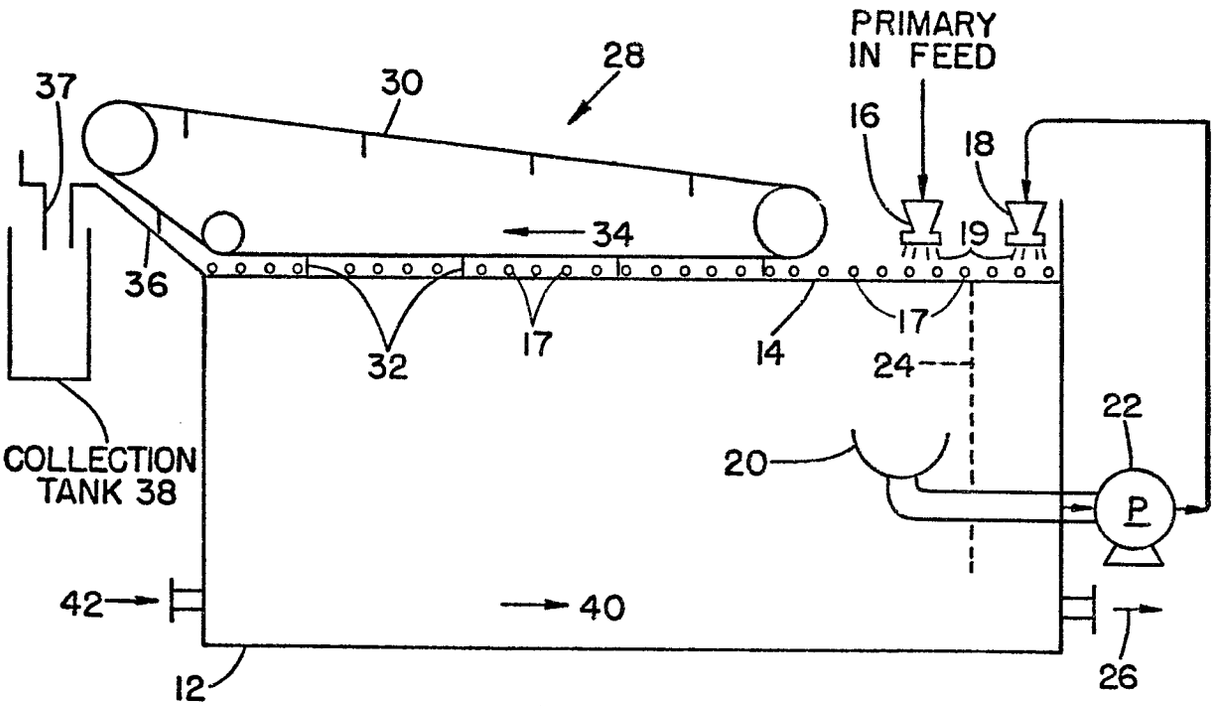
FIG. 1


PRIMARY
IN FEED
28
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16
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COLLECTION
TANK 38
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42
40
12
26

FIG. 2

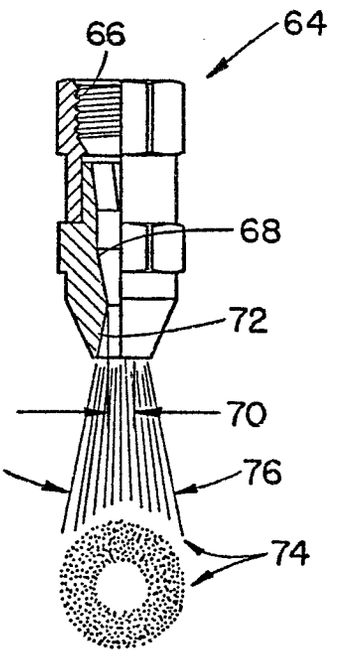
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FIG. 3

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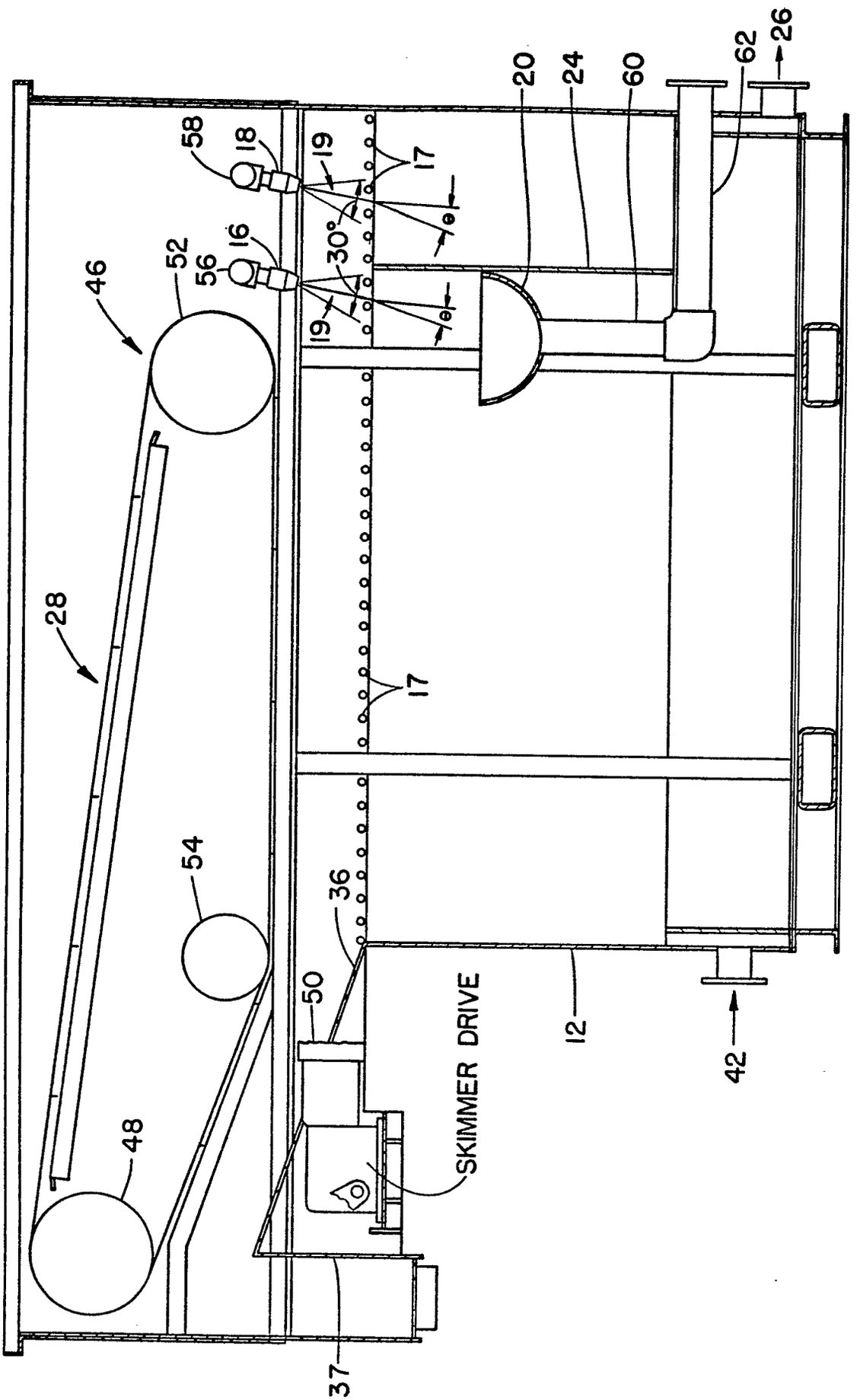

FIG. 4