US 20090139905A1

(19) United States

(12) Patent Application Publication

Kruyer

(10) Pub. No.: US 2009/0139905 A1

(43) Pub. Date: Jun. 4, 2009

(54) ENDLESS CABLE SYSTEM AND ASSOCIATED METHODS

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(21) Appl. No.: **11/948,816**

(22) Filed: **Nov. 30, 2007**

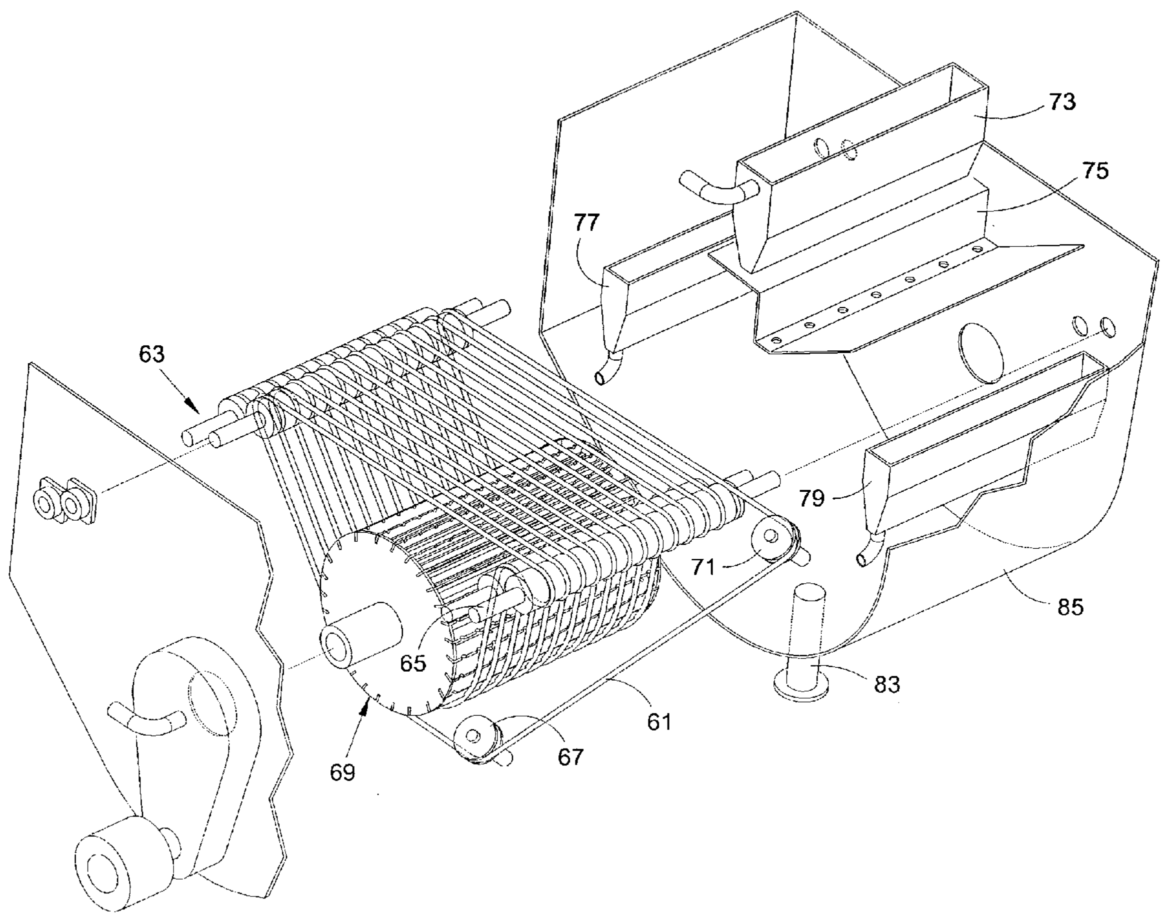
Publication Classification

(51) **Int. Cl.**
C10G 1/04 (2006.01)

(52) **U.S. Cl.** **208/390**

(57) **ABSTRACT**

A separation apparatus can include at least one endless cable. The cable can be wrapped around at least two revolvable cylindrical members a plurality of times. The wraps can form gaps between adjacent windings, which, along with the endless cable, can be used to facilitate separations processing. Additionally, the separation apparatus can optionally include a repositioning guide for each multiple wrap endless cable that can guide the endless cable in an endless route and prevent the cable from rolling off or falling off of the cylindrical members. Separation can be accomplished by oleophilic adherence to the cable, electrostatic adherence to the cable, and/or physical retention on the cable. This endless cable system can be particularly useful for separation of oil sand slurries, mass transfer operations, and physical separations.



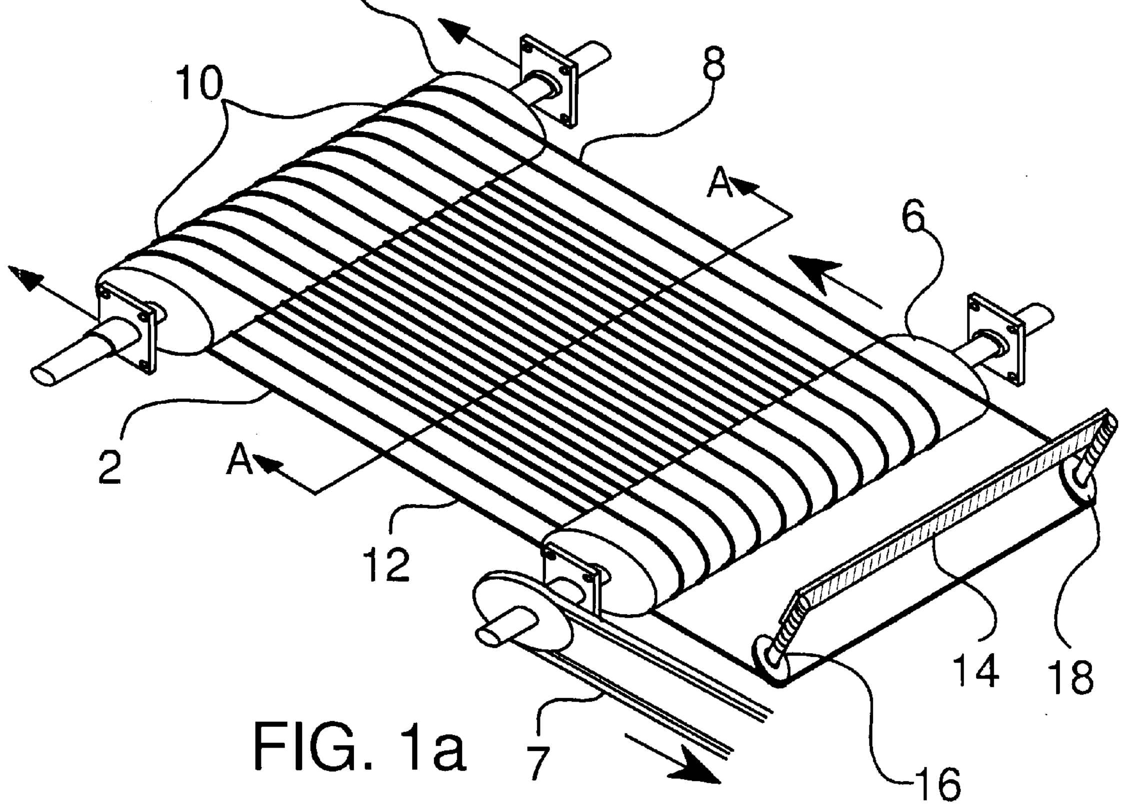


FIG. 1a

FIG. 1b


FIG. 1c


FIG. 1d


FIG. 1e

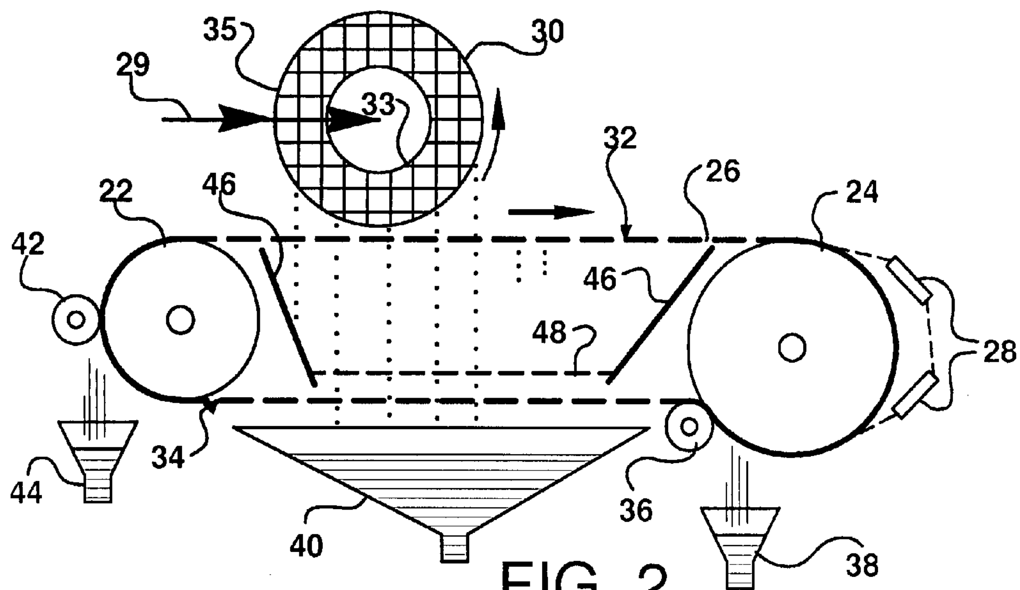


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FIG. 2

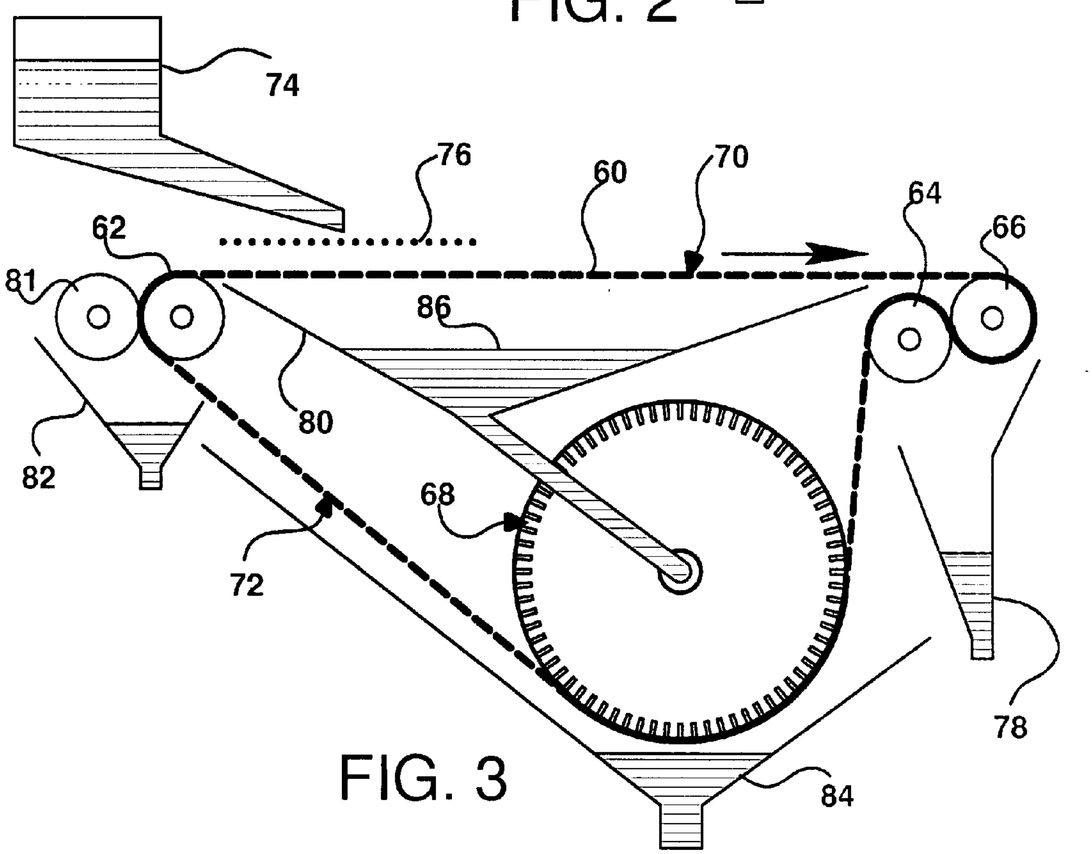
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FIG. 3

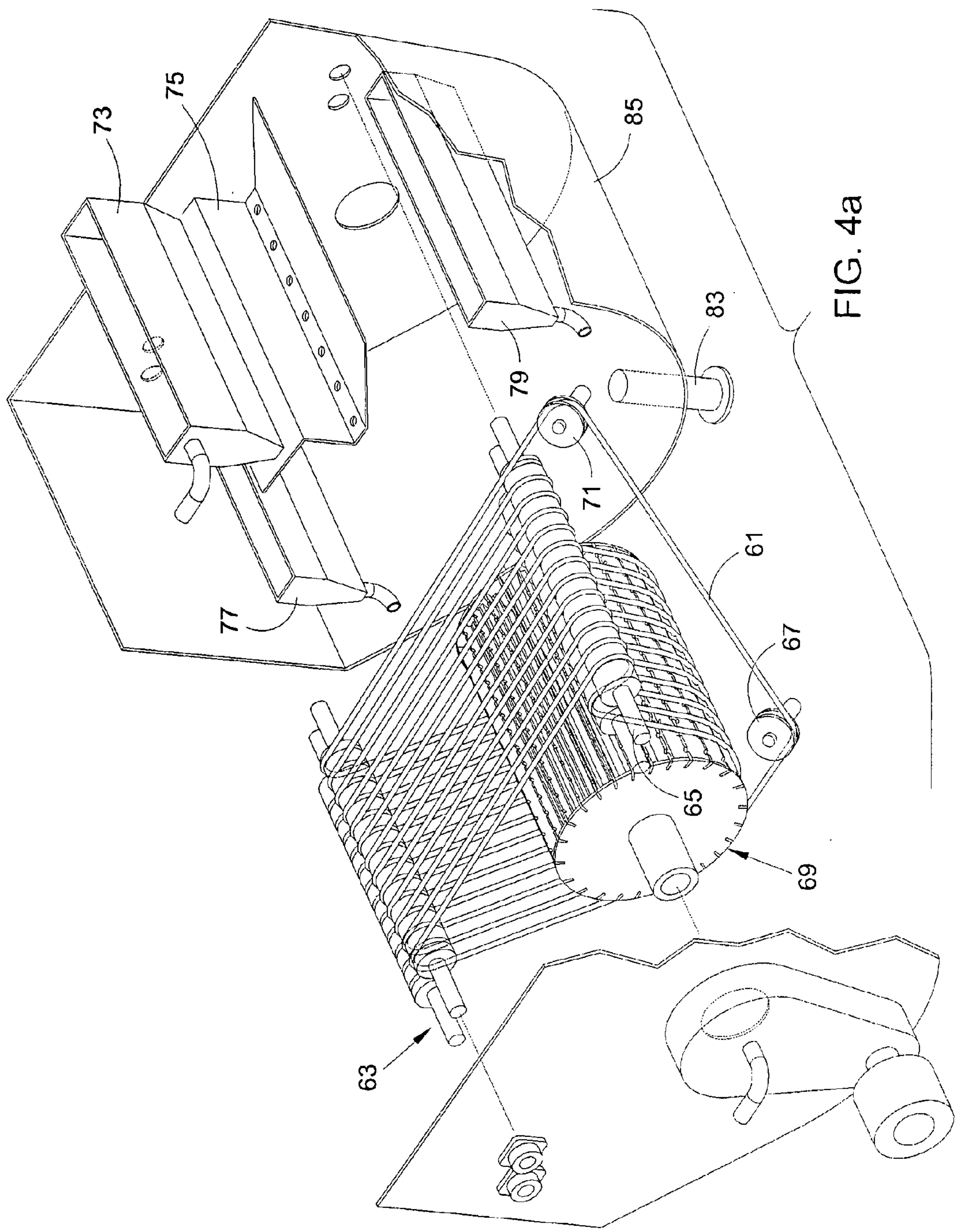


FIG. 4a

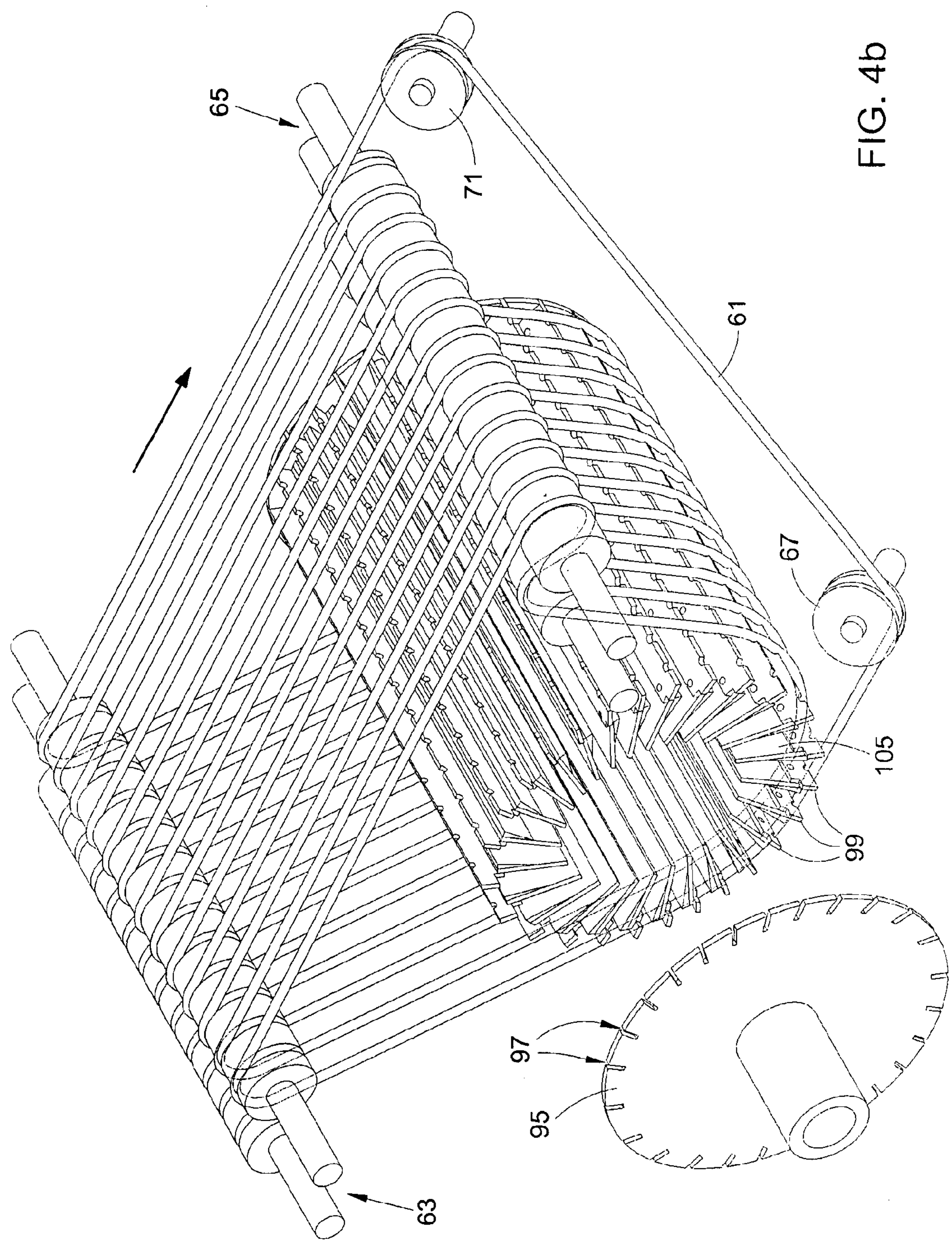


FIG. 4b

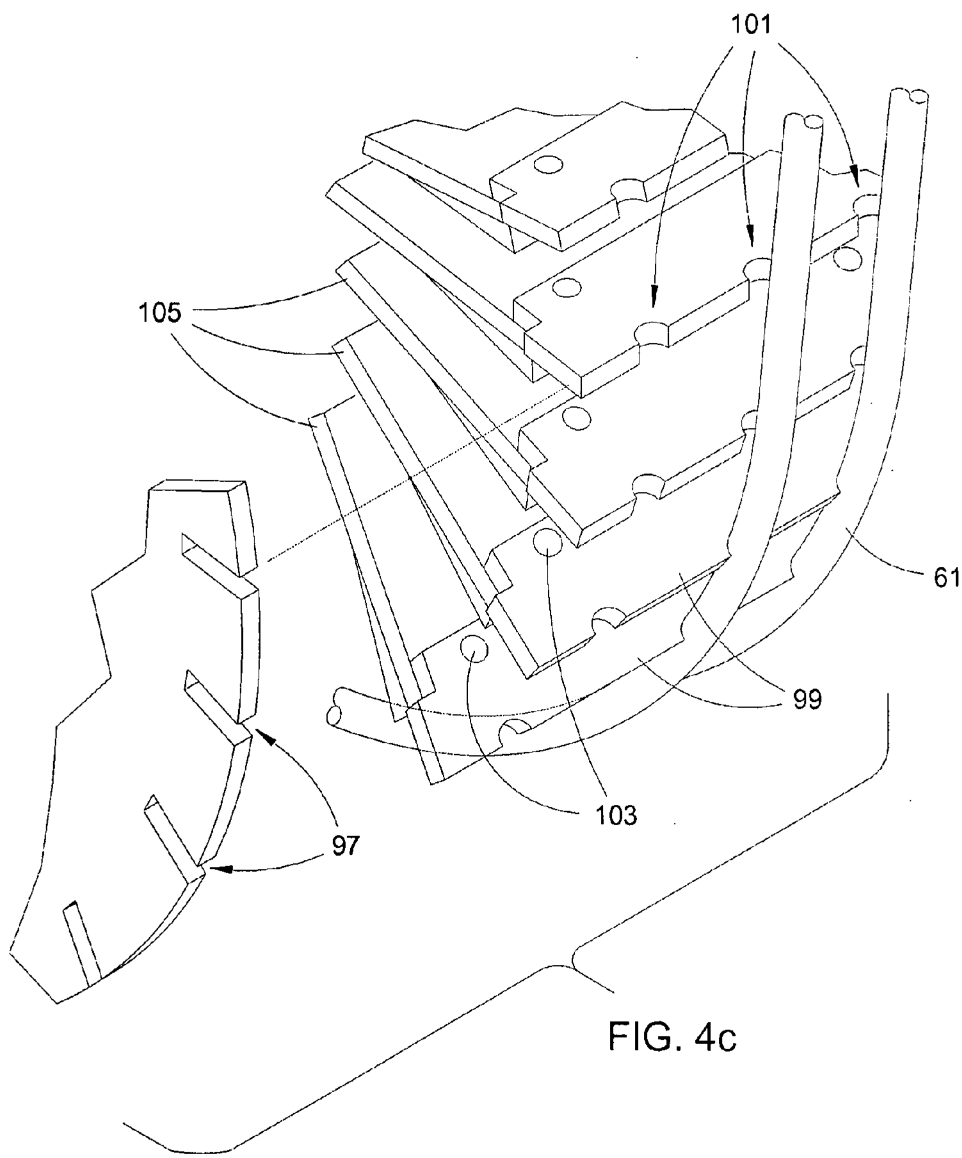


FIG. 4c

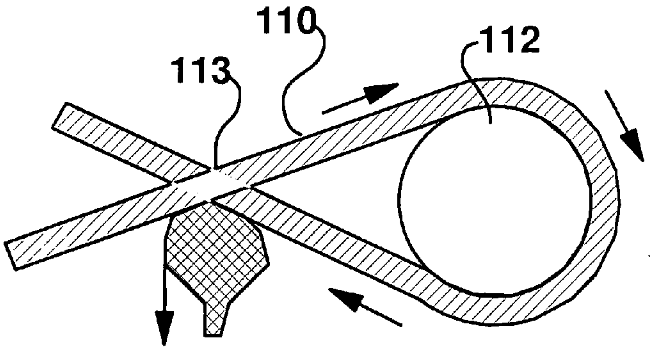


FIG. 5a

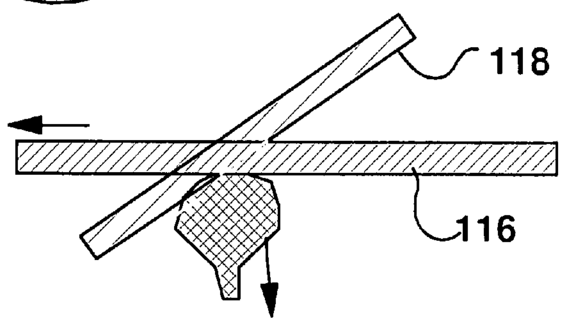


FIG. 5b

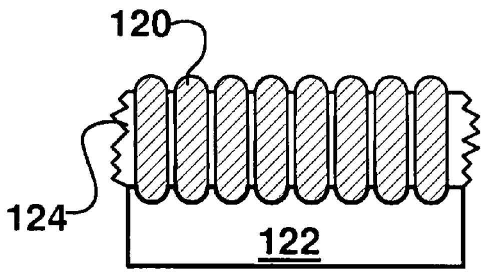


FIG. 5c

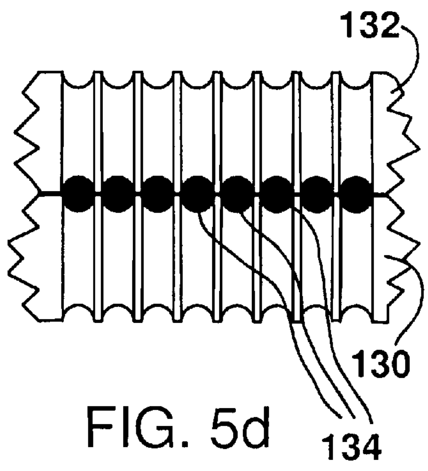


FIG. 5d

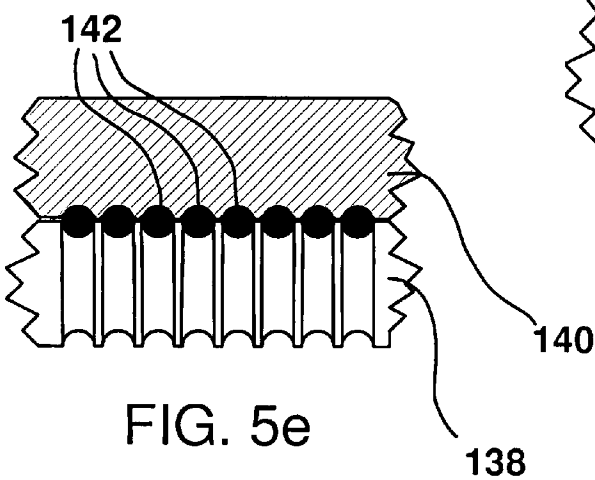
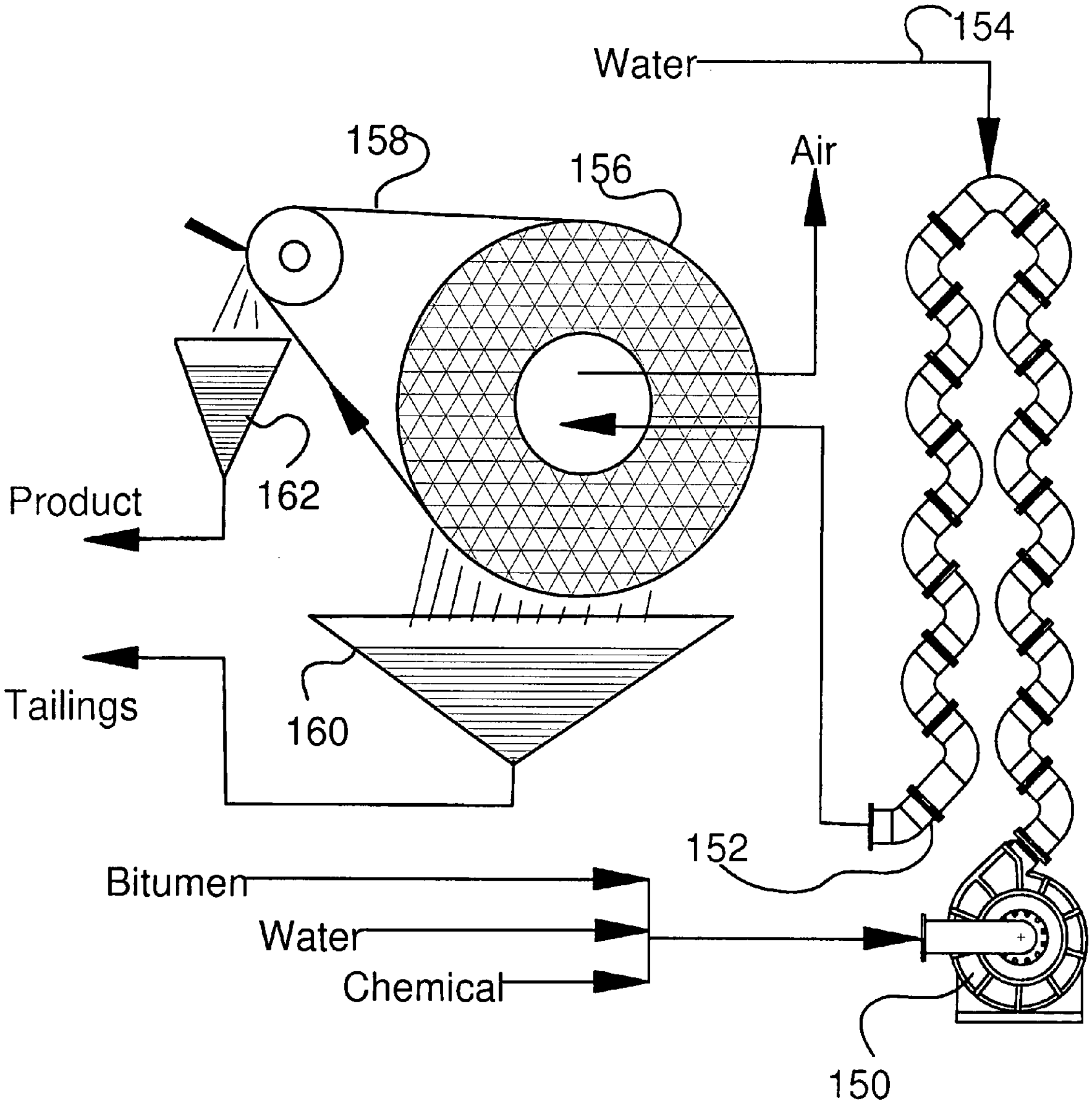


FIG. 5e


154
Water
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156
Air
162
Product
Tailings
160
152
Bitumen
Water
Chemical
150

FIG. 6

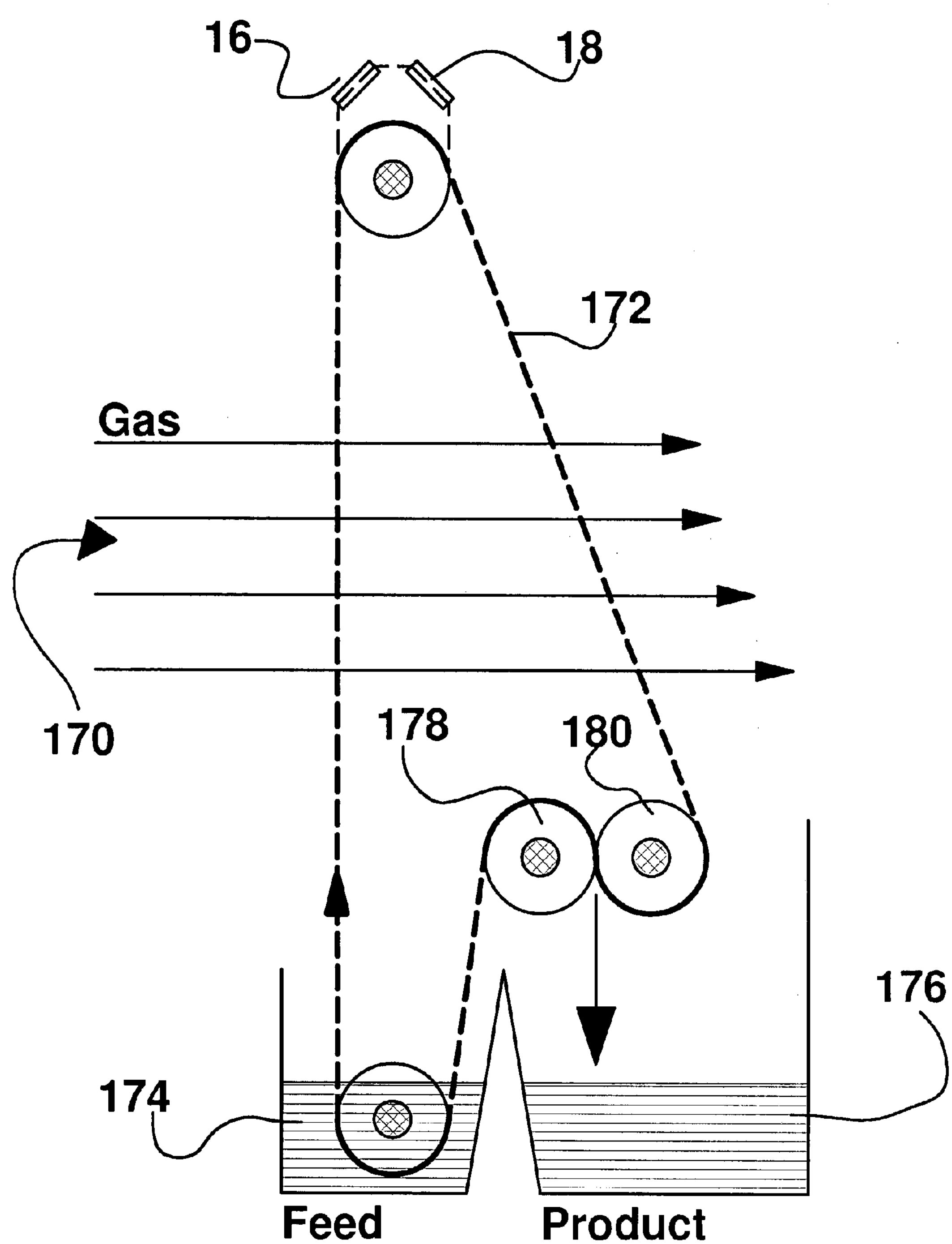
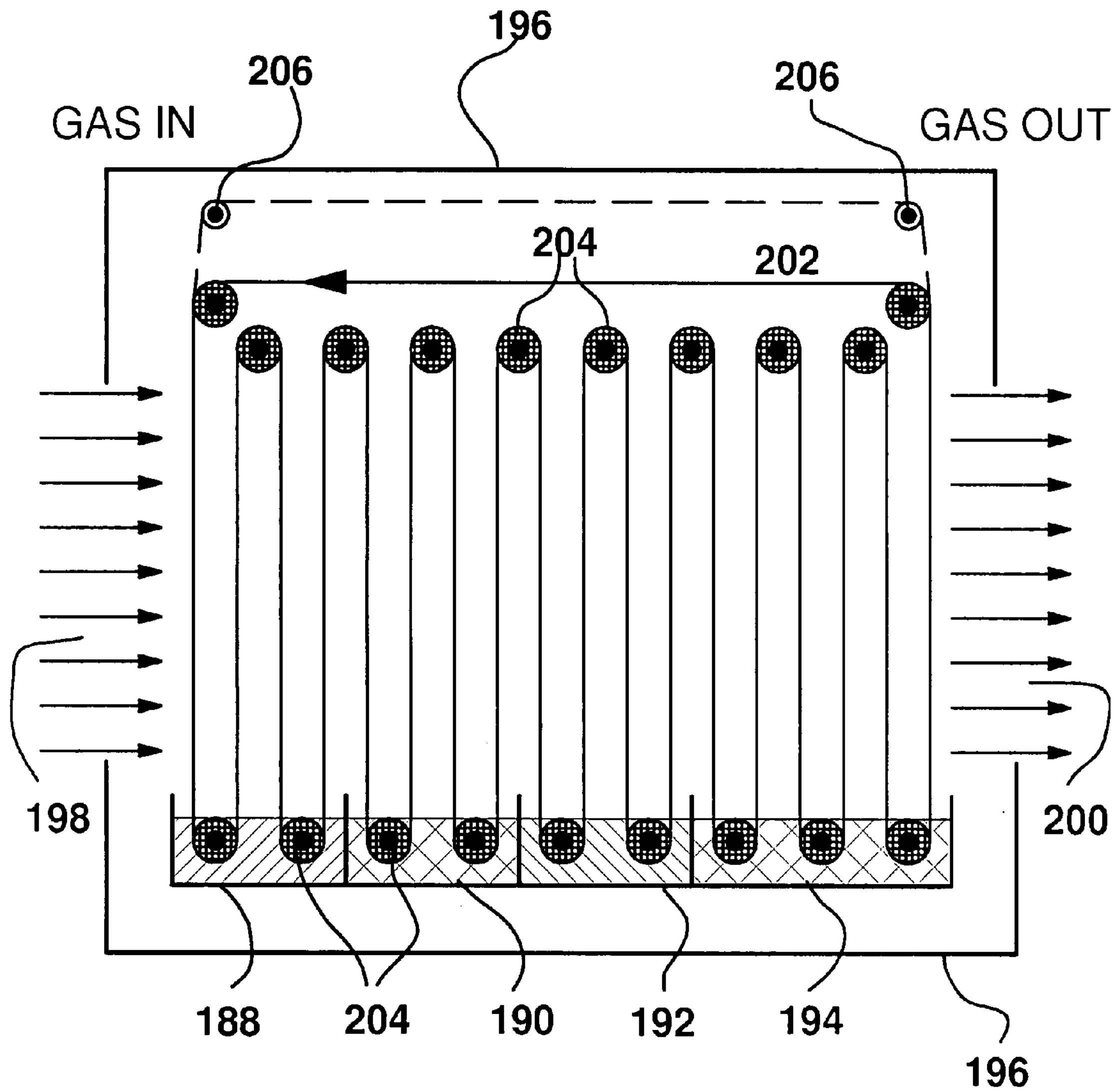


FIG. 7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GAS IN
GAS OUT
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FIG. 8

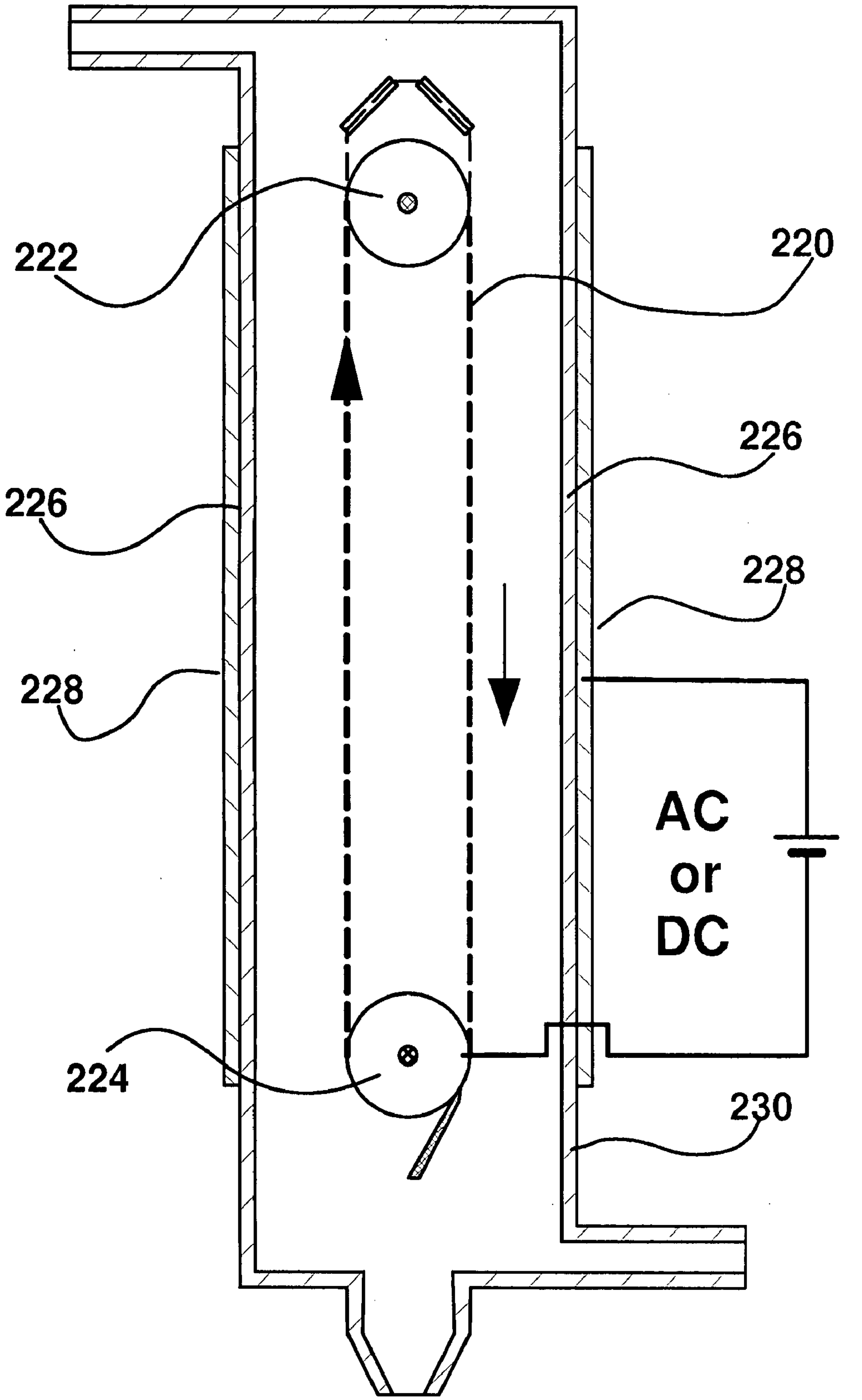

FIG. 9

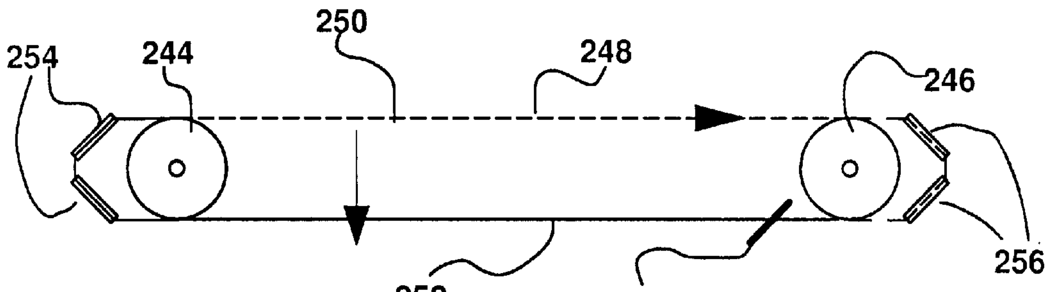

FIG. 10a

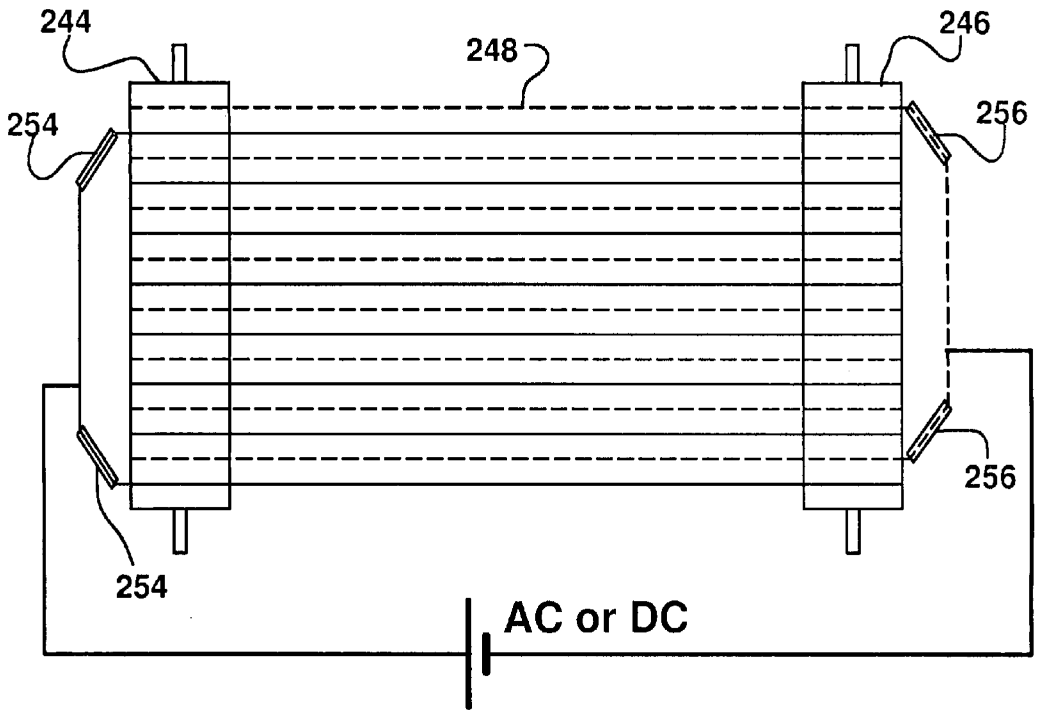

FIG. 10b

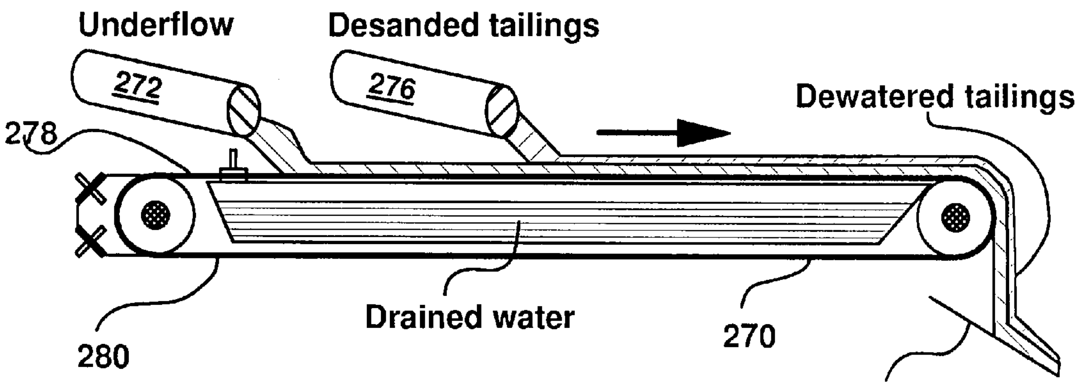

FIG. 11a

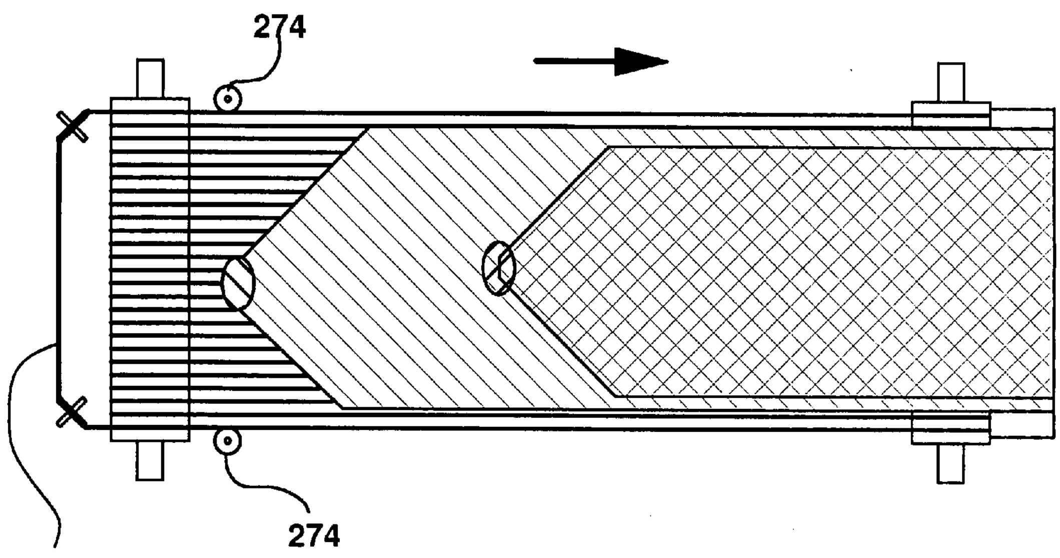

FIG. 11b

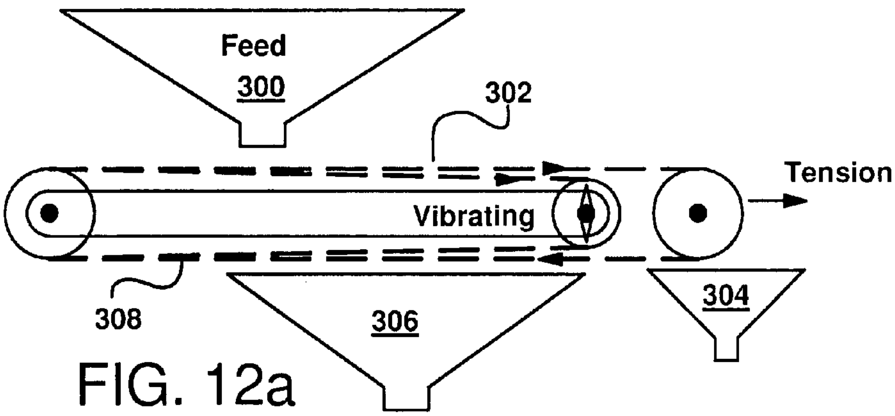

FIG. 12a

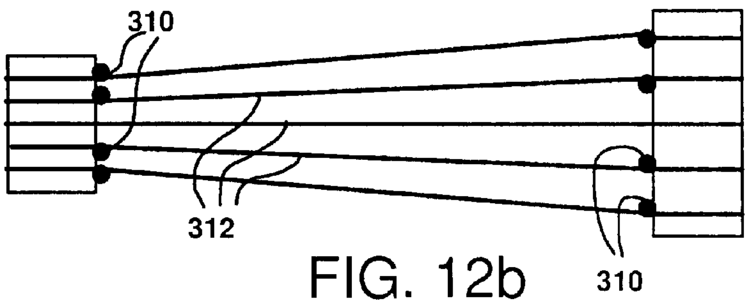

FIG. 12b

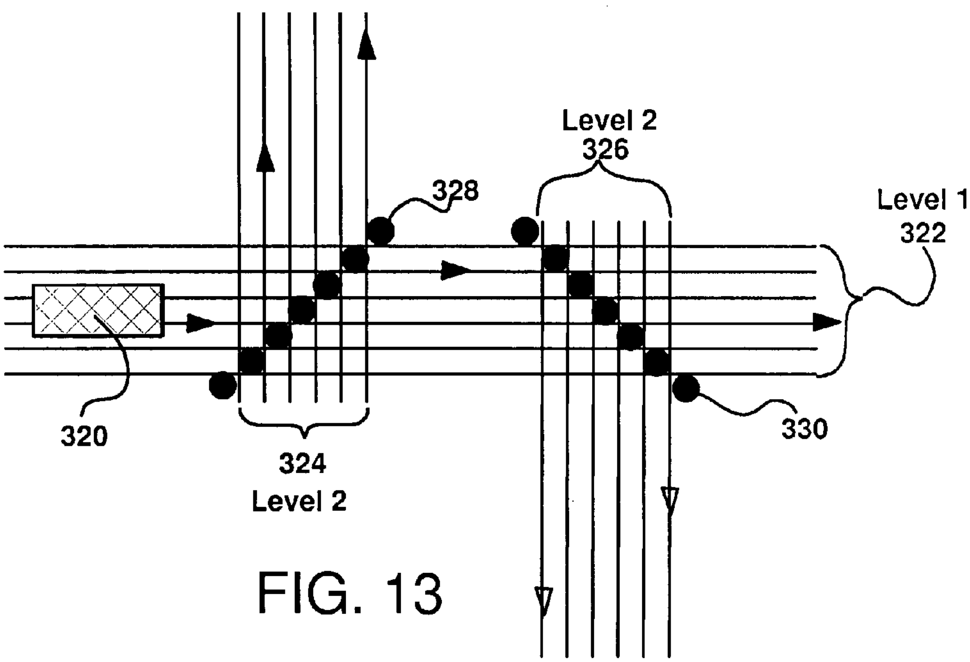

FIG. 13

ENDLESS CABLE SYSTEM AND ASSOCIATED METHODS

RELATED APPLICATIONS

[0001] This application is related to U.S. patent application Ser. Nos. 11/939,978 entitled "Sinusoidal Mixing and Shearing Apparatus and Associated Methods," filed Nov. 14, 2007 (hereinafter referred to as "Sinusoidal Mixing Application") and 11/940,099 entitled "Hydrocyclone and Associated Methods," filed Nov. 14, 2007 (hereinafter referred to as "Hydrocyclone Application"), and 11/unassigned entitled "Isoelectric Separation of Oil Sands" filed concurrently herewith (hereinafter referred to as "Isoelectric Application"), which are each incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to devices and methods for separating materials. Accordingly, the present invention involves the fields of materials science, chemistry, and chemical engineering.

BACKGROUND OF THE INVENTION

[0003] According to some estimates, oil sands, also known as tar sands or bituminous sands, may represent up to two-thirds of the world's petroleum. Oil sands resources are relatively untapped. Perhaps the largest reason for this is the difficulty of extracting bitumen from the sands. Mineable oil sand is found as an ore in the Fort McMurray region of Alberta, Canada, and elsewhere. This oil sand includes sand grains having viscous bitumen trapped between the grains. The bitumen can be liberated from the sand grains by slurrying the as-mined oil sand in water so that the bitumen flecks move into the aqueous phase for separation. For the past 40 years, bitumen in McMurray oil sand has been commercially recovered using the original Clark Hot Water Extraction process, along with a number of improvements. Karl Clark invented the original process at the University of Alberta and at the Alberta Research Council around 1930 and improved it for over 30 years before it was commercialized.

[0004] In general terms, the conventional hot water process involves mining oil sands by bucket wheel excavators or by draglines at a remote mine site. The mined oil sands are then conveyed, via conveyor belts, to a centrally located bitumen extraction plant. In some cases, the conveyance can be as long as several kilometers. Once at the bitumen extraction plant, the conveyed oil sands are conditioned. The conditioning process includes placing the oil sands in a conditioning tumbler along with steam, water, and caustic soda in an effort to disengage bitumen from the sand grains of the mined oil sands. Further, conditioning is intended to remove oversize material for later disposal. Conditioning forms a hot, aerated slurry for subsequent separation. The slurry can be diluted for additional processing, using hot water. The diluted slurry is then pumped into a primary separation vessel (PSV). The diluted hot slurry is then separated by flotation in the PSV. Separation produces three components: an aerated bitumen froth which rises to the top of the PSV; primary tailings, including water, sand, silt, and some residual bitumen, which settles to the bottom of the PSV; and a middlings stream of water, suspended clay, and suspended bitumen. The bitumen froth can be skimmed off as the primary bitumen product. The middlings stream can be pumped from the middle of the PSV to sub-aeration flotation cells to recover additional aerated bitumen froth, known as a secondary bitumen product. The primary tailings from the PSV, along with secondary tailings product from flotation cells are pumped to a tailings pond, usually adjacent to the extraction plant, for impounding. The tailings sand can be used to build dykes around the pond and to allow silt, clay, and residual bitumen to settle for a decade or more, thus forming non-compacting sludge layers at the bottom of the pond. Clarified water eventually rises to the top for reuse in the process.

[0005] The bitumen froth is treated to remove air. The deaerated bitumen froth is then diluted with naptha and centrifuged to produce a bitumen product suitable for upgrading. Centrifuging also creates centrifugal tailings that contain solids, water, residual bitumen, and naptha, which can be disposed of in the tailings ponds.

[0006] More than 40 years of research and many millions of dollars have been devoted to developing and improving the Clark process by several commercial oil sands operators, and by the Alberta government. Research has largely been focused on improving the process and overcoming some of the major pitfalls associated with the Clark process. Some of the major pitfalls are:

[0007] 1. Major bitumen losses from the conditioning tumbler, from the PSV and from the subaeration cells.

[0008] 2. Reaction of hot caustic soda with mined oil sands result in the formation of naphthenic acid detergents, which are extremely toxic to marine and animal life, and require strict and costly isolation of the tailings ponds from the environment for at least many decades.

[0009] 3. Huge energy losses due to the need to heat massive amounts of mined oil sands and massive amounts of water to achieve the required separation, which energy is then discarded to the ponds.

[0010] 4. Loss of massive amounts of water taken from water sources, such as the Athabasca river, for the extraction process and permanently impounded into the tailings ponds that can not be returned to the water sources on account of its toxicity. For example, to produce one barrel of oil requires over 2 barrels of water from the Athabasca River.

[0011] 5. The cost of constructing and maintaining a large separation plant.

[0012] 6. The cost of transporting mined oil sands from a remote mining location to a large central extraction plant by means of conveyors. Additionally, the conveyors can be problematic.

[0013] 7. The cost of dilution centrifuging.

[0014] 8. The cost of naphtha recovery.

[0015] 9. The cost of maintaining and isolating huge tailings ponds.

[0016] 10. The cost of preventing leakage of toxic liquids from the tailings ponds.

[0017] 11. The cost of government fines when environmental laws are breached.

[0018] 12. The eventual cost of remediation of mined out oil sands leases and returning these to the environment in a manner acceptable to both the Alberta and the Canadian government.

[0019] 13. The environmental impact of the tailings ponds. Some major improvements have been made that included lowering the separation temperature in the tumbler, the PSV, and the flotation cells. This reduced the energy costs to a degree but may also require the use of larger tumblers and the addition of more air to enhance bitumen flotation. Another improvement eliminated the use of bucket wheel excavators, draglines and conveyor belts to replace these with large shovels and huge earth moving trucks, and then later to replace some of these trucks with a slurry pipeline to reduce the cost of transporting the ore from the mine site to the separation plant. Slurry pipelines eliminate the need for conditioning tumblers but require the use of oil sand crushers to prevent pipe blockage and require cyclo-feeders to aerate the oil sand slurry as it enters the slurry pipeline, and may also require costly compressed air injection into the pipeline. Other improvements included tailings oil recovery units to scavenge additional bitumen from the tailings, and naptha recovery units for processing the centrifugal tailings before these enter the tailings ponds.

[0020] More recent research is concentrating on reducing the separation temperature of the Clark process even further and on adding gypsum or flocculants to the sludge of the tailings ponds to compact the fines and release additional water. However, adding gypsum hardens the water and this can require softening of the water before it can be recycled to the extraction plant. Most of these improvements have served to increase the amount of bitumen recovered and reduce the amount of energy required, but have increased the complexity and size of the commercial oil sands plants.

[0021] One particular problem that has vexed commercial mined oil sands plants is the problem of fine tailings disposal. In the current commercial process, mined oil sands are mixed and stirred with hot water, air, and caustic soda to form a slurry that is subsequently diluted with cooler water and separated in large separation vessels. In these vessels, air bubbles attach to bitumen droplets of the diluted slurry and cause bitumen product to float to the top for removal as froth. Caustic soda serves to disperse the fines to reduce the viscosity of the diluted slurry and allows the aerated bitumen droplets to travel to the top of the separation vessels fast enough to achieve satisfactory bitumen recovery in a reasonable amount of time. Caustic soda serves to increase the pH of the slurry and thereby imparts electric charges to the fines, especially to the clay particles, to repel and disperse these particles and thereby reduce the viscosity of the diluted slurry. Without caustic soda, for most oil sands the diluted slurry would be too viscous for effective bitumen recovery. It can be shown from theory or in the laboratory that for an average oil sand, it takes five to ten times as long to recover the same amount of bitumen if no caustic soda is added to the slurry. Such a long residence time would make commercial oil sands extraction much more expensive and impractical.

[0022] While caustic soda is beneficial as a viscosity breaker in the separation vessels for floating off bitumen, it is environmentally very detrimental. At the high water temperatures used during slurry production it reacts with naphthenic acids in the oil sands to produce detergents that are highly toxic. Not only are the tailings toxic, but also the tailings fines will not generally settle. Tailings ponds with a circumference as large as 20 kilometers are required at each large mined oil sands plant to contain the fine tailings. Coarse sand tailings are used to build huge and complex dyke structures around these ponds.

[0023] Due to the prior addition of caustic soda, the surfaces of the fine tailings particles are electrically charged, which in the ponds, causes the formation of very thick layers of microscopic card house structures that compact extremely slowly and take decades or centuries to dewater. Many millions of dollars per year have been and are being spent in an effort to maintain the tailings ponds and to find effective ways to dewater these tailings. Improved mined oil sands processes must be commercialized to overcome the environmental problems of the current plants. One such alternate method of oil sands extraction is the Kruyer Oleophilic Sieve process invented in 1975.

[0024] Like the Clark Hot Water process, the Kruyer Oleophilic Sieve process originated at the Alberta Research Council and a number of Canadian and U.S. patents were granted to Kruyer as he privately developed the process for over 30 years. The first Canadian patent of the Kruyer process was assigned to the Alberta Research Council and, and all subsequent patents remain the property of Kruyer. Unlike the Clark process, which relies on flotation of bitumen froth, the Kruyer process uses a revolving apertured oleophilic wall (trade marked as the Oleophilic Sieve) and passes the oil sand slurry to the wall to allow hydrophilic solids and water to pass through the wall apertures whilst capturing bitumen and associated oleophilic solids by adherence to the surfaces of the revolving oleophilic wall.

[0025] Along the revolving apertured oleophilic wall, there are one or more separation zones to remove hydrophilic solids and water and one or more recovery zones where the recovered bitumen and oleophilic solids are removed from the wall. This product is not an aerated froth but a viscous liquid bitumen.

[0026] A bitumen-agglomerating step normally is required to increase the bitumen particle size before the slurry passes to the apertured oleophilic wall for separation. Attention is drawn to the fact that in the Hot Water Extraction process the term “conditioning” is used to describe a process wherein oil sands are gently mixed with controlled amounts water in such a manner as to entrain air in the slurry to eventually create a bitumen froth product from the separation. The Oleophilic Sieve process also produces a slurry when processing mined oil sands but does not “condition” it. Air is not required, nor desired, in the Oleophilic Sieve process. As a result, the slurry produced for the Oleophilic Sieve, as well as the separation products, are different from those associated with the conventional Hot Water Extraction process. The Kruyer process was tested extensively and successfully implemented in a pilot plant with high grade mined oil sands (12 wt % bitumen), medium grade mined oil sands (10 wt % bitumen), low grade oil sands (6 wt % bitumen) and with sludge from commercial oil sands tailings ponds (down to 2% wt % bitumen), the latter at separation temperatures as low as 5° C. A large number of patents are on file for the Kruyer process in the Canadian and U.S. Patent Offices. These patents include: CA 2,033,742; CA 2,033,217; CA 1,334,584; CA 1,331,359; CA 1,144,498 and related U.S. Pat. No. 4,405,446; CA 1,141,319; CA 1,141,318; CA 1,132,473 and related U.S. Pat. No. 4,224,138; CA 1,288,058; CA 1,280,075; CA 1,269,064; CA 1,243,984 and related U.S. Pat. No. 4,511,461; CA 1,241,297; CA 1,167,792 and related U.S. Pat. No. 4,406,793; CA 1,162,899; CA 1,129,363 and related U.S. Pat. No. 4,236,995; and CA 1,085,760.

[0027] While in a pilot plant, the Kruyer process has yielded higher bitumen recoveries, used lower separation temperatures, was more energy efficient, required less water, did not produce toxic tailings, used smaller equipment, and was more movable than the Clark process. There were a number of drawbacks, though, to the Kruyer process.

[0028] One drawback to the Kruyer process is related to the art of scaling up. Scaling up a process from the pilot plant stage to a full size commercial plant normally uncovers certain engineering deficiencies of scale such as those identified below.

[0029] Commercial size apertured drums that may be used as revolving apertured oleophlilic walls require very thick perforated steel walls to maintain structural integrity. Such thick walls increase retention of solids by the bitumen and may degrade the resulting bitumen product. Alternately, apertured mesh belts may be used as revolving apertured oleophilic walls. These have worked well in the pilot plant but after much use, have tended to unravel and fall apart. This problem will likely be exacerbated in a commercial plant running day and night. Rugged industrial conveyor belts are available. These are made from pre-punched serpentine strips of flat metal and then joined into a multitude of hinges by cross rods to form a rugged industrial conveyor belt. Other industrial metal conveyor belts are made from flattened coils of wire and then joined into a multitude of hinges by cross rods to form the belts. Both types of metal belts were tested and have stood up well in a pilot plant. However, it was difficult and energy intensive to remove most of the bitumen product in the recovery zone from the surfaces of the belts before these revolved back to the separation zone.

[0030] Bitumen agglomerating drums using oleophilic free bodies, in the form of oleophilic balls that tumbled inside these drums worked very well in the pilot plant. However commercial size agglomerators using tumbling free bodies may require much energy and massive drum structures to contain a revolving bed of freely moving heavy oleophilic balls with adhering viscous cold bitumen to achieve the desired agglomeration of dispersed bitumen particles.

SUMMARY OF THE INVENTION

[0031] Accordingly, the present invention relates to apparatuses and methods for separations. Although the systems and methods have wide-spread application, in a specific embodiment, the separation mechanism can be based on the oleophilic and non-oleophilic nature of components of a flowable material.

[0032] The separation apparatus can include at least one endless cable. The cable can be wrapped multiple times around at least two revolvable cylindrical members. The wrapping of the cable can form gaps between adjacent windings that, along with the endless cable, can facilitate separation processes.

[0033] In one aspect of the present invention, the at least one endless cable includes a first multiple wrap endless cable wherein a first wrap, a plurality of subsequent wraps and a final wrap are formed by wraps of the first endless cable. In such embodiments, the endless cable passes over each of the cylindrical members a plurality of times.

[0034] Alternatively, the at least one endless cable can be formed of a plurality of single wrap cable loops such that each of the first wrap, subsequent wraps, and final wrap are formed by a corresponding single wrap cable loop. Such single wrap cable loops can be composed of the same materials as the multiple wrap endless cables where the single wrap cable loops differ from multiple wrap endless cables primarily in length. Single wrap cable loops are configured to rotate in a single loop, i.e. directly from one cylindrical member to another, or possibly between three or more cylindrical members in a single connected pass. The single wrap loops do not contact each of the cylindrical members a plurality of times, but rather follow a single track or path on a cylindrical member. In these embodiments, there is no need for repositioning guides.

[0035] The separation apparatus can further include a repositioning guide or guides when the endless cable is wrapped a plurality of times around the cylindrical members. As the endless cable moves along a route, the repositioning guide can ensure continuous movement by allowing a continuous path for the endless cable and by preventing the endless cable from rolling off or falling off of the cylindrical members.

[0036] In one aspect, the separation apparatus can include an oleophilic endless cable. Such apparatus can be used, e.g., for oleophilic-based separations such as bitumen recovery from oil sands. In a further aspect, the apparatus can include an agglomerator drum. An agglomerator drum can have openings oriented in fluid communication with the endless cable to allow passage of fluid from an interior to an exterior of the agglomerator drum. The agglomerator drum can also include oleophilic members for adhering oleophilic material. Such oleophilic members can be oleophilic baffles, tower packing or other suitable structures. A separation apparatus including an oleophilic endless cable and an agglomerator drum can have a variety of applications including, but not limited to, processing of bitumen and oil products.

[0037] In another embodiment, the separation apparatus can include a gas inlet that is oriented to direct a gas through or across one or more flights of the endless cable or cables. The apparatus can further include a first liquid reservoir wherein the revolvable cylindrical members include a feed roller and an upper roller where the feed roller is contacted by liquid from the first reservoir. In still another embodiment, the separation apparatus can include one or more endless cables configured to be charged electrically with a high potential direct or alternating current.

[0038] A separation apparatus of the type described herein can also or alternatively be used as a sand filter. In such embodiment, the revolvable cylindrical members can be oriented to form an upper flight and a lower flight of the at least one endless cable. The gaps between adjacent windings can be configured to be sufficiently narrow to allow passage of liquid therethrough and retention and conveyance of particulate solids thereon. In still another embodiment, the separation apparatus can be configured to size and sort particulate or other material.

[0039] A method is also presented for separating that can include using an endless cable. To separate components of a flowable material, the material can be passed through at least one continuously moving endless cable. A first component can pass through gaps between adjacent wrappings of the endless cable. A second component can be retained on or by the endless cable, which can then be partially or completely removed from the cable.

[0040] There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] FIG. 1*a* is a perspective view of a separation apparatus including two revolvable cylindrical members, and repositioning guide, according to one embodiment of the present invention.

[0042] FIG. **1***b* is a cross-sectional view along line A-A of FIG. **1***a*, illustrating one aspect of the present invention.

[0043] FIG. **1***c* is an alternate cross-sectional view along line A-A of FIG. **1***a*, illustrating one aspect of the present invention.

[0044] FIG. **1***d* is an alternate cross-sectional view along line A-A of FIG. **1***a*, illustrating another aspect of the present invention.

[0045] FIG. **1***e* is an alternate cross-sectional view along line A-A of FIG. **1***a*, illustrating still another aspect of the present invention.

[0046] FIG. **2** is a side view of a separation apparatus including an agglomerator oriented outside the endless cable and above the top flight, according to one embodiment of the present invention.

[0047] FIG. **3** is a side cross-sectional view of a separation apparatus including an agglomerator situated between the top and bottom flights of endless cable, according to one embodiment of the present invention.

[0048] FIG. **4***a* is an exploded perspective view of a separation apparatus including an agglomerator situated between the top and bottom flights of endless cable, where the agglomerator includes a plurality of longitudinal baffles according to one embodiment of the present invention.

[0049] FIG. **4***b* is a perspective view of the agglomerator and endless cable of FIG. **4***a*.

[0050] FIG. **4***c* is an exploded partial view of the longitudinal strips and end plate of the agglomerator shown in FIG. **4***b*.

[0051] FIG. **5***a* is a side view of an endless cable route where the endless cable is configured to travel around a revolvable member and come into close proximity with an adjacent wrap of an endless cable, according to one embodiment of the present invention.

[0052] FIG. **5***b* is a side view of a configuration where an endless cable travels through a comb to remove material therefrom, according to one embodiment of the present invention.

[0053] FIG. **5***c* is a front view of a grooved scraper blade configured adjacent to a grooved roller to remove material from wraps of an endless cable, according to one embodiment of the present invention.

[0054] FIG. **5***d* is a front view of wraps of an endless cable passing through two complimentary grooved revolvable members, according to one embodiment of the present invention.

[0055] FIG. **5***e* is a front view of wraps of an endless cable passing through two revolvable members, one of which is an impressionable rubber roller, according to one embodiment of the present invention.

[0056] FIG. **6** is a side schematic view of a system for removing hydrophilic solids from bitumen, including separations processing with an endless cable and a serpentine pipe according to one embodiment of the present invention.

[0057] FIG. **7** is a side view of an arrangement of an endless cable configured for mass transfer applications where the endless cable travels through a fluid reservoir, while gas is directed to travel past portions of the endless cable according to one embodiment of the present invention.

[0058] FIG. **8** is a side view of an arrangement of another endless cable configured for mass transfer applications where the endless cable travels through four separate fluid reservoirs, according to one embodiment of the present invention.

[0059] FIG. **9** is a side view of an endless cable configured to carry a high potential AC or DC electric charge for defogging separations according to one embodiment of the present invention.

[0060] FIG. **10***a* is a side view of another endless cable configured to carry a high potential AC or DC electric charge for electrostatic separations according to one embodiment of the present invention.

[0061] FIG. **10***b* is a top view of FIG. **10***a* but not showing the bottom flight for reasons of simplicity of the Figure.

[0062] FIG. **11***a* is a side view of an endless cable configured to act as a suspended moving filter according to one embodiment of the present invention.

[0063] FIG. **11***b* is a top view of FIG. **11***a* but not showing the bottom flight for reasons of simplicity of the Figure.

[0064] FIG. **12***a* is a side view of an endless cable arranged to separate objects based on size according to one embodiment of the present invention.

[0065] FIG. **12***b* is a top view of one optional embodiment of FIG. **12***a*, but not showing the bottom flight for reasons of simplicity.

[0066] FIG. **13** is a top view of multiple endless cables arranged together to form a conveyor system according to one embodiment of the present invention.

[0067] It will be understood that the above figures are merely for illustrative purposes in furthering an understanding of the invention. Further, the figures are not drawn to scale, thus dimensions and other aspects may, and generally are, exaggerated or changed to make illustrations thereof clearer. Therefore, departure can be made from the specific dimensions and aspects shown in the figures in order to produce the separation system using endless cables of the present invention.

DETAILED DESCRIPTION

[0068] Before the present invention is disclosed and described, it is to be understood that this invention is not limited to the particular structures, process steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

[0069] It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a splice" includes one or more of such splices, reference to "an endless cable" includes reference to one or more of such endless cables, and reference to "the material" includes reference to one or more of such materials.

DEFINITIONS

[0070] In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

[0071] As used herein, the term "endless cable" refers to a cable having no beginning or end, but rather the beginning merges into an end and vice-versa, to create an endless or continuous cable. The endless cable can be, e.g., a wire rope, a plastic rope, a single wire, compound filament (e.g. sea-island) or a monofilament which is spliced together to form a continuous loop, e.g. by long-splicing.

[0072] As used herein, "conditioning" in reference to mined oil sand is consistent with conventional usage and refers to mixing a mined oil sand with water, air and caustic soda to produce a warm or hot slurry of oversize material, coarse sand, silt, clay and aerated bitumen suitable for recovering bitumen froth from said slurry by means of froth flotation. Such mixing can be done in a conditioning drum or tumbler or, alternatively, the mixing can be done as it enters into a slurry pipeline and/or while in transport in the slurry pipeline. Conditioning aerates the bitumen for subsequent recovery in separation vessels. Likewise, referring to a composition as "conditioned" indicates that the composition has been subjected to such a conditioning process.

[0073] As used herein, "bitumen" refers to a viscous hydrocarbon that may include maltenes and asphaltenes that is found in oil sands ore interstitially between sand grains. In a typical oil sands plant, there are many different streams that may contain bitumen.

[0074] "Agglomeration drum" refers to a revolving drum containing oleophilic surfaces that is used to increase the particle size of bitumen in oil sand slurries prior to separation. Bitumen particles flowing through said drum come in contact with the oleophilic surfaces and adhere thereto to form a layer of bitumen of increasing thickness until the layer becomes so large that shear from the flowing slurry and from the revolution of the drum causes a portion of the bitumen layer to slough off, resulting in bitumen particles that are much larger than the original bitumen particles of the slurry.

[0075] As used herein, "fluid" refers to flowable matter. Fluids, as used in the present invention typically include a liquid, gas, and/or flowable particulate solids, and may optionally further include amounts of solids and/or gases dispersed therein. As such, fluid specifically includes slurries (liquid with solid particulate), flowable dry solids, aerated liquids, gases, and combinations of two or more fluids. In describing certain embodiments, the term slurry and fluid may be used interchangeably, unless explicitly stated to the contrary.

[0076] The term, "central location" refers to a location that is not at the periphery. In the case of a pipe, a central location is a location that is neither at the beginning of the pipe nor the end point of the pipe and is sufficiently remote from either end to achieve a desired effect, e.g. washing, disruption of agglomerated materials, etc.

[0077] As used herein, "velocity" is used consistent with a physics-based definition; specifically, velocity is speed having a particular direction. As such, the magnitude of velocity is speed. Velocity further includes a direction. When the velocity component is said to alter, that indicates that the bulk directional vector of velocity acting on an object in the fluid stream (liquid particle, solid particle, etc.) is not constant. Spiraling or helical flow-patterns are specifically defined to have substantially constant or gradually changing bulk directional velocity.

[0078] The term, "multiple wrap endless cable" as used in reference to separations processing refers to an endless cable that is wrapped around two or more drums and/orrollers a multitude of times to form an endless belt having spaced cables. Movement of the endless cable belt can be facilitated by at least two guide rollers or guides that prevent said cable from rolling off an edge of the drum and guide the cable back to the opposite end of the same or other drum. The spacing in the endless belt is formed by the slits or gaps between sequential wraps. The endless cable can be a wire rope, a plastic rope, a single wire, compound filament (e.g. sea-island) or a monofilament which is spliced together to form a continuous loop, e.g. by splicing. As a general guideline, the diameter of the endless cable can be as large as 3 cm and as small as 0.001 cm, although other sizes might be suitable for some applications. An oleophilic endless cable belt is a cable belt made from a material that is oleophilic under the conditions at which it operates.

[0079] As used herein, "single wrap endless cable" refers to an endless cable which is wrapped around two or more cylindrical members in a single pass, i.e. contacting each roller or drum only once.

[0080] The term "cylindrical" indicates a generally elongated shape having a circular cross-section. Therefore, cylindrical includes cylinders, conical shapes, and combinations thereof. The elongated shape has a length referred herein also as a depth as calculated from one of two points—the open vessel inlet, or the defined top or side wall nearest the open vessel inlet.

[0081] As used herein, "recovery yield" refers to the percentage of material removed from an original mixture or composition. Therefore, in a simplified example, a 100 kg mixture containing 45 kg of water and 40 kg of bitumen where 38 kg of bitumen out of the 40 kg is removed would be a 95% recovery yield.

[0082] As used herein, the term "confined" refers to a state of substantial enclosure. A path of fluid may be confined if the path is, e.g., walled or blocked on a plurality of sides, such that there is an inlet and an outlet and direction of the flow is directed by the shape and direction of the confining material.

[0083] As used herein, "retained on" refers to association primarily via simple mechanical forces, e.g. a particle lying on a gap between two or more cables. In contrast, the term "retained by" refers to association primarily via active adherence of one item to another, e.g. retaining of bitumen by an oleophilic cable. In some cases, a material may be both retained on and retained by one or more cables.

[0084] The term "roller" indicates a revolvable cylindrical member or drum, and such terms are used interchangeably herein.

[0085] As used herein, "wrapped" or "wrap" in relation to a cable wrapping around an object indicates an extended amount of contact. Wrapping does not necessarily indicate full or near-full encompassing of the object.

[0086] The term "metallic" refers to both metals and metalloids. Metals include those compounds typically considered metals found within the transition metals, alkali and alkali earth metals. Examples of metals are Ag, Au, Cu, Al, and Fe. Metalloids include specifically Si, B, Ge, Sb, As, and Te. Metallic materials also include alloys or mixtures that include metallic materials. Such alloys or mixtures may further include additional additives.

[0087] As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result.

[0088] As used herein, a plurality of components may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

[0089] Concentrations, amounts, volumes, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 inch to about 5 inches" should be interpreted to include not only the explicitly recited values of about 1 inch to about 5 inches, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc. This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

EMBODIMENTS OF THE INVENTION

[0090] It has been found that a separation apparatus that is both versatile and effective can be created using one or more endless cables. The cable or cables can be wrapped a plurality of times around at least two revolvable cylindrical members. Such wrapping can form a first wrap, a plurality of subsequent wraps, and a final wrap for each endless cable. The wrapping can be from one cylindrical member to another, so that the one or more endless cables contacts each of the at least two cylindrical members multiple times to form gaps between adjacent windings.

[0091] In one aspect of the present invention, the at least one endless cable includes a first multiple wrap endless cable wherein the first wrap, the plurality of subsequent wraps and the final wrap are formed by wraps of the first endless cable. In such embodiments, the endless cable passes over each of the cylindrical members a plurality of times. This is the embodiment illustrated in FIGS. **1***a*, **4** and others as discussed in more detail below. In order to avoid an unacceptable amount of cable twisting as the cable is wrapped around the cylinders, the endless cable can be formed, e.g. by long splice, having a twist opposite to that created when wrapping. In this way the wrapped endless cable can avoid excessive twist or bending.

[0092] Alternatively, the at least one endless cable can be formed of a plurality of single wrap cable loops such that each of the first wrap, subsequent wraps, and final wrap are formed by a corresponding single wrap cable loop. Such single wrap cable loops can, in one embodiment, be composed of the same materials as the multiple wrap endless cables. Single wrap cable loops typically differ from multiple wrap endless cables primarily in size. Cable loops are configured to rotate in a single loop, i.e. from one cylindrical member to another, or possibly between three or more cylindrical members. The single wrap loops do not contact each of the cylindrical members a plurality of times, but rather follow a single track or path on a cylindrical member. In this embodiment, there is no need for repositioning guides.

[0093] A separation apparatus can further include a repositioning guide or guides for each of the multiple wrap endless cables. As the endless cable moves along a route, the repositioning guide can be oriented to continuously allow guidance of the final wrap of a multiple wrap endless cable to roll into and assume the position of the first wrap, thus preventing the endless cable from rolling off or falling off the cylindrical members.

[0094] General

[0095] FIG. **1** is a perspective view of a single multiple wrap endless cable **2** wrapped between two revolvable cylindrical members **4**, **6** multiple times. As illustrated, the wrapping forms a first wrap **8**, a plurality of subsequent wraps **10**, and a final wrap **12**. A repositioning guide support **14** is shown including two guide rollers **16**, **18**. The final wrap **12** travels from the revolvable cylindrical member **6** to the first guide roller **16**, and then to a second guide roller **18**, where it is repositioned as the first wrap **8**. Shown is a basic concept of an endless cable belt wrapped, in this case, around two rollers in a large number of wraps using a single endless cable. A number of different configurations are possible by variations in number of endless belts, number, size and position of revolvable members, and various repositioning guides.

[0096] In FIG. **1***a*, a drive roller **6** and tension roller **4** are used. The drive roller initiates and maintains rotation of the roller, which, in turn, causes the endless cable **2** to rotate along the endless path. The drive roller can be rotated via a drive belt **7** and motor, not shown, or other suitable mechanism. The tension roller can be maintained an adjustable distance from the drive roller that maintains the endless cable at a tension that allows for use in separations processing and keeping the cable in track. For example, cables may stretch during use requiring periodic tension adjustment. The desirable tension can vary greatly and will depend on the anticipated application and type and size of endless cable. Tension adjustment may alternately be provided by a guide or guide rollers or one or more tension rollers.

[0097] The endless cable can be configured in a variety of ways. FIG. **1***a* shows line A-A, along the path of the endless cable along the top flight of the endless cable. FIGS. **1***b* through **1***e* illustrate various embodiments of endless cable arrangements as seen across the line A-A. FIG. **1***b* is a cross-sectional view of a single, multiwrap endless cable wrapped around two revolvable members, as illustrated in FIG. **1***a*. FIG. **1***c* shows two multiwrap endless cables which are wrapped on the rollers in alternating wraps. The empty circles refer to the first cable and the filled-in circles refer to the second cable. In this case two repositioning guides are required instead of one. FIG. **1***d* is a cross-section of an embodiment of FIG. **1***a* where one endless cable is wrapped around the main rollers of FIG. **1***a*, with the addition of grizzly bars situated in gaps between adjacent wraps. The grizzly bars (indicated by triangles in the Figure) can be stationary or vibrate in a vertical or orbital plane. These grizzly bars, in conjunction with the revolving wraps create shear or vibration that, in some cases, may enhance the operation of the endless cable belt, and may provide support to the upper flight of the endless cable so that it will not sag or deflect unacceptably under the weight of material on top of the flight or by the movement of material through the gaps. Although the grizzly bars are shown having a triangular cross-section with one flat edge upward, other cross-sectional shapes can be suitable such as, but not limited to, rectangular, circular, trapezoidal, or the like. FIG. **1***e* is similar to FIG. **1***c* in that two multiple wrap endless cables are used, but in this case, the wraps are grouped together per endless cable and not intertwined. Again, a repositioning guide is used for each endless cable in this case. If four endless cables are used, then four repositioning guides may be required. Each of the configurations shown in FIG. **1***b* through **1***e* can also be applied to the lower or bottom flight as an alternative to the upper flight or in combination with the same or different configurations on the top flight.

[0098] When more than one endless cable is used, it is preferred that the repositioning guides, or another element other than a revolvable member jointly used by the multiple endless cables, be used to provide the desired tension for each cable individually. Controlling tension of multiple endless cables using a common tensioner or tension roller is possible, but can be difficult in some embodiments. One method of providing satisfactory tension along the top flight of a group of a large number of single wrap endless cables is to allow slack along the bottom flight. For example, both main rollers in FIG. **1***a* could be driven counter clockwise. When each main roller is provided with a squeeze roller and the left main roller is driven at a slightly higher surface speed than the right main roller, the top flight would be in tension and the bottom flight could be slack. The slackness of the bottom flight would accommodate any small changes in the lengths of the individual single wrap endless cables while allowing the top flight to remain tight and serve the desired separating function. When more than two main rollers are used to support the single wrap endless cables, then two sets of squeeze rollers can be dedicated to provide the desired cable slack over a section of the apparatus whilst maintaining the desired cable tension for the rest of the apparatus. In this case, the set of squeeze roller feeding the cables into the slack section can be driven at a slightly higher surface speed than the surface speed of the other main rollers; and the slack section could be anywhere along the endless cables as desired, and would not necessarily have to form the bottom flight.

[0099] The endless cable or cables can comprise or consist essentially of a member selected from the group consisting of metal, plastic, fiber, and combinations thereof. All of the endless cables can be of the same composition, or, each can independently comprise or consist essentially of a member selected from the group consisting of metal, plastic, fiber, and combinations thereof. In one embodiment, at least one endless cable can comprise or consist essentially of single strand or multi strand steel, galvanized steel, tin coated steel, clad steel, plastic coated steel cable, copper, stainless steel, titanium, wire rope, twisted plastic rope, braided polymeric rope, carbon fiber rope, single monofilament rope, and combinations thereof. The desirability of a particular material for use as the cable can depend on a variety of factors, not limited to, strength, availability, cost, electrical conductivity, hydrophobicity, particular application, and the like.

[0100] The endless cable can be of any size that allows for arranging the endless cable to wrap around at least two revolvable cylindrical members in a manner that facilitates separations processing. As such, appropriate endless cable sizes are dependent on the type of separation, the weight and size of material to be separated, the endless pathway through which the endless cable travels, the gap size, etc. In a specific embodiment, one or more of the endless cables can have a diameter ranging from about 0.02 cm to about 3 cm. In a further embodiment, one or more of the endless cables has a diameter ranging from about 0.1 cm to about 1.0 cm.

[0101] Separations or gaps between windings at least partially result from the winding route of the endless cable. The gaps can be configured to allow material to flow through in the desired manner, e.g. increasing surface contact with fluids without hindering flow through gaps, retaining larger materials above while allowing smaller materials to pass through the gaps, etc. As illustrated in FIG. **1***a*, the gaps between adjacent windings can be substantially uniform. Alternatively, the gaps can be non-uniform or variable. In one aspect, the gaps between adjacent windings are from about 1% to about 10% or in some cases 50% of a diameter of the endless cable. In some embodiments, the gaps between adjacent windings range from about 50% to about 600% of the cable diameter, or more. The specific size of the gaps may vary greatly due to the application, type of separation desired, type of endless cable, etc. As a non-limiting example, and in one embodiment, the gaps can range in size from about 0.02 cm to about 5 cm, or from about 0.1 cm to about 2.0 cm.

[0102] Endless cables are continuous and include no recognizable beginning or ending. Such endless cables can be created by joining the ends of a single cable. The joining mechanism can be any type for which the separation apparatus and separations process allows. A basic example that could be used in a very forgiving system is a simple knot or crimped sleeve. Preferably, the cable is joined in a manner that leaves no noticeable area, but allows for a seamless transition from beginning to end of the cable. A long splice can be used in such situations. Such cables can, in some instances, include multiple cables joined together to form a single endless cable. In one aspect, an endless cable can include more than one standard long splice to join cable ends and to make one cable endless. A "long splice" is a well known method of joining cables in a manner which does not significantly increase the cable diameter at the splice but results in a splice that has almost the same strength as the cable itself.

[0103] There are a wide variety of arrangements of at least one endless cable wrapped between at least two cylindrical members. More than one endless cable could be used. More than two cylindrical members can be used, in which case, the route of the endless cable may not be directly from one cylindrical member to another, but may include a more intricate or circuitous route. An endless cable can be wrapped any number of times around some or all cylindrical members. For example, at least one endless cable of a separation apparatus can wrap around at least two of the cylindrical members of the separation apparatus from about 10 to about 1000 times. In a relatively simple variation of the single endless cable wrapped around two cylindrical members design, a second endless cable can be wrapped a plurality of times around the same two cylindrical members. Furthermore, the second endless cable can be wrapped around any number of cylindrical members, associated with the first endless cable or following a different path. In one embodiment including a second endless cable, the wraps of the second endless cable can be grouped together and located adjacent to the group of wraps of the first endless cable. Alternatively, the wraps of the second endless cable can alternate with the wraps of the first endless cable, or rather each succeeding wrap of the second endless cable individually can be located adjacent to each succeeding wrap of the first endless cable.

[0104] In another design variation, the cylindrical members can number more than two. For example, the cylindrical members in one embodiment can range from 3 to 10. Multiple cylindrical members can be oriented to also contact the at least one endless cable a plurality of times to form the gaps between adjacent windings. Such orientation may cause the same number of wraps or contacts with more than one of the cylindrical members, or may leave one or more rollers with more or fewer contacting cable passes. The two or more cylindrical members may have substantially the same diameter, or may have differing diameters depending the particular application and system design. In one embodiment, at least one of the cylindrical members has a diameter from about 10 cm to about 1000 cm.

[0105] In order to facilitate proper or improved flow of the fluid or solids, various parts of the separation apparatus can vibrate. Vibration can help to prevent clustering and agglomeration of material and break up previously agglomerated materials. In one aspect, one or more of the cylindrical members can be configured to vibrate. Alternatively, or in addition, the endless cable can be configured to vibrate. Material separation may be further improved by including an optional material distributor. Such material distributor can be configured to distribute material over at least a portion of the gaps between adjacent windings of an endless cable. Non-limiting examples of material distributors include screens, perforated sheets, parallel support grizzly bars, and combinations thereof. Such material distributors can be configured to vibrate to better improve the desired separation.

[0106] Once components of the fluid are separated, each component can be collected in a separate collection apparatus. The separation apparatus can, therefore, include a pass-through outlet oriented to collect material which passes through the gaps of the endless cable. The separation apparatus can also include a retained outlet oriented to collect material retained on the at least one endless cable. In one aspect, such pass-through outlet or outlets are positioned under a generally horizontally-oriented endless cable. Similarly, a corresponding retained outlet can be positioned near a cylindrical member, and often near a stripping device which removes material retained on or by the endless cable. In some embodiments, a portion of the fluid is retained by the endless cable by a manner of adhering or sticking to the cable rather than temporarily resting on the cable. In such cases, it may be necessary to strip the material from the cable. Such stripping can occur at regular or semi-regular intervals, and can continuously occur during processing and operation of the separation apparatus. Non-limiting examples of cable stripping devices include rubber squeeze rollers, complimentary grooved rollers, combs, grooved knife, cross-cables, steam heat zones, inductive heat zones, microwave heat zones, and combinations thereof. In one aspect, a separation apparatus including an endless cable can include one or more wash water sources oriented to wash material adhered to an endless cable. Additionally or alternatively, a separation apparatus can include one or more dryers configured and oriented to dry material adhered to an endless cable.

[0107] As discussed, a repositioning guide can include a plurality of guides configured to guide an endless cable along a continuous or endless path. Such repositioning guide or guides can be spaced apart from the at least two revolvable cylindrical members. A repositioning guide or guides can, in addition to moving the endless cable from the last wrap to the first wrap, be configured to control location and spacing of gaps. The revolvable cylindrical members can include a variety of surfaces. In one aspect, the surface of at least one cylindrical member can be smooth. Alternatively, the surface can be treated to have an abrasive surface. In one aspect, the surface can include a mild adhesive. In still another aspect, at least one of the revolvable cylindrical members can be a grooved cylindrical member including grooves on an exterior surface of the grooved cylindrical member. The grooves can be configured to control location and spacing of the gaps. Generally, any approach which can be used to maintain adjacent wraps or windings of the endless cables can be used in the present invention.

Oleophilic Separations

[0108] In one embodiment, one or more of the endless cables of a separation apparatus can be oleophilic. One or more oleophilic endless cables can be wrapped a multitude of times around two main rollers to form an endless cable belt. When such wrapping are between two or more rollers or cylindrical members that are horizontally spaced apart, the wraps can form a top flight and a bottom flight. Such is the case with FIG. **2** which illustrates two cylindrical members **22**, **24** or rollers of different sizes. With at least one endless cable **26** traveling between the cylindrical members in a continuous path facilitated by the repositioning guide **28**. In one aspect, one roller can be a driving roller, while the other roller is adjustable to maintain the desired tension in the wraps to prevent these wraps from sagging. The repositioning guide can optionally include two or more guide rollers that are spring loaded to maintain approximately equal tension in the wraps when one or more than one oleophilic cable is used.

[0109] In one aspect of using an oleophilic endless cable, oil sand slurry or desanded oil sand slurry forms the feed. As shown in FIG. **2**, the feed **29** is directed into an agglomerator **30** positioned above the top flight **32** of the endless cable **26**. The agglomerator can be configured to revolve. Although a variety of agglomerator configurations could work with the design presented, in one aspect, the agglomerator can have a central cylindrical apertured screen **33** and an outer cylindrical apertured screen **35** to allow the flow of slurry from the centre of the agglomerator, out through the outer screen and onto the top flight of the oleophilic endless belt.

[0110] The annular volume between the inner screen **33** and the outer screen **35** of the agglomerator **30** can optionally be filled with oleophilic tower packings or other suitable agglomerating members, e.g. fixed baffles, etc. As slurry flows through this volume, bitumen from the slurry temporarily adheres to the surfaces of the agglomerating members and then sloughs off in the form of enlarged bitumen particles. The enlarged bitumen particles are captured more readily by the oleophilic endless cable belt than small bitumen particles.

[0111] As shown in FIG. **2**, bitumen is captured and retained by the endless cable **26** as the slurry from the agglomerator **30** passes through the top flight **32**. A bitumen-reduced slurry passes through the top flight. The retained bitumen is conveyed towards and along the main roller **24** at the right until it encounters the squeeze roller **36** mounted along this main roller. The squeeze roller removes bitumen from the belt as it revolves with this main roller by preventing bitumen from passing between the two rollers. Bitumen accumulates on the underside of the two rollers and sloughs off. The thus removed bitumen can be collected as a primary product in a first product collector **38**. At least a portion of residual bitumen in the bitumen-reduced slurry can be captured as slurry passes from the top flight through the bottom flight **34**. Slurry which passes through the bottom flight can be primarily non-oleophilic and can be collected and directed to the tailings reservoir **40**. Residual bitumen retained by the bottom flight can be collected with a squeeze roller **42** along the left main roller **22** in a similar manner as with squeeze roller **36**. Bitumen removed from the bottom flight can be collected in a second product collector **44**. The first and second bitumen products can be combined for further processing or treated independently.

[0112] Baffles **46** can optionally be mounted between the top flight **32** and the bottom flight **34** to direct bitumen-reduced slurry from the top flight to the bottom flight and to keep it away from the main rollers **22**, **24**. In some cases, a mesh screen **48** or several mesh screens can be placed above the bottom flight between the baffles to slow down the flow of slurry impacting onto the bottom flight. This is done to minimize dispersion of residual bitumen droplets that fall from the top flight to the bottom flight and to improve contact between the bottom flight of endless cable and the slurry.

[0113] FIG. **3** illustrates another embodiment of a separation apparatus including an oleophilic endless cable **60**. This configuration can be used to separate oil sand slurry or desanded oil sand slurry in two stages, although other materials may also be effectively separated in this manner. One or more endless cables **60** are wrapped a multitude of wraps around rollers **62**, **64**, **66** and agglomerator drum **68** to form an endless belt. Guides or guide rollers are used as in the previous embodiments and previous figures, but these are not shown for reasons of clarity. Stage **1** separation occurs along the top flight **70** and stage **2** separation occurs along the bottom flight **72** in conjunction with an agglomerator **68** optionally filled with oleophilic tower packings. Oleophilic tower packings are used extensively in the refining industry for distillation columns and in extraction columns and are often made from polypropylene, polyethylene or from other plastics, although metal packings could also be used.

[0114] Slurry feed flows onto the top flight **70** from a dispenser **74** that spreads it evenly over the endless belt. A screen **76** or several screens may optionally be used under the dispenser to better distribute and slow down the flow of slurry onto the top flight. Bitumen captured from the slurry by the top flight is conveyed to the set of squeeze rollers **64**, **66** where the bitumen is squeezed off the belt by these two rollers and then flows into a pipe **78** or other receiver as a primary bitumen product. Tailings **86** from stage **1**, primarily including water, solids and some bitumen, pass through the gaps of the top flight and flow into a reservoir **80** connected with a pipe to a central inlet of the agglomerator **68**. A pump, not shown, may optionally be used to convey these tailings to the agglomerator. In the agglomerator bitumen particles of these tailings are further agglomerated by the oleophilic tower packings. These bitumen particles temporarily adhere to the oleophilic surfaces of the tower packings and form a layer of bitumen on the surfaces of these packings. This layer of bitumen increases in thickness until shear from water and solids, flowing through the packings, sloughs off bitumen in the form of enlarged bitumen particles, which are then captured by the bottom flight **72** as these leave the agglomerator. Bitumen thus captured by the bottom flight is conveyed to another set of rollers **81**, **62**, where it is squeezed off the belt and flows into a pipe **82** or other receiver as a bitumen product. Tailings from stage **2** drop into a tank **84** under the agglomerator and bottom flight and are sent to dewatering and disposal. These tailings are preferably substantially free of bitumen, although some residual bitumen is sometimes present.

[0115] Optionally, wash water may be used to wash adhering solids from bitumen on the top flight and air may be used to blow dry this bitumen. However such washing or drying may only be used as needed or desired.

[0116] Free bodies, such as 1 or 2 inch grinding balls or balls similar to golf balls or a mixture thereof may be used as the agglomerating medium in an agglomerator of the instant invention. Such balls tumble with the bitumen and tend to kneed the bitumen and, in many cases, assist in the agglomerating process by stripping fine solids from the surface of the bitumen and thereby encourage bitumen to agglomerate more readily. However care must be taken to prevent the charge of balls from becoming so heavy that the agglomerator drum becomes like a ball mill requiring a very heavy drum with a resulting heavy support structure. Alternative to the tower packings or other free bodies, the agglomerator **68** can include a plurality of internal baffles. In this case, tailings that have passed through the gaps of the top flight **70** fall onto a baffle, which directs these tailings into the volumes between oleophilic baffles of the agglomerator. The velocity of these tailings is such, and the angle of the oleophilic baffles is such, that the tailings are scooped up by the baffles and flow towards the centre of the agglomerator. Bitumen particles remaining in the tailings of the top flight come in contact with oleophilic baffles of the agglomerator and temporarily adhere thereto until the layer of bitumen on the baffles becomes thick enough that shear from the flowing tailings sloughs off the bitumen in the form of enlarged bitumen particles. Then, as the agglomerator revolves, these tailings containing residual bitumen reverse direction with respect to the agglomerator centre and flow outward past the baffles of the agglomerator, and towards the bottom flight **72** for capture of bitumen by the bottom flight. Bitumen product from the bottom flight is removed by means of squeeze rollers **81**, **62**, or is removed by other means. Wash water and air (not shown) may be used along the bottom flight as well, but only as needed or desired, to wash solids from the bottom flight and dry the contents of the bottom flight.

[0117] It should be noted that the agglomerator can have endwalls to contain the tailings from the top flight, but these are not shown in FIG. **3** for the sake of clarity. In one embodiment, the oleophilic baffles are attached to and are supported by steel bars or strips that connect to the endwalls of the agglomerator. FIG. **4***a* shows an exploded perspective view of such an agglomerator **69** incorporated into a separation apparatus similar to that of FIG. **3**. In particular, an endless cable **61** is wrapped around the agglomerator and between two separate sets of squeeze rollers **63** and **65** using two tension rollers **67** and **71**. A dispenser **73** can be used to distribute slurry across the top flight of the endless cable system, either with or without additional screening or distributors. As described previously, oleophilic materials within the slurry tend to adhere to the endless cable while other non-adhered portions pass through the top flight and onto a collection pan **75**. The collection pan can direct the partially separated slurry onto the agglomerator **69** through the gaps between the oleophilic baffles. Bitumen removed from each of the sets of squeeze rollers can be collected in hoppers **77** and **79**, respectively. Similarly, material and fluids which pass through the agglomerator are collected in vessel **85** and drained via line **83**.

[0118] As shown in FIG. **4***b*, the agglomerator has an endwall **95** (shown removed) which includes slanted notches **97** for receiving notched longitudinal strips **99** (in this case **26** such strips). These strips are notched or grooved to keep the wraps of the endless cable belt in alignment and to maintain the gaps or apertures between these wraps at constant width. FIG. **4***c* illustrates an exploded view where each single strip **99** has a plurality of alignment grooves **101** which are oriented facing outward of the drum as can be seen in FIGS. **4***b* and **4***c*. Retaining holes **103** can be used to attach suitable oleophilic baffles **105**. Referring again to FIG. **4***b*, as slurry flows across the longitudinal strips **99** and oleophilic baffles **105** additional bitumen is adhered to and agglomerates along these structures. The rotational speed of the agglomerator is sufficient to allow agglomerated bitumen to collect and flow towards the lower flight of the endless cable where it is collected and carried towards squeeze rollers **63**.

[0119] In one aspect of the present invention, the endless cable can separate a first component that is a hydrophilic material and the second component that is an oleophilic material. It is understood that recovery yields may not, and usually will not, reach 100% such that some minor amount of hydrophilic material may be present in the oleophilic product and visa-versa. In another aspect, a first separation product or component can primarily include water and a second component can primarily include bitumen. In one embodiment, the flowable material further includes a member selected from the group consisting of clay, silt, sand, and mixtures thereof. Various yield recoveries can be achieved by varying different aspects of the separation apparatus and can depend on the characteristics of the slurry or fluid. However, in one specific embodiment with bitumen separations, the bitumen can be separated from the slurry at a bitumen recovery yield of greater than about 95 wt %, although actual recovery yields can vary depending on the grade of oil sand used as a feed. As an illustration, for a poor quality beach sand containing 6% bitumen, recovery may be as high as 60%. For a medium grade oil sand containing 10% bitumen, recovery can exceed 92%, and for high grade oil sand ore containing 12% bitumen recovery may exceed 95%.

[0120] As previously mentioned, various methods for mechanically removing bitumen from the oleophilic endless cable belt are shown in FIGS. **5***a* through **5***e*. The temperature of bitumen adhering to the cable belt can be left unaltered and the bitumen can be recovered by the methods shown in, e.g., FIGS. **5***a*-**5***e* and alternatively or additionally, the cable wraps and the bitumen may be heated in the recovery zone using steam, heated gas, microwaves, electricity, or other heat source to reduce the bitumen viscosity. The more fluid bitumen can then be scraped or squeezed off more effectively by methods similar to the mechanical methods shown in FIGS. **5***a*-**5***e*. Bitumen may also be heated by internally heating the main rollers and/or the recovery rollers with steam or other means.

[0121] In FIG. **5***a*, cable **110** is wrapped around a roller **112** such that throughout the endless belt, each cable wrap before contacting this roller, and following its contour, is scraped on either side by two adjacent cable wraps at the location **113** where the cable wraps cross. When the slits or gaps between adjacent cable wraps are equal to the diameter of the cable, such crossing of the cable wraps serves to comb bitumen from each cable wrap approaching the roller. This method is particularly useful when the slits are equal to or only slightly larger than the cable diameter. A blade (not shown) under and in contact or near contact with the cable cross can facilitate removing bitumen from the cable wraps at the crossing location. Bitumen thus removed from the wraps falls or flows into a suitable receiver.

[0122] FIG. **5***b* uses a comb **118** to remove bitumen from the cable **116**. Tines of the comb are shaped and placed between the cable wraps and the back of the comb can either be above the wraps or below the wraps. Bitumen combed from the wraps falls or flows away from the comb into a receiver. The comb can be shaped to have complimentary grooves with the cable wraps. Further, the comb can be formed of any suitable material such as, but not limited to, ultra-high density polyethylene, stainless steel, Teflon-coated materials, polycarbonate, and the like.

[0123] FIG. **5***c* uses a scraper blade **122**, e.g. of ultra high density polyethylene, machined to follow the contour of the cable wraps **120** on a main roller **124**, which is grooved and made of wear resistant material or surface such as those listed above. While scraping, this blade will slowly wear and form itself to fit closely around the contour of the individual wraps as it scrapes bitumen from the roller and from the cable wraps.

[0124] FIG. **5***d* uses a main roller **130** and a recovery roller **132** having complimentary grooves which allow the cable to pass through. Both rollers are grooved and made from wear resistant metal and/or are hard surfaced. The grooves are machined to tolerances that will force most of the bitumen to be squeezed off the wraps **134** before the wraps pass between the rollers. Bitumen thus forced from the wraps is collected in a receiver below the wraps or rollers.

[0125] FIG. **5***e* is similar to FIG. **5***d* except that the recovery roller **140** is a rubber or impressionable roller pressing against the main roller **138**, the rubber being deformed to the contour of the cable wraps on the main roller in order to squeeze bitumen off the wraps **142**. The recovery roller may be made from rubber, urethane or any flexible wear resistant material commonly used for the fabrication of flexible long lasting rollers.

[0126] Another method for removing at least a portion of a second component, such as bitumen, from the endless cable includes heating the endless cable. Since the specific heat of water may be approximately ten times as great as the specific heat of the endless cable, the endless cable rapidly cools down when again coming into contact with the aqueous mixture it separates and thus continues to serve well in capturing bitumen at the mixture temperature of the instant invention. Optionally, the heated endless cable can be cooled or washed by rinsing with water and/or cooled gas. Regardless, excessive heating of the endless cable can be avoided which might otherwise reduce adherence of bitumen during subsequent passes or cause carbon formation on the cable surface.

[0127] An endless cable separation apparatus can be a portion of a process for removing hydrophilic solids from bitumen froth or from bitumen product. Bitumen product or bitumen froth from an oil sand extraction process normally contains water and solids which conventionally are removed by means of dilution centrifuging. This entails deaerating the froth with steam after which the deaerated froth or the bitumen product are mixed with a light hydrocarbon, such as naphtha, heated and centrifuged. The products of dilution centrifuging are clean diluted bitumen, which after naptha removal, is suitable for long distance pipelining or upgrading to synthetic crude oil, and centrifugal tailings which contain water, solids, some naphtha and some bitumen. Dilution centrifuging is a costly operation and any pretreatment which will remove even a portion of the solids and/or water from bitumen froth or from bitumen product is beneficial in reducing the cost of subsequent dilution centrifuging. Alternatively, a cleaner bitumen product may eliminate dilution centrifuging and allow the use of cheaper processing and upgrading. Thus, the separation apparatuses of the present invention can be advantageously used to treat bitumen or bitumen froth prior to dilution centrifuging.

[0128] One alternative embodiment of an overall bitumen clean up process is shown in FIG. **6**. Bitumen product or bitumen froth, water and a suitable chemical (for example a demulsifier) can be introduced into the pump **150** and from there flow through a serpentine pipe **152** described in the Isoelectric Application. The serpentine pipe can act to dislodge hydrophilic solids from bitumen and thus improve bitumen quality. High pressure water may optionally be injected through a side inlet **154** of the serpentine pipe if so desired to further dislodge or disengage hydrophilic solids from bitumen. Initially, in the bitumen product feed or in the bitumen froth, bitumen forms the continuous phase and water forms the dispersed phase. In the serpentine pipe, water and chemicals thoroughly mix with the bitumen product or the bitumen froth to such a degree that bitumen becomes the dispersed phase and water becomes the continuous phase. Hydrophilic particulates previously trapped in the bitumen phase or in the dispersed water phase are released and report to the now continuous aqueous phase.

[0129] This dispersion then flows into an agglomerator **156** surrounded by an oleophilic endless cable belt **158** with the agglomerator as one of the revolvable cylindrical members in the assembly, as described in detail previously. Dispersed bitumen droplets adhere to the tower packings of the agglomerator and grow in size due to adherence to the oleophilic surfaces of the tower packings and subsequently sloughing off in the form of enlarged bitumen droplets. From the agglomerator, the mixture flows to the oleophilic endless cable belt where bitumen is captured by the wraps of the cable belt whilst water and hydrophilic particulates pass through the gaps of the endless cable belt to a receiver **160** and from there to dewatering and disposal. Bitumen is recovered from the belt by methods described in the instant invention and collected in a bitumen product collector **162**.

[0130] Non-limiting examples of suitable chemicals that may be used in the processing may include demulsifiers, acids, buffers or divalent salts to reduce emulsification of the mixture in the serpentine pipe. For example, an acid or buffer may be used if the bitumen froth contains water having a high pH which tends to encourage the formation of tight bitumen in water emulsions in the serpentine pipe. A divalent salt, such as gypsum may be used if the bitumen froth contains natural detergents which also tend to encourage the formation of hard-to-break bitumen in water emulsions in the serpentine pipe. The gypsum would tend to counteract the emulsion formation tendency of the natural detergent by hardening the water.

[0131] In an alternate design, the tower packings in the agglomerator can be replaced by other oleophilic members for adhering oleophilic material. The agglomerator drum in this embodiment, as well as other embodiments, can be situated adjacent to the gaps of the endless cable between adjacent windings and sufficient to allow material to flow from an interior volume of the agglomerator drum through the gaps of the endless cable wraps.

[0132] In another embodiment, the agglomerator drum can be one or more of the revolvable cylindrical members between the endless cable wraps. The agglomerator drum in this case can be positioned between the top flight and the bottom flight of the endless cable, and can be adjacent to the gaps between adjacent windings sufficient to allow material to flow through the gaps of the top flight, or a direct feed, and into the interior volume of the agglomerator drum and from the interior volume of the agglomerator through the gaps of the bottom flight of said endless cable wraps. Alternatively, the revolving agglomerator drum can be spaced from and oriented either between the top flight and the bottom flight or above the top flight. Much discussion has been directed to revolving or moving agglomerators, however, in one aspect, an agglomerator drum can be a stationary vessel.

[0133] One method of assembling an agglomerator drum for use in the present application includes assembling a plurality of longitudinal strips oriented substantially parallel to one another, spaced apart, and oriented to form a cylindrical shape. The strips can be attached at ends to two end discs, one end disc at each end. In one aspect, the longitudinal strips can include notches spaced and oriented to maintain the gaps between adjacent windings of the at least one endless cable, as described in connection with FIGS. **4***a*-**4***c*.

[0134] As may be necessary, the separation apparatus disclosed herein can be located in a variety of locations. A non-limiting example of a location is underground or inside a mine shaft. Such placement can allow for more efficient removal of materials from mining-type operations of a deeply buried oil sand deposit in situ and prior to transport of bitumen product to the surface. In this case some or all the tailings may need to be transported to the surface as well. Oil sand ore normally is very tightly packed and when this ore is disturbed and separated it will tend to fluff up and create more volume than the ore originally in place.

[0135] In yet another embodiment of the present invention, the endless cable device can be used to recover bitumen from conventional caustic tailings found in tailings ponds associated with the Clark process or other similar processes. Current commercial developers of the Clark process see a tailings pond as a means for storing toxic tailings and recovering water for reuse in the commercial process but generally do not use a pond as part of the process for recovering bitumen. As a result, the current commercial plants go to great lengths and expense recover bitumen from the warm tailings before they flow into the ponds and loose their elevated temperatures. However, in accordance with the present invention, a large amount of additional bitumen may be recovered as such a tailings pond is incorporated into a bitumen recovery process utilizing the endless cable devices of the present invention. At current commercial tailings ponds, sand and silt settle out of the tailings and water floats to the top, leaving a sludge containing bitumen, clay fines and water present in a bitumen-rich middlings portion of the pond (e.g. below the water rich layer and above the sand and silt layer). The percent bitumen content of this sludge can be an order of magnitude greater than the bitumen content of the tailings flowing into the pond. In some cases, on a dry basis percentage, sludge may contain as much bitumen as mined oil sand ore. As long as the ponds are not abandoned, this bitumen is not lost but collects in the ponds and may be recovered by oleophilic devices described in this or in the Endless Cable application. Such separation may be carried out at very low temperatures, even approaching zero degrees centigrade when centrifugal tailings (or tailings from other types of hydrocarbon bitumen clean up) are blended with primary and secondary tailings flowing into the pond thereby reducing the viscosity of bitumen of primary and secondary tailings by residual solvent contained in the centrifugal tailings. Without such blending, the separation of sludge from primary and secondary tailings may be carried out by oleophilic means around 10° C. to 20° C. The bitumen rich sludge can be collected using a suitable mechanism, such as but not limited to, pumping with an intake set at the appropriate depth. The collected sludge can then be directed to the endless cable as either the sole feed (optionally mixed with water or other additives to control flowability) or in combination with a crushed sands slurry or other materials as discussed previously.

[0136] When a tailings pond becomes part of the bitumen recovery process of a commercial oil sands plant, and oleophilic means can be used to recover this bitumen. Allowing bitumen to accumulate and concentrate in tailings ponds and then recovering this bitumen at a later date can effectively increase overall annual commercial plant bitumen recovery after the commercial plant has been in operation for some time. Since caustic process aid is used in the current commercial plants, the debitumenized sludge left after recovering bitumen from a current commercial tailings pond (e.g. using the Clark process or its equivalent) remains toxic.

[0137] Mass Transfer

[0138] The endless cable belt of the present invention may be used for a range of chemical engineering mass transfer applications. These may include among others: drying, freeze drying, evaporating, humidifying, gas cleaning, reacting of components in a gas with a liquid, etc. In the application illustrated in FIG. **7**, a gas **170** is passed through slits between sequential wraps of the endless cable **172**. Although not shown in this figure, a plurality of wraps can optionally be oriented substantially parallel as described previously. A feed reservoir **174** and a product reservoir **176** are also shown. As the endless cable passes through liquid in the feed reservoir, some liquid adheres to the endless cable and is drawn upward into a contact region where gases are directed. The gas-liquid contacting can result in a wide variety of mass transfer, chemical reactions or other processes. For example, the feed liquid may be a liquid reactant and the gas may contain or consist essentially of a corresponding gas reactant. Gaseous products or components can be reacted with or be collected and liquid products can be formed and retained on or by the endless cable. Product reservoirs are not required for simple drying, for example, and only one reservoir may be used for humidifying or evaporating, unless the process of humidifying or evaporating results in the production of salts or more concentrated liquids. An optional scraper or a comb may be used to remove crystals from the cable or to remove concentrated liquids and/or liquid products. Furthermore the two rollers **178**, **180** above the product reservoir can serve to squeeze liquid from the cable or to break crystals from the cable. In gas cleaning or in reacting a liquid with the components or impurities in a gas stream, one or several more reservoirs may be required, depending upon the complexity of the unit operation. It should be noted that enclosures, drives, gas inlets and outlets and other auxiliary components are not shown for clarity but are well within the skill of those in the art.

[0139] FIG. **8** illustrates a more complex mass transfer unit than FIG. **7**, and includes four liquid reservoirs **188**, **190**, **192**, and **194**. This embodiment includes an enclosure **196**, a gas inlet **198**, a gas outlet **200**, one or more endless cable belts **202**, nineteen main cylindrical members **204**, and repositioning guides **206** to keep the endless cable or cables on the cylindrical members in the same manner as previously described. In one aspect, two or more of the separate reservoirs can include a distinct liquid composition therein or may contain a common liquid which is recoated over the endless cable upon each pass into the corresponding liquid reservoir. As with other embodiments, when more than one endless cable is used, a guide or set of guide rollers is required for each endless cable, unless single wrap endless cables are used. Such individual repositioning guides may also provide proper tension to the cables. Note that the cable or cables run from main roller to main roller in sequence and return along the top of the figure. In one aspect, one or more of the main rollers can be grooved to accept the cable and maintain predetermined gap distances. The concepts disclosed with FIG. **7** will apply to FIG. **8** in many instances, and visa versa.

[0140] Generally speaking, an apparatus of this type, when dealing with gas-liquid, can include a gas inlet oriented to direct a gas across a flight of the at least one endless cable, and a first liquid reservoir. In one aspect, the revolvable cylindrical members can include a feed roller and an upper roller, where the feed roller is oriented within the first liquid reservoir to contact liquid therein, and the upper roller is remote from the first liquid reservoir. Optionally, alternating upper rollers or respective grooves can be offset from adjacent upper rollers such that adjacent flights of the endless cables are offset in order to allow incoming gases to be more fully exposed to each flight and reduce channeling through unobstructed gas flow paths. The apparatus can optionally include a cable stripping device for use in removing a product material and/or excess liquid adhered to the endless cable.

[0141] Electrically Charged Devices

[0142] One or more endless cables can be electrically charged to achieve specific separation results as explained in more detail below. However, when an oleophilic cable is electrically charged it tends to become less oleophilic due to the mechanism of electrowetting. This means that oil adhering to a cable may become coated with a continuous film of water instead of with water droplets when an electric potential is applied to the cable. Alternately, water may seek to wet part of the cable itself under certain conditions when the cable is electrically charged. This mechanism of electrowetting can be used to advantage for removing bitumen or oil from such a cable in a recovery zone.

[0143] FIG. **9** illustrates another embodiment of an endless cable separation apparatus. This application uses an endless cable **220** that is configured to be charged electrically with a high potential direct or alternating current of a first polarity or phase via a suitable electrical source. In one aspect, the endless cable and two or more revolvable cylindrical members **222**, **224** can be oriented within a containment vessel **226**. The containment vessel can optionally be electrically charged with a high potential direct or alternating current of a second polarity or phase opposite the first polarity or phase.

[0144] The endless cable can be configured to use high voltage AC or DC to separate mixtures. High voltage can be used along with low current flow. In one aspect, one polarity or phase of the high voltage may be attached to the wraps of an endless cable belt and the other polarity or phase may be attached to an external electrode or an adjacent wrap of another endless cable belt such that the wraps of one endless cable are intertwined with the wraps of another endless cable and are of opposite polarity or phase. FIG. **9** may use the second polarity or phase attached to an external electrode **228** surrounding the insulated enclosure **230** of the apparatus.

[0145] This embodiment was tested to condense a petroleum fog resulting from the rapid cooling of a hydrocarbon gas in the presence of finely dispersed particulate matter. The particulate matter formed the nucleus of oil droplets upon condensing of the hydrocarbon gas, resulting in a fog that was very difficult to break. When the electricity was turned off, a dense fog formed in the apparatus. However, in about a second, after 15,000 volts of AC was turned on, the fog broke and produced a clear gas with liquid flowing down the walls of the glass enclosure and along the cable. Particulate matter tended to collect on the cable, which was then wiped clean with a scraper.

[0146] Another embodiment is illustrated in FIG. **10***a* and FIG. **10***b*. The main rollers **244**, **246** are insulated. The endless cable belt **248** can be used as an electrostatic precipitator or coalescer of aqueous phase dispersed in a continuous hydrocarbon phase. A high voltage DC imparts a charge to the dispersed phase as the fluid passes through the gaps of the top flight **250**. Then, as these charged droplets pass the bottom flight **252**, they are attracted to the cables that are of the opposite polarity. When a high voltage AC is used, the dispersed phase droplets vibrate due to the alternating field and some of these droplets coalesce as they come in contact with each other while passing through the top or bottom flight.

[0147] Alternately, this apparatus of FIG. **10***a*-**10***b* can be used as a multi cable separation apparatus to break a hydrocarbon fog or mist as described with FIG. **9**. FIG. **10***a*-**10***b* provides a different view or embodiment of such a device which differs in one main aspect. The device of FIG. **9** uses a single endless cable belt whilst the device of FIG. **10***a*-**10***b* uses two endless cable belts, although additional endless cables can be used. Thus, the device of FIG. **10***a*-**10***b* uses at least two endless cable belts which are wrapped alternately upon the main rollers **244**, **246** to make an intertwined cable device. One cable is charged with a high voltage DC potential or high voltage AC phase. The other cable is charged with a high voltage DC of opposite polarity or with a high voltage AC of the opposite phase. This results in the presence of a high electric potential between adjacent wraps on the insulated rollers. The high voltage DC or AC is applied to the cables by means of the repositioning guides **254**, **256** for each endless cable.

[0148] When a comb or scraper **258** is used to remove water or solids from the cables, it often is more convenient to use four rollers in order to have a region where the cables of opposite polarity are not close to each other. In those spaced regions a comb or a knife can be used to remove solids or water from the cables without danger of bridging the gap between cables of opposite polarity with water or wet solids which might create electrical discharge in view of the high potential electricity used. A four roller device therefore, would prevent or reduce electrical shorts or sparking.

[0149] Slurry Filter

[0150] A moving bed filter can be created by the use of one or more endless cables wrapped a plurality of times with very small gaps around two or more rollers. The sequential wraps can be close enough to form only very narrow gaps or slits through which liquid can flow readily but which prevent the undesirable passage of particulates of the medium to be filtered or dewatered. Undesirable passage of particulates would be any amount that can be substantially reduced without substantially blocking passage of liquids therethrough.

[0151] A two level filter is shown as FIGS. **11***a*-**11***b*, which uses one endless cable **270**. The endless cable acts as a wet or dry sieving sifter or as a slurry dewatering device for a liquid slurry, e.g., desanded tailings from an oil sands process. For example, a screened underflow **272** of a hydrocyclone mainly containing coarse sand can be deposited first onto an upper flight of the filter. The underflow can be distributed onto almost the full width of the filter to form a moving bed of coarse particulates. For simplicity in the drawing, the distributor is here shown as a pipe only. It is to be understood that other distributors can be used which more fully spread the slurry of the upper flight. The wraps of the endless cable are close enough together to prevent coarse sand from passing through the apertures. Again, for sake of illustration clarity, the wraps are shown here much wider apart. The small rollers **274** in FIG. **11***b* indicate that the wraps are kept close together. Generally, gaps between wraps can be distanced apart from about 0.5 mm to about 3 mm, although other gap spacings may be suitable for particular embodiments and slurries. In this case, it may not be as useful to have grooves in the rollers. The twist of a conventional wire rope will normally provide voids adequate for passage of water between the wraps, even when the extremities of the individual wraps are touching. The useful size of gaps depends on many variables of the apparatus, including intended application, intended separation, composition and size of endless cable, composition and particle sizes in the slurry, etc. However, in a specific embodiment, the average gaps between adjacent windings are about 0.01 cm to about 0.1 cm.

[0152] After the coarse sand bed is established, desanded tailings **276** can be deposited on top of the bed created by the coarse sand **272**. The coarse sand then acts as a filtering medium for the desanded tailings which contain water and fines, including fine sand, silt and clay, as well as a small amount of bitumen. These fines would normally pass through the gaps between the cable wraps, but the coarse sand bed underneath prevents or reduces such passage. Dewatered particulates and coarse sand leave the top flight **278** of the filter as a bottom layer and dewatered desanded tailings leave the filter as a top layer. The bottom flight **280** of the filter may be shaken, washed, or blasted with air when it becomes necessary to continuously remove from the bottom flight sticking particulates or bitumen. As with any other embodiment, the main rollers do not have to be the same size. Additional materials can be added to the top flight, and the general concept may be used for other filtering purposes, either as a single stage moving filter or as a multi stage moving filter. In this case the liquid may be water or any other liquid from which particulates are to be recovered.

[0153] Generally, a filter can be formed of the apparatus where at least two of the revolvable cylindrical members are oriented to form an upper flight and a lower flight of the endless cable or cables. The upper flight can be within 45° of horizontal, and the gaps between adjacent windings can be configured to be sufficiently narrow to allow passage of liquid therethrough and retention and conveyance of particulate solids thereon having a predetermined particle size. The apparatus can further include a liquid collection vessel oriented below the first flight and configured to receive the liquid. Additionally, a first slurry outlet can be included, which can be configured or oriented to deposit a first coarse slurry onto the upper flight. Similarly, a second slurry outlet can be included that is oriented to deposit a second slurry onto the upper flight subsequent to the first coarse slurry. Further, the separation apparatus can optionally include a cleaning mechanism operatively associated with the bottom flight to remove debris and material from one or more of the endless cables.

[0154] Physical Separations

[0155] The endless cable belt of the instant invention provides for a large range of apparatus options. In one aspect, it may be used as a particle sizing device which moves various fractions to the appropriate bins in a separation process. FIG. **12***a* illustrates a simple configuration designed to separate a particulate feed into two fractions. Feed is introduced via hopper **300** to the top flight **302** and one larger fraction **304** is removed from the top flight and a second smaller fraction **306** passes through both flights and leaves from the bottom flight **308**. Thus, the flight gaps between wraps can be adjusted to screen varying particle sizes from one another to achieve the desired wet or dry sieving.

[0156] Alternative embodiments include a receiving bin for the third, fourth and fifth fraction, for example, which may be placed under the top flight or flights. This is accomplished when the gaps or apertures between sequential cable wraps increase from one side to another, as in FIG. **12***b*. This is shown for a simple non-vibrating sizing apparatus in FIG. **12***b*. In this case, guides **310** may be useful to keep the endless cable **312** in the grooves of the appropriate roller. Alternatively, additional rollers can be oriented parallel to the outer rollers over which wraps are wound or past over in order to produce multiple zones where gap distances vary in each zone. For example, four size ranges can be produced using four rollers (first through fourth parallel rollers oriented in a plane in numerical order left to right) where the first and second rollers have x wraps, the third roller has x/2 wraps, and the fourth roller has x/4 wraps. In such a case, each subsequent zone, i.e. from left to right, will have a gap distance which is double that of the previous zone. Similarly, multiple separation apparatuses can be oriented in series and/or parallel to further separate the particulate material into additional size ranges. In such cases, each separation apparatus can have gap spacings designed and optimized for separation of a particular size fraction.

[0157] FIG. **13** illustrates still another separation application wherein the endless cable is used as a conveyor system for separating objects which are retained on the endless cable. A package **320** moves along an endless cable belt **322** main conveyor in the direction shown by the arrow. One or a plurality of endless cable belt secondary conveyors **324**, **326** revolve under the main conveyor. Two such secondary conveyors are shown, although additional secondary conveyors can be added. Sets of pins **328** and **330** are located at the gaps between the cables of the overlapping conveyors in a diagonal arrangement. These are pins or rollers, and the elevation of these pins is electronically or otherwise controlled using conventional mechanisms, e.g. hydraulic, electronic motor, spring, etc. When the package is to be directed to the left, onto the first secondary conveyor **324**, the corresponding pins **328** are raised, i.e., by computer. When the package is to be directed to the right onto the second secondary conveyor **326**, the corresponding pins **330** are raised. The processing can be fully automated by including sensors to detect bar codes on packages. These bar codes can be read by the computer which can then control onto which secondary conveyor the package is directed using conventional sorting and inventory software. In this manner a large number of packages, objects, parts, parcels or letters may be directed rapidly and automatically to their respective desired destinations. The use of pins or rollers **328** and **330** are possible because the endless belt of the instant invention does not contain cross members or cross wraps which in a conventional conveyor belt would interfere with such pins or rollers located or rising up between the cable wraps or between longitudinal members of the belt.

[0158] Of course, it is to be understood that the above-described arrangements, and specific examples and uses, are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

What is claimed is:

1. A separation apparatus, comprising:

a) at least one endless cable wrapped a plurality of times around at least two revolvable cylindrical members to form a first wrap, a plurality of subsequent wraps, and a final wrap such that the cable is wrapped from one cylindrical member to another and contacts each of the at least two cylindrical members a plurality of times to form gaps between adjacent windings.

2. The separation apparatus of claim **1**, further comprising a cable stripping device operatively associated with the at least one endless cable, configured to remove material from the endless cable.

3. The separation apparatus of claim **1**, wherein the endless cable is oleophilic.

4. The separation apparatus of claim **3**, further comprising an agglomerator drum having openings oriented in fluid communication with the endless cable to allow passage of fluid from an interior to an exterior of the agglomerator drum and including oleophilic members for adhering oleophilic material.

5. The separation apparatus of claim **1**, further comprising a gas inlet oriented to direct a gas across a flight of the at least one endless cable, and a first liquid reservoir wherein the at least two revolvable cylindrical members includes a feed roller and an upper roller, said feed roller being oriented within the first liquid reservoir sufficient to contact liquid therein and said upper roller being remote from the first liquid reservoir.

6. The separation apparatus of claim **5**, further comprising at least one additional liquid reservoir each including a corresponding additional feed roller oriented within a corresponding additional liquid reservoir.

7. The separation apparatus of claim **1**, wherein the at least one endless cable includes a first endless cable configured to be charged electrically with a high potential direct or alternating current of a first polarity or phase.

8. The separation apparatus of claim **7**, wherein the first endless cable and the at least two revolvable cylindrical members are oriented within a containment vessel, said containment vessel being electrically charged with a high potential direct or alternating current of a second polarity or phase opposite the first polarity or phase.

9. The separation apparatus of claim **7**, comprising a second endless cable wrapped a plurality of times around the at least two cylindrical members such that the second endless cable is wrapped from one cylindrical member to another and contacts each of the at least two cylindrical members a plurality of times to form gaps between adjacent windings of the second endless cable and wherein said the wraps of said second endless cable are alternating with and are located within the gaps of the first endless cable, wherein the wraps of the second endless cable are configured to be charged electrically with a high potential direct or alternating voltage of opposing polarity or of opposing phase to the wraps of the first endless cable.

10. The separation apparatus of claim **1**, wherein the at least two revolvable cylindrical members are oriented to form an upper flight and a lower flight of the at least one endless cable, the upper flight being within 45° of horizontal and wherein the gaps between adjacent windings are configured to be sufficiently narrow to allow passage of liquid therethrough and retention and conveyance of particulate solids thereon having a predetermined particle size and further comprising a liquid collection vessel oriented below the first flight and configured to receive the liquid.

11. The separation apparatus of claim **1**, wherein the gaps between adjacent windings are spaced apart a distance sufficient to size particulate material into at least two separate size ranges and further comprising at least two particulate collection members oriented to collect each the at least two separate size ranges.

12. The separation apparatus of claim **11**, wherein the adjacent windings are non-parallel sufficient to form gradually expanding distances between the adjacent windings from a narrowly spaced end to a widely spaced end of a top flight of the at least one endless cable, wherein a particulate feed inlet is oriented to distribute particulate material over more narrowly spaced portions of the top flight.

13. The separation apparatus of claim **1**, wherein the at least two revolvable cylindrical members are oriented to form an upper flight and a lower flight of the at least one endless cable and further comprising:

a) a secondary separation apparatus including a second endless cable wrapped a plurality of times around at least two secondary revolvable cylindrical members to form a plurality of secondary wraps to form secondary gaps between adjacent windings, said secondary separation apparatus having a secondary upper flight being oriented at an angle with respect to the upper flight and being substantially coplanar therewith; and

b) a plurality of directing pins oriented within junction spaces formed between the gaps and the secondary gaps, said directing pins being elevatable from a lower position to an upper directing position said lower position placing an upper end of the respective directing pin below the secondary upper flight, said plurality of directing pins being selectively elevatable to direct an object on the upper flight to move along the secondary upper flight.

14. A method of separating oleophilic material from hydrophilic material in a flowable material, comprising:

passing the flowable material through at least one continuously moving endless cable, wherein the hydrophilic material passes through gaps between adjacent wrappings in said at least one continuously moving endless cable, said at least one continuously moving endless cable having been wrapped a plurality of times around at least two cylindrical members, such that at least a portion of the oleophilic material is retained on or by the endless cable; and

removing at least a portion of the oleophilic material from the endless cable.

15. The method of claim **14**, wherein the step of removing at least a portion of the oleophilic material from the at least one endless cable includes passing the endless cable through a means for removing oleophilic material.

16. The method of claim **14**, further comprising passing the flowable material through an agglomerator sufficient to increase recovery yields of the second component.

17. The method of claim **14**, further comprising:

collecting a bitumen rich sludge from a tailings pond, said tailings pond having a bitumen rich layer between a top water rich layer and a bottom silt and sand layer; and

directing the bitumen rich sludge to the at least one continuously moving endless cable, wherein the bitumen rich sludge forms at least a portion of the flowable material.

18. A multi-phase method of contacting components of a gaseous flowable material, comprising:

passing the gaseous flowable material through at least one continuously moving endless cable, wherein a first portion of the flowable material passes through gaps between adjacent wrappings in said at least one continuously moving endless cable, said at least one continuously moving endless cable having been wrapped a plurality of times around at least two cylindrical members, such that a second portion of the flowable material contacts the endless cable.

19. The method of claim **18**, further comprising the steps of:

contacting a portion of the endless cable with a liquid sufficient for a portion thereof to coat the endless cable, wherein the endless cable is oriented to transport the coated liquid upwards to a contacting region such that the second portion of the flowable material contacts the coated liquid in the contacting region.

20. The method of claim **19**, wherein the step of contacting involves at least one of crystallization, evaporation, chemical reaction, humidifying, drying, and gas cleaning.

21. The method of claim **18**, further comprising applying a high potential voltage AC or DC to the at least one endless cable while the flowable material passes through the gaps and particulate and droplet material adheres to the wraps of the at least one endless cable for subsequent removal in the presence of an additional electrode charged with DC or AC of opposite polarity or opposite phase than the endless cable.

22. The method of claim **21**, further comprising a second continuously moving endless cable in which the wraps of the second endless cable are interlaced with the wraps of first endless cable, and wherein the wrappings create gaps through which material can flow, wherein the wraps of the second endless cable have opposite electrical charges or opposite electrical phase from the wraps of the first endless cable and wherein particulate and droplet material adheres to the wraps of said endless cables for subsequent removal.

23. The method of claim **18**, wherein the at least one endless cable is configured to charge passing particles for subsequent electrostatic separation.

24. A method of physically separating components of a flowable material containing particulates, comprising:

passing the flowable material through at least one continuously moving endless cable which is oriented and configured to form an upper flight and a lower flight allowing at least a portion of the particulates to be retained on or by the endless cable, wherein a first component of the flowable material passes through gaps between adjacent wrappings in said at least one continuously moving endless cable, said at least one continuously moving endless cable having been wrapped a plurality of times around at least two cylindrical members, such that a second component of the flowable material is retained on or by the endless cable; and

removing at least a portion of the second component from the endless cable.

25. The method of claim **24**, wherein said upper flight is within 45° of horizontal, and further comprising depositing a first coarse slurry onto the upper flight such that at least a portion of solid particulates are retained on the upper flight while at least a portion of liquids pass through the upper flight and separately collecting the portion of liquids and the portion of solid particulates.

26. The method of claim **24**, wherein the flowable material is a substantially dry particulate having a non-uniform particle size range, and wherein the method further comprises depositing the flowable material onto an upper flight of the endless cable such that a first size portion of the dry particulate passes through the upper flight while a second size portion of the dry particulate is retained on the upper flight and separately collecting each of the first size portion and the second size portion.

27. The method of claim **24**, wherein the flowable material is a wet slurry of a particulate and fluid, wherein the particulate has a non-uniform particle size range, and wherein the method further comprises depositing the wet slurry onto an upper flight of the endless cable such that a first size portion of the particulate passes through the upper flight while a second size portion of the particulate is retained on the upper flight and separately collecting each of the first size portion and the second size portion.

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