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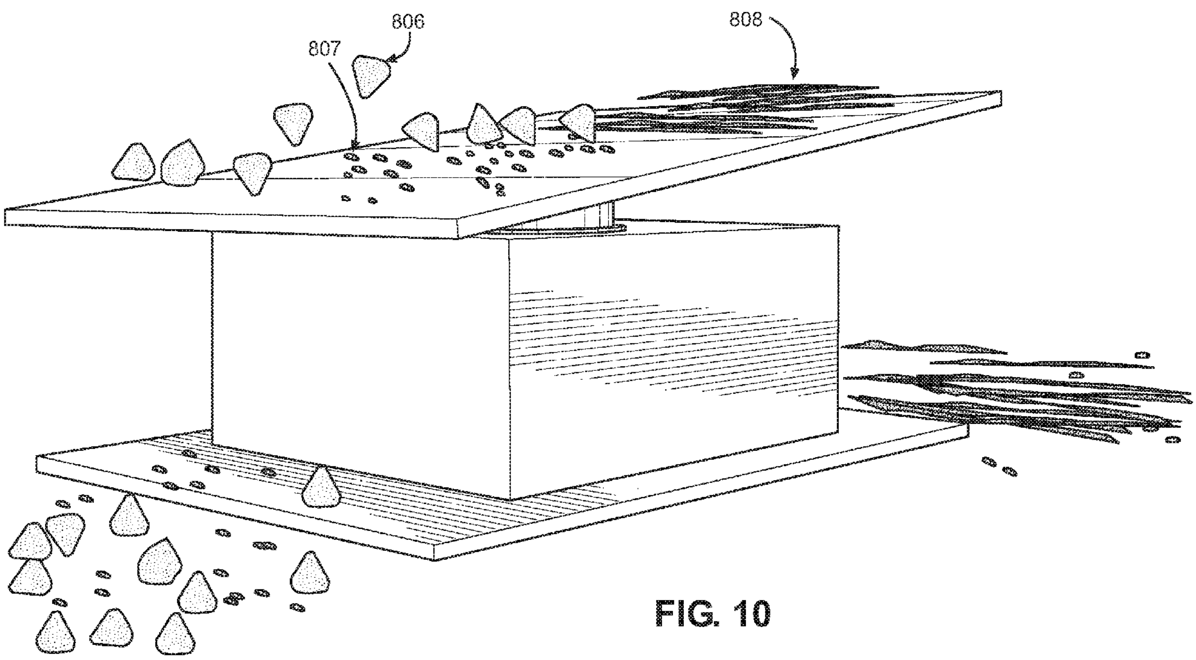

FIG. 10

(57) Abstract: A method of conveying and separating a material into constituent parts includes providing a cellulosic material on a first surface of a plate, and energizing a transducer that is mechanically coupled to a second surface of the plate opposite the first surface of the plate. The energizing of the transducer is sufficient to cause movement of the plate so that a first portion of the cellulosic material preferentially migrates across the surface of the plate in a direction of a first edge of the plate, and a second portion of the cellulosic material preferentially migrates across the surface of the plate in a direction of a second edge of the plate opposite the first edge of the plate.

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SURFACE ACOUSTICS INDUCED MATERIAL CONVEYANCE AND SEPARATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 62/599,703, filed December 16, 2017 and titled "Cymatic Conveyor and Gravity Separator," which is incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure generally relates to the processing of heterogeneous materials, for example within an industrial setting.

BACKGROUND

[0003] Many elements and compounds are naturally found in an impure or heterogeneous state, and are separated into more purified or homogeneous components before they can be put to productive use.

SUMMARY

[0004] A method of conveying and separating a material into constituent parts includes providing a cellulosic material on a first surface of a plate, and energizing a transducer (e.g., a linear actuator or a speaker) that is mechanically coupled to a second surface of the plate opposite the first surface of the plate. The energizing of the transducer is sufficient to cause movement of the plate so that a first portion of the cellulosic material preferentially migrates across the surface of the plate in a direction of a first edge of the plate, and a second portion of the cellulosic material preferentially migrates across the surface of the plate in a direction of a second edge of the plate opposite the first edge of the plate. The movement of the plate can include a substantially unidirectional oscillation. In some embodiments, the second surface of the plate is not orthogonal to an axis of the transducer. The movement of the plate can have at least one of: (1) a frequency that ranges from 0 Hz to about 100Hz, and (2) a range of travel (i.e., a vertical travel distance of the plate during actuation, for example by a linear actuator) of from 0 inches to about 6 inches. For example, the frequency can be about 10 Hz, about 20 Hz, about 25, about 30 Hz, about 40 Hz, about 50 Hz, about 60 Hz, about 70 Hz, about 7 Hz 5, about 80 Hz, about 90 Hz, or about 100 Hz. In some embodiments, the plate is actuated at a

frequency that ranges from between about 10 Hz to about 30 Hz, or about 15 Hz to about 25 Hz, or about 20 Hz to about 40 Hz, or about 25 Hz to about 50 Hz, or about 25 Hz to about 40 Hz, or about 35 Hz to about 50 Hz, or about 18 Hz to about 22 Hz, or about 10 Hz to about 50 Hz, or about 50 Hz to about 75 Hz, or about 75 Hz to about 90 Hz, or about 20 Hz to about 30 Hz, or about 30 Hz to about 60 Hz, or about 25 Hz to about 75 Hz.

[0005] In some embodiments, energizing the transducer includes applying an electronic signal to the transducer, the electronic signal having a waveform that is one of substantially sinusoidal, substantially square, substantially sawtooth, or substantially triangular.

[0006] In some embodiments, the first edge of the plate has a first height, the first portion of the cellulosic material has a first average size, the second edge of the plate has a second height greater than the first height, and the second portion of the cellulosic material has a second average size less than the first average size.

[0007] In some embodiments, the first edge of the plate has a first height, the first portion of the cellulosic material has a first average weight, the second edge of the plate has a second height greater than the first height, and the second portion of the cellulosic material has a second average weight less than the first average weight.

[0008] In some embodiments, the plate includes a sidewall disposed at least partway along a perimeter of the plate.

[0009] In some embodiments, providing the cellulosic material on the first surface of the plate includes conveying the cellulosic material, via an external conveyor, toward the first surface of the plate.

[0010] In some embodiments, an apparatus includes a transducer and a substrate. The transducer is configured to transduce an electrical input, during operation, into a mechanical oscillation output. The transducer can include a linear actuator, an array of linear actuators, a speaker, or an array of speakers. The substrate mechanically coupled to the transducer, such that during operation the substrate mechanically oscillates in response to the mechanical oscillation output of the transducer. The substrate has a pitch with respect to a long axis of the transducer, and the mechanical oscillation of the substrate has a frequency and an amplitude that are based on the electrical input. The electrical input can have an associated waveform that is one of substantially sinusoidal, substantially square, substantially sawtooth, or substantially triangular.

[0011] In some embodiments, during operation, the mechanical oscillation of the substrate causes (1) segregation of a first portion of a material disposed on the substrate from a second portion of the material, (2) movement of the first portion of the material in a first direction along a surface of the substrate, and (3) movement of the second portion of the material in a second direction along a surface of the substrate, the second direction being different from the first direction. The first direction can be substantially opposite the second direction. The substrate can include at least stiffened region configured to bias, during operation, a movement of a material disposed on the substrate along a surface of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1A shows a separator, according to some embodiments.

[0013] FIG. 1B shows an exploded, isometric projection view of the separator of FIG. 1A.

[0014] FIG. 2A shows a front view of a separator plate, according to some embodiments.

[0015] FIG. 2B shows a right side view of the separator plate of FIG. 2A.

[0016] FIG. 2C shows a rear view of the separator plate of FIG. 2A.

[0017] FIG. 2D shows a top view of the separator plate of FIG. 2A.

[0018] FIG. 3A shows a front view of a connector, according to some embodiments.

[0019] FIG. 3B shows a right side view of the connector of FIG. 3A.

[0020] FIG. 3C shows a rear view of the connector of FIG. 3A.

[0021] FIG. 3D shows a top view of the connector of FIG. 3A.

[0022] FIG. 4A is a first side view of a transducer, according to some embodiments.

[0023] FIG. 4B is a second side view of the transducer of FIG. 4A.

[0024] FIG. 4C is a top view of the transducer of FIG. 4A.

[0025] FIG. 4D is a bottom view of the transducer of FIG. 4A.

[0026] FIG. 5A is a front view of a base housing, according to some embodiments.

[0027] FIG. 5B is a side view of the base housing of FIG. 5A.

[0028] FIG. 5C is a bottom view of the base housing of FIG. 5A.

[0029] FIG. 5D is an isometric projection view of the base housing of FIG. 5A.

[0030] FIG. 6A is a front view of a shock-absorbent base, according to some embodiments.

[0031] FIG. 6B is a side view of the shock-absorbent base of FIG. 6A.

[0032] FIG. 6C is a top view of the shock-absorbent base of FIG. 6A.

[0033] FIG. 7 is a process flow diagram showing a process for material conveyance and separation, according to some embodiments.

[0034] FIG. 8 is a block diagram of a system for material conveyance and separation, according to some embodiments.

[0035] FIGS. 9A-9E show a variety of different pitch configurations for the separator, according to some embodiments.

[0036] FIG. 10 shows an isometric projection perspective view of a separator during operation and with working material on the surface, according to some embodiments.

[0037] FIGS. 11A and 11B show side and top views, respectively, of a system including a separator and a conveyor disposed above the separator to feed material onto a working plate of the separator, according to some embodiments.

[0038] FIG. 12 shows an assortment of separator plate geometries and configurations, according to some embodiments.

[0039] FIGS. 13A and 13B show side and top views, respectively, of a system in which material is fed from a conveyor to multiple separators, according to some embodiments.

[0040] FIG. 13C is a photograph showing a multiple separator system, including a feed conveyor and a splitter ramp, according to an embodiment.

[0041] FIG. 13D is a photograph showing a large, single-speaker separator system, according to an embodiment.

[0042] FIG. 13E is a photograph showing a large separator system with an array of multiple speakers, according to an embodiment.

[0043] FIGS. 13F and 13G are photographs showing multi-separator system, in a series and T-shaped configuration, respectively, according to some embodiments.

[0044] FIGS. 14A and 14B are photographs showing an example starting material, comprising cannabis trimmings, according to an embodiment.

[0045] FIGS. 15A and 15B are photographs showing an example first post-separation component, comprising flower material, according to an embodiment.

[0046] FIGS. 16A and 16B are photographs showing an example second post-separation component, comprising leaf material, according to an embodiment.

[0047] FIGS. 17A-17C are photographs showing an example third post-separation component, comprising keef material, according to an embodiment.

DETAILED DESCRIPTION

[0048] Devices and apparatuses of the present disclosure can be used for conveying, arranging, segregating, sorting, and/or separating heterogeneous solid material mixtures that remain after or originate from harvesting/mining processes and/or simply make up the components of major crops/raw resources. In some embodiments, a separator (also referred to herein as a material separation device) is configured to impart oscillations or other movements to a pitched working surface (also referred to herein as a plate, a working plate, a substrate, or a deck) using controlled frequency and amplitude (also referred to herein as a volume or height of travel) such that material disposed on the working surface vibrates in resonance with, or under the influence of, traveling surface waves up the incline of the vibrating pitched surface (e.g., motion due to surface acoustic propulsion). Constituents of the material having different properties (e.g., densities, sizes, shapes, weights, chemical compositions, aerodynamics, etc.) can travel in differing (in some cases, substantially opposite) directions when placed on the working surface and operated at sufficiently high slope and level of agitation/volume because the rounder and/or more dense material will begin to travel down the slope by bouncing (e.g., evading the traveling surface wave/acoustic propulsion more) and/or by gravity (e.g., falling or rolling), such that mixtures are separated into distinct homogeneous/concentrated solutions. In some embodiments, the material to be separated, conveyed and/or arranged is a plant material or cellulosic material.

[0049] Separation processes are important to a wide variety of industries, including mining, manufacturing, food, pharmaceuticals, and basic research, and thus can be used to process a wide variety of different types of materials. The ability to guide and move separate materials along desired paths using a relatively low amount of energy has far-reaching practical appeal.

[0050] In some embodiments, a material separation device includes one or more transducers that are configured to convert one or more input electronic signals into one or more mechanical movements (e.g., unidirectional mechanical oscillations). An example transducer is a linear actuator. The material separation device can also include a plate that is affixed to the transducer. For example, an attachment can attach to and extend from the bottom center of the plate, and also be attached/affixed to a shaft of a vertically held linear actuator. The plate can be positioned such that it is perpendicular to the shaft of the linear actuator, or the plate can be inclined relative to the ground (e.g., by a small angle). The plate can oscillate or otherwise move according to (e.g., in response to, in synchrony with, or under the influence of) the linear actuator/transducer operation. The material separation device can also include a structural base to secure the transducer in place. The base can be set level, can be set at a fixed angle, or can be adjustable (e.g., such that a tilt of the base or a surface thereof can be tilted). The material separation device can also either include, or be configured to interface with, a source of an electronic signal input. The electronic signal can have one or more waveforms associated therewith. Example waveforms include (but are not limited to): one or multiple sine waves, one or multiple square waves, one or more sawtooth waves, one or multiple triangle waves, or any combination or juxtaposition thereof. The electronic signal can influence the frequency (e.g., low frequency, such as from 0-100 Hz) of the plate, and the distance traveled (e.g., from 0 inches to about 6 inches) by the plate during operation. The material separation device can also include, or be configured to interface with, a power source to drive electronics of the material separation device. The electronics can include, but are not limited to: the transducer (e.g., an actuator), one or more signal controllers, one or more cooling devices (such as fans) and/or one or more sensors (such as temperature sensors, gyroscopes, position sensors, etc.).

[0051] In some embodiments, the material separation device is operated with an electronic input signal having a predetermined or pre-specified frequency and/or amplitude. During operation, the plate can move substantially in synchronization with (or resonant with) the electronic input signal. The predetermined or pre-specified frequency and/or amplitude can be selected, for example, to cause softer, flatter, lighter and/or less dense materials to preferentially migrate upwards ("climb up") along the surface (which may be sloped) of the vibrating plate, while harder, rounder, heavier and/or more dense materials will migrate downward (e.g., by sliding, bouncing and/or falling) down the slope.

[0052] In some embodiments, the material separation device is used as a conveyor/feeder device, can be configured (e.g., based on at least one of a plate geometry, a plate treatment/conditioning, and a property of the electronic input signal) such that at least a subset or portion of the material disposed on the plate moves either preferentially upward/uphill or preferentially downward/downhill, e.g., depending on the frequency of the electronic input signal. Such movement of the material can be achieved, for example, using a relatively low pitch angle on the plate and a relatively low signal volume or amplitude. Alternatively, such movement of the material can be achieved at relatively high signal volume in combination with the utilization of one or more stiffening and/or damping modifications on the plate. Stiffening and/or damping modifications to the plate can serve to bias the direction of motion of the material, as compared to the type of motion induced on the unmodified plate, by using surface waves/distortions and correspondingly adding to and/or modifying the distribution of displacement/agitation/amplitude along the plate. As used herein, "volume" can refer to an acoustic/sound volume level (e.g., of a speaker).

[0053] In some embodiments, the material separation device can be configured (e.g., based on at least one of a plate geometry, a plate treatment/conditioning, and a property of the electronic input signal) such that similar objects (e.g., from a plurality of objects making up a material disposed on the plate of the material separation device) are aligned or substantially aligned in a particular direction relative to device operation, for example according to or based on the individual density distributions in the objects, such that the similar objects all face the same direction (or substantially the same direction) during travel. Alternatively or in addition, the material separation device can be configured to distribute or "spread" one or more products for uniform distribution and/or transfer, for breaking up or de-clumping bulk materials, and/or in preparation for leveling/topping-off in product packing applications.

[0054] In some embodiments, the material separation device can be configured (e.g., based on at least one of a plate geometry, a plate treatment/conditioning, and a property of the electronic input signal) to create one or more gradients in a material disposed on a plate thereof. Alternatively or in addition, the material separation device can be configured to induce an assembly or arrangement of patterns in solution-based composite solutions cast onto the plate (or "vibrating deck"). In some such embodiments, a desired diffusion and/or assembly of constituent materials at particular operating parameters can be achieved, to produce patterned films as the solutions settle and dry.

[0055] In some embodiments, the material separation device can be configured for use in conjunction with one or more linear actuator phased arrays, e.g., for enhanced capturing and containment functionality.

[0056] In some embodiments, the material separation device can be powered by one or more alternative or passive energy sources, and in turn be utilized as an electrostatic generator using appropriate triboelectric materials with electrical connections to ground and to a battery, e.g., to transfer static charges and to collect said charges from the environment.

<u>Overview of Separation Methods</u>

[0057] As used herein, a "separation method" can refer to any process used to convert, subdivide, or segregate a mixture or combination of materials having different properties (e.g., different shapes, sizes, densities, weights, chemical compositions, etc.) into two or more of its distinct constituents (or subgroupings thereof). The distinct constituents, once separated out, can include one or more concentrated mixtures and/or one or more pure (non-mixture) constituents. Separated constituents can differ in one or more chemical properties and/or physical properties, such as size, shape, mass, density, and/or chemical affinity. Separation can be classified based on how the separation is achieved. In some cases, a desired degree of separation is achieved using a single separation method. In other cases, a desired degree of separation is achieved using multiple separation methods performed concurrently or sequentially. When multiple separation methods are used, the separation methods can be the same (e.g., multiple iterations of the same separation method) or different from one another (e.g., a first separation method, followed by a second separation method different from the first separation method).

[0058] Some separation techniques for liquids, gases, and solids include the use of a fluidized environment and rely on gravitational force(s) to separate/segregate materials according to their specific densities. For example, preferential flotation methods utilize a sinking chamber to accomplish such separation.

[0059] Gravity separation of disparate solids is an industrial method of separating two components, of either a suspension or a dry granular mixture, where separating the components with gravity is sufficiently practical because the components have different specific weights. A density separator can be used to separate/segregate components of a material, such that the resulting (post-separation) material exhibits a graduated progression in physical distribution from least dense material to most dense material, smallest material to largest material, and/or least aerodynamic material to most aerodynamic material. Known dry material stoner devices, by contrast, are typically limited to two-way separation (i.e., separation of a dry mixture into two components thereof). In other words, while a density separator can classify intermediate materials using a middling fraction, the typical dry material stoner device does not have this capability. Instead, the dry material stoner device removes a small amount of heavy material from large amounts of light material, producing a relatively clean, heavy concentrate without great product loss. During operation of the dry material stoner device, the starting material is fed onto a flat, porous deck that vibrates with a straight-line reciprocating motion. Unlike the density separator, the dry material stoner deck slopes in only one direction, such that heavy particles sink to the bottom of the stratified bed and are conveyed upward to the reservoir behind the discharge throat. The light product particles, lifted by the fluidizing air, flow down slope to the discharge spout at the lower end.

[0060] The term "spiral separator" can refer to either a device for separating components of a slurry according to their densities (i.e., a wet spiral separator), or to a device for sorting particles by shape (i.e., a dry spiral separator). Dry spiral separators, capable of distinguishing round particles from non-round particles, are used to sort components of a feed material based on their shape. A dry spiral separator generally includes a tower, around which is wound an inwardly inclined flight. A catchment funnel is positioned around this inner flight. Round particles roll at a higher speed than other objects, and thus are flung off the inner flight and into the collection funnel. Shapes that are not sufficiently round are collected at the bottom of the flight. Centrifugal jigs and concentrators are similar to spiral separators, but utilize a tumbler or a spinning chamber rather than a winding slope.

[0061] Reichert cones, typically used in mining, are a type of pinched sluice device, in which both lighter material and heavier material fall downhill, but lighter material separates to the top, having a radial geometry rather than a linear geometry.

[0062] Threshing is a process of loosening the edible part of grain (or other crop) from the husks and straw to which it is attached. The threshing process can remove seeds from stalks and husks, and is a step during grain preparation that takes place after reaping but before winnowing, which separates the grain from the chaff, and does not remove the bran from the grain.

[0063] Wind winnowing is an ancient agricultural method that, in its simplest form, involves throwing a material mixture into the air so that the wind blows away the lighter chaff, while the heavier grains fall back down for recovery. Variations of the wind winnowing technique have included using a winnowing fan (a shaped basket shaken to raise the chaff) or a tool (e.g., a winnowing fork or a shovel) on a pile of harvested grain. Modern versions of wind winnowing, used in developed areas, involve the use of a machine, such as a combine harvester, which harvests, threshes, and winnows the grain while it is still in the field. However, the simpler machines are still used in low-capital farming contexts, both in developing countries and in developed countries on small farms that strive for especially high levels of self-sufficiency.

[0064] Destoners are a type of modern industrial processing equipment that use dual weighted pendulums attached to a rotary motor (optionally having variable speed) to create vibration throughout an entire machine, and have an inclined/sloped plate or series of plates, which relies on the throw angle of the overall vibration to jitter lightweight material up the incline/slope while heavy material falls downwards. These machines can be very loud (>100 dB), while also being relatively heavy and costly.

[0065] Vibratory conveyors are sometimes used to physically move and sift or sort raw materials over a short distance. Instead of using a conveyor belt that runs on rollers, vibratory conveyors use an angular pitch along with a controlled throw distance from a neutral rest position to propel material (or product) forward within a conveyor trough. Similarly (but with notable differences), a screw conveyor or auger conveyor uses a rotating helical screw blade, usually within a tube, to move liquid or granular materials.

[0066]

Vibrational Studies

[0067] Cymatics, from Greek meaning "wave", is a subset of modal vibrational phenomena. The term was coined by Hans Jenny (1904-1972), a Swiss follower of the philosophical school known as anthroposophy. When the surface of a plate, diaphragm, or membrane (optionally held level) is vibrated, regions of maximum and minimum displacement can be made visible using a thin coating of particles or liquid on the surface. Different patterns can emerge within the working medium depending, for example, on the geometry of the plate and the driving frequency. When observing the movement of sand on a vibrating plate in the 1780s, Ernst Chladni noticed that the sand tended to move toward a predictable set of points/regions, depending on the frequency at which the plate was vibrating. These points/regions can be referred to as 'nodal lines' - a phrase coined by the scientist Michael Faraday, and are the areas of the vibrating plate which are not experiencing vibration because they exist at the boundary of two regions of the plate that are vibrating in opposite directions, canceling one another out.

[0068] When a surface is subject to vibration, it can distort in a non-uniform way, having areas/regions of greater and lesser distortion. Imagine attaching a rod to the center of a large floppy piece of card and holding the rod in your hand with the card on top, now move the rod directly up and down. The card begins to flex or distort its flat appearance. The energy from the movement of the rod radiates outwards from the center of the card where the rod is attached, in the form of vibrational waves that travel through and distort the surface of the card or plate. Such vibrational waves can be referred to as bending waves. Now imagine, rather than being moved up and down by hand, that the rod was attached to a device that can vibrate tens or hundreds or thousands of times per second with precise strokes. This latter description describes the action of some embodiments of the present disclosure.

[0069] Areas or regions of the greatest distortion to the surface of a vibrating plate can be generated in response to the frequency of vibration from waves reflecting at the edges of the plate, and in between these areas or nodes, nodal lines can be disposed. When a working/feed/starting material, such as sand, is sprinkled onto the plate to reveal these distortions, the material can be displaced by the peaks and troughs (or areas/regions of greatest distortion) that shift or "push" the material out of the way, causing it to settle along the nodal lines. The distribution of product that has settled on/along nodal lines, visible on the working plate during or after operation of the separator, can be regarded as an inverted representation of the wave shape that moves/moved through the plate as the working material was moved and/or separated on the working plate, ultimately gathering/collecting where the wave was/is absent. In some embodiments, increasingly complex patterns can be obtained by using increased frequencies of vibration of the working plate.

[0070] The vibration of plates can be considered a special case of the more general problem of mechanical vibrations. Equations governing the motion of plates can be simpler than those for general three-dimensional objects, since one of the spatial dimensions of a plate is typically much smaller than the other two. As such, a two-dimensional plate theory can serve as an excellent approximation of the actual three-dimensional motion of a plate-like object. Several theories have been developed to describe the motion of plates, the most commonly-used being the Kirchoff-Love theory and the Mindlin-Reissner theory. Additional details on these theories can be found in (1) Jump up, A. E. H. Love, *On the small free vibrations and deformations of elastic shells*, Philosophical trans. of the Royal Society (London), 1888, Vol. série A, N° 17 p. 491–549, and (2) Reddy, J. N., 2007, Theory and analysis of elastic plates and shells, CRC Press, Taylor and Francis, the entire contents of each of which is herein incorporated by reference in its entirety for all purposes.

[0071] Solutions to the governing equations predicted by these theories can provide insight into the behavior of plate-like objects under both free conditions and forced conditions. The modellable behavior can include wave propagation as well as the study of standing waves and vibration modes in plates.

[0072] Boundary conditions for the vibration of plates were described in 1850 by G. R. Kirchhoff, and a mathematical description of vibrational behavior of a rectangular flexible membrane, which is important for the understanding of the sound emitted by drums, was solved for the first time by Simeon Poisson. The vibration of a circular membrane was studied by R. F. A. Clebsch in 1862. Since that time, vibration studies have been performed on a variety of practical mechanical and structural systems. For example, in 1877, Lord Baron Rayleigh published his work on the theory of sound, considered a classic on the subject of sound and vibration. Notable among the many contributions of Rayleigh is the method of finding the fundamental frequency of vibration of a conservative system by making use of the principle of conservation of energy (now known as Rayleigh's method). This method proved to be a helpful technique for the solution of difficult vibration problems. An extension of that method, which can be used to find multiple natural frequencies, is known as the Rayleigh-Ritz method.

[0073] Recently, a method was devised for the controlled movement of multiple objects using a single sound source. See Quan Zhou, Veikko Sariola, Kourosh Latifi, and Ville Liimatainen, *Controlling the motion of multiple objects on a Chladni plate*, Nature Communications, 7, 2016, the entire contents of which are herein incorporated by reference in their entirety for all purposes. As detailed in *Zhou*, objects could be manipulated such that the objects spelled out words on a surface. The manipulation included guiding the objects over the surface into a pattern, in a manner that could be captured by time-lapse photography. To achieve the pattern, "melodies" were constructed, such that the transitioning notes would cause the objects to move in a predictable manner/programmed path along nodal lines specific to that resonant frequency.

[0074] Since Chladni published his observations in *Discoveries in the Theory of Sound* in 1787, the prevailing view has been that although the movement of particles on a vibrating plate toward nodal lines can be predicted based on the frequency of the plate's vibration, the movement of particles outside these nodal lines is essentially random. The randomness of particles outside of nodal lines meant that the movement of these particles could not be controlled. *Zhou*, however, demonstrated that object movement outside of nodal lines can be predicted, and that multiple objects can be manipulated with a high degree of precision.

[0075] Another study, by *Viswarupachari*, investigated transport of particles on a cantilevered plate (i.e., a plate that is fixed along one edge), when vibrated asymmetrically in its plane. A friction model with both dry and viscous friction terms was considered. Nonlinear frictional interaction between the particle and the plate, and asymmetry in the vibrations of the plate, were deemed essential for the transport process. Two kinds of asymmetry - namely spatial asymmetry and temporal asymmetry - in the plate vibrations were also considered. The transport mechanism and transport properties for both kinds of input motion (spatial and temporal asymmetries) were identified, with three dimensionless parameters characterizing the transport properties, and two energy metrics defined for describing the efficiency of the transport process. Additional details can be found in Ch. Viswarupachari, Anirvan DasGupta and S. Pratik Khastgir, *Vibration Induced Directed Transport of Particles*, *J. Vib. Acoust* 134(5), 2012, the entire contents of which are herein incorporated by reference in their entirety for all purposes.

[0076] Levitation technology, or "acoustic levitation," is the manipulation of material with sound. It has been established that ultrasonic standing waves are capable of suspending small particles within sound pressure nodes, and to date have been used to levitate lightweight particles and water droplets. A study by *Ochiai* considered extended acoustic manipulation whereby various millimeter-sized particles were levitated and moved three-dimensionally using localized ultrasonic standing waves generated by multi-dimensional phased linear actuator arrays. Additional details on these theories can be found in Yoichi Ochiai, Takayuki Hoshi, Jun Rekimoto, *Three-dimensional Mid-air Acoustic Manipulation by Ultrasonic Phased Arrays*, 2006, the entire contents of which are herein incorporated by reference in their entirety for all purposes.

<u>Overview of Separator System and Methods</u>

[0077] In some embodiments of the present disclosure, a separation technique includes physical vibration (optionally with distributions in vibration across a surface) and gravitational force, performed on and/or above the surface, can be performed under atmospheric conditions (but is not limited to ambient atmosphere), and is used to separate/segregate solid matter (but is not limited to solids). Depending upon the embodiment or implementation, one or more of (1) an overall pitch of the machine, plate and/or working surface, (2) a frequency or type of traveling wave (e.g., low frequency, ~12-20 Hz, or higher frequency, ~30-60 Hz, modes), (3) the volume or level of agitation and throw distance/speed, and (4) the feed rate of the material is adjustable and/or tunable to achieve a desired operation.

[0078] In some embodiments, a separator includes a transducer (optionally comprising an actuator) or an array of transducers that drives a substantially horizontally oriented, and optionally inclined with respect to the horizontal plane (i.e., semi-horizontal), plate/surface (or series of plates). The transducer(s) can cause the plate/surface(s) to oscillate with a precise, predefined periodicity and/or amplitude. The transducer(s) and plate(s)/surface(s) can have any of a wide variety of configurations, shapes, and sizes. During operation of the separator, material including, for example, distinctly lighter and heavier pieces, can be separated into constituent parts thereof by placing the material (which may be a mixture) onto the plate/surface, optionally tilting the plate/surface such that it defines an inclined plane that is angled with respect to the horizontal plane, and vibrating the plate/surface (e.g., via a driving/actuation motion along an axis that is perpendicular with respect to the ground/horizontal plane) at a predefined frequency and volume such that at least a portion of the material (e.g., one or more constituents thereof) preferentially migrates/climbs upwards toward (and, optionally, falls off) the highest edge of the plate/surface, while dissimilar material bounces, rolls and/or falls down the sloped surface toward (and, optionally, off) the bottom edge of the plate/surface.

[0079] FIG. 1A shows an electromechanical separator in an assembled/constructed form. As shown in FIG. 1A, the separator 100 includes a plate 101 having a working surface (e.g., the topmost planar surface thereof), a connector 102 (e.g., a cylindrical coupler) disposed between the bottom center of the plate and a transducer 103 (and contacting and/or affixed to each), a base or housing 104 configured to receive and/or support the transducer 103 and the plate 101 attached to the transducer 103, and an optional shock absorbent/isolating base/pad 105. FIG. 1B shows an exploded isometric view of the separator of FIG. 1A. The transducer 103 can include a linear actuator. Alternatively or in addition, the transducer 103 can be an electromagnetic transducer, The transducer 103 can be configured to move the plate 101, optionally without the use of springs, belts, bearings, lubricants, pumps/jets, or mechanical engine/motor components. An input to the transducer (not shown) can be connected to the output of a controller/amplifier/waveform generator (which may be internal to the separator and/or external to the separator) and to a power source (which may be internal to the separator and/or external to the separator).

[0080] In some embodiments, components of the separator 100 (e.g., plate 101, connector 102) are formed from or include lightweight but dense/rigid materials, such as high-density sandwiched foam core and industrial adhesives.

[0081] FIGS. 2A-2D show front, right side, rear and top views, respectively, of a separator plate, according to some embodiments. The side view of FIG. 2B shows that the separator plate can be positioned at an angle/pitch. FIGS. 3A-3D show front, right side, rear and top views, respectively, of a connector for a separator, according to some embodiments. FIGS. 4A-4D show first side, second side, top and bottom views, respectively, of a transducer for a separator, according to some embodiments. FIGS. 5A-5D show front, side, bottom and isometric projection views, respectively, of a base housing for a separator, according to some embodiments. As shown in FIG. 5D, a hole/recess is defined in the base housing, to at least partially receive, support and/or connect to a transducer. FIGS. 6A-6C show front, side, and top views, respectively, of a shock-absorbent base for a separator, according to some embodiments. The shock-absorbing base can serve as an isolating foundation during operation of the separator.

[0082] FIG. 7 is a process flow diagram showing a process for material conveyance and separation, according to some embodiments. As shown in FIG. 7, the process 700 includes providing a material onto a separator plate (or substrate, or deck) surface, at 752, optionally by conveying the material toward the separator plate (730). A transducer of the separator is then energized, at 734, to cause at least one of conveyance, separation, and arrangement of the material into multiple constituent parts/portions.

[0083] Table 1, below, shows experimental data comparing a variety of starting materials ("Inputs") to corresponding separated/sorted portions thereof ("Outputs"), and providing analytical data regarding the results of the experimental run for each row. All starting materials described in Table 1 may be referred to as "standard cannabis trimmings" – a mixture of leaf-rich material with < about 50% flower, which includes keef powder (which was collected), and which has stems that were ignored. The data was obtained using a 24" x 39" rectangular plate, weighing about 6 pounds and being pitched about 2 degrees from level with the horizontal plane. The transducer was operated with an input 20Hz sine wave. The power and volume of the amplifier/speaker was adjusted to achieve a throw distance of about 1 centimeter (cm). The "Percent Yield" is based on an amount of flower and powder obtained/yielded from the starting material. For each experimental run shown in Table 1, the separation efficiency was > 90% for a single pass of the starting material through the system.

In other words, more than 90% of the desired flower was successfully separated/removed from the unwanted leaf from the overall collection of trimmings.

INPUTS			OUTPUTS			ANALYSIS		
Material Strain	Total Initial Weight	Run Time	Flower Weight	Leaf Weight	Powder Weight	Percent Yield	Separation Speed	Yield Speed
Holy Grail	2547 g	1.5 hr	391 g	1986 g	170 g	22.06%	3.74 lbs/hr	0.82 lbs/hr
Platinum OG	4647 g	3.92 hr	1750 g	2857 g	40 g	38.52%	2.62 lbs/hr	1.01 lbs/hr
Dosido	5965 g	4.17 hr	1810 g	4042 g	113 g	16.38%	3.16 lbs/hr	0.52 lbs/hr
Lemon Banana Serbert	10964 g	5.92 hr	659 g	9987 g	318 g	17.54%	4.09 lbs/hr	0.72 lbs/hr
Platinum OG	7983 g	4 hr	783 g	6968 g	232 g	12.71%	4.4 lbs/hr	0.56 lbs/hr
Dosido	10869 g	6.5 hr	938 g	9415 g	516 g	13.38%	3.69 lbs/hr	0.49 lbs/hr
GB Kush	2022 g	1.5	831 g	1103 g	88 g	45.45%	2.97 lbs/hr	1.35 lbs/hr
Rollins	1499 g	1.17 hr	212 g	1279 g	8 g	14.68%	2.83 lbs/hr	0.42 lbs/hr
Dosido	1542 g	1.7 hr	384 g	1142 g	16 g	25.94%	2 lbs/hr	0.52 lbs/hr
OG Platinum	4976 g	7.08 hr	830 g	3782 g	364 g	24%	1.55 lbs/hr	0.37 lbs/hr
Gelato	4536 g	1.5 hr	1458 g	2767 g	311 g	39%	6.67 lbs/hr	2.6 lbs/hr
Holy Grail	11113 g	4.5 hr	3023 g	7757 g	333 g	30.20%	5.44 lbs/hr	1.64 lbs/hr
Lemon Banana Serbert	12700 g	5 hr	2970 g	9253 g	477 g	27.14%	5.6 lbs/hr	1.52 lbs/hr
Rollins	2041 g	1 hr	535 g	1406 g	100 g	31.11%	4.5 lbs/hr	1.4 lbs/hr
Dosido	7257 g	4 hr	1492 g	5330 g	435 g	26.56%	4 lbs/hr	1.06 lbs/hr

Table 1: Experimental data for multiple separation runs with differing starting materials

[0084] FIG. 8 is a block diagram of a system for material conveyance and separation, according to some embodiments. As shown in FIG. 8, the system 800 includes a separator 842, an optional external conveyor 840, and an optional collection receptacle 844. The separator 842 includes a plate 842A, a transducer 842C, a connector 842B disposed between the plate 842 and the transducer 842C and coupling them mechanically and/or electrically to one another, a base 842D mechanically coupled to the transducer 842C, and an optional shock absorber 842E mechanically coupled to the based 842D.

[0085] In some embodiments, a variable frequency/volume drive is used to operate the transducer of the separator. The power for driving the transducer can be relatively low (e.g., less than 1 horsepower, or less than 750W). Alternatively or in addition, a noise level associated with the operation of the separator can be relatively low (e.g., less than about 55 dB). Alternatively or in addition, the transducer of the separator can be operated at a relatively low frequency (e.g., about 20 Hz).

[0086] In some embodiments, a relatively heavy and shock-absorbent base (e.g., base 104 in FIG. 1A-1B) to house/support the transducer (e.g., transducer 103 in FIG. 1A-1B). For example, the transducer can be secured tightly and flush with the hole/recess defined in a top face of the base (e.g., as shown in FIG. 5D), by using the appropriate hardware connections. In some implementations, the base is configured not to move (or to exhibit substantially no movement) in response to the transducer operation, and/or is configured not to transmit the transducer signal through its body, rather remaining motionless or substantially motionless. The base can also be configured to dissipate vibrational signals well. In some embodiments, the base is positioned atop (and optionally affixed to) shock absorbent/insulating pad/mat (e.g., shock absorbent/isolating base/pad 105 in FIG. 1A-1B), which can be formed, for example, from a dense foam or rubber material, or any other suitable shock-absorbing material. In other words, the base can be acoustically isolated from its surroundings as much as possible, and/or can serve to passively dampen reaction forces that are created from the dynamic motion of the plate. The ability of the base to passively dampen such forces can be due, for example, to having an appropriate mass and/or dampening material properties.

[0087] One or both of the base (which may itself hold the transducer, for example level with the ground) and the plate can be inclined relative to the transducer, or can be pitched at alternative angles. FIGS. 9A-9E show a variety of different pitch configurations for the separator (e.g., positional relationships between the transducer and the plate), according to some embodiments. FIG. 9A shows the case where the transducer (e.g., a linear actuator) is held level and the plate is also held level. FIG. 9B shows the case where the plate is orthogonal (i.e., is not angled) with respect to the transducer, but the transducer actuator itself is no longer level (i.e., is angled/pitched), and therefore the overall plate is pitched relative to the ground. FIG. 9C shows the case where the transducer is held level but the plate is pitched relative to the transducer, and therefore is pitched relative to the ground. FIG. 9D shows the case where the plate is pitched relative to the transducer and the transducer is pitched towards the low end of the inclined plate. FIG. 9E shows the case where the plate is pitched relative to the transducer and the transducer is pitched towards the high end of the inclined plate, but the overall plate angle is still sloped relative to ground. A further pitch configuration (not shown) is where the overall pitch angle of the plate is level (i.e., parallel with a ground/horizontal plane) as a result of a pitch of the plate and an opposing pitch of the transducer canceling each other out.

[0088] Pitching of the plate can serve to bias rounder/more dense material to fall, and the overall pitch can be determined by taking into account, for example, two major angles of concern: the angle of the plate relative to the transducer (the "plate angle/pitch," which may dictate an amount of gravity separation involved) and the angle of the transducer relative to the ground (the "linear actuator angle," which corresponds to the physical "throw angle" or direction of bouncing the working material).

[0089] The pitching of the transducer (e.g., linear actuator) relative to a plane that is level with the ground can result in a small amount of lateral force in that direction. Pitching the transducer towards the high end of the plate can bias the throw angle (i.e., the direction of throwing or oscillating/bouncing of the working material) such that the working material (the material to be refined/separated) will climb uphill more easily, while pitching the transducer at an angle towards the low end of the plate will make it more difficult for material to climb up the slope of the inclined surface even when the maximum cymatic response/forces are utilized (i.e., imposed using the appropriate frequency and volume and distortion distribution). In some embodiments, the plate can be secured such that the angle of the plate relative to the ground is adjustable, or such that the whole plate can be attached, removed, and reattached (e.g., using appropriate fasteners) to the transducer, for example to account for vibration damping, without moving or changing the pitch of the base and transducer, thereby keeping the base and transducer level. In other embodiments, the base includes adjustable feet or leveling casters that can be used to level the separator or to change the pitch of the separator.

[0090] Embodiments of the present disclosure facilitate the control of an input signal to the transducer. For example, one or more of the input signal frequency, input signal amplitude/signal volume, and shape/type of the input waveform can be controlled, according to a desired conveyance, distribution/patterning, and/or separation results. Frequency refers to the repetition of cycles up and down that the plate is oscillated per unit time (e.g., per second), and corresponds to or defines the speed at which the plate oscillates/vibrates, thereby governing the resulting surface waves. In some embodiments, a desired climbing and falling behavior for a material can be achieved over a relatively small range of frequencies (e.g., between from about 20 Hz to about 25 Hz), in which case the highest working frequency performs with more rapid material mobility compared to lower frequencies (as more oscillations are being performed per second).

[0091] In some embodiments, increasing the amplitude or volume (e.g., causing greater distortion in the plate, in response to the greater intensity of oscillation) of an input oscillatory signal will cause material to move greater distances per cycle/oscillation (as the plate moves a greater distance per oscillation), and therefore moves more distance in the same amount of time, resulting in an enhanced travel speed/mobility compared to lower volume for a given frequency. Greater volume can also increase the forceful agitation of the material (which can serve to break up and/or scatter the materials, and to make heavier materials bounce and fall, or in other words, to climb less).

[0092] FIG. 10 shows an isometric projection perspective view of a separator during operation and with working material on the surface, according to some embodiments. As shown in FIG. 10, the separator can be configured such that, during operation, lighter/flatter material climbs and rises over the highest edge of the plate while heavier/rounder material travels toward, and falls down off of, the lowest edge of the plate. Significantly, when the plate has differences in stiffness, the stiffer regions can distort less at a given volume, however all regions may exhibit some increase in distortion/deflection with a corresponding increase in volume.

[0093] With regard to the shape of a working material, in some embodiments flatter material may rise along the plate under the influence of an appropriate frequency, as may materials with higher aspect ratios, such as twigs or sticks, which typically make their way up the incline as compared to rounder materials which tend to roll downhill. Significantly, disparate materials (like twigs and sticks, which are not only long and thin but can be soft or hard) may be biased to climb or to fall down the slope preferentially depending on the separator configuration and operation, and the ease of biasing such behavior can depend on the constituents and concentration of the material to be separated. FIG. 10 shows that larger round material constituents (806) or smaller round material constituents (807) and dense materials may travel downward along the slope of a pitched plate, whereas flatter material constituents (808), which can be large or small as well but typically are relatively less dense in general, may travel upward along the slope of the pitched plate. Round materials can be more conducive to bouncing and rolling downhill even at lower volume, although at sufficiently low volume (and sufficiently low plate slope) all types of material will gently/slowly move ("shimmy") uphill. Even for relatively high-pitched slopes (e.g., around 5 degrees from level/horizontal), many materials will not readily travel/fall down the slope of the plate when placed on the plate's surface, in view of their light weight and/or sufficient friction with the plate. For example, some organic materials may slide to a stop on inclined surfaces pitched from 0-20 degrees from level or more, and beyond such angles the pitch may become sufficient for gravity itself to maintain a motion of the materials sliding down the slope. In other words, sufficiently high plate slopes can cause materials to fall/slide along the plate surface without additional/applied force.

[0094] In some embodiments, surface traveling waves (a type of surface acoustic propulsion) or dynamic vibratory responses are employed to move material in a predetermined/desired fashion, rather than randomly shaking the material or focusing it into aggregated domains or series of domains on the plate. During operation of some separator embodiments, the flow of the working material on the plate can have an optical illusion type appearance, for example when material moves uphill in chorus, rather than downhill as it would if bounced perpendicular to the ground, where reflected waves at a particular frequency are not resonant or standing waves, but rather are traveling or scanning from one side of the plate to the other, as made visually apparent by the motion of the material. Under certain conditions, using a frequency response that induces traveling waves that scan upwards in the case of an inclined plate, material (e.g., mixtures) can be made to climb the plate surface. In some embodiments, material movement is influenced in part by gravity and a minimum amount of agitation/volume to separate heavy/dissimilar material downhill, if desired. In some such implementations, reducing contact with the traveling waves on the working surface can prevent bouncier material from climbing the incline of the plate surface.

[0095] In some embodiments, the separation of lighter and heavier materials is controlled or influenced by the utilization of an appropriate frequency for a given plate, optionally in balance with one or more other parameters (e.g., frequency, signal volume, for a specified plate stiffness/structure and associated surface area relative to the transducer, and/or pitch/slope/angle relative to the ground). The amplitude of the electronic drive signal can be limited by the power capability of the transducer(s)/power source and/or the weight of the plate, which will govern the maximum allowable volume, and can also depend on the quality of the materials and/or connections (mechanical and/or electrical) used, or more specifically, their ability to transmit or dissipate vibration where/when desired. Embodiments of the present disclosure can be scaled up or down in size, for example using transducers of varying sizes in different numbers and/or configurations. The surface area of the working plate can be increased, while controlling the plate surface area overhanging a single transducer, by using an array of transducers (which can be larger and fewer or smaller and increased in number, with appropriate distances separating them) connected to one enlarged corresponding plate. Depending upon the application, separator embodiments can include one plate or multiple plates in series.

[0096] In some embodiments, a separator plate has relatively short vertical sidewalls that, if appropriately light and well connected, can act as physical barriers to prevent material from falling off the sides of the plate. Alternatively or in addition, a separator plate can include one or more skirts or enclosure panels to serve as shielding for confinement and mitigating material loss during processing, which can optionally be transparent to permit viewing of the separator operation.

[0097] In some embodiments, one or more stiffening/dampening properties can be imparted to the plate, for example to change the distortion response of the plate from the transducer (e.g., linear actuator) movements/oscillations acting along the length of the plate (particularly towards and reflecting from the edges), such that one end of the plate may exhibit more agitation or less agitation than an opposite end of the plate or a different portion of the plate, or to achieve a desired distribution in agitation across the plate. Material on the plate surface may tend to move preferentially in a direction of a dampened region due to the reduced relative vibrations.

[0098] During separation operations, in some embodiments, heavier material rolling downhill is agitated to a degree sufficient to prevent the heavier material from climbing uphill, but also needs to be able to overcome the displacement action/bucking/kicking/repelling at the low end (e.g., high distortion region) of the plate. Using stiffeners/dampeners only at the top/high end of an inclined plate can cause all or most material to tend to climb uphill rapidly in one direction, especially when the plate is pitched at a lower angle using low volume, which can be exploited to use the separator as a conveyor/feeder.

[0099] In some embodiments, plate stiffening/damping includes the placement of spars or struts or frames in various configurations that are added/affixed to any or all sides or edges of a flat plate, to increase rigidity without adding much weight. Alternatively or in addition, walls can be positioned on the top side(s) of the plate to prevent material from bouncing over the sides. In other embodiments, plate stiffening/damping includes the placement of scoops/gutters/slanted walls along the plate edges, to allow for different functions, such as to cause relatively less drag/suction in the downward direction, and/or to push air during the upwards stroke so that air is pushed back upward or onto the plate, for example to promote the creation of additional non-solid air walls that can help to keep material from reaching or going over the plate's edges during operation (e.g., by repelling it with the pushed air, or conversely by sucking material off the edge). Alternatively or in addition, designing the plate such that greater distortion is present at the side walls, for example by having more overhang/cantilever of the plate from where it is affixed to the transducer, or by having reduced rigidity in the lateral direction of the plate, can act well to repel material from those side edges.

[0100] In some embodiments, a certain amount of overhang (i.e., a length of the plate that is cantilevered, extending outward from where it is affixed to the transducer underneath) is desired for sufficient/desired transference of the surface wave, or for sufficient/desired physical displacement/vibration/distortion. The surface area of the plate, and/or the diameter or surface area of the connector can be modified (increased or decreased) to change the amount of plate overhang, or the amount of cantilevered plate length. Surface area that overhangs where the plate is connected to the transducer can impart a stress due to the cantilever force or moment of inertia, and the boundary conditions of the edges (fixed, modified, or free) may dictate the reflection/response of the traveling waves/distortion. Under oscillatory vibration/operation, the plate can still exhibit a distribution of distortion that is more noticeable at the free-standing edges (where the plate is not fixed). Traveling waves, or surface waves produced on the plate, will also travel/transfer more easily and with less noise in more rigid plates - so much so that, in some cases, they may transmit the signal without sufficient distortion to agitate materials on the surface.

[0101] In some embodiments, a plate is positioned off-center from the connector/coupler between transducer and the plate, such that different ends of the vibrating plate/surface protrude by different distances as measured from the center of the separator (or of the connector), thus effectively biasing the amount of cantilever. Depending on the plate's material properties, longer or shorter cantilevers may mechanically yield ("give") and/or respond with more or less deflection depending on stiffness and weight to length, for example because some short cantilevers may agitate more than long ones if the material is light, and then the length of the long cantilever can be damped by the additional amount of material, particularly if less stiff, all depending on the overall shape of the plate and/or the frequencies used.

[0102] A variety of different plate shapes and sizes, such as longer and narrower plates, or trapezoidal plates, can be used, for example to bias the boundary conditions and traveling waves and/or the level of agitation/distortion that particular regions of the plate are exposed to (which, in turn, may also depend on the frequencies used, as discussed above). Furthermore, enhanced behavior (e.g., a more clear transfer of the input harmonics to the vibrating plate, or more desirable performance) can be obtained utilizing proper material synergy (e.g., using similar materials rather than dissimilar ones, optionally all made from one piece (monolithic) or having seamless connections) and appropriate material properties (e.g., using higher quality insulating/damping materials where appropriate, and optionally more rigid materials, or a variety of soft and hard surfaces, as appropriate) to transfer the loads optimally and to mitigate noise effects.

[0103] In some embodiments, a method stiffening/damping includes using a plate that has a gradient in material properties built directly into the body of the plate (e.g., along its length or in some distribution/pattern/geometry). For example, a plate can be fabricated such that it has a periodic or non-periodic distribution of porosity, density, and/or rigidity.

[0104] In some embodiments, plate stiffening/damping includes clamping/affixing additional weight and/or cantilevers to the sides and/or edges of the plate, for example to introduce dampening (and/or points/lines of stress) by way of strain due to the added mass.

[0105] In some embodiments, a method of distributing distortion along a plate (achieving an effect similar to that of stiffening/damping) includes using multiple transducers (e.g., linear actuators) affixed to a single plate but with different acoustic/audio volume controls for each, so that the associated volumes can be increased or decreased relative to the other(s), and certain regions of the plate can be agitated more or less. This can result in a complex wave response, and/or a superposition of reflected waves. In some embodiments, a single frequency, together with the act of changing the volume between linear actuators , can be used to distribute the intensity in agitation/distortion.

[0106] In some embodiments, a light stream of constant or pulsed air can be introduced from above the plate, the air originating external from the separator/system, e.g., along a line perpendicular to a direction of material motion along the width of the plate. The light stream of air can, for example, gently push some of the falling more aerodynamic, but lighter, material, while denser and more aerodynamic material can continue to fall down the plate's slope and past the stream of gentle air. Pulsed air, or low-pressure blowing air, can also be utilized in cooperation with operating modes of the current disclosure (such as the embodiment where the machine collects material towards the top and discards material out the bottom), such that streams or jets of air can be used to wash the plate clean off the top, or downwards, for example periodically. Alternatively, the board could wipe itself clean when ready by letting/making all material fall or climb, particularly the material that collects on the plate.

[0107] In some embodiments, the vibratory plate can have one or more of a wide variety of different textures, shapes, structures, and/or layers. In one embodiment, the plate is flat, rigid, somewhat rough, and lightweight, with a complete/robust/seamless connection to the transducer. The seamless connection can help to reduce or avoid unwanted pressure points, pinching, or stress on the plate that may cause an unwanted shift/complexity in the frequency response and field line patterns for vibration waves traveling through the plate. Examples of various structures and shapes are shown in FIG. 12.

[0108] In some embodiments, all surfaces in contact with the working material are "food grade." One embodiment for making a surface "food grade" involves coating the top surface of the working plate (or any surface in contact with the working material) with a material that is "food grade" and easy to clean under standard procedures, for example a food grade epoxy coating or a self-adhesive backed plastic film. The coating can include, for example, a patterning technique that gives texture to the surface and/or that results in distributions in thickness and/or texture, to create some friction (and/or biased directionality) for objects having a tendency to slide downward along a sloped surface (e.g., not concerning heavier/round material that will bounce and roll). Another way to achieve this is to texturize and/or pattern the plate, and then spray the texturized/patterned plate to produce a uniform "food grade" coating that still conforms to/exhibits the underlying texture. Examples of various textures and patterning are depicted in FIG. 12.

[0109] In some embodiments, a temporary top plate is attached to a permanent plate (e.g., plate 101 of FIGS. 1A-1B) that, in turn, is affixed or mechanically coupled to the transducer. The temporary plate can be disposable (e.g., a film or affixable surface), such that it can be discarded and replaced between operations involving different materials, to reduce the need for additional cleaning procedures/materials.

[0110] The placement of a working material onto a plate can be achieved by a wide variety of feeding methods. The feed rate of an incoming material to be separated can be significant. FIGS. 11A-11B show the use of a conveyor belt or feeding mechanism (909) to drop material in a line along the plate in a direction perpendicular to the separating direction/material motion while the transducer is in operation, and considering that the feed conveyor/direction may be pointed in the downhill direction of the vibrating deck to bias the enhanced removal of rounder heavier materials due to their momentum. The height of the drop as well as the position of the dropping can be controlled over the area of the plate, which can be different when optimized for different materials or for similar materials with varying properties. In considering these parameters, sufficient length of a single plate can also be an important design consideration, to allow maximum separation to occur, as well as maximum width of the plate, for maximum material throughput. In some embodiments, larger amounts of material can be preloaded in the feed conveyor by using a hopper that holds a large volume of material and/or that slowly emits/dispenses the material for transport by the conveyor belt.

[0111] In some embodiments, short sluice/slide/ramp is used, after the feed conveyor and as part of a feeding process. The sluice can be pointed toward the vibrating plate, and can serve to agitate and break up (i.e., de-clump) material before it hits the vibrating plate, and/or to rapidly and passively speed up the material feed over a short distance and in a designated direction or along a controlled route, thereby preprocessing/preparing the material for more effective separation by the vibrating plate. An example embodiment using a sluice/slide/ramp is shown in FIG. 13A. Appropriate ramp designs and/or multiple ramps will facilitate the feeding (e.g., by a user) of material from one conveyor to multiple plates simultaneously, as shown in FIG. 13B.

[0112] In some embodiments, passive bin sorting, or the application of extended/textured sluices/slides to capture residual/unwanted material , can be used, e.g., as an in-line post-processing refinement, as shown in FIG. 13A.

[0113] FIG. 13C is a photograph showing a multiple separator system, according to an embodiment. As shown in FIG. 13C, the system includes a feed conveyor and a splitter ramp to feed two distinct separator machines simultaneously (or substantially simultaneously). Once a starting material (e.g., cannabis trimmings) is conveyed along the conveyor to the splitter ramp, and fed onto the separator machines, the separator machines act on the starting material to separate the starting material into portions/components thereof. The separated portions are collected in four bins – for example, two bins for leaf material in the upper portion of the photograph, and two bins for the flower material (which migrates downhill, in this example) in the lower portion of the photograph.

[0114] FIG. 13D is a photograph showing a large, single-speaker separator system, according to an embodiment (with collection bins on either side of the plate. FIG. 13E is a photograph showing a large separator system with an array of multiple speakers, according to an embodiment (collection bins not shown).

[0115] FIGS. 13F and 13G are photographs showing multi-separator system, in a series configuration (13F) and a T-shaped configuration (13G), according to some embodiments.

[0116] FIGS. 14A and 14B are photographs showing an example starting material, comprising cannabis trimmings, according to an embodiment. FIGS. 15A and 15B are photographs showing an example first post-separation (i.e., post-processing by a separator of the present disclosure) component, comprising flower material, according to an embodiment. FIGS. 16A and 16B are photographs showing an example second post-separation component, comprising leaf material, according to an embodiment. FIGS. 17A-17C are photographs showing an example third post-separation component, comprising keef material, according to an embodiment. In some embodiments, a result of a separation process performed on starting material such as is shown in FIGS. 14A and 14B, is that each of the first, second, and third post-separation components (such as those shown in FIGS 15a-B, 16A-B and 17A-B, respectively) are positioned in associated bins disposed adjacent to (or attached to or integral with) the separator.

[0117] In some embodiments, material constituents having distributions in density can be aligned and organized (e.g., using the proper frequency to drive climbing, and/or low signal volume/amplitude, for example resulting in reduced throw distance and/or reduced intensity of physical agitation) due to the tendency of lighter constituents to move in a direction that is uphill under the proper conditions (and, optionally, is in the direction of overall object motion), while the heavier constituents tend to fall/follow or continue to point in an opposite direction downhill. This behavior can have a low error rate if the materials are fed onto the separator gently/slowly and/or are already oriented in the desired direction.

[0118] In some embodiments, a separator plate includes temporary walls (or "gates") disposed, for example, at top and bottom ends/edges of the plate (which may be rectangular and/or vibrating). In some such embodiments, the plate already includes general side walls, and the temporary walls/gates are in addition to those. The temporary walls/gates can be added/closed or removed/opened when desired, such that material collects at the bottom and top of the plate during operation, and is selectively released when desired. This can facilitate easier calibration of the separator while minimizing material loss over the sides of the plate. This can improve the yields of the separator, by ensuring better separation before allowing the material to pass on/off the plate.

[0119] In some embodiments, static charges and triboelectric materials are used to preferentially capture smaller particles or powders distinct form the bulk mixture of macroscopic constituents of the material. In other words, static charges in the environment may be exploited and directed, for example via biased surfaces/pathways between desired regions of the plate, to collect and/or repel powders/dust/small particles. In other words, differences in material properties between components of the system can be exploited, so as to create a driving force for charge carrier transport (e.g., with directionality and an amount of force) and/or collection. By designing regions such that they accumulate a particular type and/or amount of charge, powdered materials can also be captured, directed and/or biased, depending on their charge.

[0120] In some embodiments, one or more separator components can include one or more triboelectric materials or static-generating materials that, when rubbed, transfer electric charge. In some instances, charge transfer increases with increased contact pressure and/or friction. Operation (e.g., vibration) of the separator can cause rubbing/friction of the static-generating material, such that significant amounts of static charge can be rapidly generated/built up from the environment. Using proper grounding and electrical connections, such static charge/voltage can be transported and used, for example, to charge a capacitor or a battery. In other words, static electricity can be generated while the separator is in operation (e.g., as a conveyor or separator), and the generated electricity can offset some or all of the energy demands of the separator. Alternatively or in addition, an alternative power source, such as solar panels or wind turbines, could be utilized operate the separator as a static electricity generator,

[0121] In some embodiments, a phased array of speakers can be used, as a substitute for or in addition to the plate walls, and the speakers can be directed at each other (e.g., orthogonally with respect to associated edges of the plate, which may be opposite to one another) so as to create standing waves in the air between them, or to create regions of relatively high pressure and relatively low pressure, for example to hold/levitate lightweight materials that are suspended in air (e.g., small polystyrene balls). This levitation method for small lightweight particles can be exploited, for example to separate channels of laminar flow and more agitated flow into distinct channels on the plate. Such techniques can serve to: (1) isolate materials statically, (2)confine materials such that they travel/move along isolated channels on the plate, and/or (3) grab and hold/retain specific materials that bounce from the plate, essentially removing them from the material moving along/closer to the plate surface, which can be performed periodically, for example to catch and drop certain materials as desired when they pass by the affected zone defined by the opposing speakers used to generate the soundwaves.

[0122] In some embodiments, a separator plate is designed with a large surface area, and a control/patterning of regional agitation/deflection/pressure is performed to create gradients or to induce the assembly of patterned material regions, for solution-based composite solutions cast onto the vibrating plate. During operation, a desired diffusion and assembly of constituent materials can be achieved at predetermined operating parameters, for example to produce patterned polymeric composite films as the solutions settle and dry.

[0123] Although a variety of different materials for the separator components have been described herein, the present disclosure is not limited by such materials. Separator components can include one or more of wood, plastic, rubber, foam, metals and alloys, and any other suitable materials.

[0124] All combinations of the foregoing concepts and additional concepts discussed herewithin (provided such concepts are not mutually inconsistent) are contemplated as being part of the subject matter disclosed herein. The terminology explicitly employed herein that also may appear in any disclosure incorporated by reference should be accorded a meaning most consistent with the particular concepts disclosed herein.

[0125] The skilled artisan will understand that the drawings primarily are for illustrative purposes, and are not intended to limit the scope of the subject matter described herein. The drawings are not necessarily to scale; in some instances, various aspects of the subject matter disclosed herein may be shown exaggerated or enlarged in the drawings to facilitate an understanding of different features. In the drawings, like reference characters generally refer to like features (e.g., functionally similar and/or structurally similar elements).

[0126] To address various issues and advance the art, the entirety of this application (including the Cover Page, Title, Headings, Background, Summary, Brief Description of the Drawings, Detailed Description, Embodiments, Abstract, Figures, Appendices, and otherwise) shows, by way of illustration, various embodiments in which the embodiments may be practiced. The advantages and features of the application are of a representative sample of embodiments only, and are not exhaustive and/or exclusive. Rather, they are presented to assist in understanding and teach the embodiments, and are not representative of all embodiments. As such, certain aspects of the disclosure have not been discussed herein. That alternate embodiments may not have been presented for a specific portion of the innovations or that further undescribed alternate embodiments may be available for a portion is not to be considered to exclude such alternate embodiments from the scope of the disclosure. It will be appreciated that many of those undescribed embodiments incorporate the same principles of the innovations and others are equivalent. Thus, it is to be understood that other embodiments may be utilized and functional, logical, operational, organizational, structural and/or topological modifications may be made without departing from the scope and/or spirit of the disclosure. As such, all examples and/or embodiments are deemed to be non-limiting throughout this disclosure.

[0127] Also, no inference should be drawn regarding those embodiments discussed herein relative to those not discussed herein other than it is as such for purposes of reducing space and repetition. For instance, it is to be understood that the logical and/or topological structure of any combination of any program components (a component collection), other components and/or any present feature sets as described in the figures and/or throughout are not limited to a fixed operating order and/or arrangement, but rather, any disclosed order is exemplary and all equivalents, regardless of order, are contemplated by the disclosure.

[0128] The term "automatically" is used herein to modify actions that occur without direct input or prompting by an external source such as a user. Automatically occurring actions can occur periodically, sporadically, in response to a detected event (e.g., a user logging in), or according to a predetermined schedule.

[0129] The term "determining" encompasses a wide variety of actions and, therefore, "determining" can include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" can include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" can include resolving, selecting, choosing, establishing and the like.

[0130] The phrase "based on" does not mean "based only on," unless expressly specified otherwise. In other words, the phrase "based on" describes both "based only on" and "based at least on."

[0131] The term "processor" should be interpreted broadly to encompass a general purpose processor, a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a controller, a microcontroller, a state machine and so forth. Under some circumstances, a "processor" may refer to an application specific integrated circuit (ASIC), a programmable logic device (PLD), a field programmable gate array (FPGA), etc. The term "processor" may refer to a combination of processing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core or any other such configuration.

[0132] The term "memory" should be interpreted broadly to encompass any electronic component capable of storing electronic information. The term memory may refer to various types of processor-readable media such as random access memory (RAM), read-only memory (ROM), non-volatile random access memory (NVRAM), programmable read-only memory (PROM), erasable programmable read only memory (EPROM), electrically erasable PROM (EEPROM), flash memory, magnetic or optical data storage, registers, etc. Memory is said to be in electronic communication with a processor if the processor can read information from and/or write information to the memory. Memory that is integral to a processor is in electronic communication with the processor.

[0133] The terms "instructions" and "code" should be interpreted broadly to include any type of computer-readable statement(s). For example, the terms "instructions" and "code" may refer to one or more programs, routines, sub-routines, functions, procedures, etc. "Instructions" and "code" may comprise a single computer-readable statement or many computer-readable statements.

[0134] Some embodiments described herein relate to a computer storage product with a non-transitory computer-readable medium (also can be referred to as a non-transitory processor-readable medium) having instructions or computer code thereon for performing various computer-implemented operations. The computer-readable medium (or processor-readable medium) is non-transitory in the sense that it does not include transitory propagating signals per se (e.g., a propagating electromagnetic wave carrying information on a transmission medium such as space or a cable). The media and computer code (also can be referred to as code) may be those designed and constructed for the specific purpose or purposes. Examples of non-transitory computer-readable media include, but are not limited to, magnetic storage media such as hard disks, floppy disks, and magnetic tape; optical storage media such as Compact Disc/Digital Video Discs (CD/DVDs), Compact Disc-Read Only Memories (CD-ROMs), and holographic devices; magneto-optical storage media such as optical disks; carrier wave signal processing modules; and hardware devices that are specially configured to store and execute program code, such as Application-Specific Integrated Circuits (ASICs), Programmable Logic Devices (PLDs), Read-Only Memory (ROM) and Random-Access Memory (RAM) devices. Other embodiments described herein relate to a computer program product, which can include, for example, the instructions and/or computer code discussed herein.

[0135] Some embodiments and/or methods described herein can be performed by software (executed on hardware), hardware, or a combination thereof. Hardware modules may include, for example, a general-purpose processor, a field programmable gate array (FPGA), and/or an application specific integrated circuit (ASIC). Software modules (executed on hardware) can be expressed in a variety of software languages (e.g., computer code), including C, C++, Java™, Ruby, Visual Basic™, and/or other object-oriented, procedural, or other programming language and development tools. Examples of computer code include, but are not limited to, micro-code or micro-instructions, machine instructions, such as produced by a compiler, code used to produce a web service, and files containing higher-level instructions that are executed by a computer using an interpreter. For example, embodiments may be implemented using imperative programming languages (e.g., C, Fortran, etc.), functional programming languages (Haskell, Erlang, etc.), logical programming languages (e.g., Prolog), object-oriented programming languages (e.g., Java, C++, etc.) or other suitable programming languages and/or development tools. Additional examples of computer code include, but are not limited to, control signals, encrypted code, and compressed code.

[0136] Various concepts may be embodied as one or more methods, of which at least one example has been provided. The acts performed as part of the method may be ordered in any suitable way. Accordingly, embodiments may be constructed in which acts are performed in an order different than illustrated, which may include performing some acts simultaneously, even though shown as sequential acts in illustrative embodiments. Put differently, it is to be understood that such features may not necessarily be limited to a particular order of execution, but rather, any number of threads, processes, services, servers, and/or the like that may execute serially, asynchronously, concurrently, in parallel, simultaneously, synchronously, and/or the like in a manner consistent with the disclosure. As such, some of these features may be mutually contradictory, in that they cannot be simultaneously present in a single embodiment. Similarly, some features are applicable to one aspect of the innovations, and inapplicable to others.

[0137] In addition, the disclosure may include other innovations not presently described. Applicant reserves all rights in such innovations, including the right to embodiment such innovations, file additional applications, continuations, continuations-in-part, divisionals, and/or the like thereof. As such, it should be understood that advantages, embodiments, examples, functional, features, logical, operational, organizational, structural, topological, and/or other aspects of the disclosure are not to be considered limitations on the disclosure as defined by the embodiments or limitations on equivalents to the embodiments. Depending on the particular desires and/or characteristics of an individual and/or enterprise user, database configuration and/or relational model, data type, data transmission and/or network framework, syntax structure, and/or the like, various embodiments of the technology disclosed herein may be implemented in a manner that enables a great deal of flexibility and customization as described herein.

[0138] All definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms.

[0139] As used herein, in particular embodiments, the terms "about" or "approximately" when preceding a numerical value indicates the value plus or minus a range of 10%. Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range is encompassed within the disclosure. That the upper and lower limits of these smaller ranges can independently be included in the smaller ranges is also encompassed within the disclosure, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure.

[0140] The indefinite articles "a" and "an," as used herein in the specification and in the embodiments, unless clearly indicated to the contrary, should be understood to mean "at least one."

[0141] The phrase "and/or," as used herein in the specification and in the embodiments, should be understood to mean "either or both" of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with "and/or" should be construed in the same fashion, i.e., "one or more" of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the "and/or" clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to "A and/or B", when used in conjunction with open-ended language such as "comprising" can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

[0142] As used herein in the specification and in the embodiments, "or" should be understood to have the same meaning as "and/or" as defined above. For example, when separating items in a list, "or" or "and/or" shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as "only one of" or "exactly one of," or, when used in the embodiments, "consisting of," will refer to the inclusion of exactly one element of a number or list of elements. In general, the term "or" as used herein shall only be interpreted as indicating exclusive alternatives (i.e. "one or the other but not both") when preceded by terms of exclusivity, such as "either," "one of," "only one of," or "exactly one of." "Consisting essentially of," when used in the embodiments, shall have its ordinary meaning as used in the field of patent law.

[0143] As used herein in the specification and in the embodiments, the phrase "at least one," in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, "at least one of A and B" (or, equivalently, "at least one of A or B," or, equivalently "at least one of A and/or B") can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

[0144] In the embodiments, as well as in the specification above, all transitional phrases such as "comprising," "including," "carrying," "having," "containing," "involving," "holding," "composed of," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of" and "consisting essentially of" shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2111.03.

[0145] While specific embodiments of the present disclosure have been outlined above, many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, the embodiments set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the disclosure.

CLAIMS

1. A method, comprising:

providing a cellulosic material on a first surface of a plate; and

energizing a transducer that is mechanically coupled to a second surface of the plate, the second surface opposite the first surface, the energizing sufficient to cause movement of the plate such that a first portion of the cellulosic material preferentially migrates across the surface of the plate in a direction of a first edge of the plate, and a second portion of the cellulosic material preferentially migrates across the surface of the plate in a direction of a second edge of the plate opposite the first edge of the plate.

2. The method of claim 1, wherein the movement of the plate includes a substantially unidirectional oscillation.

3. The method of claim 1, wherein the transducer is a linear actuator.

4. The method of claim 1, wherein the energizing the transducer includes applying an electronic signal to the transducer, the electronic signal having a waveform that is one of substantially sinusoidal, substantially square, substantially sawtooth, or substantially triangular.

5. The method of claim 1, wherein the second surface of the plate is not orthogonal to an axis of the transducer.

6. The method of claim 1, wherein the movement of the plate has at least one of: (1) a frequency that ranges from 0 Hz to about 100Hz, and (2) a range of travel of from 0 inches to about 6 inches.

7. The method of claim 1, wherein:

the first edge of the plate has a first height;

the first portion of the cellulosic material has a first average size;

the second edge of the plate has a second height greater than the first height; and

the second portion of the cellulosic material has a second average size less than the first average size.

8. The method of claim 1, wherein:

the first edge of the plate has a first height;

the first portion of the cellulosic material has a first average weight;

the second edge of the plate has a second height greater than the first height; and

the second portion of the cellulosic material has a second average weight less than the first average weight.

9. The method of claim 1, wherein the plate includes a sidewall disposed at least partway along a perimeter of the plate.

10. The method of claim 1, wherein the providing the cellulosic material on the first surface of the plate includes conveying the cellulosic material, via an external conveyor, toward the first surface of the plate.

11. An apparatus, comprising:

a transducer configured to transduce an electrical input, during operation, into a mechanical oscillation output; and

a substrate mechanically coupled to the transducer, such that during operation the substrate mechanically oscillates in response to the mechanical oscillation output of the transducer,

the substrate having a pitch with respect to a long axis of the transducer, and

the mechanical oscillation of the substrate having a frequency and an amplitude that are based on the electrical input.

12. The apparatus of claim 11, wherein the electrical input has a waveform that is one of substantially sinusoidal, substantially square, substantially sawtooth, or substantially triangular.

13. The apparatus of claim 11, wherein the mechanical oscillation of the substrate, during operation, causes:

segregation of a first portion of a material disposed on the substrate from a second portion of the material;

movement of the first portion of the material in a first direction along a surface of the substrate; and

movement of the second portion of the material in a second direction along a surface of the substrate, the second direction being different from the first direction.

14. The apparatus of claim 13, wherein the first direction is substantially opposite the second direction.

15. The apparatus of claim 11, wherein the substrate includes at least stiffened region configured to bias, during operation, a movement of a material disposed on the substrate along a surface of the substrate.

16. The apparatus of claim 11, wherein the transducer is a speaker.

17. The apparatus of claim 11, wherein the transducer is an array of speakers.

18. The apparatus of claim 11, wherein the transducer is a linear actuator.

19. The apparatus of claim 11, wherein the transducer is an array of linear actuators.

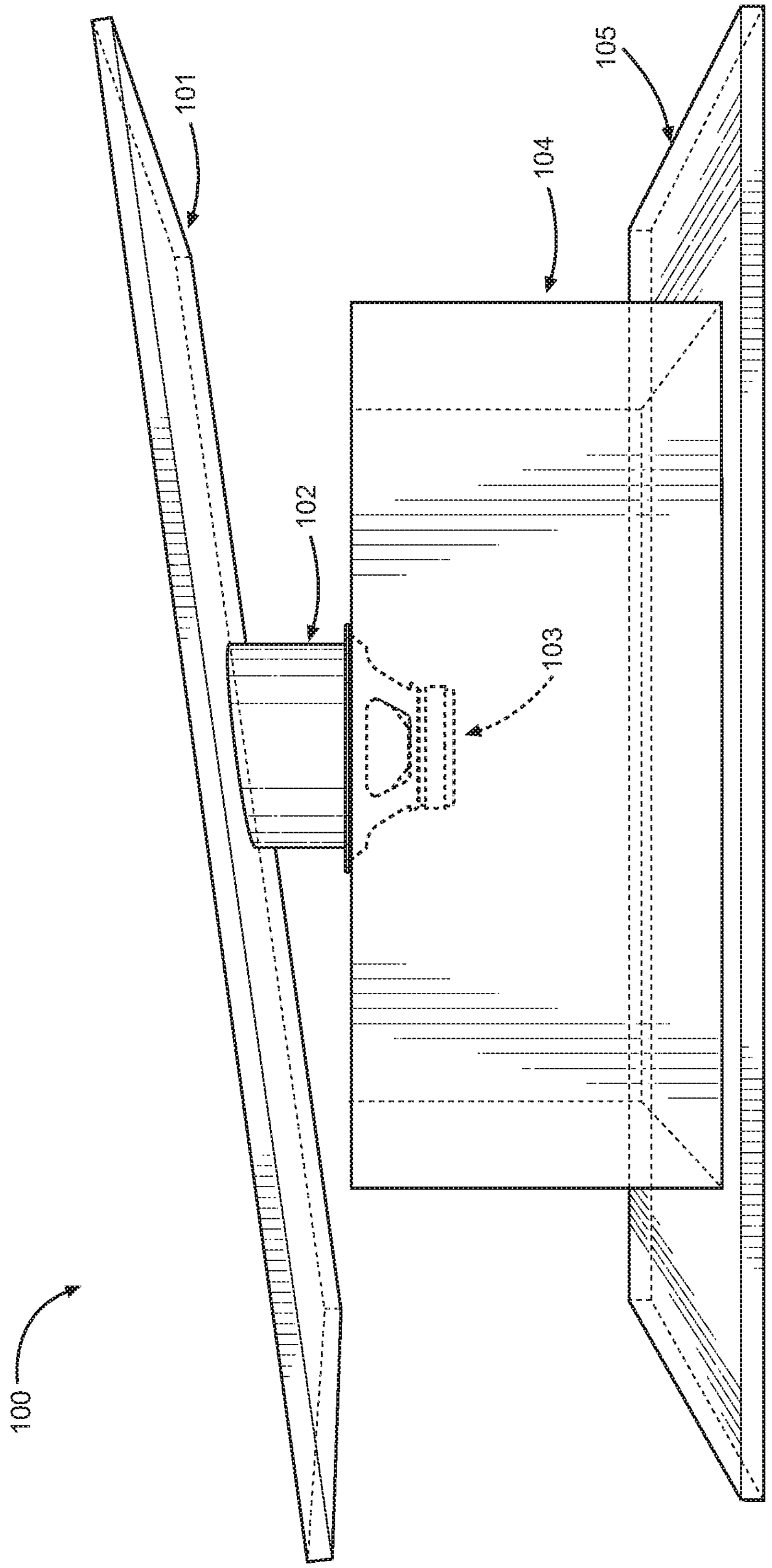

FIG. 1A

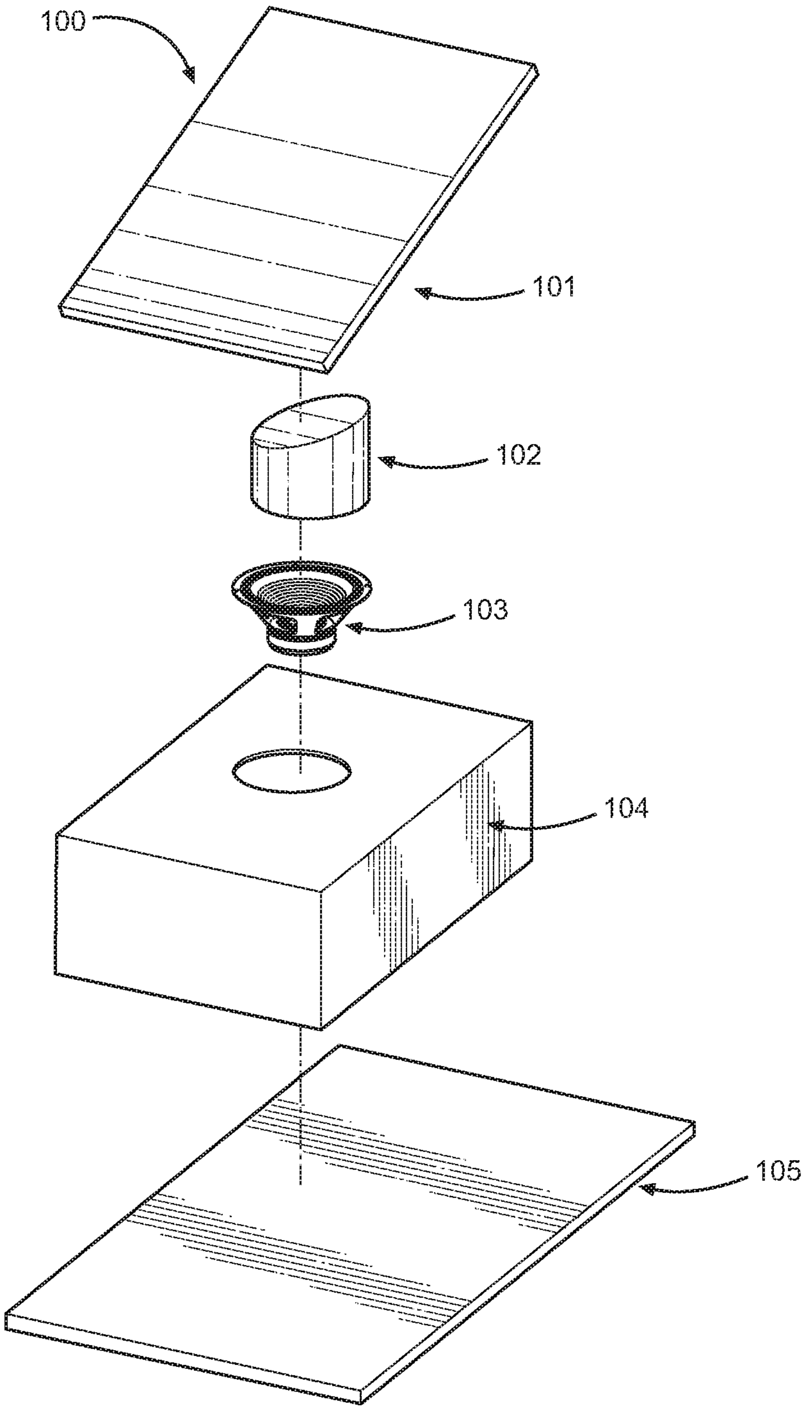

FIG. 1B

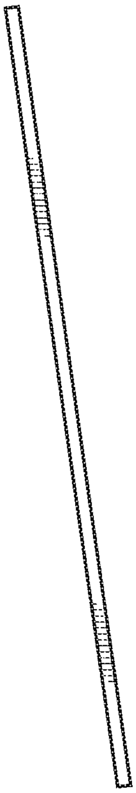

FIG. 2B

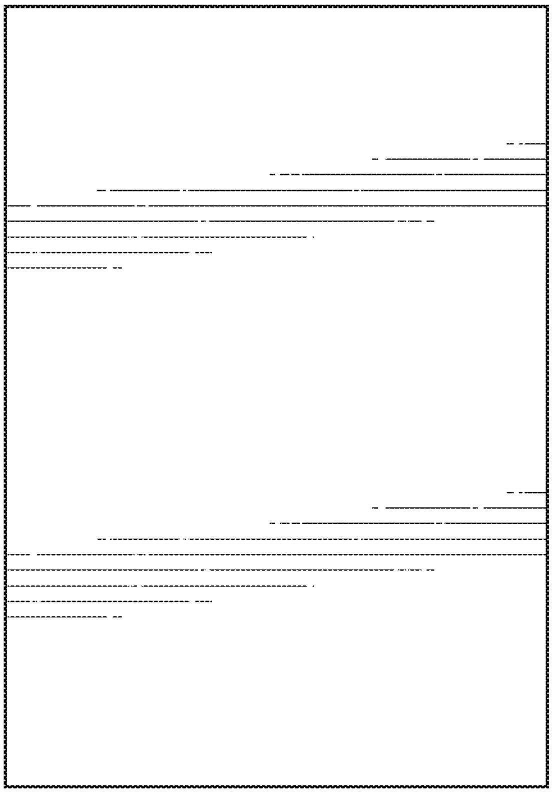

FIG. 2D

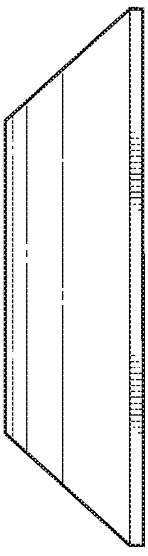

FIG. 2A

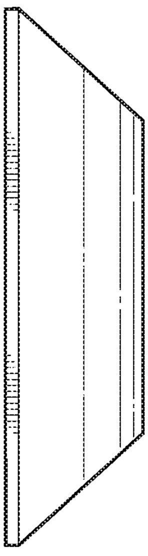

FIG. 2C

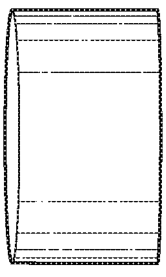

FIG. 3A

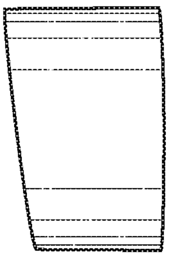

FIG. 3B

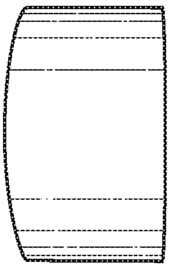

FIG. 3C

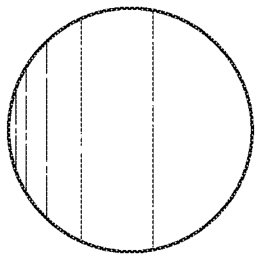

FIG. 3D

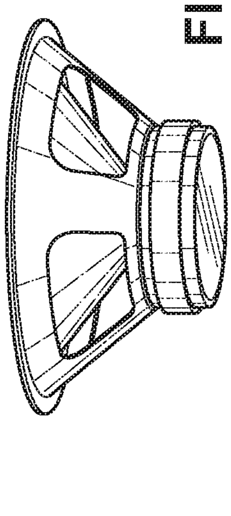

FIG. 4A

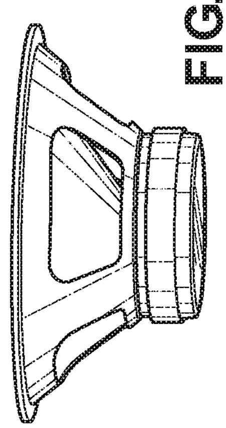

FIG. 4B

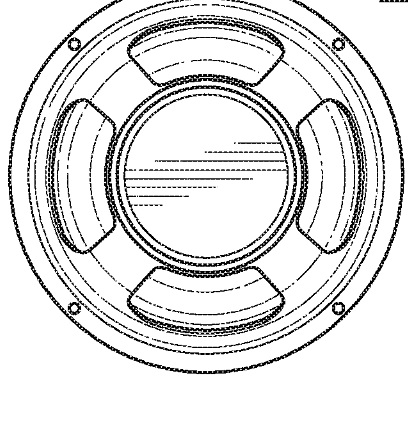

FIG. 4C

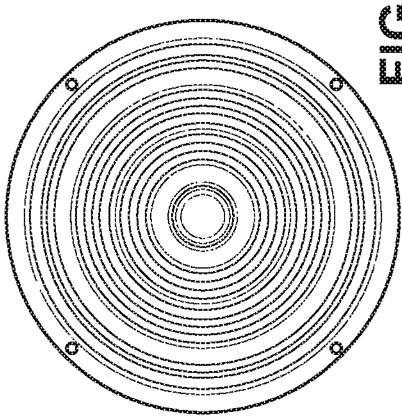

FIG. 4D

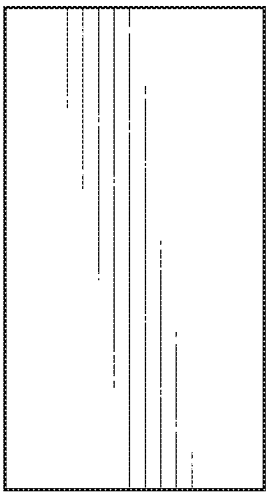

FIG. 5A

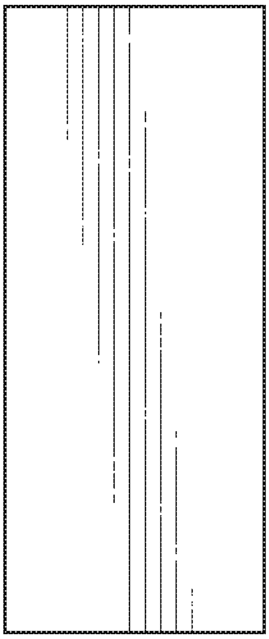

FIG. 5B

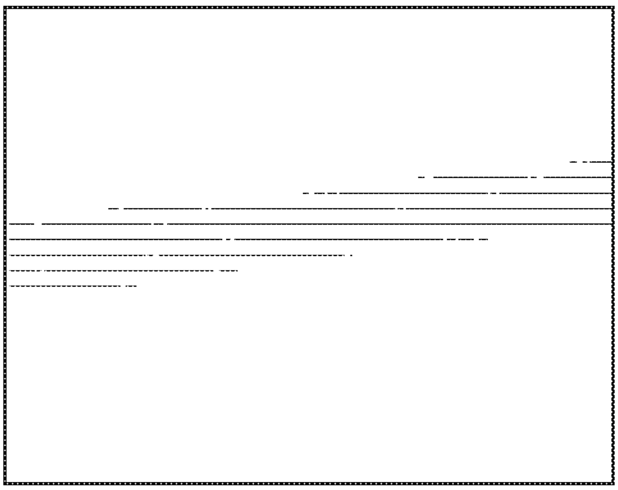

FIG. 5C

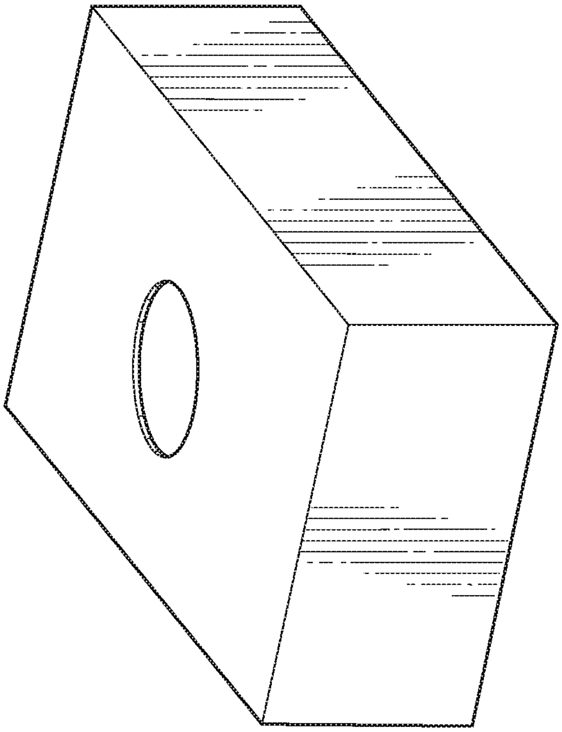

FIG. 5D

FIG. 6A

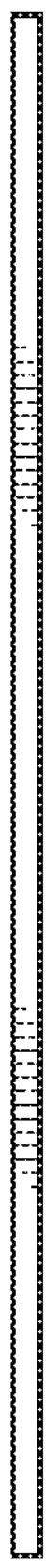

FIG. 6B

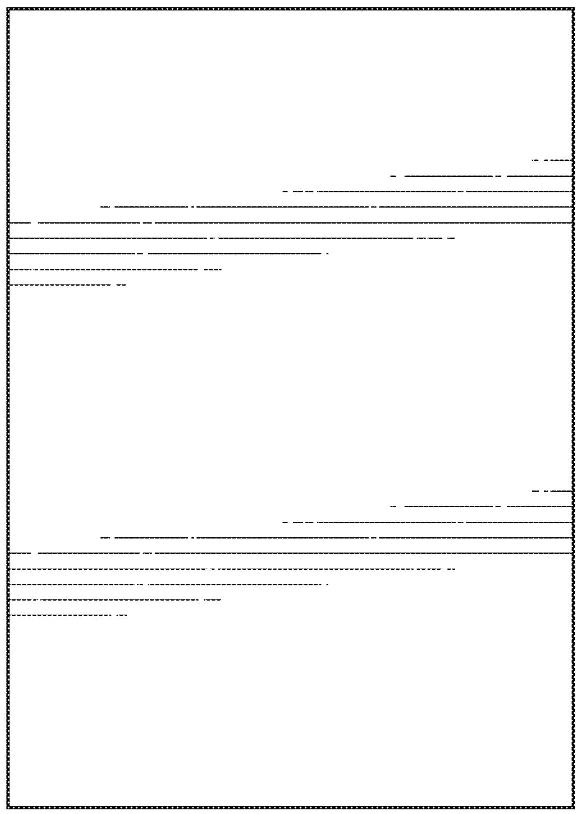

FIG. 6C

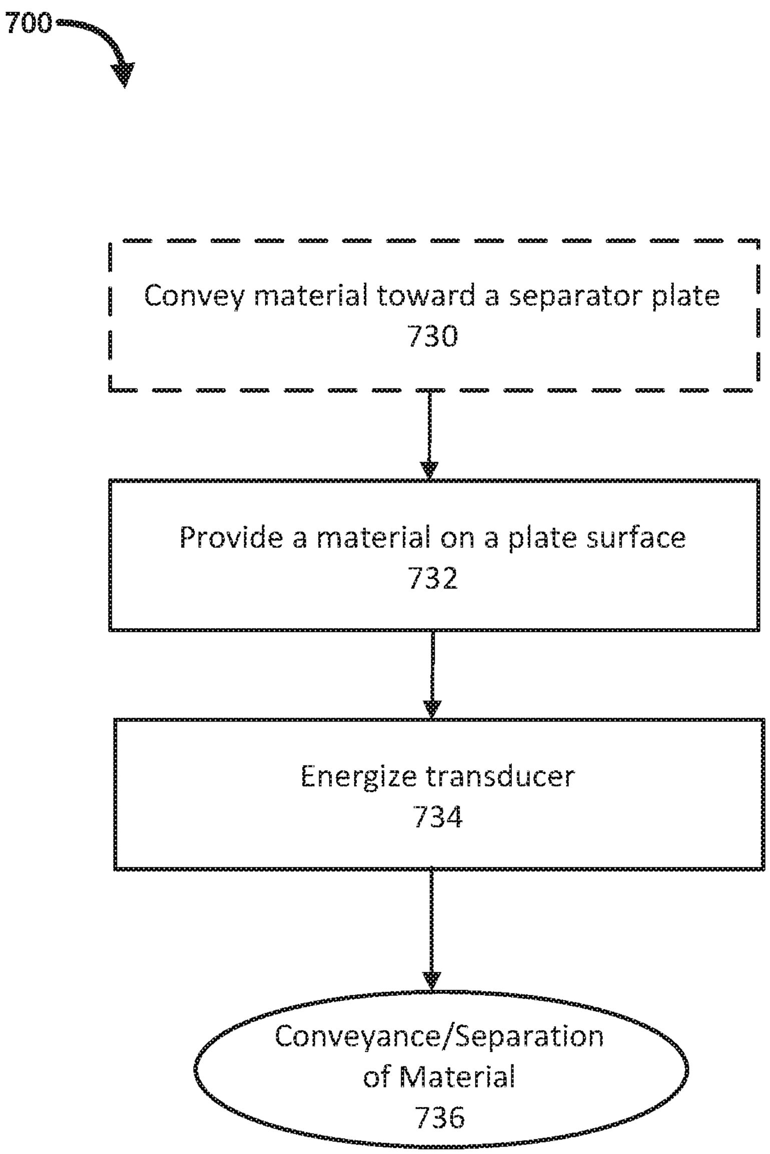
700
Convey material toward a separator plate
730
Provide a material on a plate surface
732
Energize transducer
734
Conveyance/Separation
of Material
736

FIG. 7

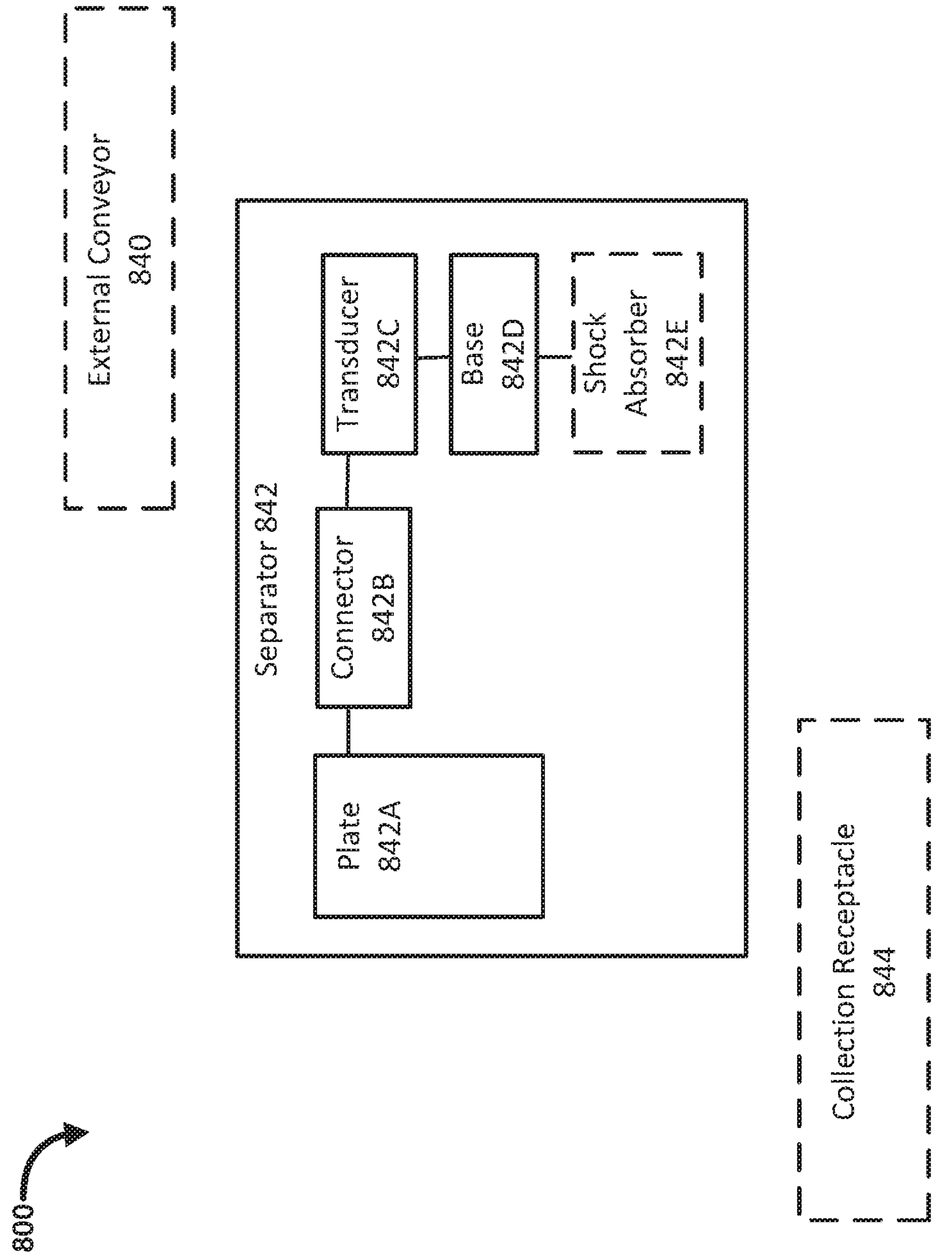
External Conveyor
840
Separator 842
Plate
842A
Connector
842B
Transducer
842C
Base
842D
Shock
Absorber
842E
Collection Receptacle
844
800

FIG. 8

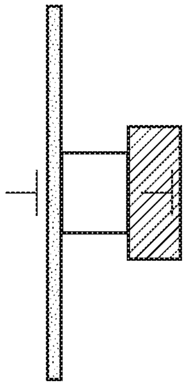

FIG. 9A

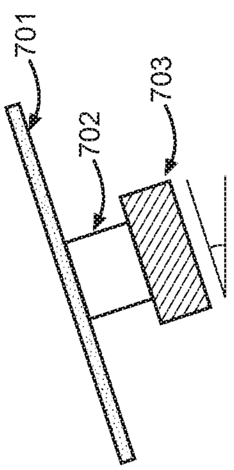

FIG. 9B

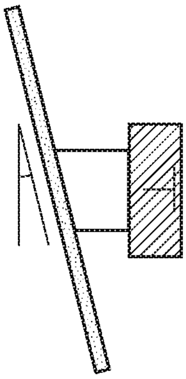

FIG. 9C

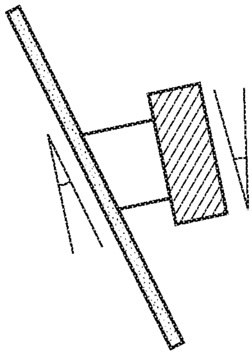

FIG. 9D

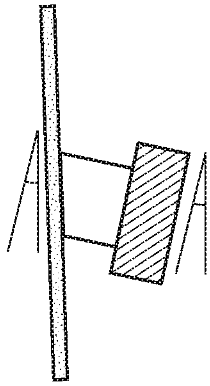

FIG. 9E

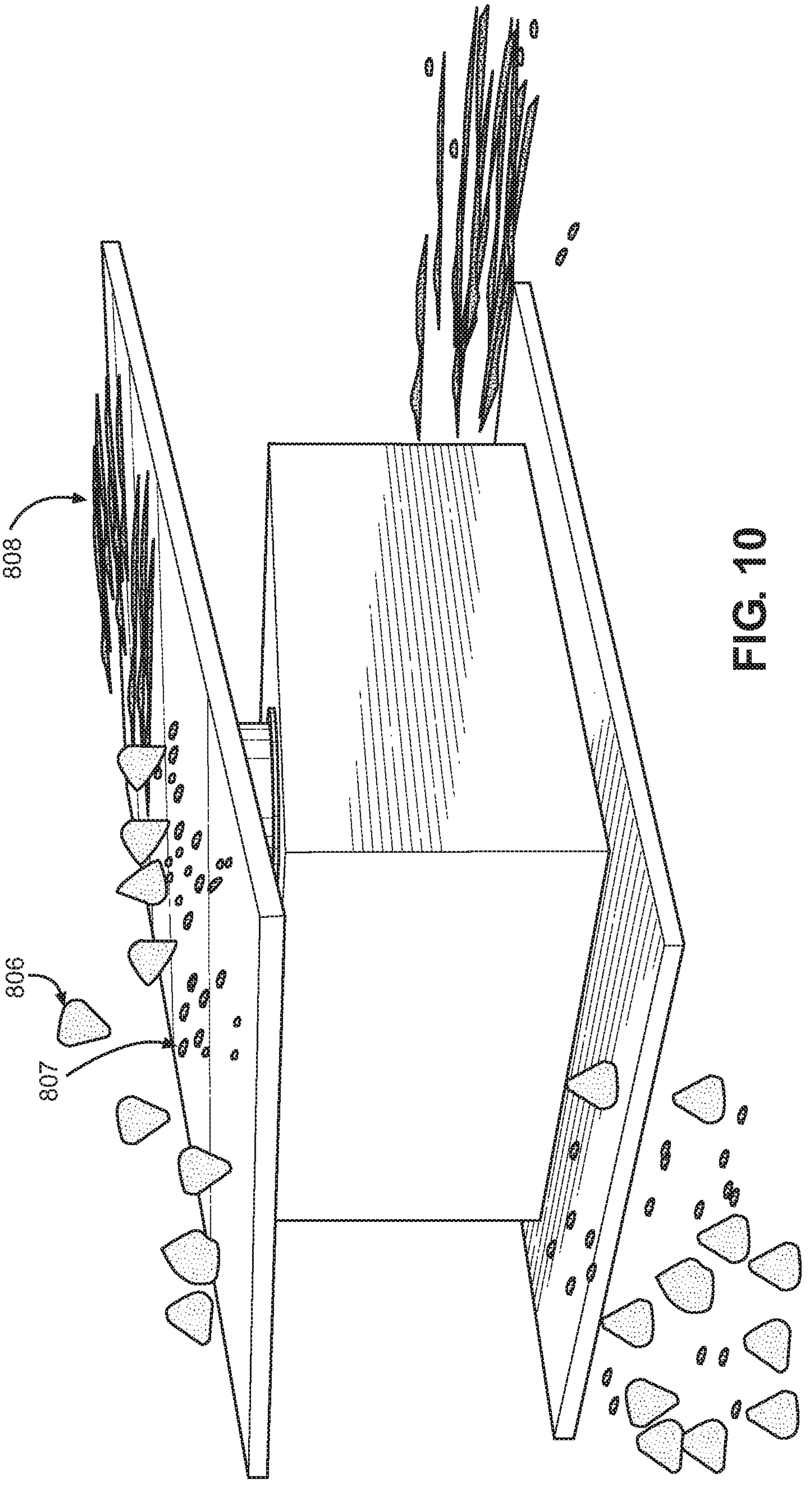

FIG. 10

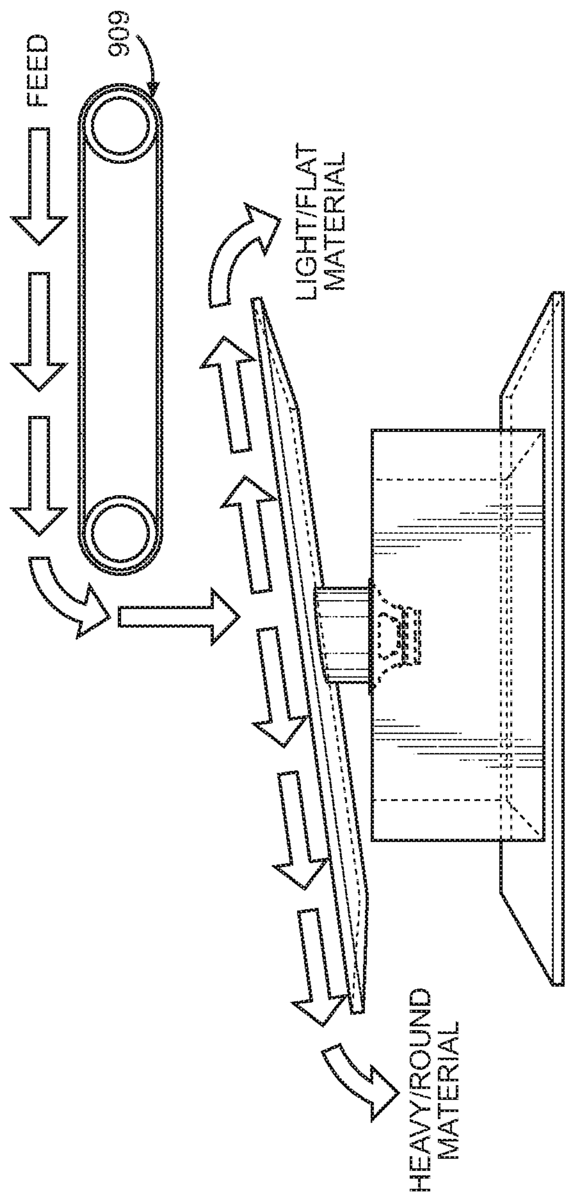

FIG. 11A

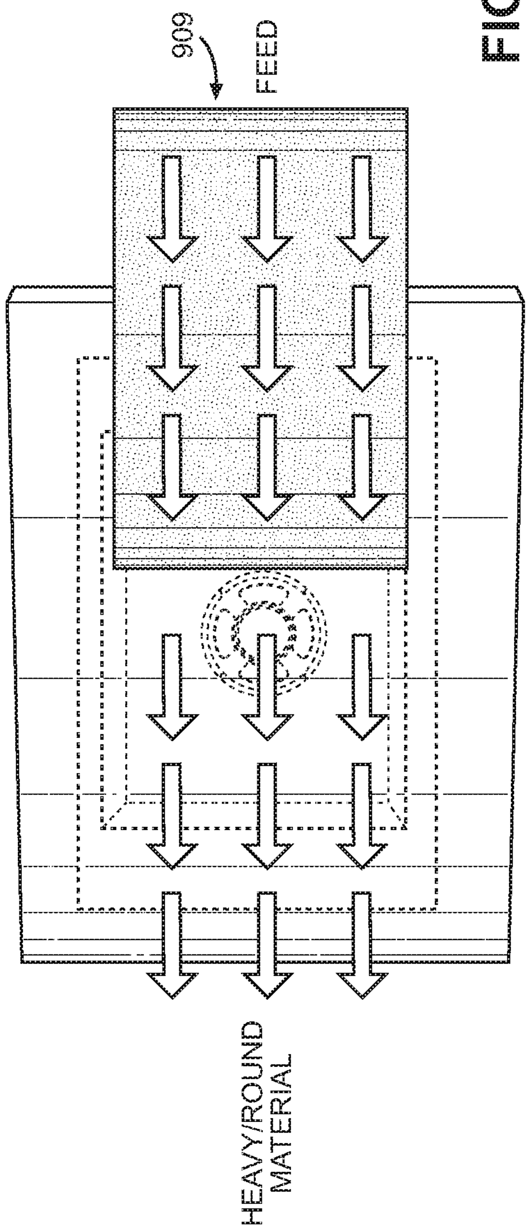

FIG. 11B

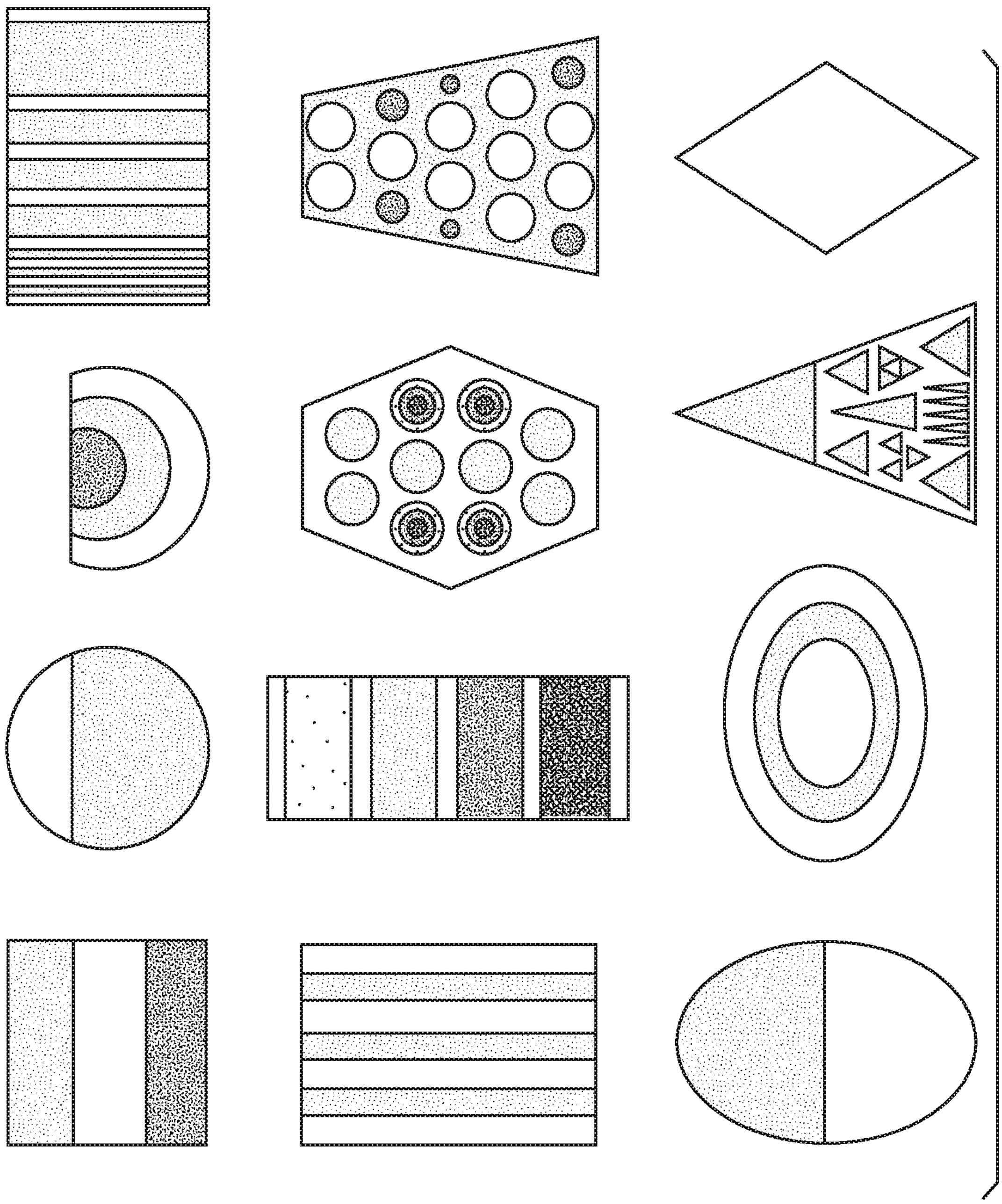

FIG. 12

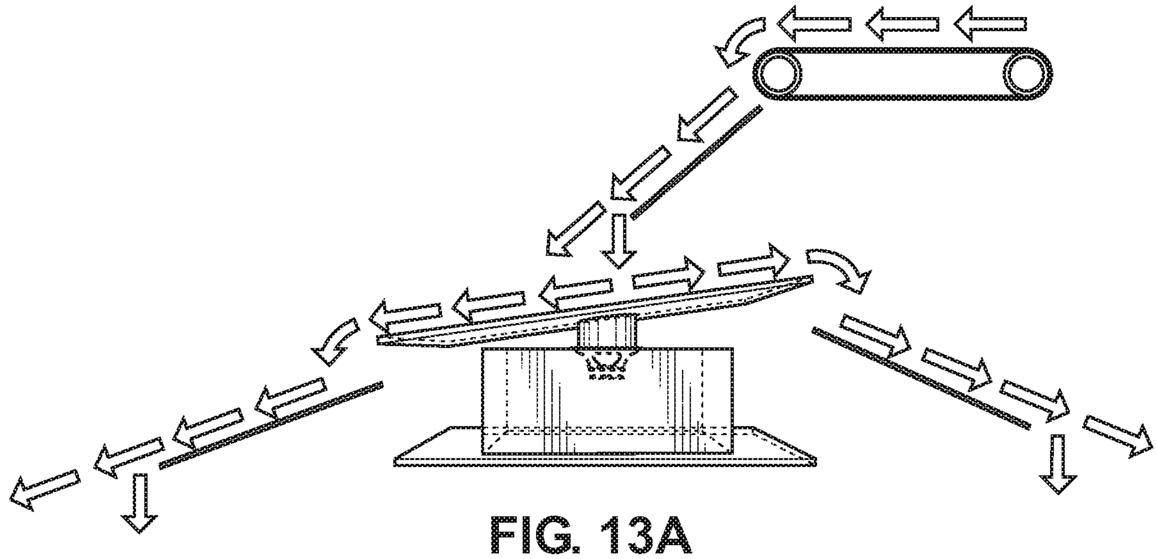

FIG. 13A

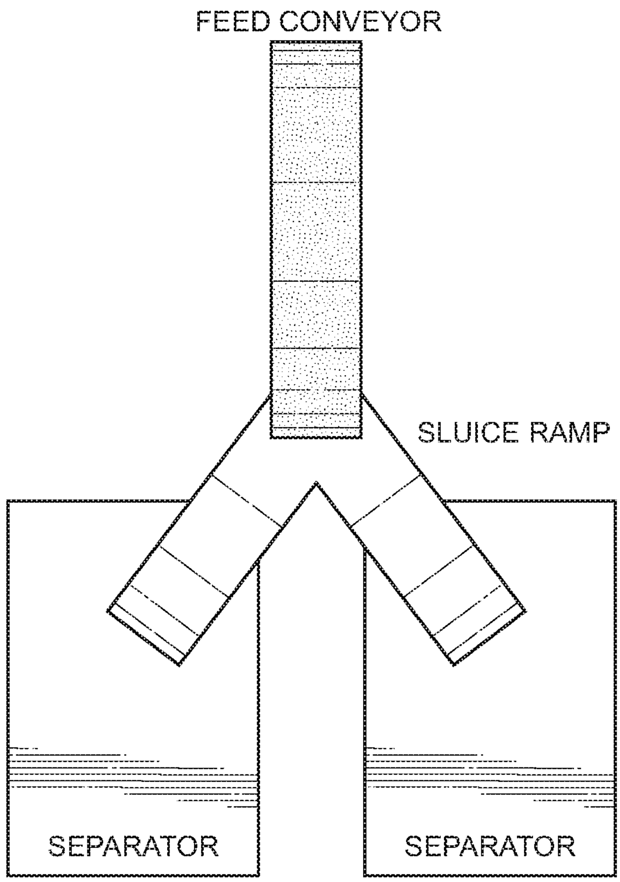

FIG. 13B

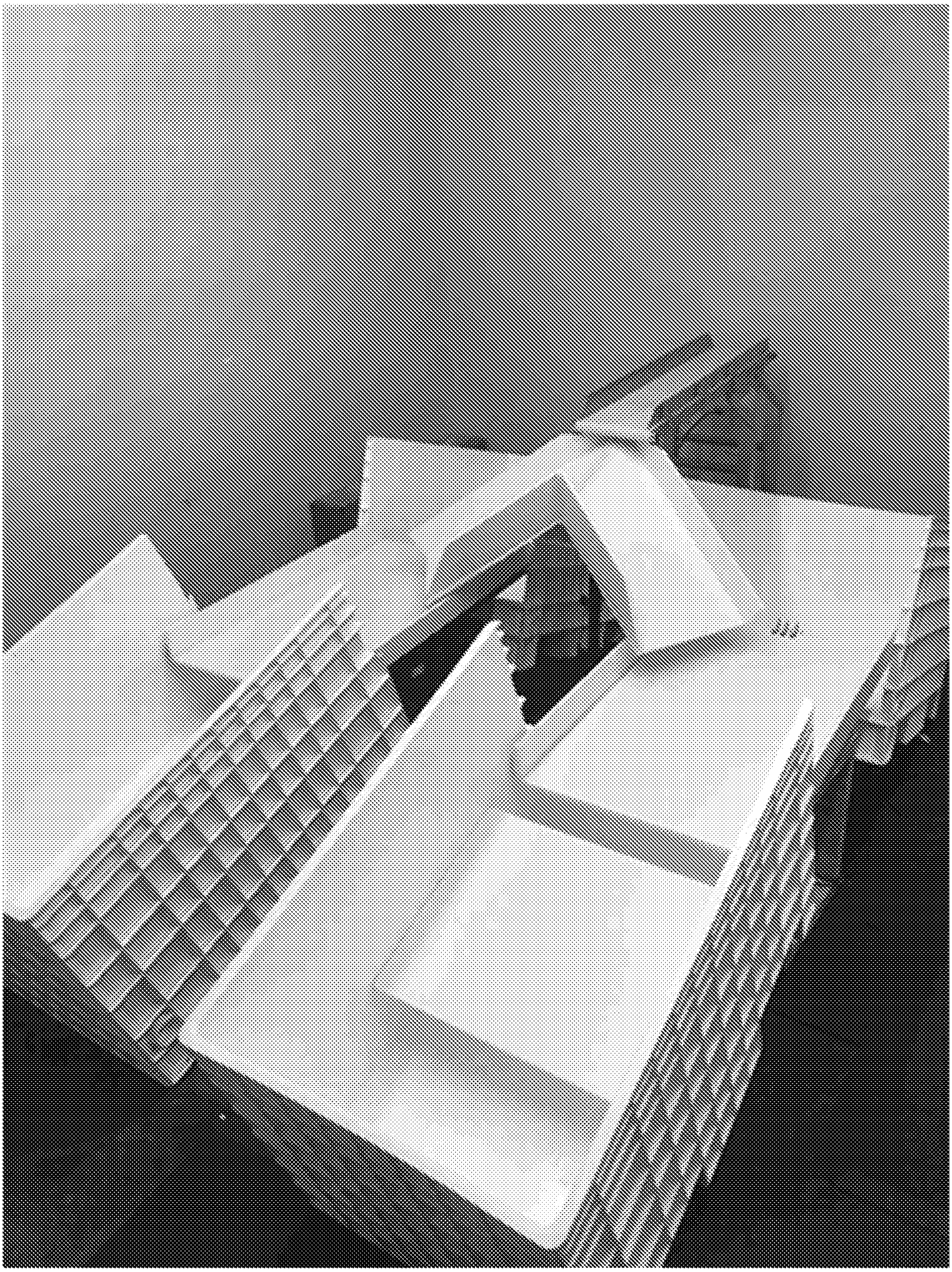

FIG. 13C

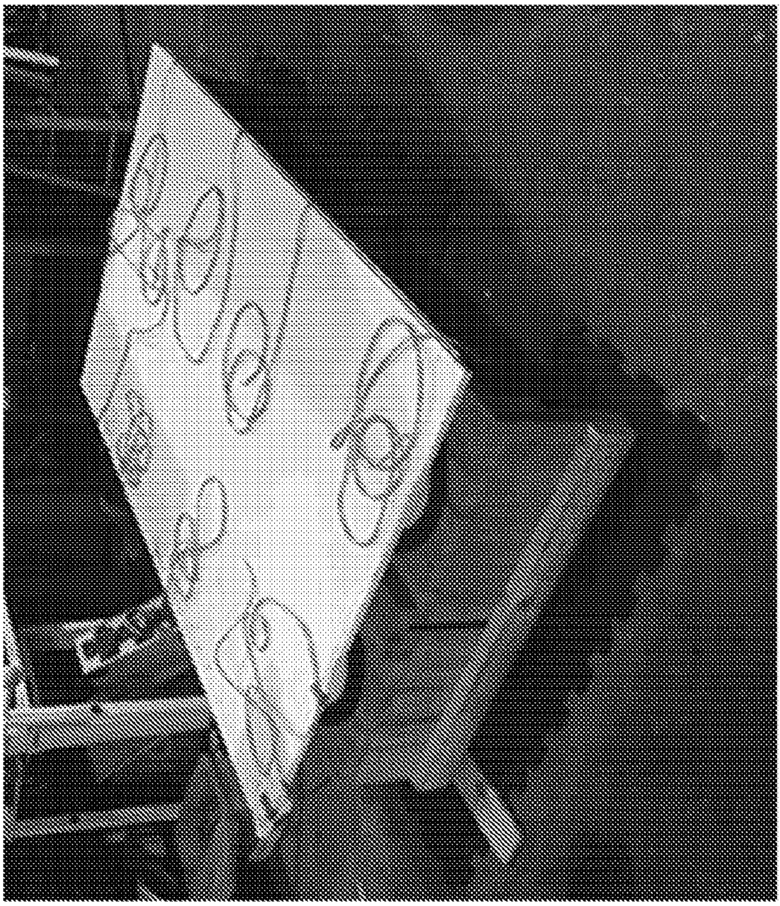

FIG. 13E

FIG. 13D

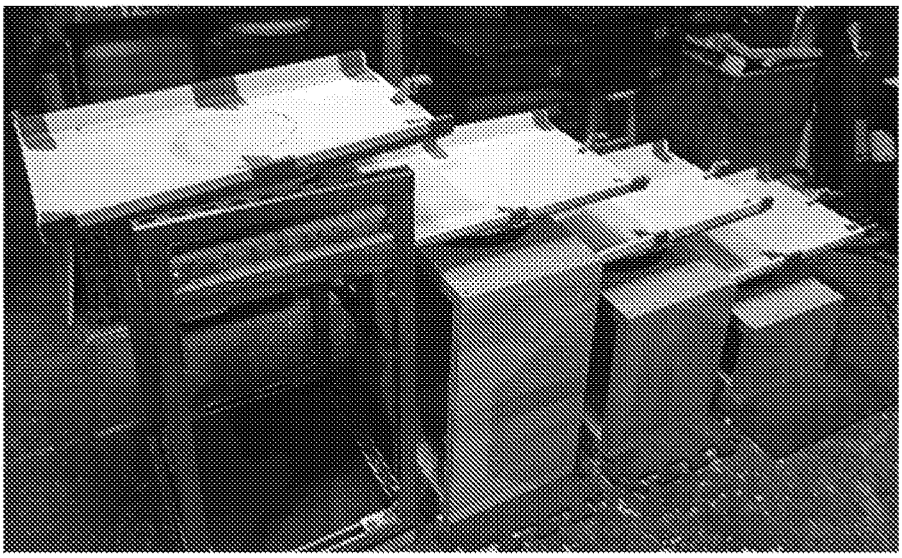

FIG. 13F

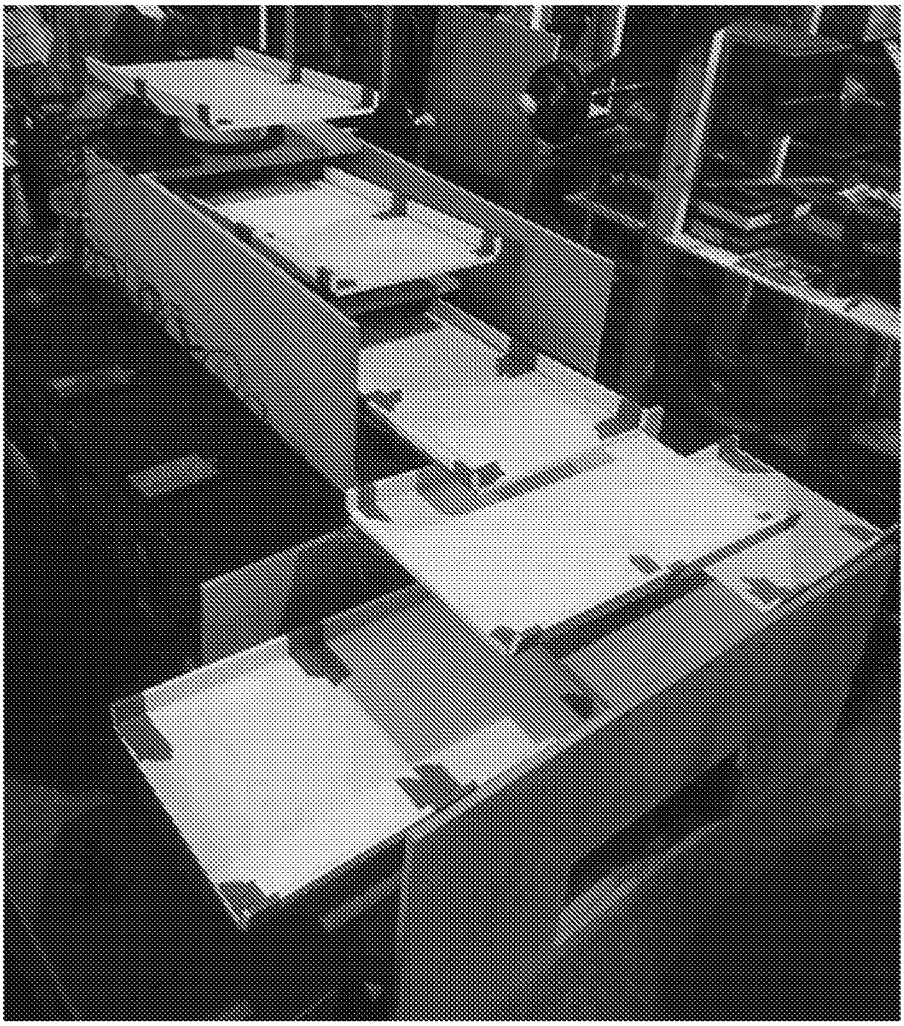

FIG. 13G

FIG. 14B

FIG. 14A

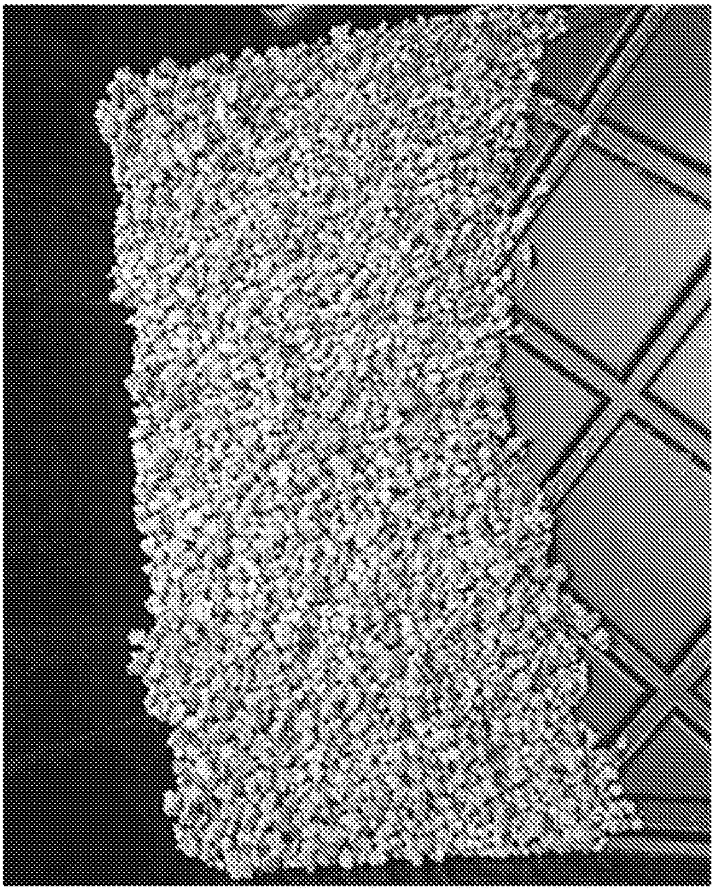

FIG. 15B

FIG. 15A

FIG. 16B

FIG. 16A

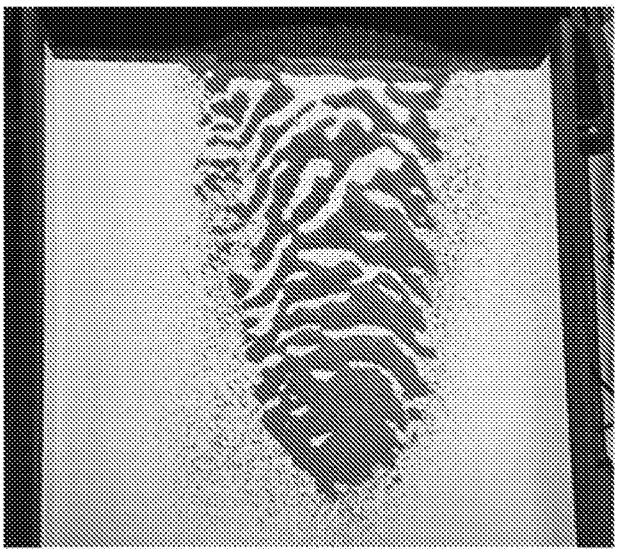

FIG. 17A

FIG. 17B

FIG. 17C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/065964

A. CLASSIFICATION OF SUBJECT MATTER
INV. B65G27/00 B07B13/11
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B65G B08B B07B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 464 550 A (BIELER BARRIE H ET AL) 2 September 1969 (1969-09-02)	1,2,5, 7-11, 13-15
Y	columns 1-4; figures 1-4	3,4,6, 12,16-19
X	DE 35 01 777 A1 (VOELSKOW PETER) 8 August 1985 (1985-08-08) pages 1-7; figures 1-3	1,11
X	CH 314 861 A (INST TECH FORSCHUNG UND ENTWIC [AT]) 15 July 1956 (1956-07-15) pages 1-5; figures 1-10	1,11
X	US 3 599 791 A (CONDOLIOS ELIE) 17 August 1971 (1971-08-17) columns 1-6; figures 1-9	1,11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2019	08/03/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Martin, Benoit

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International application No
PCT/US2018/065964

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	CN 102 284 703 A (DUOLENG NEW MATERIAL CO LTD) 21 December 2011 (2011-12-21) figures 1,2	1,11
Y	EP 0 642 115 A2 (SHINKO ELECTRIC CO LTD [JP]) 8 March 1995 (1995-03-08) columns 1-27; figures 1-23	3,4,6, 12,16-19
A	US 2012/288356 A1 (LYNCH KEVIN [US] ET AL) 15 November 2012 (2012-11-15) paragraph [0047]; figures 1-13	3,4,6, 12,16-19

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INTERNATIONAL SEARCH REPORT

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International application No

PCT/US2018/065964

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