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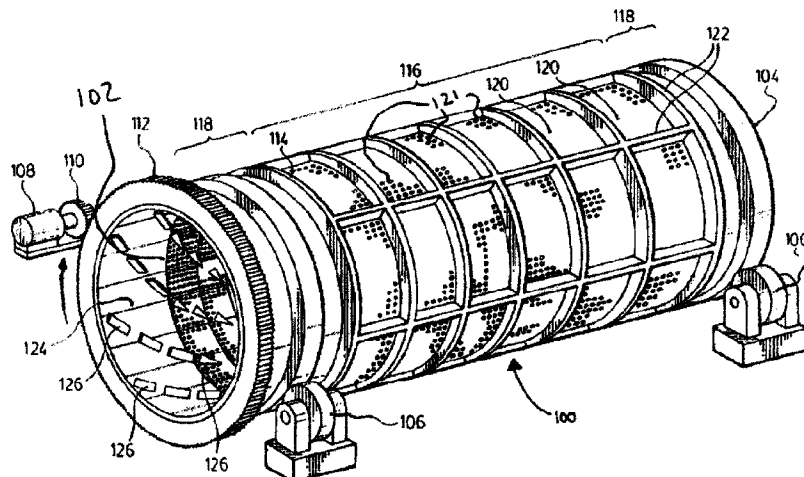
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(54) Title: ROTARY BREAKING FOR CREATING AN OIL SAND SLURRY



(57) Abrégé/Abstract:

Enhanced methods and apparatuses for preparing an oil sand slurry can include depositing mined oil sand ore into a rotatable breaker tube. As the rotary breaker rotates, the ore is advanced and broken. Process fluid may be differentially distributed throughout the length of the rotary breaker, forming an oil sand slurry and assisting in the comminution and ablation of the ore. The comminuted oil sand and process fluid pass through perforations in the rotary breaker, and are collected below, while oversized ore lumps are ejected out of the discharge end of the rotary breaker. The rotatable breaker may have various features related to perforation sizing, design of lifting and advancing elements, and process fluid supply configurations.



ABSTRACT

Enhanced methods and apparatuses for preparing an oil sand slurry can include depositing mined oil sand ore into a rotatable breaker tube. As the rotary breaker rotates, the ore is advanced and broken. Process fluid may be differentially distributed throughout the length of the rotary breaker, forming an oil sand slurry and assisting in the comminution and ablation of the ore. The comminuted oil sand and process fluid pass through perforations in the rotary breaker, and are collected below, while oversized ore lumps are ejected out of the discharge end of the rotary breaker. The rotatable breaker may have various features related to perforation sizing, design of lifting and advancing elements, and process fluid supply configurations.

ROTARY BREAKING FOR CREATING AN OIL SAND SLURRY

FIELD OF THE INVENTION

This invention relates to ore processing. In particular, this invention relates to a method and apparatus for creating a slurry from oil sand ore.

BACKGROUND OF THE INVENTION

Oil sand ore, also referred to as tar sand ore, is found in certain geographical locations. For example, the Northern Alberta Oil Sands are considered to be one of the world's largest remaining oil reserves. The oil sands are typically composed of about 70 to about 90 percent by weight mineral solids, including sand and clay, about 1 to about 10 percent by weight water, and bitumen, that comprises from trace amounts up to as much as 21 percent by weight. Typically, ores containing a lower percentage by weight of bitumen contain a higher percentage by weight of fine mineral solids ("fines") such as clay and silt.

Oil sand ore is abrasive as the bitumen is locked onto mineral grains. In order to commercially mine oil sand ore, large volumes of ore must be rapidly processed with the addition of process fluid to extract the bitumen from the mineral material. The resulting slurry of mined oil sand ore and process fluid is highly abrasive. The commercial viability of an ore body is dependent in part upon the volume of oil sand ore that may be processed over a period of time. In particular, processing frozen ore is extremely difficult due to its resistance to comminution.

Unlike conventional oil deposits, the bitumen is extremely viscous and difficult to separate from the water and mineral mixture in which it is found. Initially, the oil sand is excavated from its location and passed through a crusher or comminutor to comminute the chunks of ore into smaller pieces. The comminuted ore is then typically combined with process fluid to aid in liberating the oil. Process fluid may be water, or a combination of water and one or more process aids. The combined oil sand and process fluid is typically referred to as a "slurry". Other

agents, such as additional process aids or flotation aids may be added to the slurry. Process fluid is commonly heated to assist in breaking down mined oil sand ore and release entrapped bitumen.

The slurry is then passed through a "conditioning" phase in which the slurry is allowed to mix and dwell for a period to create froth in the mixture. The term "conditioning" generally refers to a process whereby sufficient energy has been expended such that the bitumen has left the mineral component to form an entity capable of recovery. The extent of conditioning is influenced by the characteristics imparted to the slurry during its preparation. Such characteristics include the lump size, slurry density, amount of mechanical energy imparted to the slurry, amount of thermal energy imparted to the slurry, aeration of the slurry and the addition of chemicals (if any). Once the slurry has been conditioned, it is typically passed through a series of separators for removing the bitumen froth from the slurry.

An apparatus for preparing an oil sand slurry, known to those skilled in the art as a rotary breaker, is described in Canadian Patent 2,235,938 (the '938 patent). The objective of a rotary breaker is to comminute sized oil sand ore, produce an oil sand slurry, and selectively filter out rocks and other hard material, likely not containing bitumen. The described rotary breaker generally comprises a rotatable perforated tube, having a feed end and a discharge end. Mined ore and process fluid, such as hot process water, are injected into the rotary breaker at the feed end. Rotation of the tube causes the ore slurry to be lifted and tumbled, comminuting the ore lumps. The water and ore lumps of a predetermined size pass through the perforations of the rotatable tube, while the oversized lumps traverse through the vessel, towards the discharge end. Any oversize ore lumps reaching the discharge end are ejected out of the vessel. Ejected oil sand ore may preferably be returned to the feed end for re-processing while ejected rock and clay material may be discarded. The ore that has passed through the perforations is collected beneath the rotatable tube for hydro-transport.

The operation of a rotary breaker such as that described in the '938 patent may be improved to allow for higher feed rates of oil sand ore to be processed. Since large volumes of mineral solids must be processed to extract the bitumen, increasing the feed rate may improve the economics of the process. This may allow for the processing of oil sand with a wider range of bitumen concentrations economically. Ideally a rotary breaker will reduce all of the infeed mined oil sand ore to granular material for passage through the perforations of the rotatable vessel.

It has become known that rotary breakers used to prepare an oil sand slurry are prone to backflow, wherein the mined ore deposited in the rotary breaker accumulates at the feed end of the breaker, and discharges back out of the feed end of the breaker, instead of either being broken down to pass through the perforations or being ejected out the discharge end. Backflow in rotary breakers typically occurs when mined oil sand ore infeed rates are increased, depending upon the condition and composition of the mined oil sand ore.

An additional problem faced by rotary breakers used to prepare an oil sand slurry is occlusion of the perforations by previously deposited oil sand, blocking newly deposited oil sand from passing through the perforations. Occlusion of the perforations leads to reduced throughput of slurry, increased ejection of material and increases the likelihood that oil sand will backflow out of the feed end of the rotary breaker.

A further problem faced by rotary breakers used to prepare an oil sand slurry, is sufficiently wetting the infeed oil sand ore when infeed rates are increased.

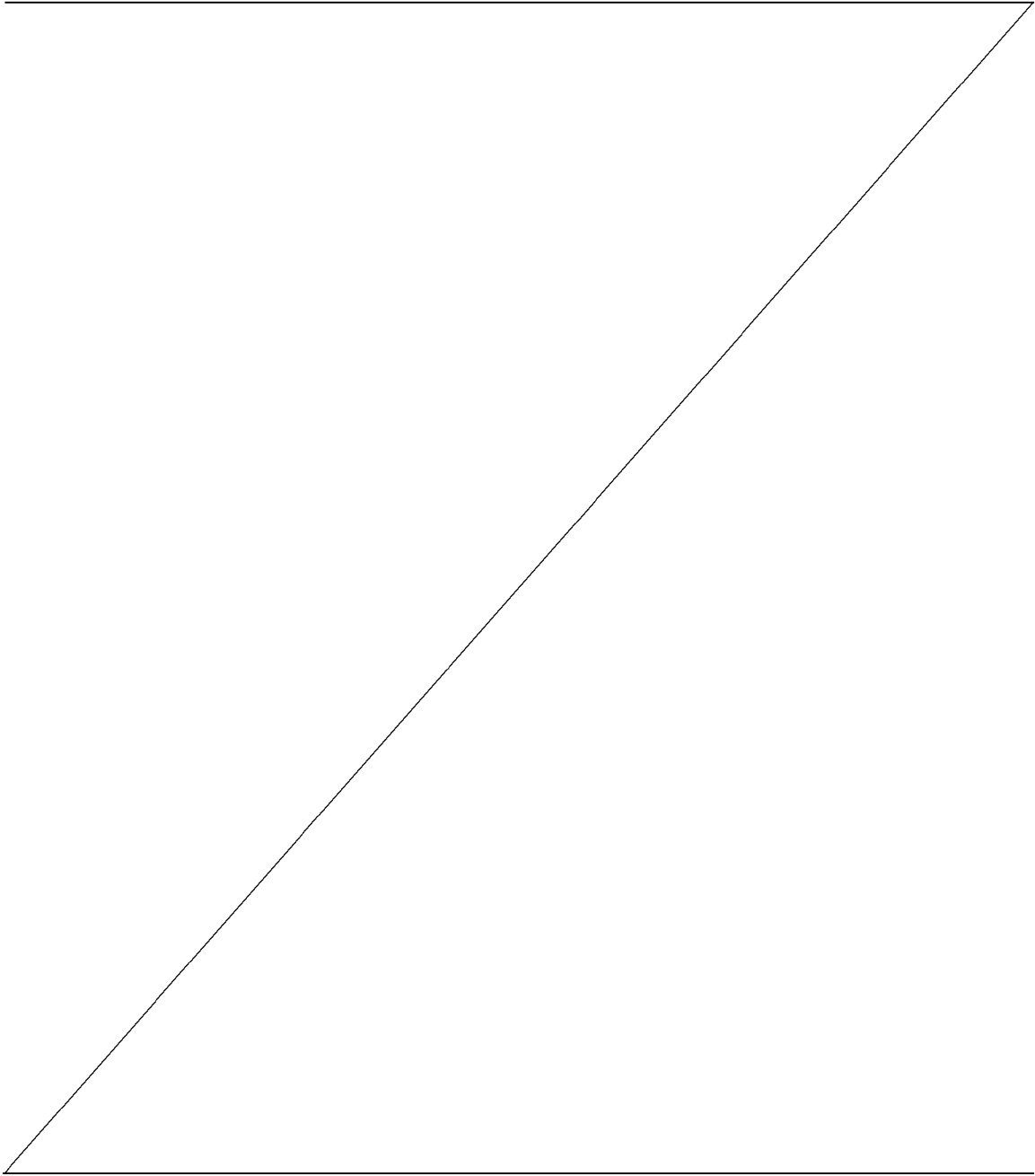
Accordingly there is a need for improving the efficiency of a rotary breaker used to prepare an oil sand slurry. There is a need for a rotary breaker and method of operating a rotary breaker that allow for higher oil sand throughput. There is a need for a rotary breaker and method of operating a rotary breaker that reduce the likelihood that oil sand backflows out of the rotary breaker.

In some implementations, there is provided an apparatus for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being perforated to define a perforated section of the tube and at least a portion of the perforated section comprising lifting elements affixed to and extending from an interior surface of the tube, the lifting elements comprising a combination of multiple sets of neutral lifters for lifting ore and advancer lifters for lifting and advancing ore, each set of neutral lifters being delineated by a set of advancer lifters.

In some implementations, there is provided an apparatus for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being perforated to define a perforated section of the tube and at least a portion of the perforated section comprising lifting elements affixed to and extending from an interior surface of the tube, the lifting elements comprising neutral lifters arranged in neutral lifter rings and advancer lifters arranged in advancer lifter rings radially about the tube, wherein at least one advancer lifter ring is located in between at least one adjacent pair of neutral lifter rings.

In some implementations, there is provided a method of producing a pumpable oil sand slurry from mined oil sand ore and a process fluid supplied to a rotating tube, the method comprising: depositing the ore into an infeed end of the rotating tube; advancing the deposited ore into a perforated section of the rotating tube; in at least a portion of the perforated section: breaking lumps of the ore by lifting and dropping the lumps to a bottom portion of the rotating tube to form broken ore; separating sized ore materials including the broken ore by passing the sized ore material through perforations in the perforated section to obtain passed sized ore material; advancing unpassed ore along the portion of the perforated section; and subjecting a reject fraction of the ore to advancement to a discharge end of

the rotating tube; wherein the breaking of the lumps and the advancing of the unpassed ore comprise moving ore material through advancement lifting zones and neutral lifting zones of the portion of the perforated section of the tube, wherein each adjacent pair of neutral lifting zones has one of the advancement lifting zones in between; collecting the passed sized ore material and process fluid to produce the oil sand slurry.



BRIEF DESCRIPTION OF THE DRAWINGS

In drawings, which illustrate by way of example only, embodiments of the invention,

Figure 1 is an isometric view of a rotatable breaker tube.

Figure 2 is a schematic view of an interior surface of an embodiment of a rotatable breaker tube.

Figures 3a to 3d are cutaway views of alternative embodiments of perforations in the rotatable breaker tube of Figure 1.

Figures 4, 5, 6, 7 and 8 are isometric views of embodiments of internal projections for the rotatable breaker tube of Figure 1.

Figures 9a and 9b are schematic isometric views of embodiments of a rotatable breaker tube.

Figure 9c is a schematic isometric view of a further embodiment of a rotatable breaker tube.

Figures 9e, 9f and 9g are schematic views of a rotatable breaker tube showing ore processing within different zones of the rotatable breaker tube of Figure 9d.

Figures 10, 11 and 12 illustrate embodiments of process fluid sources within a rotatable breaker tube.

Figures 13 and 14 illustrate further embodiments of process fluid sources.

Figures 15a, 15b and 15c illustrate embodiments of nozzle arrangements for a process fluid source.

Figures 16a, 16b and 16c illustrate further embodiments of nozzle arrangements for a process fluid source.

Figures 17a-e illustrate a further embodiment of a nozzle arrangement for a process fluid source.

Figures 18 and 19 are partial isometric views of embodiments of an infeed measurement system and method.

DETAILED DESCRIPTION

In an embodiment, an apparatus is provided for preparing an oil sand ore slurry by combining oil sand ore and process fluid, the apparatus comprising, a tube rotatable about its longitudinal axis, at least a portion of the tube being perforated to define a perforated section of the tube; an infeed end of the tube for receiving oil sand ore; a discharge end of the tube for discharging reject material; a plurality of projecting elements affixed to an interior surface of the tube and, adapted to advance and lift received ore as the tube rotates; and, a process fluid source for directing process fluid at a portion of the interior surface of the rotatable tube in the perforated section of the tube, for generation of the oil sand ore slurry comprising the process fluid and the oil sand ore received into the infeed end, less the reject material.

The process fluid source may supply process fluid at differential rates at different locations within the tube. In an embodiment, the process fluid source may supply a greater quantity of process fluid near the infeed end than the quantity of process fluid supplied near the discharge end.

In an embodiment the process fluid source may comprise a sparge pipe extending through the tube. The sparge pipe may further comprise a baffle plate for dividing the sparge pipe into two sections, an infeed sparge pipe section exiting and supplied with process fluid from the infeed end and a discharge sparge pipe section exiting and supplied with process fluid from the discharge end.

In an embodiment the process fluid source may comprise a slope sheet for receiving process fluid at a top portion of the slope sheet and delivering process fluid to a portion of the interior surface below a bottom portion of the slope sheet.

In an embodiment the process fluid source may comprise an infeed supply pipe positioned at the infeed end of the breaker tube; and, nozzles on the infeed supply pipe are arranged to direct process fluid into the breaker tube at a portion of the interior surface.

The apparatus may further comprise a discharge supply pipe positioned at the discharge end of the breaker tube; and, nozzles on the discharge supply pipe are arranged to direct process fluid into the breaker tube at a portion of the interior surface.

In an embodiment, an apparatus is provided for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising, a tube rotatable about its longitudinal axis, the tube having a wall thickness and at least a section of the tube being perforated such that the perforation extend through the wall thickness; an infeed end of the tube for receiving oil sand ore; a separation zone of the perforated section near the infeed end comprising one or more sets of advancing elements affixed to and extending from an interior surface of the tube, the advancing elements being adapted to advance the received ore away from the infeed end as the tube rotates; a breaking zone of the perforated section for receiving advanced ore from the separation zone, the breaking zone comprising at least a set of lifting elements affixed to and extending from an interior surface of the tube, the lifting elements having contact faces with smaller angles relative to the longitudinal axis compared to contact faces of the advancing elements, and being adapted to lift and drop lump ore; and, a discharge end of the tube for receiving oversized material from the breaking zone as reject material and discharging reject material.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from mined oil sand ore and a process fluid supplied to an interior surface of a rotating breaker tube, the method comprising: depositing the ore into an infeed end of the breaker tube, the breaker tube having a wall thickness; advancing the deposited ore into a separation zone; in the separation zone, separating a sized

fraction of the ore from a lump fraction by passing the sized fraction and a portion of the process fluid through perforations that extend through the wall thickness of the breaker tube and advancing the lump fraction to a breaker zone; in the breaker zone, breaking the advanced lump fraction by lifting and dropping the advanced lump fraction to a bottom portion of the breaker tube, separating a further sized fraction by passing the further sized fraction and a remainder of the process fluid through perforations that extend through the wall thickness of the breaker tube and advancing a reject fraction to a discharge end; discharging reject material out the discharge end; and, collecting the passed sized fraction, the portion of the process fluid, the passed further sized fraction and the remainder of the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from mined oil sand ore and a process fluid, the method comprising: depositing the ore into a separation zone of a breaker tube, the breaker tube having a wall thickness; directing a supply of the process fluid towards an interior surface of the breaker tube; in the separation zone, advancing a lump fraction of the ore through the action of a set of advancing elements extending from the interior surface into a breaking zone, a sized fraction of the ore and a portion of the process fluid passing through perforations that extend through the wall thickness of the breaker tube and being separated from the lump fraction; in the breaking zone, breaking the lump fraction of the ore through the action of a set of lifting elements extending from the interior surface, and separating a further sized fraction by passing the further sized fraction of the ore and a remainder of the process fluid through further perforations that extend through the wall thickness of the breaker tube, and advancing a reject fraction of the ore; discharging the reject fraction out the discharge end; and collecting the passed sized fraction, the portion of the process fluid, the passed further sized fraction and the remainder of the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from a process fluid and oil sand ore consisting of perforation sized material

and lump material, the method comprising: depositing the ore into an infeed end of a breaker tube, the breaker tube having a wall thickness; directing a supply of the process fluid towards an interior surface of the breaker tube; separating a lump fraction from a perforation sized fraction by passing the perforation sized material through perforations that extend through the wall thickness of a first section of the breaker tube and advancing the lump fraction; breaking a lump fraction of the ore by lifting and dropping the lump fraction to create further perforation sized material and simultaneously separating a further perforation sized fraction by passing the perforation sized material, the further perforation sized material and the process fluid through further perforations that extend through the wall thickness of a second section of the breaker tube; and, collecting the passed material and the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from a process fluid and oil sand ore consisting of perforation sized material and lump material, the method comprising: delivering the ore onto a feed conveyor; measuring a quantity of ore carried by the feed conveyor to provide an ore quantity measurement; and adjusting the processing of the ore based on the ore quantity measurement, the processing comprising: depositing the ore into an infeed end of a rotating breaker tube; supplying process fluid into the breaker tube; separating sized ore material through perforations in the breaker tube and breaking lump ore material into further sized material; and, collecting the passed material, the further perforation sized material and the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from a process fluid and oil sand ore consisting of perforation sized material and lump material, the method comprising: depositing the ore into an infeed end of a breaker tube; directing an adjustable supply of the process fluid at differing rates towards an interior surface of the breaker tube to contact the ore deposited into the breaker tube; breaking the lump fraction of the ore by lifting and dropping the lump fraction creating further perforation sized material; passing the perforation sized material, the further perforation sized material and the process fluid through

the perforations in the breaker tube; and, collecting the passed material and the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from mined oil sand ore and a process fluid supplied to an interior surface of a rotating breaker tube, the method comprising: depositing the ore into an infeed end of the breaker tube, the breaker tube having a wall thickness and having a separation zone and a breaker zone, the separation zone being upstream of the breaker zone along the breaker tube; advancing the deposited ore into the separation zone; in the separation zone, separating a sized fraction of the ore from a lump fraction by passing the sized fraction and a portion of the process fluid through perforations that extend through the wall thickness of the breaker tube and advancing the lump fraction to the breaker zone; in the breaker zone, breaking the advanced lump fraction by lifting and dropping the advanced lump fraction to a bottom portion of the breaker tube, separating a further sized fraction by passing the further sized fraction and a remainder of the process fluid through perforations that extend through the wall thickness of the breaker tube and advancing a reject fraction to a discharge end; discharging reject material out the discharge end; and collecting the passed sized fraction, the portion of the process fluid, the passed further sized fraction and the remainder of the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from mined oil sand ore and a process fluid, the method comprising: depositing the ore into an infeed end of a breaker tube, the breaker tube having a wall thickness and having a separation zone and a breaking zone; directing a supply of the process fluid towards an interior surface of the breaker tube; advancing the deposited ore into the separation zone; in the separation zone, advancing a lump fraction of the ore through the action of a set of advancing elements extending from the interior surface into the breaking zone, a sized fraction of the ore and a portion of the process fluid passing through perforations that extend through the wall thickness of the breaker tube and being separated

from the lump fraction; in the breaking zone, receiving ore material consisting of the lump fraction from the separation zone, breaking the lump fraction of the ore through the action of a set of lifting elements extending from the interior surface, separating a further sized fraction by passing the further sized fraction of the ore and a remainder of the process fluid through further perforations that extend through the wall thickness of the breaker tube, and advancing a reject fraction of the ore; discharging the reject fraction out a discharge end; and collecting the passed sized fraction, the portion of the process fluid, the passed further sized fraction and the remainder of the process fluid to produce the oil sand slurry.

In an embodiment, a method is provided for producing a pumpable oil sand slurry from a process fluid and oil sand ore consisting of perforation sized material and lump material, the method comprising: depositing the ore into an infeed end of a breaker tube, the breaker tube having a wall thickness; directing a supply of the process fluid towards an interior surface of the breaker tube; separating a lump fraction from the perforation sized material by passing the perforation sized material through a first arrangement of perforations that extend through the wall thickness of a first section of the breaker tube and advancing the lump fraction; breaking the lump fraction of the ore by lifting and dropping the lump fraction to create further perforation sized material, and simultaneously separating a further perforation sized fraction by passing the further perforation sized material through a second arrangement of perforations that extend through the wall thickness of a second section of the breaker tube, wherein an upstream end of the second section of the breaker tube is contiguous with a downstream end of the first section of the breaker tube for receiving the lump fraction from the first section; passing the process fluid through the perforations in the breaker tube; and collecting the passed material and the process fluid to produce the oil sand slurry.

In an embodiment, an apparatus is provided for preparing an oil sand ore slurry by combining oil sand ore and process fluid, the apparatus comprising: a tube rotatable about a longitudinal axis thereof and having an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least

a portion of the tube being perforated to define a perforated section of the tube; and a process fluid source for directing process fluid at a portion of an interior surface of the rotatable tube, the process fluid source comprising a sparge pipe extending through the tube and being positioned off-center in a direction of intended rotation of the tube.

In an embodiment, an apparatus is provided for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being perforated to define a perforated section of the tube and at least a portion of the perforated section comprising lifting elements affixed to and extending from an interior surface of the tube, the lifting elements comprising a combination of multiple sets of neutral lifters for lifting ore and advancer lifters for lifting and advancing ore, each set of neutral lifters being delineated by a set of advancer lifters.

In an embodiment, an apparatus is provided for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being cylindrical and perforated to define a perforated section of the tube, the perforated section comprising a first set of perforations defining a first open area and a second set of perforations defining a second open area, the first set of perforations being closer to the infeed end than the second set of perforations, and the first open area being greater than the second open area; and a process fluid source for delivering process fluid in order to contact the oil sand ore to form the oil sand ore slurry.

In an embodiment, there is provided a method of producing a pumpable oil sand slurry from a process fluid and oil sand ore, the method comprising:

depositing the ore into an infeed end of a rotating breaker tube;

separating sized ore material through perforations provided in a perforated section of the breaker tube and breaking lump ore material into further sized material, wherein the perforated section is cylindrical and comprises a first set of perforations defining a first open area and a second set of perforations defining a second open area, the first set of perforations being closer to the infeed end than the second set of perforations, and the first open area being greater than the second open area; and

contacting the sized ore material and further sized material that passed through the perforations with the process fluid to form the oil sand slurry.

In another embodiment, there is provided an apparatus for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being and perforated to define a perforated section of the tube, the perforated section comprising a first set of perforations defining a first open area and a second set of perforations defining a second open area, the first set of perforations being closer to the infeed end than the second set of perforations, and the first open area being greater than the second open area; and a process fluid source for delivering process fluid in order to contact the oil sand ore to form the oil sand ore slurry; wherein the infeed end comprises an infeed zone of the tube for receiving the oil sand ore deposited thereon, the infeed zone having no perforations and having advancer projections extending inwardly for advancing the oil sand ore toward the perforated section.

In another embodiment, there is provided an apparatus for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being and perforated to define a perforated section of the tube, the perforated section comprising a first set of perforations defining a first

open area and a second set of perforations defining a second open area, the first set of perforations being closer to the infeed end than the second set of perforations, and the first open area being greater than the second open area; a process fluid source for delivering process fluid in order to contact the oil sand ore to form the oil sand ore slurry; and an ejection zone at a downstream end of the tube, the ejection zone having no perforations and having advancer elements.

In another embodiment, there is provided a method of producing a pumpable oil sand slurry from a process fluid and oil sand ore, the method comprising:

depositing the ore into an infeed end of a rotating breaker tube;

separating sized ore material through perforations provided in a perforated section of the breaker tube and breaking lump ore material into further sized material, wherein the perforated section comprises a first set of perforations defining a first open area and a second set of perforations defining a second open area, the first set of perforations being closer to the infeed end than the second set of perforations, and the first open area being greater than the second open area; and

contacting the sized ore material and further sized material that passed through the perforations with the process fluid to form the oil sand slurry; and

wherein the infeed end comprises an infeed zone of the tube for receiving the oil sand ore deposited thereon, the infeed zone having no perforations and having advancer projections extending inwardly for advancing the oil sand ore toward the perforated section.

In another embodiment, there is provided a method of producing a pumpable oil sand slurry from a process fluid and oil sand ore, the method comprising:

depositing the ore into an infeed end of a rotating breaker tube;

separating sized ore material through perforations provided in a perforated section of the breaker tube and breaking lump ore material into further sized material, wherein the perforated section comprises a first set of perforations defining a first open area and a second set of perforations defining a second open area, the first set of perforations being closer to the infeed end than the second set of perforations, and the first open area being greater than the second open area; and

contacting the sized ore material and further sized material that passed through the perforations with the process fluid to form the oil sand slurry; and

wherein the tube further comprises an ejection zone at a downstream end of the tube, the ejection zone having no perforations and having advancer elements.

Figure 1 is an isometric drawing showing rotatable breaker tube 100 with infeed end 102 and discharge end 104. Breaker tube 100 is shown mounted on trunion bearings 106 (it will be appreciated that in the configuration of Figure 1, there are two further trunion bearings, not shown). Motor 108 is shown with drive gear 110 engaged with toothed outer portion 112 of breaker tube 100. Breaker tube 100 is driven by motor 108 to rotate in a defined direction of rotation. In an alternative drive configuration (not shown), motor 108 may be alternatively coupled or geared to drive the breaker tube 100 such as by driving one or more of the trunion bearings 106.

As shown in Figure 1, breaker tube 100 is preferably divided into a perforated section 116, with perforations 121 extending through the wall of the breaker tube 100, and one or more blind sections 118 having no perforations 121. Figure 1 illustrates an embodiment where perforated section 116 comprises curved plates 120 removably affixed to ribs 122. In the embodiment illustrated, plates 120 have a generally uniform number of perforations 121 per unit area. In an alternate embodiment plates 120 may have varied numbers of perforations 121 in different sections of the breaker tube 100 as more fully described below.

Breaker tube 100 may be oriented with its longitudinal axis aligned with the horizontal. Alternatively, the longitudinal axis may be aligned at a slight declination toward the discharge end 104. The latter orientation assists in processing and moving material from the infeed end 102 toward the discharge end 104.

Preferably the perforations 121 comprise passages that are tapered from a narrower opening at the interior surface 124 of the breaker to a slightly larger opening at the exterior surface of the breaker tube 100 to reduce blinding of the perforations 121 when the breaker tube is in use.

The perforation size of this embodiment is preferably selected to screen a maximum desired size of material passing through breaker tube 100 (perforation sized material) to downstream processing facilities. Perforation sized material generally consists of granular material as well as small lump material able to fit through the perforations 121. Due to the erosive nature of oil sand ore, preferably the wider opening of a perforation 121 at the exterior of the breaker tube 100 is sized at manufacture to the intended maximum screening size and the narrow opening of the perforation 121 at the interior of the breaker tube 100 is sized slightly smaller than the intended maximum screening size.

Typically in high volume oil sands operations downstream processing facilities may require a maximum material size to be limited to a maximum dimension of about 2"-6". Accordingly, the perforations 121 may be sized to screen material to the maximum size permitted by the downstream facilities. In an embodiment the perforations 121 may vary in size up to that maximum material size. Varying the size of the perforations 121 in different portions of the breaker tube 100 provides different throughput and process fluid retention capacities in each portion.

The perforations 121 may comprise a variety of geometric shapes. For instance, the perforations 121 may comprise round holes, square holes, triangular holes or hexagonal holes through the wall of the breaker tube 100. Generally for ease of manufacturing round or square holes may conveniently be used. The

thickness of the plates 120 and the resistance of perforations 121 to erosive wear by passage of the abrasive oil sand ore determine the useful life of the plates. Typically plates 120 are replaced once or twice year at the change of season to balance the cost of downtime for maintenance with the material cost of building more robust plates 121.

Preferably the breaker tube 100 is positioned over a slurry vessel (not shown) adapted to receive and collect slurry, consisting of sized ore and process fluid, that has passed through the perforated section 116 and to feed the collected slurry to a hydrotransport pump, not shown, adapted to pump oil sand slurry through a hydrotransport pipeline to a slurry processing facility.

In addition to perforated section 116, Figure 1 shows two blind sections 118, a first such blind section 118 being located at infeed end 102 and the second blind section located at discharge end 104. As a bearing surface for trunion bearings 106, blind sections 118 have no perforations 121 such that no slurry or other material will be permitted to pass through the wall of breaker tube 100 in such sections. In an alternate embodiment the first blind section 118 near the infeed end 102 may be extended to provide additional mixing of infeed oil sand ore and process fluid.

The isometric diagram of Figure 1 shows a limited portion of interior surface 124. Breaker tube 100 includes a set of internal projections 126 on interior surface 124, a limited number of which internal projections may be seen at infeed end 102 of breaker tube 100 in Figure 1. As will be described in more detail with reference to Figure 2 and Figures 7 and 8, internal projections 126 may be adapted to provide for varying effective action in different locations within breaker tube 100.

Figure 2 is a schematic diagram of the interior surface 124 of breaker tube 100 showing an arrangement of internal projections 126 on interior surface 124 of breaker tube 100. Figure 2 shows a flattened map of half the interior surface of breaker tube 100. A column of internal projections 126 in Figure 2 are understood to represent half of a complete ring of projections about the interior of breaker tube

100 at a particular location along the longitudinal axis. Typically each ring will have a consistent pattern of projections 126, though it is not necessary to have uniform projections 126 within each ring.

The arrangement of differently configured internal projections 126, as between different groups of rings, provides sections or zones along the longitudinal axis of breaker tube 100. The differing arrangements and structures of internal projections 126 in the different zones of the interior surface 124 result in a different processing action on the oil sands material in each of the zones as the material progresses through breaker tube 100.

Breaker tube 100 preferably comprises at least two zones comprising a separation zone 152 and a breaking zone 154. The separation zone 152 acts to separate lump material unable to pass through perforations 121 from perforation sized material by allowing perforation sized material to pass through perforations 121 in the internal surface 124 of the breaker tube 100 while preferentially advancing lump material toward the discharge end 104.

Internal projections 126 in the separation zone 152 comprise advancing elements which act to advance infeed material while separating lump material from perforation sized material either by mixing or tumbling infeed material, or by preferentially lifting and advancing lump material out of the infeed material. Either type of action acts to improve the effective open area (the unblocked perforations 121 available to screen perforation sized material). This is achieved by preventing lump material from occluding perforations 121 and advancing previously deposited infeed material toward the discharge end 104, thus providing a clear section of internal surface 124 near the deposition site available to receive newly deposited infeed material. Maximizing the available open area improves throughput in the separation zone 152 and reduces backflow.

The breaking zone 154 acts to lift and drop lump material with breaking contact, breaking the lump material down into smaller pieces until small enough to pass through the perforations 121 in the internal surface 124 of the breaker tube

100. The breaking contact may either be against a lower portion of the internal surface 124 of the breaker tube 100, or against other lump material situated at the lower portion. A majority of infeed granular material is preferably screened out of the breaker tube 100 in the separation zone 152 before reaching the breaking zone 154 as granular material tends to absorb impact and reduce the instances of breaking contact. The breaking zone 154 may include internal projections 126 adapted to assist in lifting material, as well as internal projections 126 adapted to advance material.

In the context of a breaker tube 100, the term open area may be used to describe the sum of the area available for perforation sized material to pass through the surface of the breaker tube 100. The open area may be changed by selecting appropriate sizes and numbers of perforations 121 per unit area.

A breaker tube 100 may be optimized by adjusting the open area of each zone to provide sufficient open area for passage of perforation sized material in that zone while maintaining sufficient structural strength for the action provided by that zone. In separation zone 152 open area is preferably maximized to provide increased throughput of perforation sized material as infeed material is mainly advanced through feed action of advancing elements. Feed action provides limited lifting a dropping of material as material tends to remain concentrated in a localized section of a lower portion of breaker tube 100.

In breaking zone 154 open area may be reduced relative to separation zone 152 to provide additional structural strength to resist the impact of lump material that is lifted and dropped in breaking zone 154 as a significant portion of the perforation sized fraction of the infeed material has been separated out in separation zone 152 by passing through perforations 121. Breaking zone 154 provides breaking action by lifting and dropping lump material from an upper portion of breaker tube 100. Since material is lifted up to an upper portion of breaker tube 100, material is distributed over a larger area of a section of internal surface 124 in the breaking zone 154 than in the separation zone 152.

In general breaker tube 100 may be arranged to allow for greater structural strength at the cost of less throughput capacity in breaking zone 154 and less structural strength with more opening per unit area in separation zone 152 to permit maximum throughput of perforation sized material in that zone.

In an embodiment, fewer perforations 121 per unit area may be provided in breaking zone 154 to provide additional structural support and a greater number of perforations 121 per unit area provided in separation zone 152 to provide additional throughput of perforation sized material.

In an embodiment, the perforations 121 are uniformly at the maximum size and arranged at a maximum number of perforations 121 per unit area throughout the separation zone 152. In an embodiment the perforations 121 may be provided at a size less than the maximum size and/or less than a maximum number of perforations 121 per unit area at an infeed end of separation zone 152 and an increased size and/or increased number of perforations 121 per unit area at a discharge end of separation zone 152. Such an embodiment provides for additional process fluid 344 retention at the deposition site to ensure sufficient wetting of infeed ore before separation of perforation sized material from lump material.

In an embodiment, the perforations 121 may be provided at a size less than the maximum size and/or at a number less than the maximum number of perforations 121 per unit area in the breaking zone 154. In an alternate embodiment the throughput capacity may decrease (by reducing the number of perforations 121 per unit area and/or size of the perforations 121) through the breaking zone 154 towards the discharge end 104.

In an embodiment illustrated in Figure 2, the separation zone 152 and breaking zone 154 are complemented by an infeed zone 150 and an ejection zone 156. Infeed zone 150 and ejection zone 156 include internal projections 126 which may be configured to include one or more types of advancing elements such as those shown in Figure 2 as advancing elements 160, 162, 164 (i.e. ploughs 160

and 162 and paddles 164). Preferably advancing elements 160, 162, 164 extend a distance from the internal surface 124 comparable to the size of expected infeed lump material. Preferably each of advancing elements 160, 162, 164 present an elongate surface to the discharge end 104 of breaker tube 100. The elongate surface is arranged at an angle to the longitudinal axis of breaker tube 100 such that as breaker tube 100 rotates, the rotationally leading end of the surface is closer to the infeed end 102 than the rotationally trailing end of the surface. Most preferably each of advancing elements 160, 162, 164 present an elongate surface at an angle of about 20-45° relative to the longitudinal axis to provide a feeding action giving a strong advancement of material towards discharge end 104 when such material contacts the surface in rotation.

Infeed zone 150 is illustrated as having different sized advancing elements 160, 162 for flexibility in manufacture and maintenance. In the embodiment illustrated, these advancing elements include short ploughs 160 and long ploughs 162, which are more fully described below. In the embodiment illustrated, infeed zone 150 corresponds with blind section 118 at the infeed end of breaker tube 100 while ejection zone 156 corresponds to blind section 118 at the discharge end 104 of breaker tube 100. The ploughs 160, 162 may comprise sections that when affixed in-line provide a combination that effectively forms a larger plough body or may be affixed with a gap between sections. Alternatively, a continuous plough body may be formed from a single piece of material. It is generally preferred to create the plough body from multiple ploughs 160, 162 for ease of manufacturing, installation and maintenance.

Ejection zone 156 may include advancing elements comprising one or more sets of ploughs 160, 162 or other appropriately arranged and selected internal projections 126 to assist in advancing reject material out the discharge end 104 of the breaker tube 100. Since a majority of the reject material comprises rock, metal or other hard material that could not be processed in breaker tube 100, preferably internal projections 126 in ejection zone 156 are robustly constructed. Preferably internal projections 126 in ejection zone 156 comprise projections such as

advancing elements 160, 162, 164 that are adapted to provide more of an advancing action than a lifting action to reduce wear caused by lifting and dropping reject material.

In the embodiment of Figure 2, separation zone 152 contains advancing elements that are configured as paddles 164. Separation zone 152 is shown in the embodiment of Figure 2 to be located in the first one quarter of the length of perforated section 116 of breaker tube 100, though the size of separation zone 152 may be varied. Paddles 164 are configured and arranged to lift and preferentially advance lump material from infeed material, as is described in more detail below. Preferably paddles 164 of one ring are arranged such that their contact surfaces are aligned with paddles 164 of adjacent rings.

In an alternate embodiment, separation zone 152 may contain ploughs 160, 162. The ploughs 160, 162 in separation zone 152 advance and mix infeed material, separating lump material as the perforation sized material falls through the perforations 121 in the internal surface 124 of the breaker tube 100. Ploughs 160, 162 in separation zone 152 lift and advance material while advancing the material into the breaker tube 100. Granular and perforation sized material will tend to roll/wash off the ploughs 160, 162 at a lower point of rotation than lump material, providing a separation action that tumbles and advances infeed material, preferentially screening perforation sized material through the perforations 121 and advancing lump material to the breaking zone 154.

In the embodiment of Figure 2, the balance of perforated section 116 in breaker tube 100 forms breaking zone 154. In the illustrated embodiment of breaking zone 154, internal projections 126 comprise lifting elements 166, 168 and consist of a combination of advancer lifters 166 and neutral lifters 168. Advancer lifters 166 provide a lifting action with some advancement to assist in urging material toward the discharge end 104. Neutral lifters 168 provide a lifting action to lift and drop lump material. The embodiment of Figure 2 comprises three repeating sets of advancer lifter 166 and neutral lifter 168 combinations. Each set

comprises a first ring of advancer lifters 166, followed by three rings of neutral lifters 168. The number and combination of advancer lifters 166 and neutral lifters 168 may vary depending upon the requirements of throughput and breaking action required.

Figures 3a, 3b, 3c, 3d illustrate alternate configurations of perforations 121 through a portion of a plate 120. In the embodiments illustrated the perforations 121 are of consistent size and concentration within the portion illustrated. In an alternate to the embodiment to Figure 3d (not shown), circular perforations 121 may be staggered to provide more perforations 121 per unit area.

The embodiments illustrated and described below are for a breaker tube 100 aligned with a horizontal longitudinal axis. In embodiments where breaker tube 100 is aligned with a longitudinal axis on a decline toward the discharge end 104, a reduced angle of the leading face of each of the internal projections 126 relative to the longitudinal axis may be provided.

The embodiments illustrated are for exemplary internal projections 126 and specific location of attachment points, reinforcement or geometry are not intended to be limiting. The internal projections 126 are described herein as being adapted to provide a leading contact face that lifts, advances or lifts and advances oil sand toward the discharge end 104 as the breaker tube 100 rotates in its intended direction. The angle of a contact face is described with reference to the longitudinal axis of the breaker. For an advancing element, as breaker tube 100 rotates, the rotationally leading end of the contact surface is closer to the infeed end 102 than the rotationally trailing end of the surface such that the leading end of the face contacts material first during rotation, urging the contacted material toward the discharge end 104. The angle of a contact face affects a balance between lifting action and advancing action with an angle of 0° providing primarily lifting action, an angle close to 45° providing significant advancing action. Advancing elements 160, 162, 164 typically comprise elements with contact faces aligned at 30°-45° to provide desired advancing action. Lifting elements 166, 168 typically comprise

elements with contact faces aligned at 0°-25° to provide desired a lifting or lifting and advancing action.

In a preferred embodiment, infeed zone 150 comprises advancing elements 160, 162, 164 with contact faces aligned with the longitudinal axis at about 45° to provide strong advancement of infeed material from the deposition point through the separation zone 152.

In a preferred embodiment, separation zone 152 comprises advancing elements 160, 162, 164 with contact faces aligned with the longitudinal axis at about 45° to provide strong advancement of infeed material while screening perforation sized material through perforations 121.

In a preferred embodiment, breaking zone 154 comprises advancer lifters 168 with contact faces aligned at about 5°-20° to provide lifting action with some advancement to maintain flow of material toward the discharge end 104 and away from the infeed end 102. In a preferred embodiment, breaking zone 154 comprising neutral lifters 166 with contact faces aligned at about 0°.

It will be understood by those skilled in the art that the angular references provided will be subject to operating conditions of the rotary breaker.

In a preferred embodiment, discharge zone 156 comprises advancing elements 160, 162, 164 with contact faces aligned at about 45° to provide desired primarily advancing action.

Figure 4 illustrates an embodiment of a short plough 160 that may be fixed to interior surface 124 in the locations shown in the schematic representation of Figure 2. Figure 4 shows connector plates 302 and 304 used to bolt short plough 160 to interior surface 124. Short plough 160 is adapted to present face 161 at an angle to oil sand material contacted as the breaker tube 100 rotates about its longitudinal axis. As described above, the angle is selected such that when the breaker tube 100 rotates, oil sand material in the breaker is first contacted by the rotationally leading end of face 161 closer to the infeed end 102, urging the oil

sand material towards discharge end 104 so as to provide an advancement action on infeed material.

Long plough 162 (not shown) has the same overall configuration as short plough 160 but has a longer length than short plough 160 and may include further connection points to secure long plough 162 along its length to the interior surface 124. Combinations of short ploughs 160 and long ploughs 162 are preferably used in place of larger ploughs to allow repair and replacement of ploughs that may be damaged without removal of large plough elements that would be otherwise required.

In the embodiment illustrated the attachment points for internal projections 126 are oriented in-line with the longitudinal axis of breaker tube 100. In alternate embodiments (not shown) the attachment points may be oriented at an angle to the longitudinal axis and accordingly the arrangement of the bolt holes on internal projections 126 may vary from the embodiments illustrated herein.

Figure 5 is an isometric illustration of an embodiment of paddle 164. In the embodiment illustrated paddle 164 comprises upstanding member 316 and base member 317. Base member 317 is arranged to provide a secure connection point for securing paddle 164 to breaker tube 100 (for instance with bolts or welding). Preferably, paddle 164 presents face 308 to provide preferential lifting and advancement of lump material from the infeed material. In an embodiment paddle 164 presents face 308 at an angle of 30°-45° to the longitudinal axis.

Figure 6 is an isometric drawing of an embodiment of neutral lifter 168. In the embodiment illustrated neutral lifter 168 comprises upstanding member 313 and base member 311. Base member 311 is arranged to provide a secure connection point for neutral lifter 168 to breaker tube 100 (for instance with bolts or welding). Neutral lifter 168 is adapted to present face 310 at a neutral angle, substantially parallel to the longitudinal axis of the breaker tube 100 when installed (for a horizontally aligned breaker tube 100). The neutral angle of face 310 provides a lifting action to material located at a bottom portion of breaker tube 100

as it rotates about its longitudinal axis. Further, face 310 may include protruding sections 312 to resist wear and prevent lifted material from prematurely falling off face 310 as the material is lifted with the rotation of breaker tube 100.

The length and width of face 310 may be selected to provide lifting action to lumps of a predetermined size and neutral lifters 168 may be characterized as large or small based upon the size of face 310 and how high it extends from interior surface 124. Larger lumps tend to roll off relatively small neutral lifters 168 at a lower portion of breaker tube 100. Larger neutral lifters 168 tend to cause more wear to interior surface 124 from impact as they lift all lump material, including large lump material, to a top portion of breaker tube 100. Preferably neutral lifters 168 are minimally sized to the lump material to provide sufficient breaking at a given feed rate and quality of infeed ore. Generally neutral lifters 168 will be sized smaller than the larger lump material near the infeed end 102 to minimize wear on the plates 120.

Figure 7 is an isometric drawing of an embodiment of advancer lifter 166. In the embodiment illustrated advancer lifter 166 comprises upstanding member 306 and base member 315. Base member 315 is arranged to provide a secure connection point for advancer lifter 166 to breaker tube 100 (for instance with bolts or welding). Advancer lifter 166 is adapted to present face 314 at an angle to the longitudinal axis of the breaker tube 100 when installed. Advancer lifter 166 is installed on the interior surface 124 of the breaker tube 100 to present face 314 at an angle to oil sand material contacted as the breaker tube 100 rotates about its longitudinal axis. Typically advancer lifters 166 may be arranged to present face 314 at an angle less than about 20° but greater than about 5° to provide a combination of advancing and lifting action. At higher infeed rates advancer lifters 166 near the infeed end 102 may be presented with a larger angle in the range to provide relatively greater advancing action. Advancer lifters 166 in the middle of the breaking zone 154 are typically provided with a smaller angle, for example, about 15° to provide primarily lifting action with some advancing action. Advancer lifters 166 in this location preferably have a smaller contact angle to increase the

dwelling time of material in the breaking zone 154. Further, face 314 has protruding sections 316 (similar to those found on face 310) to resist erosion and prevent lifted material from prematurely falling off face 314 as the material is lifted with the rotation of breaker tube 100.

Figure 8 is an isometric drawing showing an embodiment of an internal projection 126 having a larger contact surface 318. In the embodiment of Figure 8 the internal projection comprises an advancer lifter 167. In the embodiment illustrated advancer lifter 167 comprises upstanding member 321 and base member 319. Base member 319 is arranged to provide a secure connection point for advancer lifter 167 to breaker tube 100 (for instance with bolts or welding). Advancer lifter 167 is adapted to present face 318 at an angle to the longitudinal axis of the breaker tube 100 when installed.

As will be appreciated, factors such as strength, weight, face size and orientation, and resistance to wear are considered in selecting the structural arrangements of the various internal projections 126. Although Figures 4 to 8 illustrate example ploughs, paddles and lifters, other structures may be used to provide internal projections to act on oil sand material as rotation of breaker tube 100 occurs, in accordance with this description.

Figure 9a is an isometric schematic diagram showing breaker tube 100 and its relationship with a process line for processing mined oil sand ore into a pumpable oil sand slurry (note that Figure 9 is a reverse view from the view of breaker tube 100 in Figure 1). A conveyor 320 is positioned with its discharge end 322 located to discharge conveyed oil sand ore into breaker tube 100. A slope sheet 324 is positioned below discharge end 322 extending from conveyor 320 into breaker tube 100 to collect and direct granular material and process fluid 344 that may otherwise fall short of the intended deposition point.

In the embodiment illustrated in Figure 9a slope sheet 324 comprises a collector for collecting process fluid and fine granular material and directing them into breaker tube 100. Also as illustrated, slope sheet 324 may comprise a process

fluid source supplying process fluid 344 directed down a top surface of slope sheet 324 to provide additional process fluid 344 delivery means at the deposition point downstream of discharge end 322 of the conveyor 320.

Figure 9b illustrates an alternate embodiment where conveyor 320 is positioned to extend into breaker tube 100 with no slope sheet 324. Preferably in this embodiment a scraper plate 325 is provided under conveyor 320 to remove any remaining oil sand ore.

Slope sheet 324 may be a flat sheet as illustrated in Figure 9a, or alternatively as illustrated in Figure 9c may include side walls 327 to provide a shallow trough for delivering oil sand ore 326. In an alternate embodiment (not shown), the slope sheet 324 comprises a V-shaped trough for delivering oil sand ore 326.

In the embodiment illustrated in Figures 9a, 9b and 9c, sparge pipe 340 is suspended within and extends through breaker tube 100. As will be described below, other arrangements provide alternate means to deliver process fluid 344 that do not require a sparge pipe 340. Sparge pipe 340 has nozzles 342 disposed along its length for delivery of process fluid 344 directed towards a portion of the interior surface 124 of breaker tube 100 to provide for mixing of process fluid with oil sand ore material in the breaker tube 100 material (not shown in Figures 9a, 9b, 9c).

Figures 9d, 9e, 9f, 9g are illustrations schematically representing oil sand ore 345 and 346 within different zones 150, 152, 154 of breaker tube 100. In Figures 9e, 9f, 9g, oil sand ore material is shown schematically as sized material 345 (i.e. oil sand ore material that has dimensions to permit passage through openings of the dimensions of perforations 121) and lump material 346 (i.e. material with dimensions that preclude such passage). In the schematic cross section of Figure 9g (referencing a ring in zone 150, viewed towards discharge end 104), material 345 and 346 are shown as deposited into infeed zone 150. The material is predominantly located at a lower or bottom portion of breaker tube 100.

Alternatively, as described above, oil sand ore could be deposited directly into separation zone 152, in which case the portion of separation zone 152 at the deposition site would exhibit a similar oil sand ore distribution. Figure 9f schematically represents a ring of breaker tube 100 in separation zone 152 (viewed towards discharge end 104). Figure 9f shows material 345 and 346 distributed across a bottom portion of breaker tube 100 and, relative to the distribution in Figure 9g, slightly raised up but still within a lower portion of the lifting wall of breaker tube 100. Figure 9e shows, schematically, a ring in breaking zone 154 in which much of the perforation sized material 345 has passed through perforations 121 leaving predominantly lump material 346 remaining in breaking zone 154 where such material is lifted for breaking deposition into smaller sized material 346 as is suggested in Figure 9e. As is described further, below, water 344 is shown as differentially distributed in the schematic representations of Figures 9e, 9f, 9g.

Figure 10 is a schematic cross-section drawing showing breaker tube 100 and trunion bearings 106. Representative neutral lifter 168 is shown with a lump 346 being lifted in a clockwise direction. As will be appreciated, the lump 346 will tend to disengage from neutral lifter 168 and follow a trajectory that is determined by the original rotational motion of breaker tube 100 and by gravity.

Preferably, sparge pipe 340 is positioned in a top portion of breaker tube 100. Locating sparge pipe 340 as shown in Figure 10, positioned near a top portion of breaker tube 100 and offset from the vertical center line, provides additional clearance between sparge pipe 340 and the tumbling ore trajectory as, for example, lump 346 falls off neutral lifter 168. This will reduce the likelihood that ore lump material 346 will impact sparge pipe 340 when breaker tube 100 is operated (and particularly at higher rotational speeds).

To further avoid damage to sparge pipe 340 from the impact from tumbling ore, there is provided, as illustrated in the schematic cross section of Figures 11 and 12, protection for the sparge pipe in the form of a protective shell 350 enclosing

sparge pipe 340. In the embodiment of Figure 11, nozzle 342 may extend beyond protective shell 350. Protective shell 350 may also provide structural support for supporting sparge pipe 340 along its length within breaker tube 100. An alternative protective arrangement is illustrated in the schematic cross-section of Figure 12, in which sparge pipe 340 and nozzle 342 are both enclosed by protective shell 350. A further alternate embodiment of protective shell 350, sparge pipe 340 and nozzles 342 is illustrated in Figure 17b.

Returning to Figures 9a, 9b and 9c, baffle plate 360 preferably divides sparge pipe 340 into two sections: an infeed section supplied with process fluid 344 from the infeed end 102 of breaker tube 100 and a discharge section supplied with process fluid 344 from a discharge end 104 of breaker tube 100. Such a division permits differential delivery of process fluid 344 to different zones of breaker tube 100. Further, the embodiment of Figures 9a, 9b and 9c may be combined with varied number and diameter of nozzles 342 to allow fine-tuning of the distribution of process fluid 344 in each zone (an example of which is shown in Figures 9e, 9f and 9g). As an alternative to use of a baffle plate 360 in a single sparge pipe 340, separate supply lines may be provided for each section.

The schematic drawing of Figure 13 shows an alternative arrangement of pipes and nozzles for delivery of process fluid 344. In Figure 13, conveyor 320 is shown arranged such that discharge end 322 is located outside breaker tube 100 near infeed end 102. This arrangement permits slope sheet 324 to be located partly within breaker tube 100 and partly outside the infeed end 102 of the breaker tube 100. As a result, process fluid 344 may be sprayed onto ore 326 after it progresses off the discharge end 322 of conveyor 320 while it travels down slope sheet 324. Process fluid 344 is shown being delivered by exterior supply pipe 370. Supply pipe 370 comprises nozzles 342 arranged to spray process fluid 344 onto slope sheet 324. Additional process fluid source(s) may in combination with supply pipe 370 supply process fluid 344 to an upper surface of slope sheet 324, such as the embodiments illustrated in Figures 9a, 9b and 9c.

Infeed supply pipe 372, with associated nozzles 342, is located in proximity to infeed end 120 to deliver process fluid 344 into breaker tube 100 directed at interior surface 124. As illustrated, infeed supply pipe 372 and its associated nozzles 342 are positioned to avoid the mined oil sand ore 326 flow as it enters breaker tube 100. Discharge supply pipe 374, with associated nozzles 342, is located in proximity to discharge end 104 to deliver process fluid 344 into breaker tube 100 directed at interior surface 124. In the configuration of Figure 13, discharge supply pipe 374 is arranged to avoid the material that is discharged from breaker tube 100.

Infeed supply pipe 372 and discharge supply pipe 374 are depicted as comprising different exemplary pipe configurations, an inverted U-shaped section and a generally semi-circular section respectively, however both elements could comprise either of the exemplary configurations.

Figure 14 is a cross-sectional schematic drawing of the breaker tube 100 with infeed supply pipe 372, discharge supply pipe 374 and slope sheet 324 comprising side walls 327. Figure 14 shows nozzles 342 oriented to direct process fluid 344 throughout a lower portion of perforated section 116 of breaker tube 100. A variation of this embodiment includes distributing the process fluid 344 differentially along the perforated section 107, wherein more process fluid 344 is distributed at the infeed end 102 of breaker tube 100.

In an embodiment (not shown), only the infeed supply pipe 372 or the discharge supply pipe 374 may be provided, alone or in combination with an alternate process fluid source such as slope sheet 324 or sparge pipe 340.

Process fluid 344 may be uniformly distributed within breaker tube 100 or, preferably, may be differentially distributed within breaker tube 100, as illustrated in the exemplary embodiments of Figures 15a, 15b, 15c, 16a, 16b and 16c.

Each of Figures 15a, 15b, 15c, 16a, 16b and 16c show breaker tube 100 in schematic cross-section having sparge pipe 340 with nozzles 342 having

alternative dimensions and locations for delivery of process fluid 344. Each of the arrangements in Figures 15a, 15b, 15c, 16a, 16b and 16c shows variation in delivery of process fluid 344

In general, the infeed section of the sparge pipe 340 may supply a greater fraction of the total volume of process fluid 344 supplied to the breaker tube 100. In a typical embodiment approximately 70-80% of the total volume of process fluid 344 may be supplied by the infeed section of sparge pipe 340 to improve oil sand throughput capacity near the infeed end 102.

In general, a first quantity of process fluid may be supplied to assist in the separation of perforation sized ore from lump ore and a second quantity of process fluid may be supplied to assist in the breaking of lump ore. The supply of process fluid 344 acts to wet ore and flush perforation sized ore through perforations. In the breaking zone 154, process fluid 344 may act to assist in the breaking action by flushing perforation sized ore through perforations and to wet ore newly exposed during the breaking action.

As illustrated in Figure 15a, the infeed section 347 of sparge pipe 340 near the infeed end 102 of breaker tube 100 may comprise a greater concentration of nozzles 342 than the discharge section 348 of sparge pipe 340 near the discharge end 104. Alternatively, as illustrated in Figure 15b, nozzles 343 disposed along the infeed section 347 may be larger than those disposed near the discharge section 348 of the sparge pipe 340 such that each larger nozzle 343 supplies more process fluid 344 than a corresponding smaller nozzle 342 in the discharge section 348. Figure 15c illustrates an embodiment where the differential delivery of process fluid 344 is achieved by differing the supply flow rate between the two sections while the nozzle size and quantity is similar as between the two sections. In the embodiment illustrated a greater proportion of process fluid 344 is delivered to the infeed section 347, flooding the separation section 348 with process fluid 344. Alternatively a combination of differential supply flow rate and nozzle size, or

quantity may be employed to achieve the differing supply flow rate between the two sections.

Figure 16a illustrates an embodiment similar to Figure 15a, with the exception that the endmost nozzles 345 are directed to distribute the majority of their flow towards a middle portion of breaker tube 100. Figure 16b illustrates an embodiment for supplying varied flow within a section of sparge pipe 340. In the embodiment of Figure 16b, a central portion 349 of the discharge section 348 near baffle plate 360 has a greater concentration of nozzles 342 to provide increased supply of process fluid 344 in the near a middle portion of breaker tube 100 and progressively less process fluid 344 towards the discharge end 104. The embodiment of Figure 16b is further illustrated in Figure 17.

Figure 16c illustrates an embodiment wherein the endmost nozzles 345 are directed to distribute the majority of their flow into a middle portion of breaker tube 100 and a greater concentration of nozzles 342 are located at an oil sand deposition point in breaker tube 100 to supply a higher concentration of process fluid 344 at the oil sand deposition point near the infeed end 102.

In a further illustration of the embodiment of Figure 16b, Figure 17a illustrates a section of sparge pipe 340 near baffle plate 360. The infeed section 347 portion of the sparge pipe 340 at the infeed side of baffle plate 360 comprises a greater concentration of nozzles 342 than the central portion 349 of the discharge section 348 of the sparge pipe 340 at the discharge side of baffle plate 360. In the embodiment illustrated alternate nozzles 342 are offset to provide alternating process fluid 344 trajectories. For instance, one nozzle may be directed on the lifting wall of breaker tube 100 and the next nozzle on the bottom portion of the breaker tube 100. Alternating nozzle trajectories assists in providing even coverage of process fluid 344 to assist in washing the perforation sized material resulting from broken lumps through the perforations 121.

As described above, process fluid 344 is added to mined oil sand ore to form a slurry. It is preferable to match the supply of process fluid 344 to specific

zones within breaker tube 100. Infeed zone 150 is intended to feed mined ore from the infeed end 102 into the body of breaker tube 100 to clear the infeed end 102 to make space for additional mined oil sand ore that is continuously supplied. The delivery of process fluid 344 in the infeed zone 150 is intended to provide wetting of the ore. At the deposition site, the oil sand ore is mainly located at a bottom portion of the breaker tube 100 offset slightly in the direction of rotation. Accordingly, the supply of process fluid 344 in this zone is preferably directed to cover the approximately one quarter to one half of the breaker tube 100 wall area where a substantial portion of infeed material is located as illustrated in Figure 9g. In an embodiment jet nozzles are used to supply process fluid 344 to infeed zone 150 and separation zone 152 to impart a jet action onto the ore as it tumbles for efficient wetting and mixing of the ore. In separation zone 152, the jet action also assists in clearing the perforations 121 in this high volume portion of breaker tube 100.

Figures 17b-17e are simplified cross-section illustrations through breaker tube 100 at various locations along its length showing an embodiment of sparge pipe 340 providing differential delivery of process fluid 344. In the embodiment of Figures 17b-17e, pairs of alternating nozzles 342 are used to provide varied distribution of process fluid 344. In an embodiment the nozzles may be located at different offsets about the sparge pipe 340 to provide alternate spray trajectories.

Figure 17b illustrates a cross-section taken near the feed end 102 where process fluid 344 is directed at a bottom portion of breaker tube 100, concentrated in an area where oil sand is deposited. Figure 17c illustrates a cross-section taken in the separation zone 152 where process fluid 344 is directed at a bottom portion of breaker tube 100, extending somewhat up the lifting wall. Figure 17d illustrates a cross-section taken in the breaking zone 154 where process fluid 344 is directed at a bottom portion of breaker tube 100 and extends up the lifting wall. Figure 17e illustrates a cross-section taken near the ejection zone 156 where process fluid 344 is directed in a wide angle wash.

Figures 9e-9g illustrate the application of process fluid 344 in combination with ore composition in different zones within the breaker tube 100. Figure 9e illustrates a schematic cross-section in the breaking zone 154 showing process fluid 344 directed across the bottom portion of the breaker tube 100 as well as across the lifting wall of breaker tube 100 to contact lump material as it is lifted. In Figure 9f, in an infeed end of the separation zone 152, oil sand ore material is shown shifted somewhat in the direction of rotation up the lifting wall of the breaker tube 100. The process fluid 344 is directed across an increased portion of breaker tube 100, concentrated where oil sand is distributed. Figure 9g illustrates a cross-section near the deposition site. Preferably process fluid 344 is directed in a concentrated spray at a lower portion of the breaker tube 100 at the deposition site to assist in wetting the ore and flushing perforation sized ore through the perforations 121. A wide angle wash of process fluid 344 (shown in Figure 17e) may be used near the discharge end 104 to wash away any remaining bitumen and granular material.

The density of a resulting oil sand slurry is preferably adjusted by controlling the addition of process fluid 344 inside breaker tube 100. Supplying process fluid 344 for the slurry into the breaker tube 100, as opposed to providing makeup fluid to a slurry vessel capturing the output from breaker tube 100, provides for a more consistent slurry as well as additional aeration of the slurry which assists downstream slurry conditioning and processing.

Figure 18 illustrates in embodiment of a portion of a conveyor 320 with mined oil sand ore 326 being conveyed towards a breaker tube 100. Level sensor 400, such as a radar or laser sensor, is shown in the embodiment of Figure 18, arranged relative to conveyor 320 so as to permit a scan to be performed to measure or detect the distance between level sensor 400 and the top of mined oil sand ore 326 being conveyed to determine a height of the mined oil sand ore 326 on conveyor 320. By sampling the height level with the feed rate of conveyor 320 an estimate of oil sand infeed rate may be determined. A further alternative to level sensor 400 is shown in Figure 19 where level sensor 402 comprises horizontally

arranged sensing means to measure the distance between a height of ore 326 travelling below level sensor 402 from which an estimate of ore height may be calculated.

Regarding the process carried out by the level sensor 400 or 402 in the embodiment of Figures 18 and 19, granulated ore typically presents a consistent level to weight measurement. Reduced quantities of granulated ore typically presents a decrease in the absolute values of the level measurement and the weight measurement with a relatively consistent level to weight measurement. Ore containing large lump material will typically present a discrepancy in the level to weight measurement as compared with the absolute value of the weight measurement. Where a discrepancy exists between the level to weight measurement and the absolute value of the weight measurement and/or level measurement, a processor unit may slow, or accelerate, an apron feed conveyor delivering ore to conveyor 320 for a period of time, such that breaker tube 100 may receive a relatively consistent ore feed for processing despite variation in consistency of ore feed along the conveyor 320.

Conveyor 320 may also be equipped with a scale/weightometer (not shown) in addition to, or as an alternative to, level sensor 400. The weightometer provides a continuous weight measurement which may be used to determine the infeed rate of oil sand material. The weightometer may be employed to control the infeed rate by adjusting the feed of oil sand ore onto conveyor 320, for instance by adjusting the feed rate of an apron feeder fed by a hopper.

Where a combination of weightometer and level sensor 400 is employed, level sensor 400 measures the height of the incoming ore feed 326 being carried by conveyor 320 and the scale measures the weight of the ore travelling along the conveyor 320. The two measurements may be compared to render a more accurate estimate of infeed rate.

In operation, the process capacity of a breaker tube 100 for mined oil sand ore 326 is related to the amount of material that is passed from the interior of

breaker tube 100, through perforations 121 near the infeed end 102 of the breaker. As mined oil sand ore is subject to motion and impact within rotating breaker tube 100, sized material is obtained. Increasing the proportion of perforation sized material that passes through perforations 121 closer to infeed end 102 reduces the likelihood of material backflow out infeed end 102, reduces the amount of reject material ejected from discharge end 104 and increases the process capacity of breaker tube 100.

Further, the process capacity of a rotary breaker for mined oil sand ore 326 may be increased if sized material is separated from lump material closer to infeed end 102. If ore lumps remain unseparated from perforation sized material, the lumps have a greater chance of occluding perforations 121 in the internal surface 124 of breaker 100 and reducing the effective perforated area available to allow passage of the perforation sized material. Ore lumps may be separated from sized material near the internal surface 124 either by preferentially lifting and advancing lump material, for instance by the action of paddles 164, or by mixing or tumbling infeed material, for instance by the action of ploughs 160, 162.

Efficient breaking of ore lumps, especially winter ore lumps, is enhanced if the ore lumps are lifted and dropped by the motion of breaker tube 100 such that the location at which the ore lumps land at a bottom portion of internal surface 124 of breaker tube 100 has a minimal amount of granular material so as to improve the chances of breaking contact with either surface 124 or other lump material. Accordingly, separation of perforation sized material, consisting of granular material and small lumps, from the infeed ore near the infeed end 102 enhances the process capacity of the breaker tube 100.

Aspects of the breaker tube 100 embodiments illustrated in the Figures, and described above, increase the efficiency of breaking of mined oil sands ore 326 within breaker tube 100, as the breaker tube 100 operates to produce a slurry. In one aspect, the design and arrangement of internal projections 126 on interior surface 124 as described will assist in the efficiency of the rotary breaker used for

producing a slurry of mined oil sand ore. As indicated, the configuration and placement of such internal projections 126 define zones or sections within breaker tube 100.

Returning to the embodiment illustrated in Figure 2, breaking zone 154 comprises multiple lifting zones shown as zones D1, D2, D3 in the figure. Each such lifting zone is preceded by an advancing zone C1, C2, C3. Advancing zone C1 contains advancer lifters 166 that lift and advance the ore material into lifting zone D1. Lifting zone D1 contains neutral lifters 168 that lift lumps with the rotation of breaker tube 100 to drop the lumps onto the bottom portion of the breaker tube 100 so as to break such lumps into smaller pieces and granular material. This type of lifting and breaking action is illustrated in more detail in Figure 10. Preferably, and as shown in Figure 2, in lifting zones D1, D2, D3, the neutral lifters 168 in each row or ring are offset from those in the adjacent row or ring so as to permit sized material to remain at the bottom portion of breaker tube 100 for passage through perforations 121 while preferentially lifting the lump material.

The selective lifting movement of material in breaking zone 154, such that lump material tends to be lifted while sized material tends not to be lifted to the same degree, increases the effective open (perforated) area available for passage of perforation sized material and further separates lump material from sized material. As is described in more detail below with reference to the delivery of process fluid 344, as ore material advances down the length of breaker tube 100 towards discharge end 104, sized material is washed through the perforations 121, clearing breaker tube 100 for contact with lump material that is lifted and dropped to the bottom of breaker tube 100 in the lifting zones D1, D2, D3. It is preferred to lift and drop lump material directly onto the interior surface 124 of breaker tube 100 or other lump material rather than onto granular material as granular material tends to absorb the impact and reduce the breaking action imparted on the lump material.

Improved efficiency in the passage of perforation sized material through perforations 121 in breaker tube 100 reduces the amount of process fluid 344

required to operate breaker tube 100 at higher infeed rates. For higher infeed rates, an extension of separation zone 152 similar to that shown in Figure 2 may be provided. Extending separation zone 152 increases the capacity of breaker tube 100 for preferentially separating sized material from infeed material through perforations 121 before lifting and dropping lump material.

Advancing zone C2 contains advancer lifters 166 that are configured and arranged to lift and advance material in zone C2 into lifting zone D2. Typically material will remain in lifting zone D1 until either random tumbling causes it to pass through to the advancing zone C2 advancers 166, or additional infeed material is advanced through advancing zone C1 into lifting zone D1, displacing the material already in lifting zone D1.

The use of multiple lifting zones D1, D2, D3 each delineated by an advancing zone C1, C2, C3 is preferable over a single large lifting zone with no advancing zone C1, C2, C3 to ensure material progresses toward discharge end 104. The inclusion of a breaking zone 154 including advancing zones C1, C2, C3 containing rings of advancer lifters 166 provides an advantage in maintaining ore progression through breaker tube 100, irrespective of the infeed rate of new material. This allows breaker tube 100 to operate efficiently with both high infeed rates as well as variation in the infeed quality and rate. Where the longitudinal axis of breaker tube 100 is aligned on a decline with respect to the horizontal, it may not be necessary to include rings of advancer lifters 168 as the orientation of a declined breaker tube 100 will cause material to progress toward discharge end 104.

Lifting zone D2 contains neutral lifters 168 that lift lumps with the rotation of breaker tube 100 so as to drop the lumps with breaking contact onto the bottom portion of breaker tube 100, or other lump material located there, and thereby to break the lumps into smaller pieces. In Figure 2, neutral lifters 168 in lifting zone D2 are shown as being arranged in a similar pattern to those in zone D1. This arrangement in zone D2 will serve to give a dwell time for ore material in that zone

roughly equivalent to the dwell time in zone D1. Alternatively, neutral lifters 168 may be arranged in a different pattern to increase the dwell time of material that has been advanced into lifting zone D2. One way to achieve such a longer dwell time is to reduce the number of such neutral lifters 168 in zone D2.

In one arrangement, neutral lifters 168 in lifting zone D1 are arranged to allow a dwell time as shown by their arrangement in Figure 2, whereas neutral lifters 168 in lifting zone D2 are fewer in number and therefore have a longer dwell time (this arrangement is not shown). In the arrangement shown in Figure 2 for zone D1, lump material is intended to be preferentially lifted relative to granular material and is thereby eventually advanced into lifting zone D2, thereby clearing lifting zone D1 of lump material. It may also be useful to preferentially lift and advance lump material out of the granular material where higher infeed rates cause granular material to pass through from the separation zone 152 into lifting zone D1. In an embodiment, what is shown in Figure 2 as lifting zone D1 may include one or more advancer lifters 166 or paddles 164 to impart a more aggressive advancing action to urge lump material toward discharge end 104. Generally, however, it is preferred to provide advancer lifters 166 with a small angle to provide primarily lifting action to assist in breaking lump material and maintain a minimum dwell time within the breaker tube 100.

Material may be advanced out of D2 either as random tumbling of material causes it to pass through to the advancing zone C3 advancers, or additional infeed material is advanced through advancing zone C2 into lifting zone D2, displacing the material already in zone D2. To reduce the amount of bitumen inadvertently ejected from the discharge end 104, it is advantageous to reduce the chances that random tumbling of material will cause advancement by increasing the dwell time of lump material in lifting zones D2 and D3 closer to the discharge end 104. In this fashion material typically exits a zone due to the advancement of additional material into the zone, displacing the material presently in the zone, or the material has been broken down sufficiently to pass through the perforations 121.

Advancing zone C3 contains advancer lifters 166 that advance the material into lifting zone D3. Typically, material will remain in lifting zone D2 until either random tumbling causes it to pass through to the advancing zone C3 advancer lifters 166, or additional infeed material is advanced through advancing zone C2 into lifting zone D2, displacing the material already in lifting zone D2.

Lifting zone D3 contains neutral lifters 168 that lift lump material with the rotation of breaker tube 100 to drop the lump material onto the bottom portion of the breaker 110 to break the lump material into smaller pieces. The neutral lifters 168 in lifting zone D3 may either be arranged in a similar pattern to lifting zones D1 and D2, or alternatively may be arranged in a different pattern to increase the dwell time of material advanced into the lifting zone D3.

Various embodiments of the present invention having been thus described in detail by way of example, it will be apparent to those skilled in the art that variations and modifications may be made without departing from the invention. The invention includes all such variations and modifications as fall within the scope of the appended claims.

CLAIMS

1. An apparatus for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being perforated to define a perforated section of the tube and at least a portion of the perforated section comprising lifting elements affixed to and extending from an interior surface of the tube, the lifting elements comprising a combination of multiple sets of neutral lifters for lifting ore and advancer lifters for lifting and advancing ore, each set of neutral lifters being delineated by a set of advancer lifters.
2. The apparatus of claim 1, wherein each set of advancer lifters comprises a ring of advancer lifters radially distributed about the interior surface of the tube.
3. The apparatus of claim 1, wherein each set of advancer lifters consists of one ring of advancer lifters radially distributed about the interior surface of the tube.
4. The apparatus of claim 2 or 3, wherein the advancer lifters of each ring of advancer lifters are evenly spaced apart from each other about the interior surface of the tube.
5. The apparatus of any one of claims 2 to 4, wherein each ring of advancer lifters comprises only advancer lifters about the ring.
6. The apparatus of any one of claims 2 to 5, wherein the advancer lifters of each ring are identical to each other in construction.
7. The apparatus of any one of claims 2 or 6, wherein each set of neutral lifters comprises at least one ring of neutral lifters radially distributed about the interior surface of the tube and provided side-by-side with a corresponding ring of advancer lifters.
8. The apparatus of claim 7, wherein the at least one ring of neutral lifters comprises at least two side-by-side rings of neutral lifters.
9. The apparatus of claim 7, wherein the at least one ring of neutral lifters comprises a series of rings of neutral lifters, wherein each series of rings comprises an uptube ring, an intermediate ring and a downtube ring.

10. The apparatus of claim 9, wherein the series of rings of neutral lifters consists of the uptube ring, the intermediate ring and the downtube ring.
11. The apparatus of claim 9 or 10, wherein the uptube ring of neutral lifters is side-by-side with a corresponding ring of advancer lifters upstream thereof.
12. The apparatus of any one of claims 9 to 11, wherein the set of neutral lifters comprises at least two of the series of rings of neutral lifters.
13. The apparatus of any one of claims 9 to 11, wherein the set of neutral lifters comprises three of the series of rings of neutral lifters, comprising an uptube series, an intermediate series and a downtube series.
14. The apparatus of claim 13, wherein the set of neutral lifters consists of the uptube series, the intermediate series and the downtube series.
15. The apparatus of claim 13 or 14, wherein, for at least the uptube series and the intermediate series of neutral lifters, the downtube ring of neutral lifters is side-by-side with a corresponding ring of advancer lifters downstream relative thereto.
16. The apparatus of claim 13 or 14, wherein, for the downtube series of neutral lifters, the downtube ring of neutral lifters is side-by-side with the discharge end of the tube.
17. The apparatus of claim 16, wherein the discharge end comprises advancing elements affixed to and extending from the interior surface of the tube.
18. The apparatus of any one of claims 13 to 17, wherein the set of advancer lifters comprises a first ring of advancer lifters upstream and side-by-side with the uptube series of neutral lifters, a second ring of advancer lifters in between and side-by-side with the uptube series and intermediate series of neutral lifters, and a third ring of advancer lifters in between and side-by-side with the intermediate series and downstream series of neutral lifters.
19. The apparatus of claim 18, wherein the advancer lifters of the second ring are configured to cause less advancement of the ore compared to the advancer lifters of the first and third rings.

20. The apparatus of any one of claims 7 to 19, wherein the neutral lifters of each ring of neutral lifters are evenly spaced apart about the interior surface of the tube.
21. The apparatus of any one of claims 7 to 20, wherein each ring of neutral lifters comprises only neutral lifters about the ring.
22. The apparatus of any one of claims 7 to 21, wherein the neutral lifters of side-by-side rings of neutral lifters are offset with respect to each other.
23. The apparatus of any one of claims 7 to 22, wherein the advancer lifters and the neutral lifters of side-by-side rings are offset with respect to each other.
24. The apparatus of any one of claims 1 to 23, wherein the advancer lifters each have a contact surface that is angled between 5° and 20° with respect to a longitudinal axis of the tube.
25. The apparatus of any one of claims 1 to 24, wherein the neutral lifters each have a neutral lifter contact surface that is angled at 0° with respect to a longitudinal axis of the tube.
26. The apparatus of any one of claims 1 to 23, wherein the advancer lifters each comprise:
 - an upstanding member having a contact face; and
 - a base member affixed to the interior surface of the tube.
27. The apparatus of claim 26, wherein the contact face of each advancer lifter comprises protruding sections extending forward from opposed ends, the protruding sections being configured to resist erosion and/or prevent lifted ore from prematurely falling off the contact face as the ore is lifted with rotation of tube.
28. The apparatus of claim 26 or 27, wherein the base member is configured to be bolted to the tube.
29. The apparatus of claim 26 or 27, wherein the base member is configured to be welded to the tube.

30. The apparatus of any one of claims 26 to 29, wherein the advancer lifters each further comprise spaced-apart wall members extending from a rear face of the upstanding members along the base member.
31. The apparatus of claim 30, wherein the wall members include two opposed end wall members, and at least one middle wall member.
32. The apparatus of any one of claims 26 to 31, wherein the advancer lifters each have a tapered shape viewed from above.
33. The apparatus of any one of claims 1 to 32, wherein the neutral lifters each comprise:
 - a neutral lifter upstanding member having a neutral lifter contact face; and
 - a neutral lifter base member affixed to the interior surface of the tube.
34. The apparatus of claim 33, wherein the contact face of each neutral lifter comprises neutral lifter protruding sections extending forward from opposed ends of the neutral lifter contact face, the neutral lifter protruding section being configured to resist erosion and/or prevent lifted ore from prematurely falling off the neutral lifter contact face as the ore is lifted with rotation of tube.
35. The apparatus of claim 33 or 34, wherein the neutral lifter base member is configured to be bolted to the tube.
36. The apparatus of claim 33 or 34, wherein the neutral lifter base member is configured to be welded to the tube.
37. The apparatus of any one of claims 33 to 36, wherein the neutral lifters each further comprise spaced-apart neutral lifter wall members extending from a rear face of the neutral lifter upstanding members along the neutral lifter base member.
38. The apparatus of claim 37, wherein the wall members include two opposed end neutral lifter wall members, and at least one middle neutral lifter wall member.
39. The apparatus of any one of claims 33 to 38, wherein the neutral lifters are each laterally symmetrical.

40. The apparatus of any one of claims 1 to 39, wherein the portion of the perforated section comprising the lifting elements is a breaking section, and the perforated section further comprises a separation section uptube of the breaking section, the separation section comprising advancing elements affixed to the interior surface of the tube and being configured to provide greater advancement of the ore compared to the advancer lifters.
41. The apparatus of claim 40, wherein the separation section is side-by-side with the breaking section.
42. The apparatus of claim 40 or 41, wherein the infeed end is uptube and side-by-side with the separation section, and the discharge end is downtube and side-by-side with the breaking section.
43. The apparatus of claim 42, wherein the infeed end and the discharge end are perforationless.
44. The apparatus of any one of claims 1 to 43, wherein the infeed end comprises infeed advancing elements affixed to the interior surface of the tube.
45. The apparatus of any one of claims 1 to 43, wherein the discharge end comprises discharge advancing elements affixed to the interior surface of the tube.
46. An apparatus for preparing an oil sand ore slurry by combining oil sand ore and a process fluid, the apparatus comprising a tube rotatable about its longitudinal axis with an infeed end for receiving oil sand ore and a discharge end for discharging reject material, at least a portion of the tube being perforated to define a perforated section of the tube and at least a portion of the perforated section comprising lifting elements affixed to and extending from an interior surface of the tube, the lifting elements comprising neutral lifters arranged in neutral lifter rings and advancer lifters arranged in advancer lifter rings radially about the tube, wherein at least one advancer lifter ring is located in between at least one adjacent pair of neutral lifter rings.
47. The apparatus of claim 46, wherein the advancer lifters of each advancer lifter ring are evenly spaced apart from each other about the interior surface of the tube.

48. The apparatus of claim 46 or 47, wherein each advancer lifter ring comprises only advancer lifters.
49. The apparatus of any one of claims 46 to 48, wherein the advancer lifters of each advancer lifter ring are identical to each other in construction.
50. The apparatus of any one of claims 46 to 49, wherein the neutral lifter rings comprise a plurality of series of neutral lifter rings arranged in side-by-side relation.
51. The apparatus of claim 50, wherein each series of neutral lifter rings comprises an uptube ring, an intermediate ring and a downtube ring.
52. The apparatus of claim 51, wherein each series of neutral lifter rings consists of the uptube ring, the intermediate ring and the downtube ring.
53. The apparatus of claim 51, wherein the uptube ring of neutral lifters is side-by-side with a corresponding advancer lifter ring upstream thereof.
54. The apparatus of any one of claims 51 to 53, wherein the plurality of series of neutral lifter rings comprises three series of neutral lifter rings, comprising an uptube series, an intermediate series and a downtube series.
55. The apparatus of claim 54, wherein the neutral lifter rings consist of the uptube series, the intermediate series and the downtube series of neutral lifter rings.
56. The apparatus of claim 54 or 55, wherein, for at least the uptube series and the intermediate series of neutral lifter rings, the downtube ring is side-by-side with a corresponding advancer lifter ring that is downstream relative thereto.
57. The apparatus of claim 54 or 55, wherein, for the downtube series of neutral lifter rings, the downtube ring is side-by-side with the discharge end of the tube.
58. The apparatus of any one of claims 54 to 57, wherein the advancer lifter rings comprise a first advancer lifter ring upstream and side-by-side with the uptube series of neutral lifter rings, a second advancer lifter ring in between and side-by-side with the uptube series and intermediate series of neutral lifter rings, and a third advancer lifter ring in between and side-by-side with the intermediate series and downtube series of neutral lifter rings.

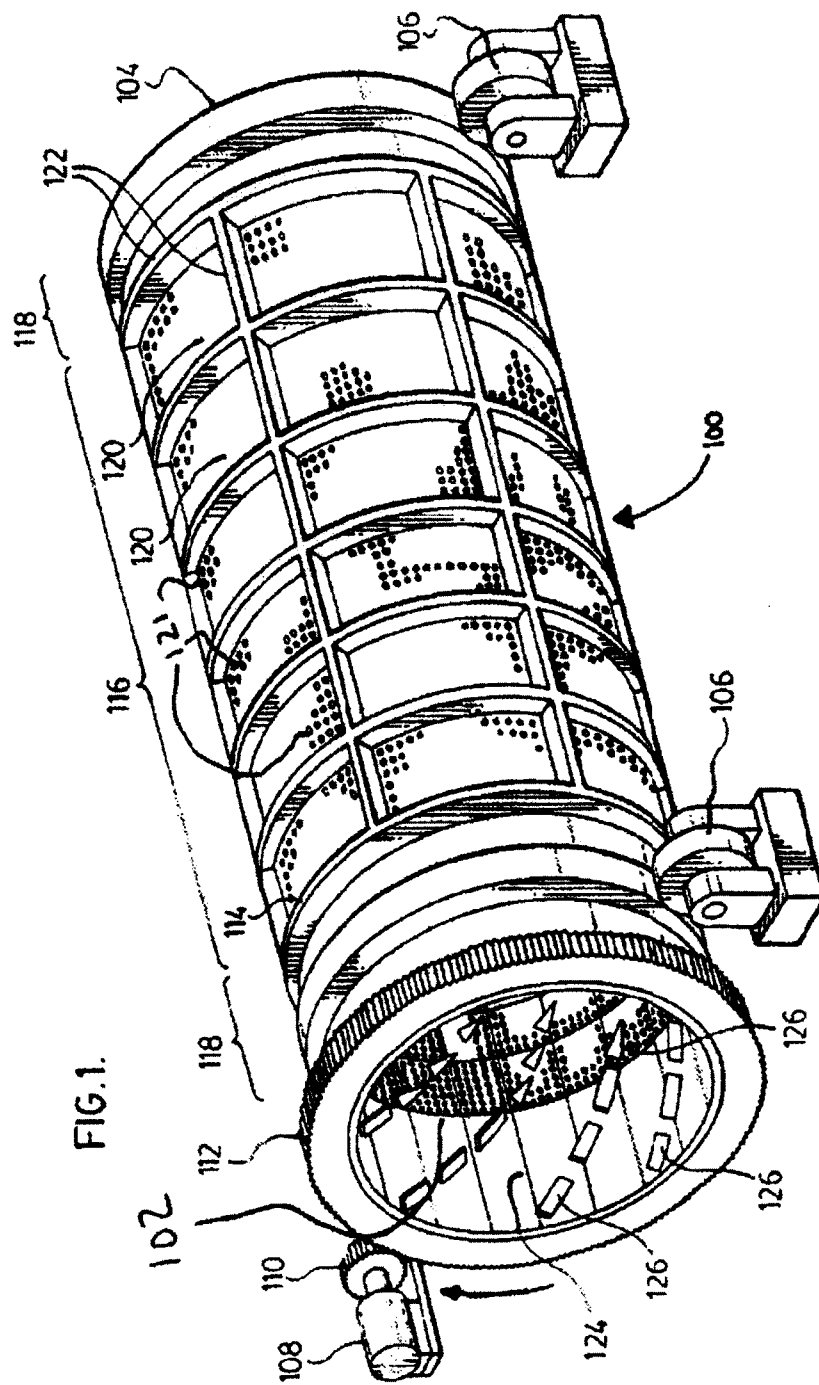
59. The apparatus of claim 58, wherein the advancer lifters of the second advancer lifter ring are configured to cause less advancement of the ore compared to the advancer lifters of the first and third advancer lifter rings.
60. The apparatus of any one of claims 46 to 59, wherein the neutral lifters of each neutral lifter ring are evenly spaced apart about the interior surface of the tube.
61. The apparatus of any one of claims 46 to 60, wherein each neutral lifter ring comprises only neutral lifters.
62. The apparatus of any one of claims 46 to 61, wherein the neutral lifters of side-by-side neutral lifter rings are offset with respect to each other.
63. The apparatus of any one of claims 46 to 62, wherein the advancer lifters and the neutral lifters of side-by-side rings are offset with respect to each other.
64. The apparatus of any one of claims 46 to 63, wherein the advancer lifters each have a contact surface that is angled between 5° and 20° with respect to a longitudinal axis of the tube.
65. The apparatus of any one of claims 46 to 64, wherein the neutral lifters each have a neutral lifter contact surface that is angled at 0° with respect to a longitudinal axis of the tube.
66. The apparatus of any one of claims 46 to 65, wherein the advancer lifters each comprise:
- an upstanding member having a contact face; and
 - a base member affixed to the interior surface of the tube.
67. The apparatus of claim 66, wherein the contact face of each advancer lifter comprises protruding sections extending forward from opposed ends of the contact face, the protruding sections being configured to resist erosion and/or prevent lifted ore from prematurely falling off the contact face as the ore is lifted with rotation of tube.
68. The apparatus of claim 66 or 67, wherein the base member is configured to be bolted to the tube.

69. The apparatus of claim 66 or 67, wherein the base member is configured to be welded to the tube.
70. The apparatus of any one of claims 66 to 69, wherein the advancer lifters each further comprise spaced-apart wall members extending from a rear face of the upstanding members along the base member.
71. The apparatus of claim 70, wherein the wall members include two opposed end wall members, and at least one middle wall member.
72. The apparatus of any one of claims 66 to 71, wherein the advancer lifters each have a tapered shape viewed from above.
73. The apparatus of any one of claims 46 to 72, wherein the neutral lifters each comprise:
- a neutral lifter upstanding member having a neutral lifter contact face; and
 - a neutral lifter base member affixed to the interior surface of the tube.
74. The apparatus of claim 73, wherein the contact face of each neutral lifter comprises neutral lifter protruding sections extending forward from opposed ends of the neutral lifter contact face, the neutral lifter protruding sections being configured to resist erosion and/or prevent lifted ore from prematurely falling off the neutral lifter contact face as the ore is lifted with rotation of tube.
75. The apparatus of claim 73 or 74, wherein the neutral lifter base member is configured to be bolted to the tube.
76. The apparatus of claim 73 or 74, wherein the neutral lifter base member is configured to be welded to the tube.
77. The apparatus of any one of claims 73 to 76, wherein the neutral lifters each further comprise spaced-apart neutral lifter wall members extending from a rear face of the neutral lifter upstanding members along the neutral lifter base member.
78. The apparatus of claim 77, wherein the neutral lifter wall members include two opposed end neutral lifter wall members, and at least one middle neutral lifter wall member.

79. The apparatus of any one of claims 73 to 78, wherein the neutral lifters are each laterally symmetrical.
80. The apparatus of any one of claims 46 to 79, wherein the portion of the perforated section comprising the lifting elements is a breaking section, and the perforated section further comprises a separation section uptube of the breaking section, the separation section comprising advancing elements affixed to the interior surface of the tube and being configured to provide greater advancement of the ore compared to the advancer lifters.
81. The apparatus of claim 80, wherein the separation section is side-by-side with the breaking section.
82. The apparatus of claim 80 or 81, wherein the infeed end is uptube and side-by-side with the separation section, and the discharge end is downtube and side-by-side with the breaking section.
83. The apparatus of claim 82, wherein the infeed end and the discharge end are perforationless.
84. The apparatus of any one of claims 46 to 83, wherein the infeed end comprises infeed advancing elements affixed to the interior surface of the tube.
85. The apparatus of any one of claims 46 to 84, wherein the discharge end comprises discharge advancing elements affixed to the interior surface of the tube.
86. The apparatus of any one of claims 50 to 59, wherein at least one of the advancer lifter rings is located in between each adjacent series of neutral lifter rings.
87. The apparatus of claim 86, wherein a single one of the advancer lifter ring is located in between each adjacent series of neutral lifter rings.
88. The apparatus of any one of claims 50 to 59, 86 or 87, wherein at least one of the advancer lifter rings is located upstream of each series of neutral lifter rings.
89. The apparatus of claim 88, wherein a single advancer lifter ring is located upstream of each series of neutral lifter rings.

90. The apparatus of any one of claims 1 to 89, comprising a process fluid supply system configured to supply water as the process fluid into the tube.
91. The apparatus of claim 90, wherein the process fluid supply system is configured to supply hot process water as the process fluid into the tube.
92. A method of producing a pumpable oil sand slurry from mined oil sand ore and a process fluid supplied to a rotating tube, the method comprising:
- depositing the ore into an infeed end of the rotating tube;
 - advancing the deposited ore into a perforated section of the rotating tube;
 - in at least a portion of the perforated section:
 - breaking lumps of the ore by lifting and dropping the lumps to a bottom portion of the rotating tube to form broken ore;
 - separating sized ore materials including the broken ore by passing the sized ore material through perforations in the perforated section to obtain passed sized ore material;
 - advancing unpassed ore along the portion of the perforated section; and
 - subjecting a reject fraction of the ore to advancement to a discharge end of the rotating tube;
 - wherein the breaking of the lumps and the advancing of the unpassed ore comprise moving ore material through advancement lifting zones and neutral lifting zones of the portion of the perforated section of the tube, wherein each adjacent pair of neutral lifting zones has one of the advancement lifting zones in between;
 - collecting the passed sized ore material and process fluid to produce the oil sand slurry.
93. The method of claim 92, wherein the portion of the perforated section comprises three neutral lifting zones.

94. The method of claim 93, wherein the portion of the perforated section comprises an advancement lifting zone upstream of each neutral lifting zone.
95. The method of any one of claims 92 to 94, wherein the neutral lifting zones are longer than the advancement lifting zones.
96. The method of any one of claims 92 to 95, wherein the neutral lifting zones comprise neutral lifters affixed to an interior surface of the tube.
97. The method of claim 96, wherein the advancement lifting zones comprise advancer lifters affixed to the interior surface of the tube.
98. The method of claim 97, wherein the advancer lifters are arranged in corresponding advancer lifter rings about the interior surface of the tube.
99. The method of claim 98, wherein the neutral lifters are arranged in corresponding neutral lifter rings about the interior surface of the tube.
100. The method of claim 99, wherein each neutral lifting zone comprises multiple neutral lifter rings.
101. The method of claim 100, wherein each advancement lifting zone comprises a single advancer lifter ring.
102. The method of any one of claims 99 to 101, wherein the advancer lifters and the neutral lifters in side-by-side rings are offset with respect to each other, the advancer lifters each have a contact surface that is angled between 5° and 20° with respect to a longitudinal axis of the rotating tube, and the neutral lifters each have a neutral lifter contact surface that is angled at 0° with respect to the longitudinal axis of the tube.
103. The method of any one of claims 92 to 102, wherein the process fluid comprises water.



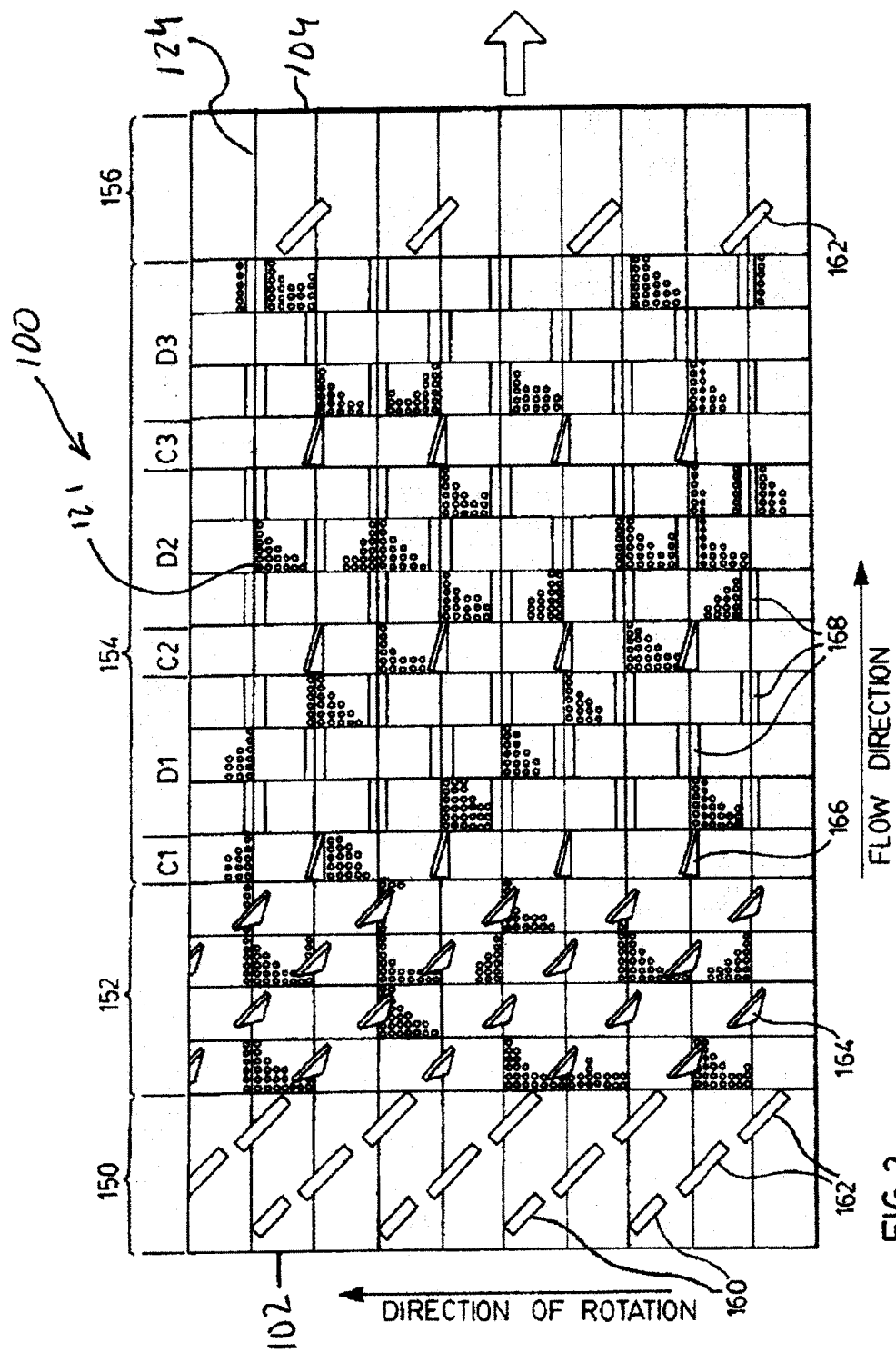


FIG. 2.

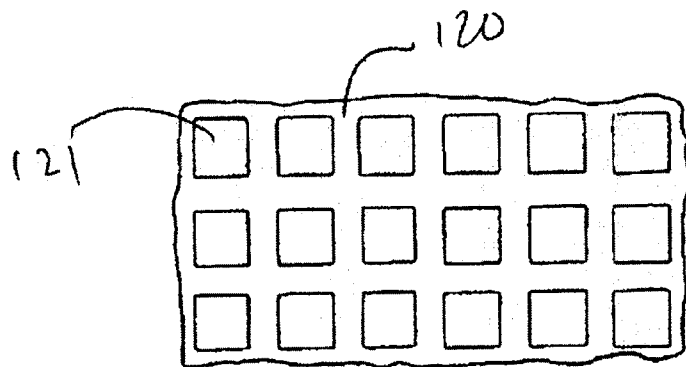


Figure 3a

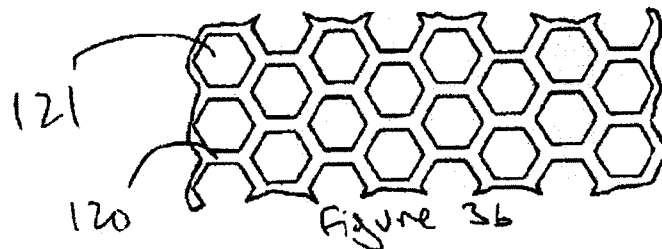


Figure 3b

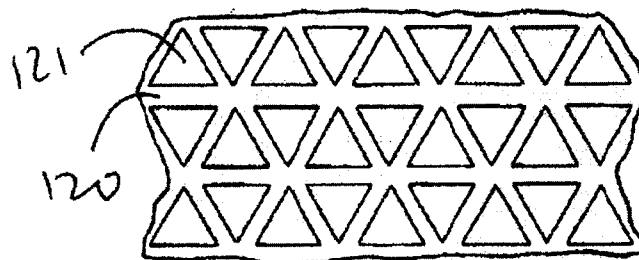


Figure 3c

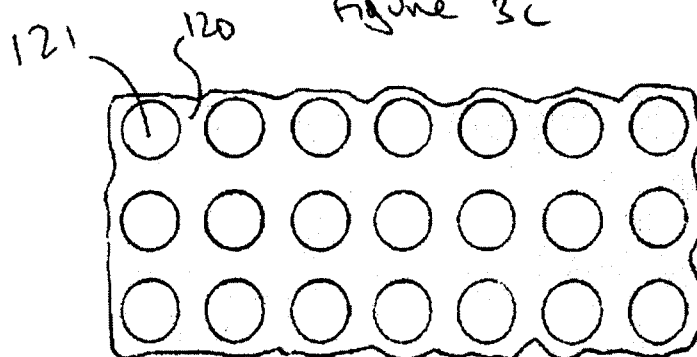
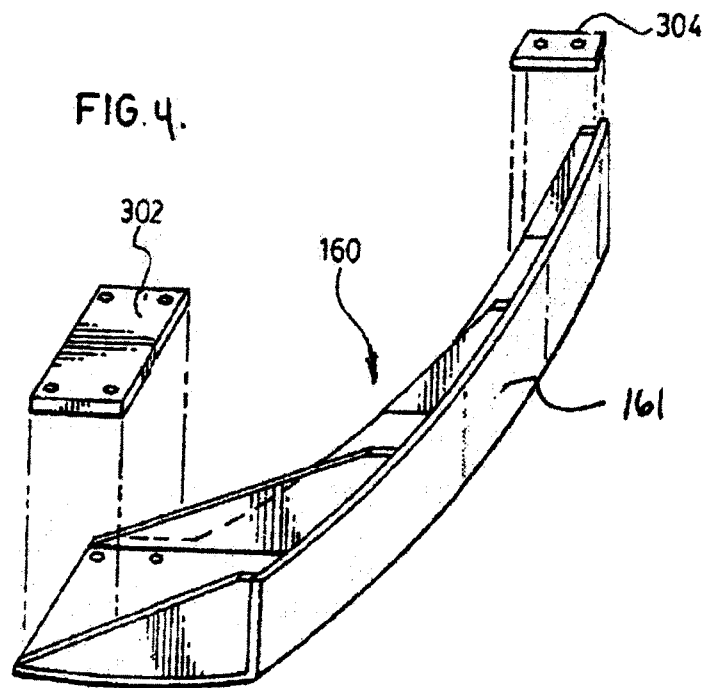


Figure 3d



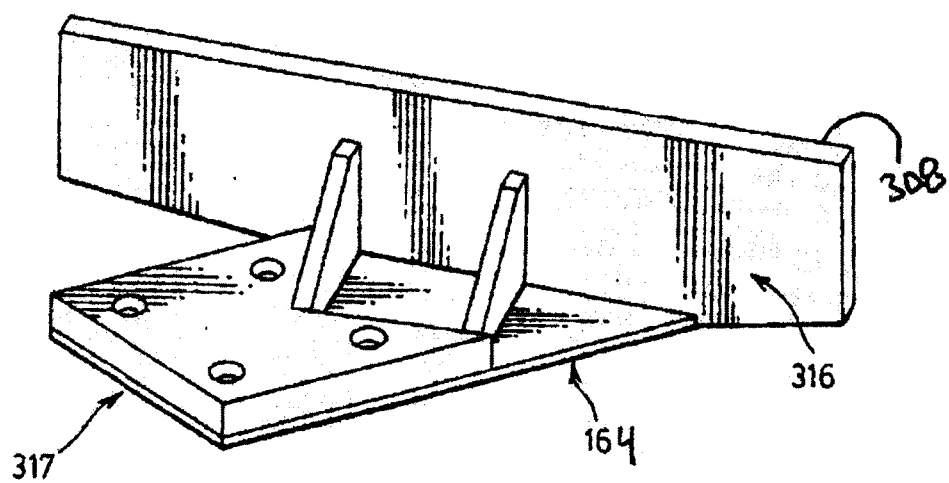
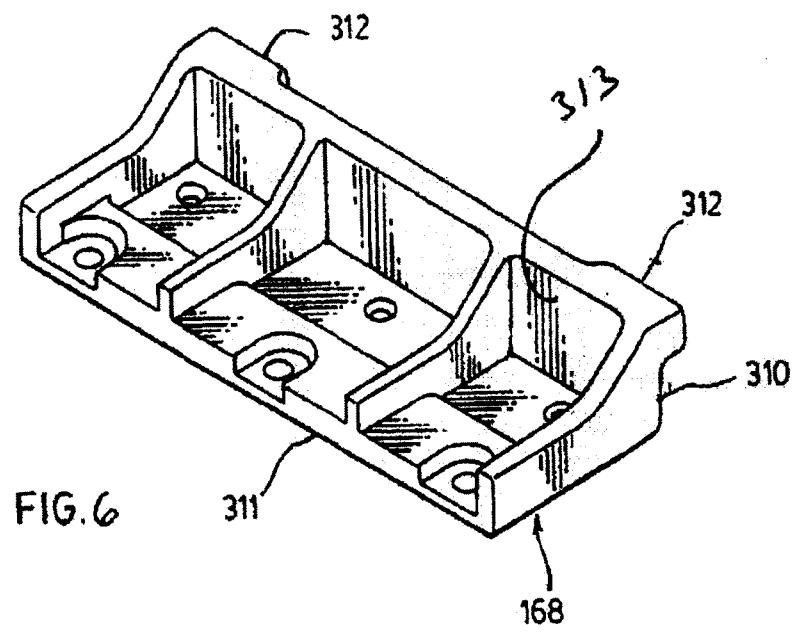
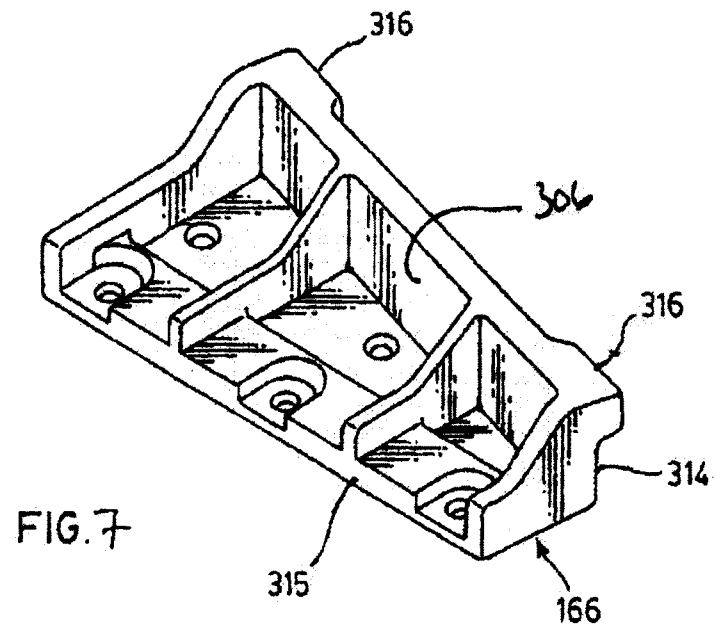
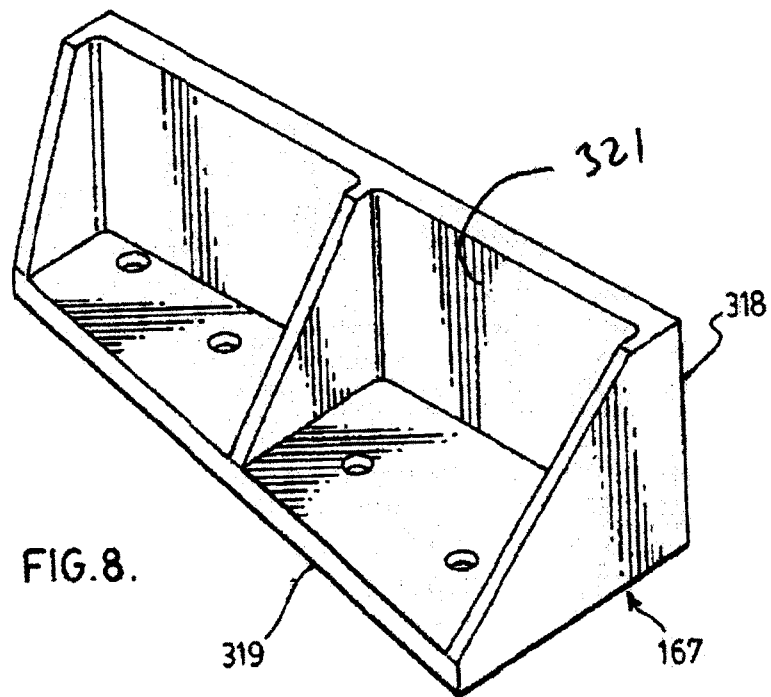
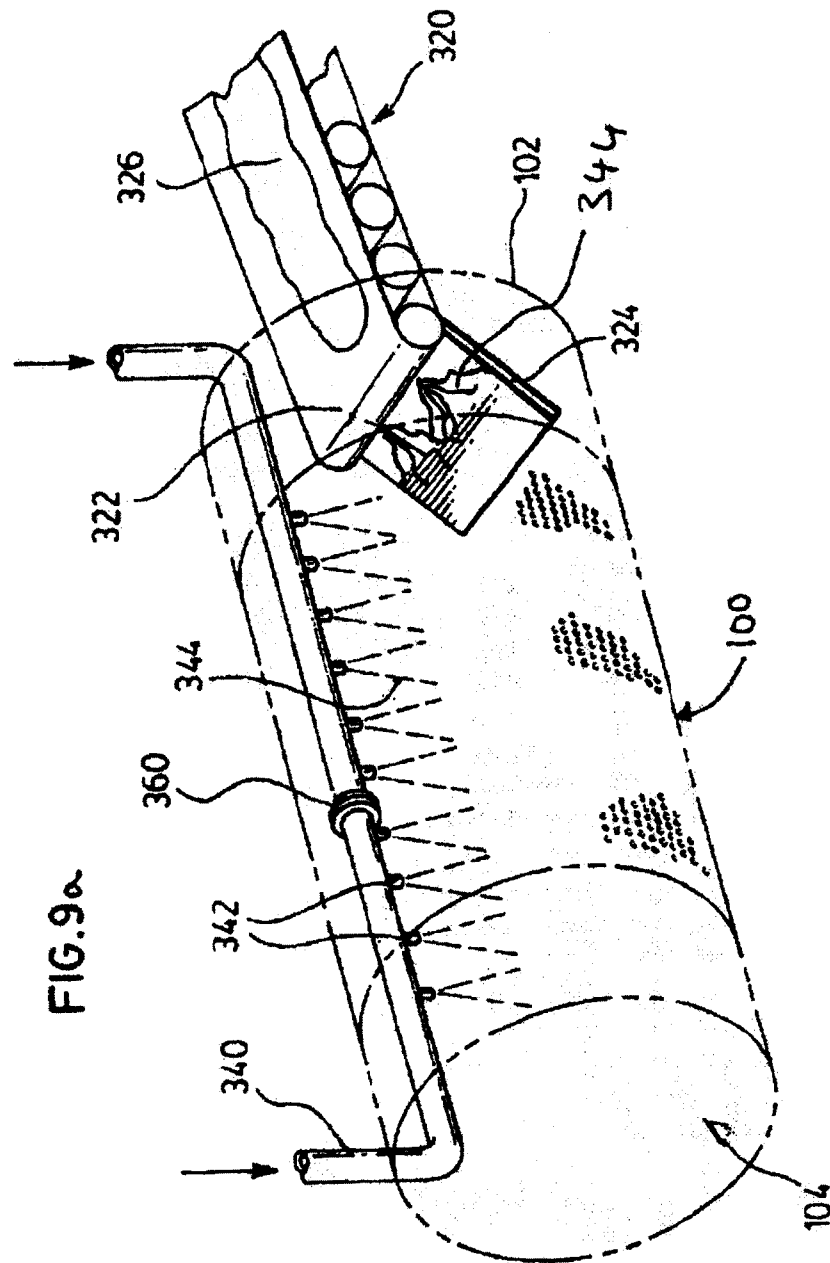


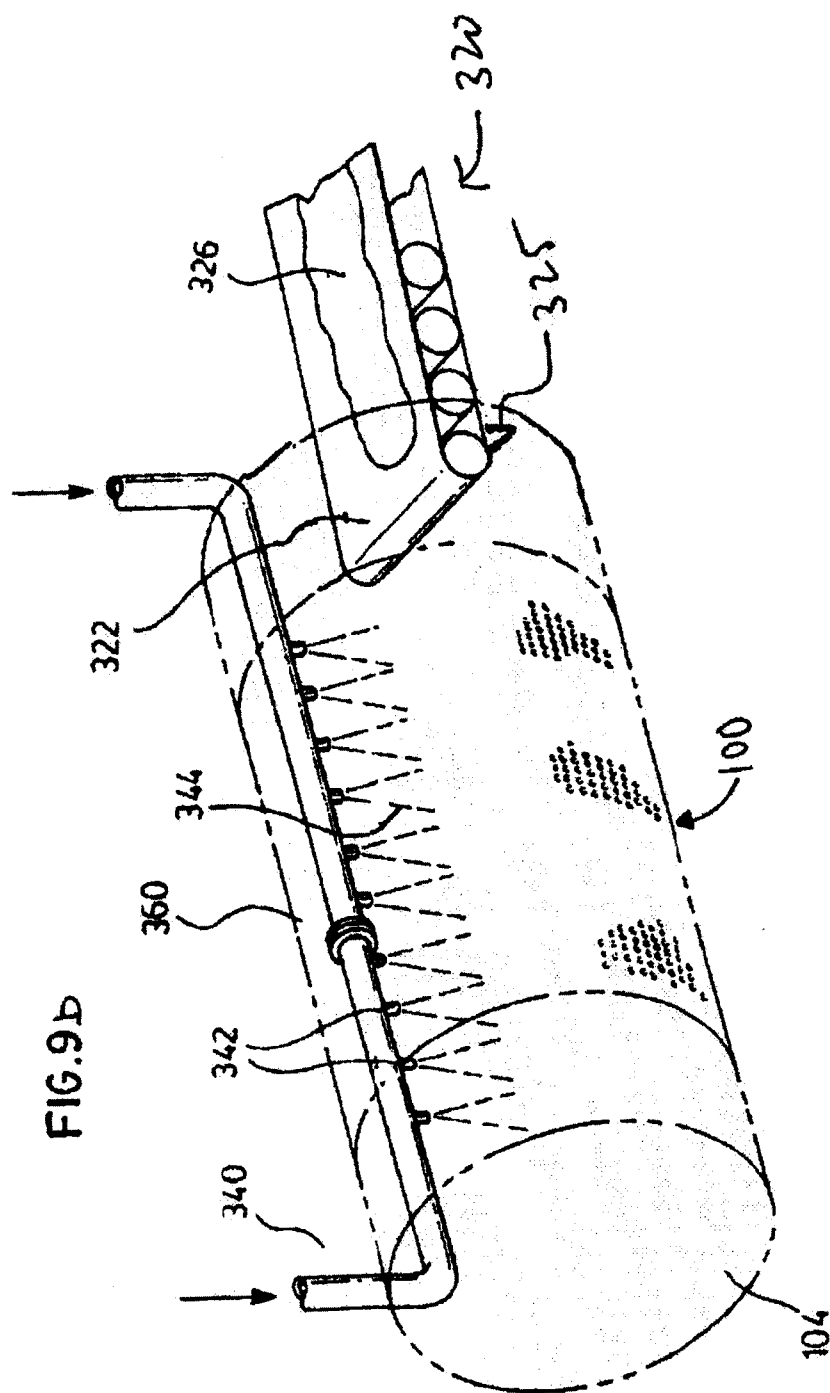
FIG 5

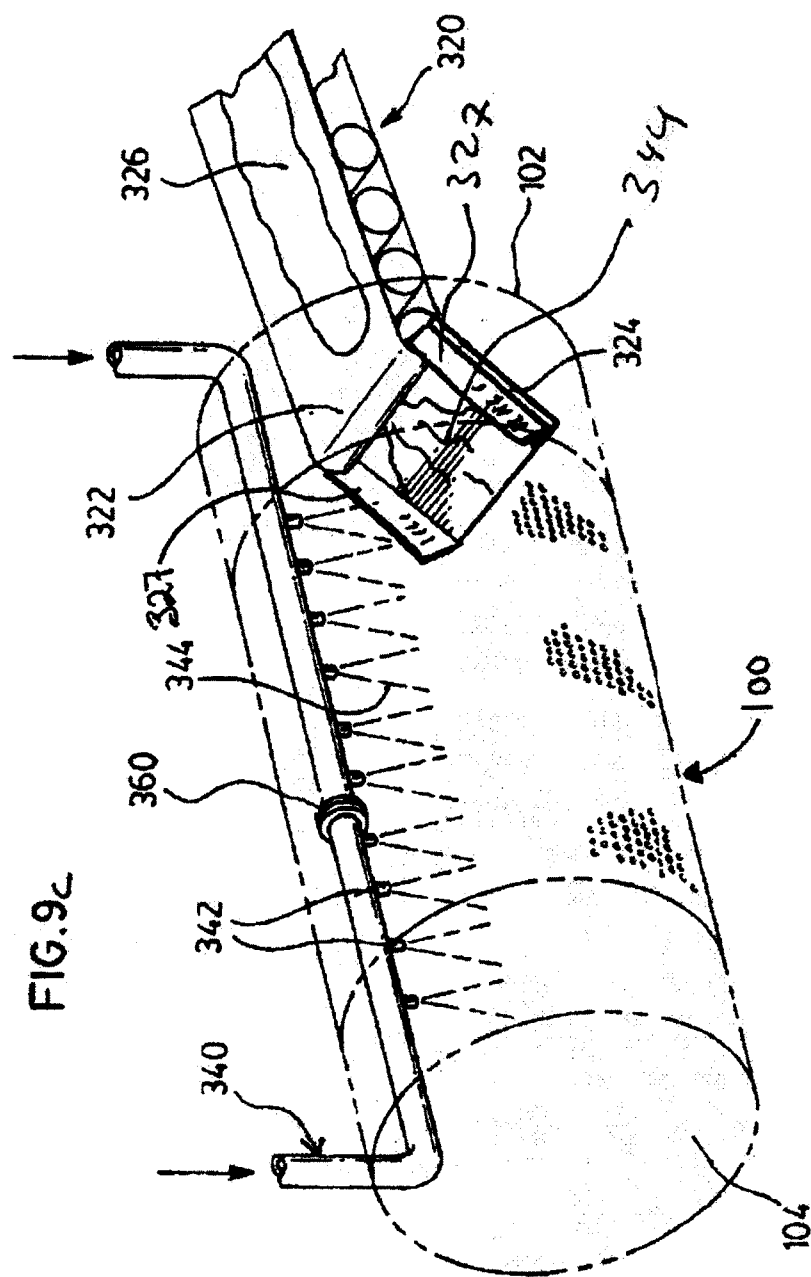


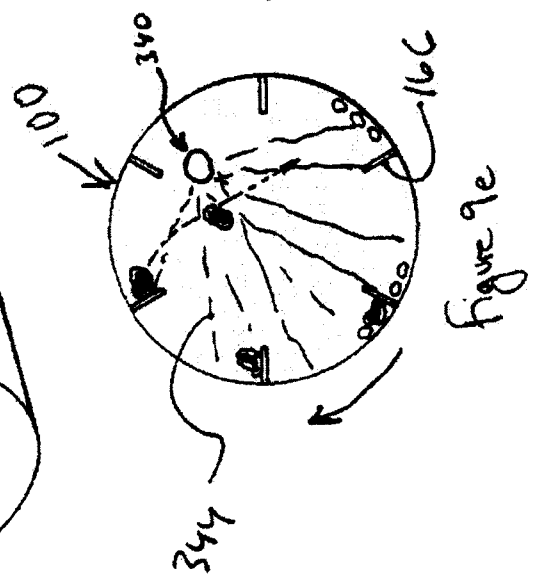
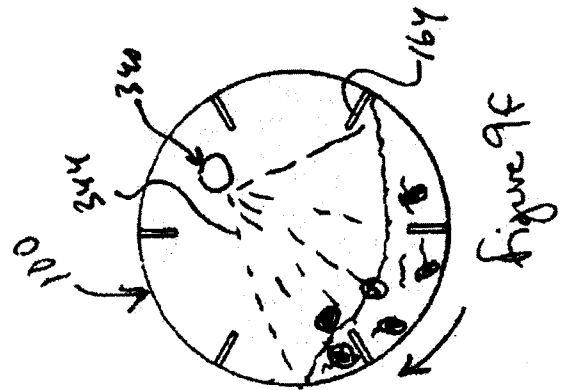
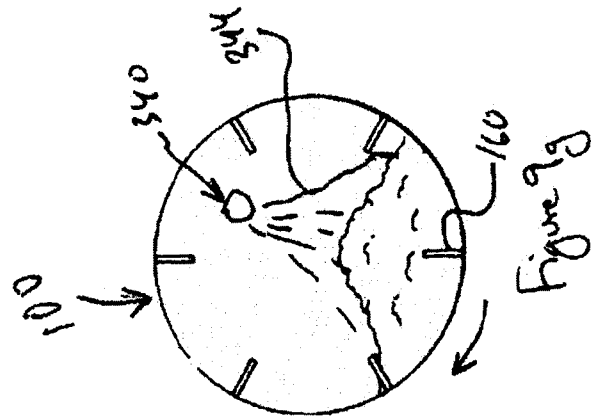
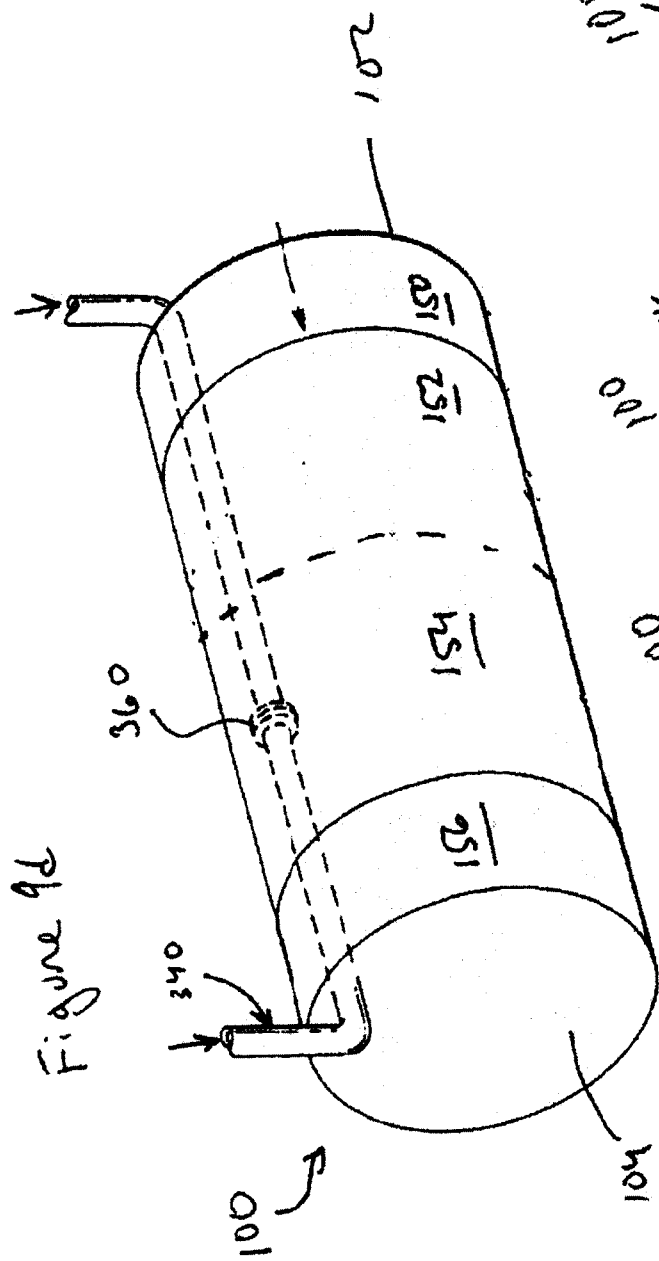


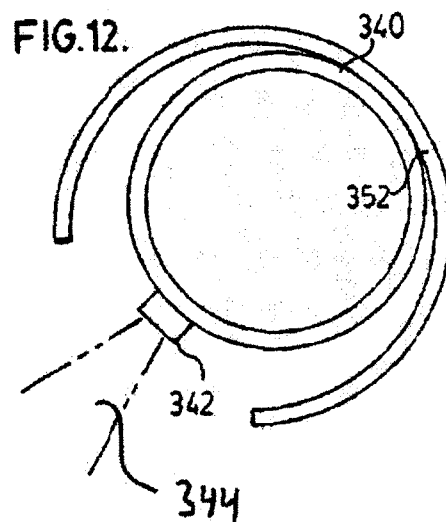
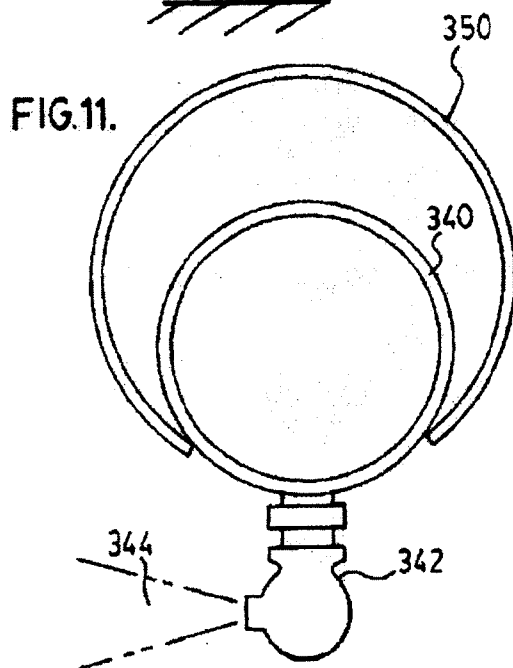
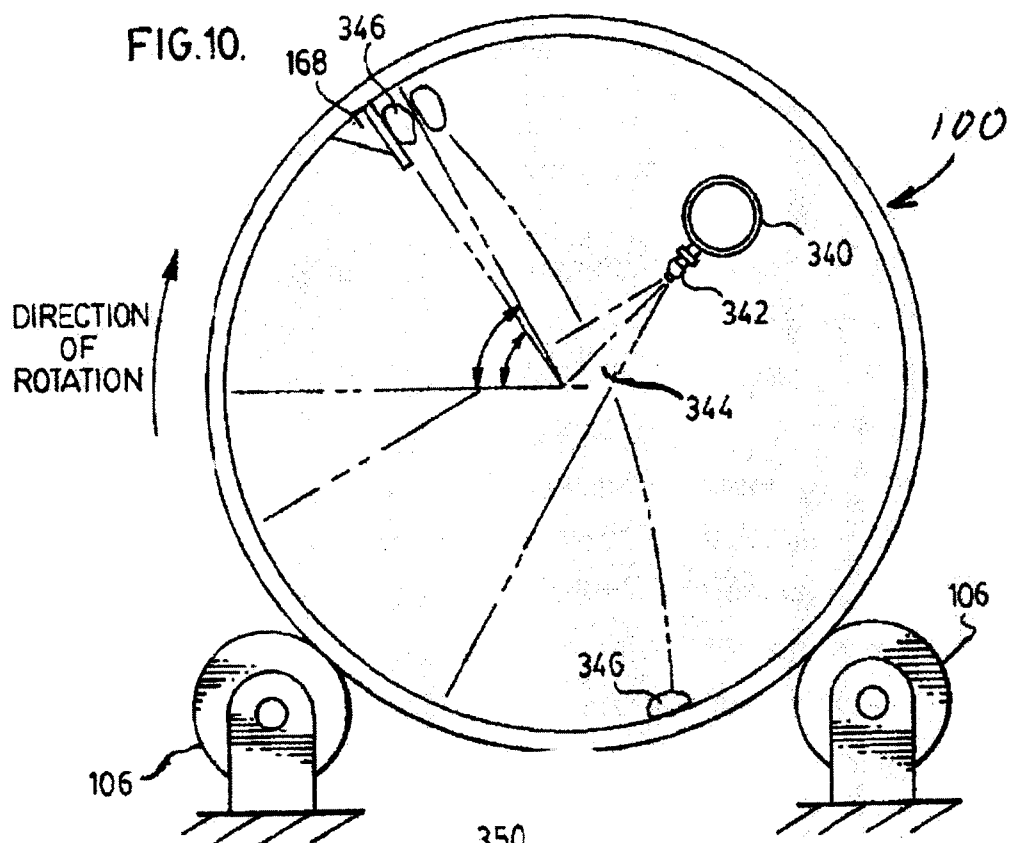


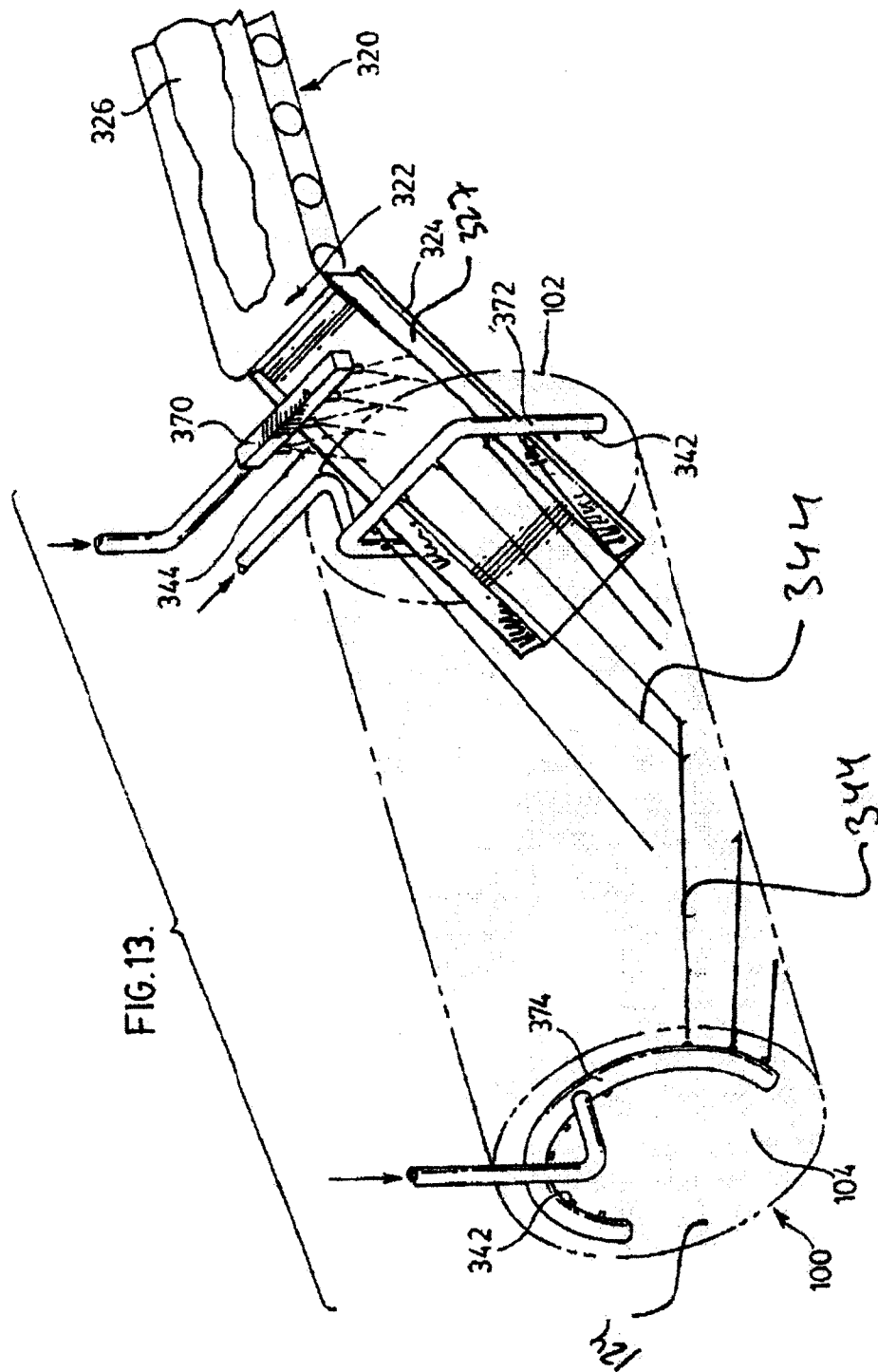












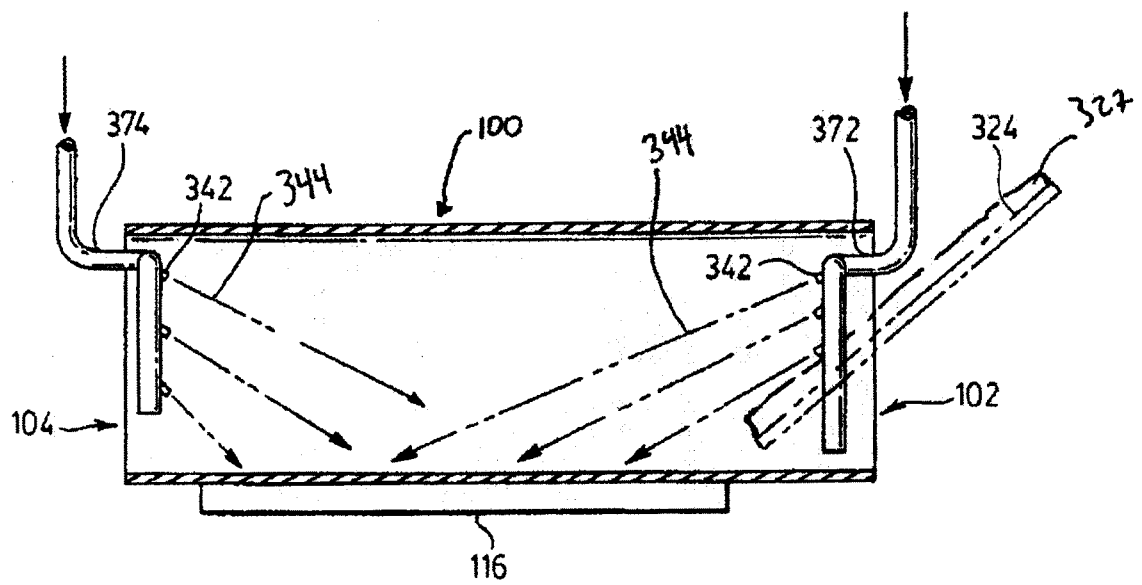


FIG. 14.

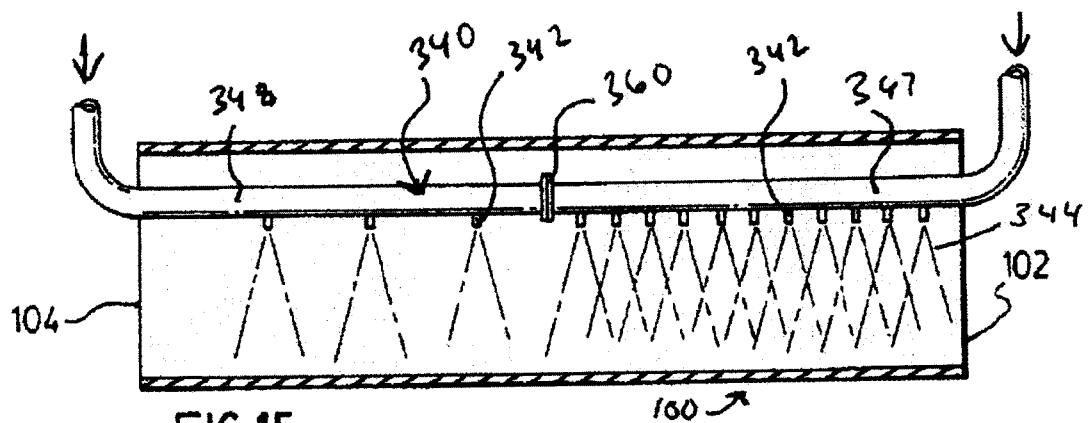


FIG. 15a

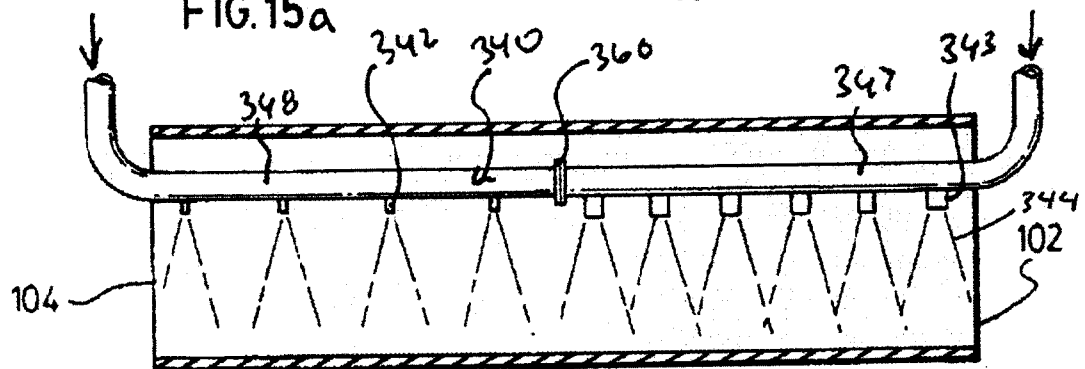


FIG. 15b

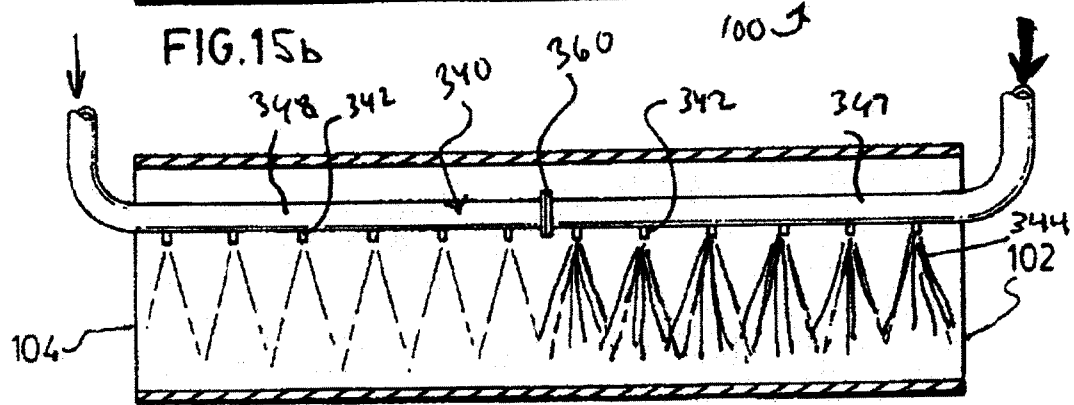
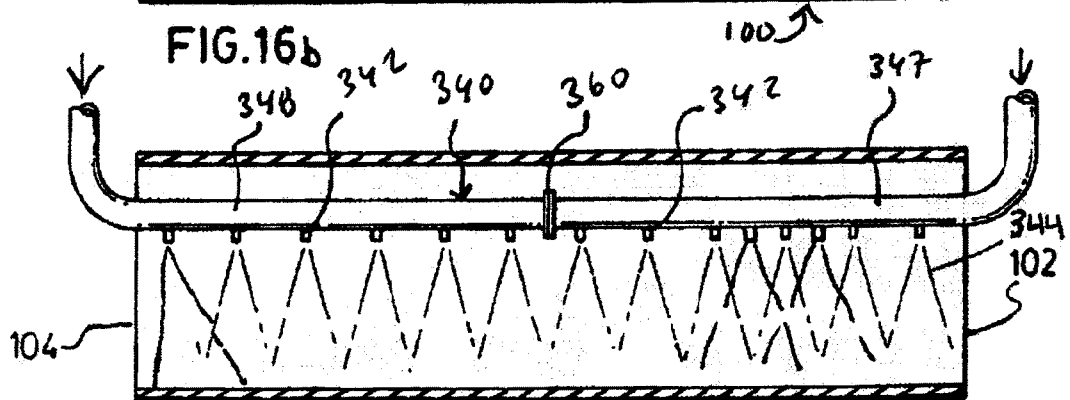
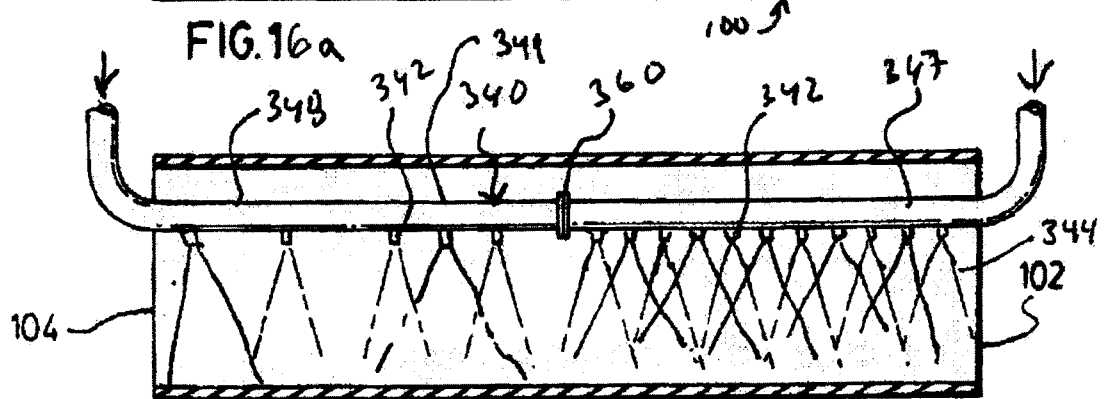
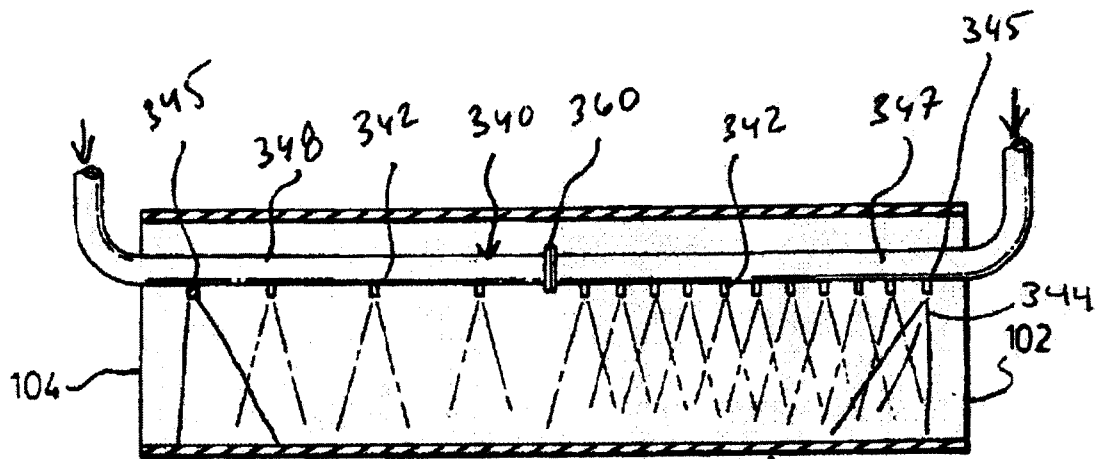


FIG. 15c



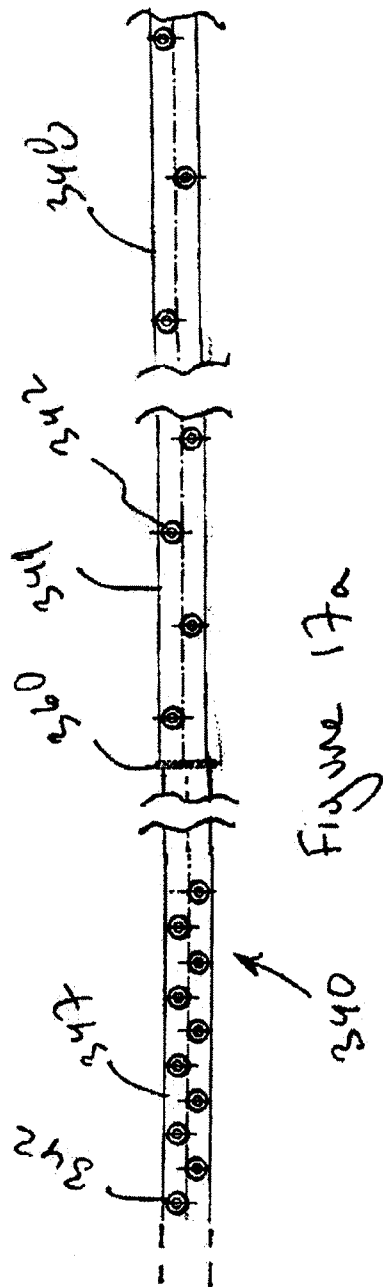


Figure 17a

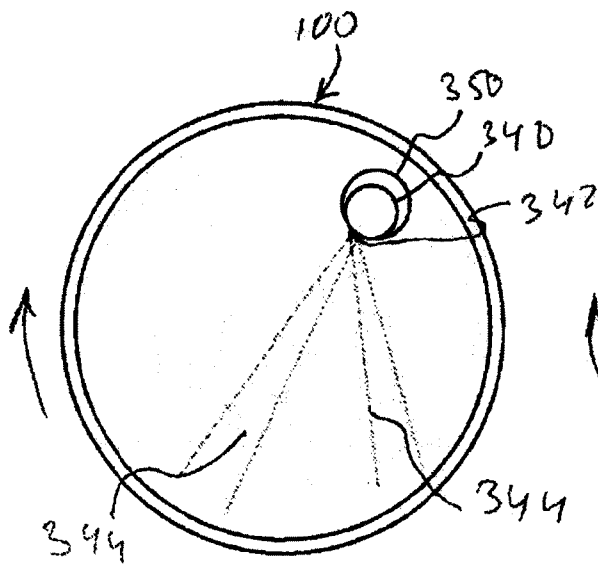


Figure 17b

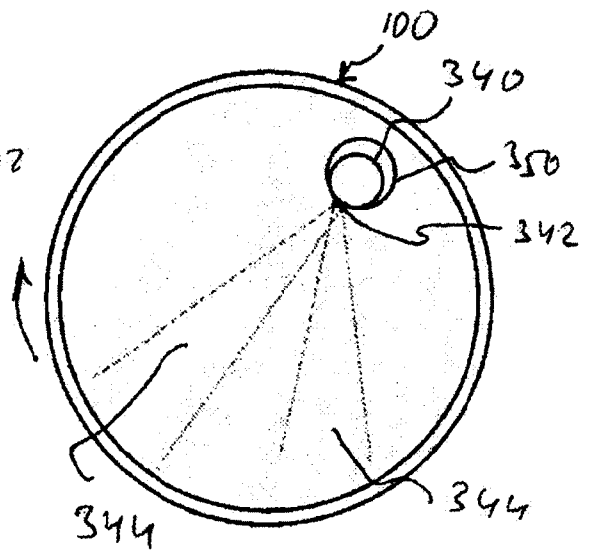


Figure 17c

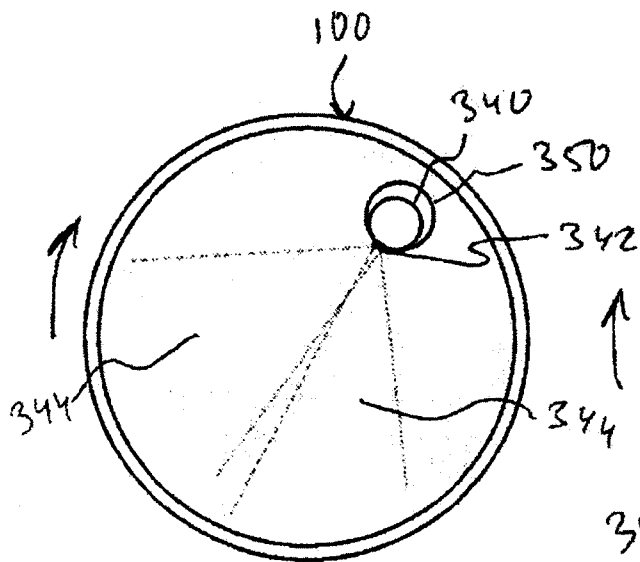


Figure 17d

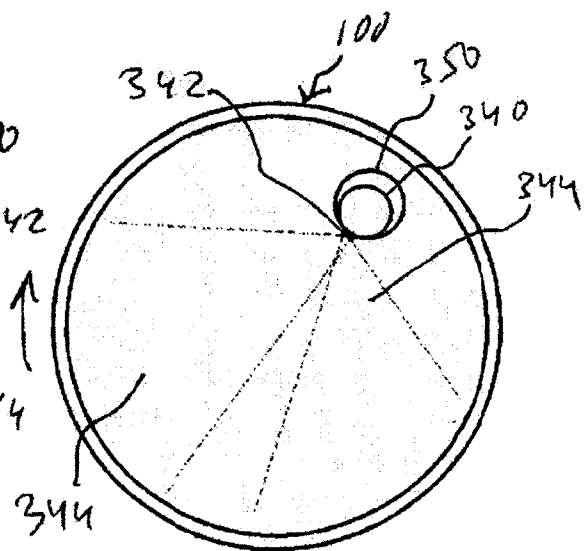


Figure 17e

