

(57) Abrégé(suite)/Abstract(continued):

separated by a revolving oleophilic apertured screen formed from adjacent endless cable wraps. The apertured cylindrical wall of the agglomerator is constructed from adjacent metal hoops that are welded at the inside diameter to strong metal cross bars that are attached to agglomerator end walls to provide a rigid and strong agglomerator. A central core may be used to further increase the rigidity of the agglomerator. Oleophilic cable wraps are positioned between sequential hoops of the agglomerator and continuously revolve between separation zone and bitumen removal zone. Feedstock separation by the methods and apparatus of the present invention is about an order of magnitude faster than separation by bitumen froth flotation and the bitumen product is of superior quality. Agglomerator scale up calculations are introduced for determining the size of agglomerators for commercial equipment.

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ABSTRACT

10 A rapidly rotating agglomerator is disclosed and claimed for processing feedstocks of
oil sand slurries, oil sand middlings, oil sand fluid tailings or oil sand emulsions to
increase bitumen particles size of the feedstock before the agglomerated feedstock is
separated by a revolving oleophilic apertured screen formed from adjacent endless
15 cable wraps. The apertured cylindrical wall of the agglomerator is constructed from
adjacent metal hoops that are welded at the inside diameter to strong metal cross bars
that are attached to agglomerator end walls to provide a rigid and strong
agglomerator. A central core may be used to further increase the rigidity of the
agglomerator. Oleophilic cable wraps are positioned between sequential hoops of the
20 agglomerator and continuously revolve between separation zone and bitumen
removal zone. Feedstock separation by the methods and apparatus of the present
invention is about an order of magnitude faster than separation by bitumen froth
flotation and the bitumen product is of superior quality. Agglomerator scale up
calculations are introduced for determining the size of agglomerators for commercial
equipment.

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SCALING UP THE OLEOPHILIC SIEVE PROCESS

RELATED APPLICATIONS

5 This application is related to Canadian Patent applications number 2,704,175
filed approximately May 20th, 2010 entitled **“Removing Hydrophilic Minerals
from Bitumen Products”**, number 2,700,446 filed April 22nd, 2010 entitled **“Speed
of Separation – Mine Face Oil Sand extraction”**, number 2,690,951 filed January
27th, 2010 entitled **“Endless Cable Belt Alignment Apparatus and Methods for
10 Separation”**, number 2,661,579 filed April 9th, 2009 entitled **“Helical Conduit
Hydrocyclone Methods”**, number 2,647,855 filed January 15th, 2009 entitled
“Design of Endless Cable Multiple Wrap Bitumen Extractors” and number
2,638,596 filed August 6th, 2008 entitled **“Endless Cable System and Associated
Methods”**, which are referenced in these specifications by number.

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FIELD OF THE INVENTION

 The present invention relates to scaling up the oleophilic sieve process for the
recovery of bitumen from aqueous suspensions of oil sand bitumen and particulate
20 solids. The scale up factors described include:

1. RPM of bitumen agglomerators, which impact on the surface speed of
 revolving apertured oleophilic screens,
 2. Internal diameter of agglomerator drums, and
 3. Length of agglomerator drums or width of sieve.
- 25 Operation and design information is introduced that will provide adequate strength of
construction for large size bitumen agglomerators while achieving effective
agglomeration at high rates of rotation, high feedstock throughputs and efficient
screening to separate bitumen phase from aqueous phase. Accordingly, the present

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invention involves the fields of process engineering, chemistry and chemical engineering.

BACKGROUND OF THE INVENTION

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A detailed description of oil sand, tar sand or bituminous sand deposits, and of the processing of these ore deposits to produce bitumen product is provided in the above referenced patent applications. The Northern Alberta oil sands resource may in time be found to contain almost half of the remaining economically recoverable world oil reserves.

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Alberta oil sand ore consist of sand grains covered with a thin envelope of water, with the voids between the grains filled with mineral fines, water and bitumen. Between 10 and 20 percent of the oil sand ore is less than 100 meters below the surface and in time all this ore may be strip-mined after overburden removal. With current technology some of the remainder may be recovered by in situ methods that use steam or combustion to bring bitumen products to the surface. The current commercial method for processing mined oil sand, invented by Karl Clark about 80 years ago, mines the oil sand and mixes it with water, process aid and air to form a thick aerated slurry that is subsequently flooded with water and then is separated in large flotation vessels where aerated bitumen particles rise to the top and are skimmed off to become the bitumen products of separation. Steam is used to remove air from the bitumen froth product before it is cleaned. The de-aerated bitumen product, containing water and mineral particulates, is processed further to eventually yield refinery oil products.

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An alternate process developed by the present inventor does not use bitumen froth flotation or flotation vessels but screens bitumen product out of aqueous oil sand mixtures. This process was introduced in patents granted to the present inventor many years ago, and is disclosed and claimed in more practical detail in his pending patents referred to above.

There are several configurations of froth flotation used by the various commercial plants, and one such configuration may be described with the use of Figure 1. After the removal and stockpiling of overburden, the oil sand ore is surface mined by means of very large mechanical power shovels and is moved by dump
5 trucks, that can handle 400 tons of oil sand per load, to roll crushers that break the oil sand, clay lenses and rocks to a manageable size. In one commercial plant the crushed oil sand is further broken into smaller sizes using ore breakers similar in concept to those disclosed in expired Canadian patent 1,162,899 entitled "Rotative Grizzly for Oil Sand Separation" granted to the present inventor on February 28th,
10 1984.

Commercially the crushed ore is mixed with water and air in a cyclo feeder and introduced into a slurry pipeline where it flows in turbulent flow for 2 to 10 kilometers to condition the oil sand ore to a digested and aerated slurry suitable for separation in a primary separation vessel (PSV) or primary separation cell (PSC).
15 Caustic process aid normally is added to properly condition the ore with water and form an aerated thick pipeline slurry, that is then flooded with flood water before it enters the PSV. Aerated bitumen rises to the top of the PSV or PSC and is skimmed off as the froth product, which is cleaned up thereafter to remove air, water and solids to produce a product that can be upgraded to synthetic crude oil or that can be diluted
20 and shipped by pipeline to a refinery. In the commercial plants the middlings and bottoms of the PSV are pumped to a tailings oil recovery vessel (TORV) or to subaeration flotation cells to float off additional bitumen froth which in some cases is returned to the PSV or PSC for recovery. From there the tailings flow to a tailings pond. Commercial plants have many flow loops and careful control is required to
25 optimize bitumen recovery which averages between 80 and 95 percent depending on plant configuration and on the grade and type of oil sand ore processed. The many suspension flow loops, shown for example in Figure 1, are labour intensive and require careful chemistry and flow control for plant optimization. The bitumen product of a commercial oil sand froth flotation plant averages about 60 wt%
30 bitumen, 10 wt% mineral solids and 30 wt% water.

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Flooded pipeline slurry takes about 70 minutes or more of residence time in a typical commercial oil sands plant to achieve acceptable bitumen recovery. Any residual unrecovered bitumen ends up in the tailings ponds and represents a loss of revenue. The reason for the required long bitumen froth flotation residence time may
5 be found in the fact that it takes time for bitumen particles, attached to air bubbles, to rise upwards through an aqueous suspension of downward settling sand, silt and clay. The caustic process aid used disperses this aqueous suspension, and make it less viscous, so that aerated bitumen can rise upward at an acceptable rate, but it still takes a long time for bitumen attached to air bubbles to reach the tops of PSV, TORV, PSC
10 or subaerqation flotation cells.

The chemistry of mineral particle and bitumen dispersion; the reduction of slurry viscosity, the effective bitumen attachment to air bubbles in the presence of very small clay particles, and the subsequent upward flotation of aerated bitumen past downward settling minerals is very complex but is not the topic of the present
15 invention. The present invention deals with the much simpler process of screening bitumen from an aqueous suspension of water and particulate minerals, and doing so in an efficient manner, using a residence time that is as short as possible.

Due to the chemical and mechanical procedures used in the current froth flotation commercial oil sand extraction plants, the commercial tailings contain ultra-
20 fine mineral particles, small bitumen particles and biwetted solids. These have a strong tendency to form colloidal thixotropic gel structures in the fluid tailings of tailings ponds after the sand drops out. The gels prevent dewatering of the fluid tailings after these have settled to about 30 to 35 percent mineral content. After that, the natural compacting of fluid tailings is very slow, and most estimates suggest that
25 many hundreds of years will pass before undisturbed mature fluid tailings will reach consolidation.

Gel formation in fluid tailings is somewhat analogous to the process that takes place when jello powder is dissolved in warm water and is then allowed to cool and set to form the familiar jello desert, containing a very high percentage of bound water.

The concepts described in the present invention and in its companion copending patents are very different from froth flotation. In the present invention, oil sand slurried in water is agglomerated in a revolving agglomerator and the ultra-fine minerals and the bi-wetted solids become part of the bitumen product. In this manner the gel forming solids are removed, do not report of the tailings, and this results in fluid tailings that can be dewatered.

OVERVIEW OF BITUMEN SCREENING

As described in the above referenced patents, bitumen screening does not make use of bitumen froth flotation in a PSV, PSC, TORV or subearation flotation cells, but rather agglomerates the small bitumen particles of a dispersed oil sand aqueous slurry and then passes the agglomerated slurry through an endless revolving apertured oleophilic screen in the form of multiple adjacent wraps of endless cable. Agglomerated bitumen is captured by the cable wrap surfaces and de-bituminized slurry passes through the slits between cable wraps in a separation zone. The captured bitumen is removed from the cable wrap surfaces in a bitumen removal zone, as described in the above referenced copending Canadian patent application numbers 2,704,175 , 2,700,446 , 2,690,951 , 2,661,579 , 2,647,855 , and 2,638,596 . The screens do not have cross members, can be made to be very strong and long lasting and may be heated before removal, and combed or squeezed by rigid grooved or by pliable rubber rollers for easy removal of bitumen from the cable wraps in bitumen removal zones. The present invention describes methods and equipment for optimizing and speeding up the bitumen agglomeration and screening process.

One flow diagram of an oleophilic screen proposed for separating mined oil sand ore is shown in Figure 2. Oil sand is mined and transported to roller crushers. Dump trucks are not shown in this Figure to show one option of locating the extraction process close to the mine face made potentially possible by the small size of separation equipment of the present invention. The crushed ore is conveyed to a high speed ablation drum described in application CA 2,700,446 of the present

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inventor. As an option, the coarse crushed ore may be broken up by a rotating grizzly as described in granted patent CA 1,162,899 of the present inventor before entering the high speed ablation drum. After removal of rock and gravel oversize by a vibrating grizzly, the slurry flows into a confined path hydrocyclone to remove fine gravel and coarse sand as described in application CA 2,661,579 of the present inventor. In this hydrocyclone a small amount of fluid is injected into the slurry along the confined path upstream from the hydrocyclone vessel to drive dispersed bitumen from the outside lane to the inside lane of the confined path and cause more bitumen to report to the overflow of the hydrocyclone. This injected fluid may be water, a gas, or a gas dissolved at high pressure in water. The fluid essentially washes trapped bitumen and ultrafines out of the coarse slurry stream flowing along the outside lane of the confined path and moves these to the inside lane.

The confined path hydrocyclone underflow removes fine gravel and coarse sand from the slurry to prevent blinding of the oleophilic apertured screen by gravel and also to reduce the amount of abrasive sand contacting the surfaces of the screen cable wraps. The overflow from the hydrocyclone enters the agglomerator. In the agglomerator drum, bitumen particles adhere to oleophilic surfaces inside the drum in increasing thicknesses until shear forces in the drum strip off or slough off enlarged bitumen from these surfaces. Thus, dispersed bitumen particles of the slurry enlarge in size in the agglomerator before the slurry leaves the agglomerator through an apertured cylindrical drum wall. Slurry leaving the drum through the drum apertures passes through an oleophilic screen, formed by cable wraps which are in contact with the apertured drum wall. Bitumen phase is captured by the screen in a separation zone. The screen is in the form of adjacent wraps of endless cable suitable for capturing bitumen, and the cable may be plastic rope or metal wire rope or monofilament.

Bitumen captured by cable wraps in a separation zone is removed from cable wrap surfaces in a bitumen removal zone to become the bitumen product. The debituminized slurry, called effluent, representing agglomerated slurry from which bitumen has been removed, passes through the apertures of the screen in the

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separation zone, said apertures comprising the apertures of the agglomerator drum partly covered by cable wraps. The effluent of slurry screening joins the hydrocyclone underflow for dewatering. The mineral particle size of the effluent is smaller than the particle size of the hydrocyclone underflow and this allows the hydrocyclone underflow to act as a sand filter for removing fines from the effluent during dewatering. This water run off may be used as recycle water for producing more slurry. Water run off from the solid tailings may additionally be processed by a conventional high velocity hydrocyclone shown in Figure 2 to remove part of its fines before this water is used to produce more slurry. In that case, the underflow of the conventional hydrocyclone joins the agglomerator and screen effluent for filtering by confined path hydrocyclone underflow.

In the bitumen agglomeration and screening process, most of the ultrafines and biwetted solids of the oil sand slurry become part of the bitumen phase that is recovered from the screen surfaces in a bitumen removal zone, and does not end up in the effluent. The water run off from the solid tailings may be returned to the process as recycle water since bitumen agglomeration and screening is very tolerant of fine mineral content in recycle water. The moist solid tailings of the process may contain 20 to 25 percent water, resulting in a need for additional water to prepare more slurry in the ablation drum. This additional water may be hot water to achieve a slurry temperature of about 35 degrees centigrade or lower during winter time when mined oil sand ore is frozen. Reagents may be added to this fresh water if needed. Additional run-of water may be recovered and used for slurry preparation after the tailings are returned to the mine site and drained to less than 25 percent water for site remediation.

SCALE UP OF AGLOMERATION AND SCREENING

Performance of bitumen agglomerators and apertured oleophilic screens were studied in the Kruyer Oleophilic Sieve pilot plant. These agglomerators and screens

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were small enough to accommodate the available feedstock and yet were large enough to give representative data.

One very effective unit was designed for a suspension feed rate of 1.0 metric ton per hour. However, the test program indicated that the feed rate could be
5 increased many fold without deteriorating the performance of the separator. The drum diameter was 1.108 meters, its length was 0.095 meters and the maximum designed rotation rate was 3 RPM. The unit easily handled a feed rate exceeding 2.5 metric tonnes per hour of suspension, representing approximately 2 cubic meters per hour, or two and a half time design capacity at that speed. During the test program it became
10 obvious that the separation process could be speeded up significantly by increasing RPM of the agglomerator. However, the equipment was not designed for higher speeds.

Based on these pilot plant tests, a standard agglomerator drum with associated screen was defined for the purpose of scale up calculations. This standard drum has a
15 diameter of 1.0 meter, a sieve width of 1.0 meter and a rotation rate of 1.0 RPM.

For a properly designed separator, sieving is a function of the diameter of the apertured cylindrical wall of the agglomerator; but agglomeration is a function of the cross sectional area of the agglomerator drum and oleophilic ball loading when the drum is partly filled with a bed of balls. Therefore, the overall bitumen
20 agglomeration and screening scale up factor for this process may be a function of agglomerator drum diameter raised to some power between 1 and 2. However for the initial calculations it was taken to be a function of drum diameter to the exponent of one. Only additional pilot plant experiments with larger separators can refine the actual exponent for separating each suspension feedstock, because each type of
25 feedstock will require a different amount of agglomeration.

Based on the above discussion, scale up of the equipment will involve three variables. These are RPM, inside diameter of the apertured cylindrical wall of the drum (represented by D) and apertured agglomerator length, which is equal to the width of the apertured screen, represented by L. Apertured cylindrical wall is used
30 here as a reference since an agglomerator may have a cylindrical wall that is

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apertured for only part of its length when extensive agglomeration is required, or when the agglomerator drum diameter is small. Generally, a larger diameter agglomerator has a larger ball volume and this results in a higher degree of agglomeration. Thus the standard agglomerator drum and associated screen defined for the purpose of scale up calculations has a drum diameter of 1.0 meter, a sieve width of 1.0 meter and a rotation rate of 1.0 RPM. The following procedure may then be used to anticipate the scale up performance of an agglomerator with its associated apertured oleophilic endless screen belt.

We first adjust the pilot plant data to 1.0 RPM, which converts the feed rate into $(2)(1)/(3) = 0.67$ cubic feed of suspension per hour for a 95 cm long drum. We then adjust the pilot plant data to convert it to a standard 1.0 meter drum diameter. This results in a feed rate of $(0.67)(1)/(1.108) = 0.60$ cubic feed of suspension per hour. We next adjust the 95 cm long apertured pilot plant drum to 1.0 meter long to obtain a standard feed rate of $(0.60)(1.0)/(0.095) = 6.3$ cubic feed of suspension per hour with the standard agglomerator and screen.

Thus a standard 1 meter diameter drum, with a 1 meter long apertured cylindrical wall to serve a 1 meter wide screen and rotating at 1 RPM has a separating capacity of 6.3 cubic meters per hour of suspension feedstock. For scale up calculations, the anticipated feedstock separation capacity of any oleophilic screen separator is taken as 6.3 cubic meters per hour multiplied by the agglomerator diameter (D) multiplied by the sieve width (L) and multiplied by the drum rotation rate (RPM). For effective agglomeration the drum should operate below catteracting bed speed, since a catteracting bed may interfere with the agglomerating process for most oil sand suspensions. Catteracting of a bed in a revolving drum normally starts around 75% of the critical drum speed. A more reasonable speed may be less than that, for example 50% of the critical drum speed. The table below illustrates the critical speeds of drums of various diameters, along with the corresponding catteracting speed based on 75% of the critical drum speed. These catteracting speeds are for mixtures that do not contain viscous bitumen. The presence of viscous bitumen in suspensions tumbling with balls in an agglomerator will alter to a small degree the catteracting speed. For that

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reason the agglomerators of the present invention should normally be rotated at a rate below the cateracting speed.

	Diameter.	Area.	Critical	75% critical	Circum.	Speed
5	m.	sq. m.	RPM	RPS	m.	m./s.
	1.108	0.964	40.19	0.502	3.48	1.75
	1	0.785	42.31	0.529	3.14	1.66
	2	3.142	29.92	0.374	6.28	2.35
	3	7.069	24.43	0.305	9.42	2.88
10	4	12.57	21.15	0.264	12.57	3.32
	5	19.64	18.92	0.237	15.71	3.72
	6	28.27	17.27	0.216	18.85	4.07

Thus, a 2 meter apertured drum has a cross sectional area of 3.142 square meters, its critical rotation rate is 29.92 RPM and its 75% critical rotation rate is 0.374 revolutions per second, its circumference is 6.28 meters, the surface speed of the apertured wall is 2.35 meters per second at cateracting speed. The surface speed of an apertured oleophilic screen in contact with the apertured drum wall is the same.

SAMPLE SCALE UP CALCULATION

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A typical commercial oil sands extraction plant may have 4 trains, each processing 7000 metric tons of oil sand ore per hour in a 3 meter diameter agglomerator to produce 75,000 barrels per day of bitumen suitable for upgrading. Determine the anticipated width of the apertured screen.

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Assume that 7000 metric tons of water are required to produce the desired slurry for separation. The total volume of slurry per hour, assuming an oil sand density of 2.1 metric tons per cubic meter is $(7000)/(2.1) + (7000)/(1.0) = 10,333$ cubic meters.

Critical RPM for a 3 meter diameter drum is 24.43 RPM and cateracting starts at approximately 75%, or 18.3 RPM. Selecting an agglomerator RPM of 15,

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which is below the catering speed, and referencing this to the standard drum defined above computes into the following result:

The reference drum speed is 1 RPM, diameter is 1 meter, screen width is 1 meter, flow rate is 6.3 cubic meters per hour. The proposed commercial drum rotates at 15 RPM, its diameter is 3 meters, and the flow rate is 10,333 cubic meters per hour. The screen width (or agglomerator effective length) is solved for as follows:

Adjusting for speed: $(6.3 \text{ m}^3/\text{hr}) (15 \text{ RPM}/1 \text{ RPM}) = 95 \text{ m}^3/\text{hr}$

Adjusting for diameter $(95 \text{ m}^3/\text{hr}) (3) / (1) = 284 \text{ m}^3/\text{hr}$

The length is: $(10,333 \text{ m}^3/\text{hr}) / ((284 \text{ m}^3/\text{hr}) / 1\text{m}) = 36 \text{ meters.}$

Another approach is $(10,333) / ((6.3)(15)(3)) = 36.4 \text{ meters of screen width.}$

Thus the screen width and the apertured length of the 3 meter diameter commercial agglomerator is 36 meters to separate a suspension of 7000 metric tons of oil sand and 7000 metric tons of water. Alternately two agglomerators may be used in parallel that use 18 meter wide sieves, or four agglomerators with 9 meter wide screens. Figure 7 illustrates the relative sizes of a current commercial primary separation cell (PSC) and subaeration flotation cells to process 7000 tons of oil sand ore per hour are compared with the above two 18 meter long agglomerators that are expected to achieve the same suspension throughput and bitumen recovery efficiency.

AGGLOMERATOR WEIGHT AND PRIOR ART

The weight of a 3 meter diameter, 18 meter long agglomerator partly filled with tumbling balls and rotating at 15 RPM can be very substantial, requiring very rigid drum construction. The pilot plant separator used a perforated steel sheet for the agglomerator cylindrical wall and used an endless mesh belt for the apertured oleophilic screen. Such an apparatus is not strong enough for use in a commercial plant using 3 meter or larger diameter drums that need to operate year round without major break downs. The present invention describes equipment designs and operation that overcome such scale up problems

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1. One type of commercial oil sands plant using a PSV and a TORV.

Fig. 2. A general flow diagram for a potential commercial plant processing
5 mined oil sand by agglomeration and bitumen screening.

Fig. 3A. An internal sectional view along the length of an agglomerator that
uses adjacent steel hoops aligned by steel rods to form the agglomerator apertured
cylindrical wall. The agglomerator is partly filled with a bed of balls. **Fig. 3B**
provides construction details of hoops welded to the steel rods and showing the
10 location of endless cable wraps between the hoops.

Fig. 4A...A cross sectional view accross the agglomerator of Fig. 3A but also
showing a single cable wrap in contact with the apertured agglomerator wall in a
separation zone and in contact with rollers in a bitumen removal zone. **Fig. 4B.** A
multy tine scraper for transferring bitumen from hoops to cable wraps.

15 **Fig. 5A.** This drawing is similar to the drawing of Figure 3A but in this case
the agglomerator is separated by an apertured circular disc into two compartments.
Suspension flows into the first compartment that is filled with tower packings to
agglomerate the flowing suspension by means of contact with a revolving fixed bed
of tower packings. After that the partly agglomerated suspension passes through the
20 apertured disc into a second compartment that is partly filled with a bed of tumbling
balls which complete the agglomeration process and kneads the agglomerated
bitumen. Only the second compartment has an apertured cylindrical wall in the form
of hoops similar to the hoops of the agglomerator of Figure 3A, and provided with
cable wraps in between the hoops to form a separation zone. **Fig. 5B.** This drawing is
25 similar to Figure 5A except that the first compartment is concentric with the second
compartment. The first compartment contains a fixed bed of tower packings that
rotate with the agglomerator and the second compartment contains a bed of tumbling
balls that partly fill this second compartment. The compartments are separated by a
cylindrial apertured wall in the form of a punched metal sheet rolled into a cylinder,
30 mounted inside a set of rigid bars that provide strength and rigidity to the

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agglomerator and also prevent major damage by balls to the metal sheet separating the two compartments. In this case the cylindrical wall of the agglomerator drum spans nearly the full length of the drum and is made up of hoops, with cable wraps in between, as is the case with Figure 3A. **Fig. 5C** shows one possible location for
5 rollers to support slewing rings of Figure 5A and 5 B. **Fig. 5D** shows a more preferred location for rollers to support slewing rings of Figure 5A and 5B.

Fig. 6A shows an internal sectional view of a rotating drum with a catering bed. **Fig. 6B** is an isometric drawing of the drum of Figure 5A, also showing the location of bitumen removal rollers and cable wraps between apertured drum wall and
10 rollers, but not showing drum supports or drive. An effluent guide baffle is shown under the apertured wall portion of the drum. **Fig. 6C.** is an isometric drawing of multiple wraps of endless cable on two rollers taken from pending patent CA 2,638,596 to show the guide rollers needed to keep multiple wraps of a single endless cable on rollers or drums and to prevent the cable from rolling off. **Fig. 6D** is a
15 photograph of a spherical Jaeger Tri-pack

Fig. 7. illustrates the size of the main vessels of a current oil sand extraction plant and of an anticipated oleophilic sieve extraction plant with the same capacity. As shown, the equipment needed for commercial bitumen screening is expected to be at least an order of magnitude smaller than the equipment needed for commercial
20 bitumen froth flotation.

DEFINITIONS

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

30 It must be noted that, as used in this specification and the appended

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claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a splice” includes one or more of such splices, reference to “an endless cable” includes reference to one or more of such endless cables, and reference to “the material” includes reference to
5 one or more of such materials.

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below. When reference is made to a given terminology in several definitions, these references should be considered to augment or support each other or shed additional light.

10 **“ablation”** refers to digesting oil sand ore with water due to turbulence at a temperature warm enough to cause disengagement of bitumen from water covered sand grains .

“agglomerating” refers to a process in which an aqueous suspension of bitumen particles and mineral particulates is contacted by oleophilic surfaces, such as
15 from a bed of rotating tower packings with oleophilic surfaces or a bed of tumbling oleophilic balls in a drum agglomerator, wherein bitumen coats the surfaces of the tower packings or of the ball surfaces in increasing thickness until shear forces, due to suspension flow and rotation of the agglomerator, strip enlarged bitumen particles from these oleophilic surfaces. In many cases bitumen that coats oleophilic balls
20 tumbling in a drum agglomerator will fill the voids between the balls and this bitumen will be moved and extruded out of these voids by the kneading action of the moving bed of balls surrounded by a revolving cylindrical drum wall. The agglomerated bitumen normally is extruded to an apertured oleophilic screen in contact with a bottom portion of an apertured cylindrical agglomerator exit wall. Grinding balls,
25 bearing balls, rubber coated balls or a mixture of light balls, for example golf balls, and metal balls may be used for such bed of balls. Also spherical Jaeger Tri-packs (See Fig 6D) or stronger tower packings may be used as balls instead of golf balls for mixing with metal balls to form a bed of tumbling balls of suitable average density. The average density of the balls must be large enough that the bed will tumble inside
30 the drum agglomerator in the presence of viscous bitumen at a desired operating

temperature. However the average ball density must be low enough to prevent an agglomerator drum to take on the weight of a ball mill. Hence, a agglomerator drum is not a ball mill but is of lighter construction. The bed of balls (including voids between the balls) may fill between 10 and 90 percent of the volume of the drum, depending on the shape of the agglomerator and on the desired amount of agglomeration desired. A bed of tower packings does not normally tumble inside of a drum filled with a bitumen containing mixture since the viscosity of bitumen at process temperature tends to prevents tumbling of light tower packings by themselves. When not tumbling, tower packings rotate in unison with the agglomerator walls and the suspension flowing through the tower packings comes into intimate contact with the surfaces of the tower packings as the suspension passes through the agglomerator compartment through the voids of the tower packings, causing agglomeration of the bitumen particles of the suspension due to temporary adhesion to bitumen coated tower packing surfaces.

“**agglomeration**” refers agglomerating, which is to increasing the size of bitumen particles in a continuous aqueous mixture by means of a drum agglomerator prior to the removal of enlarged bitumen particles from the mixture by an oleophilic apertured screen formed by adjacent cable wraps. When a bed of tumbling oleophilic balls is used in the drum, these balls agglomerate the bitumen and also knead the collected bitumen. This kneeding does not occur when, instead of tumbling balls, tower packings are used in the drum agglomerator that remain stationary with respect to the drum wall.

“**aqueous phase**” or water phase refers to water that may contain solids and dispersed bitumen.

“**bitumen phase**” refers to bitumen that may contain dispersed water and solids.

“**bitumen removal zone**” refers to a section along an apertured oleophilic screen. In a bitumen removal zone, adhering bitumen phase is removed from the screen surfaces to become the product of separation. In the present invention the screen surfaces are cable wrap surfaces.

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“**bitumen**” refers to a viscous hydrocarbon that contains maltenes and asphaltenes and is found originally in oil sand ore interstitially between sand grains. Maltenes generally represent the liquid portion of bitumen in which asphaltenes of extremely small size are thought to be dissolved or dispersed. Asphaltenes contain the bulk of the metals of bitumen and probably give bitumen its high viscosity. In a typical oil sands plant, there are many different streams that may contain bitumen particles that have disengaged from the sand grains. These streams may, but do not have to contain sand grains. Asphaltenes may be removed from bitumen by dissolving bitumen in straight chain hydrocarbons, resulting in precipitation of asphaltenes.

“**bitumen product**” or “**raw bitumen**” both refer to bitumen originally derived from an oil sand deposit and may be the raw uncleaned bitumen product of separating oil sand slurry from mined oil sand ore, may be the raw bitumen product of in situ bitumen production, may be the raw bitumen product of separating oil sand tailings pond sludge (fluid tailings) or may be the raw bitumen product derived from processing an intermediate process stream of an oil sands plant. The raw bitumen may be obtained by means of an oleophilic apertured screen, by means of bitumen froth flotation or by in situ methods. Bitumen froth obtained by means of bitumen froth flotation contains air. Bitumen obtained by screening with an apertured oleophilic screen normally does not contain much air.. In the present invention it can be advantageous to heat the bitumen product before it is recovered in a bitumen removal zone. Such heating may be done, for example, by sparging live steam into the bitumen product after it leaves a separation zone and moves towards a bitumen removal zone, or when bitumen is removed in a bitumen removal zone. One nice feature of the separator design of Figure 4A is that either or both rollers (41 and 42) may be filled with flowing cold water to cool the cable wraps, heated as a result of prior steam sparging of adhering bitumen, before these wraps return to the separation zone.

“**bitumen recovery**” or “**bitumen recovery yield**” refers to the percentage of bitumen removed from an original mixture or composition. Therefore, in a simplified

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example, a 100 kg mixture containing 45 kg of water and 40 kg of bitumen where 38 kg of bitumen out of the 40 kg is removed, the bitumen recovery or recovery yield would be a 95%.

5 **“cable”** refers to a non metallic rope, a metal wire rope, a single wire, a monofilament or a multistrand filament rope.

“cable wraps” refers to the wraps of endless cable wrapped around two or more rollers where the spaces between sequential cable wraps form apertures through which aqueous phase can pass, giving up most of its bitumen content to the wraps as it passes through the wrap apertures.

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

20 **“confined”** refers to a state of substantial enclosure. A path of fluid may be confined if the path is, e.g., walled or blocked on a plurality of sides, such that there is an inlet and an outlet, and the flow is controlled to some degree by the shape of the confining material, enclosure or housing. Confined path refers to a path that is confined by an enclosure. For example, a fluid flowing in a pipe is confined by the
25 walls of the pipe.

“cylindrical” as used herein indicates a generally elongated shape having a circular cross-section of approximately constant diameter. The elongated shape has a length referred herein also as a depth as calculated from a defined end wall.

30 **“endless cable”** or **“endless wire rope”** is used in this disclosure to refer to a cable having no beginning or end, but rather the beginning merges into an end and

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vice-versa, to create an endless or continuous cable. The endless cable can be, e.g., a wire rope, a non metallic rope, a carbon fiber rope, a single wire, compound filament or a monofilament which is spliced together to form a continuous loop, e.g. by a long splice, by several long splices, by 9 strand splices, or by welding or by adhesion.

5 **“enlarged bitumen”** refers to bitumen particles that have been agglomerated in an agomerator drum to form enlarged bitumen phase particles or bitumen phase fluid streamers for subsequent capture by an apertured oleophilic screen, for example by oleophilic cable wraps that form a screen without cross members.

“generally” refers to something that occurs most of the time or in most
10 instances, or that occurs for the most part with regards to an overall picture, but disregards specific instances in which something does not occur.

“fluid” refers to flowable matter. Fluids specifically includes water, bitumen, slurries, suspensions or mixtures, and combinations of two or more fluids. In describing certain embodiments, the terms sludge, slurry, mixture, mixture fluid and
15 fluid are used interchangeably, unless explicitly stated to the contrary. A fluid may also be a gas or a gas dissolved under pressure in water.

“mesh belt” refers to a revolvable flexible belt woven into a mesh belt and spliced to make it endless. For example, a nomex mesh belt is commercially available that is woven from strong artificial fibres, has cross members, and is re-
20 enforced with thin strands of beryllium copper wire woven in the fabric to keep the belt more rigid. Alternately polyester monofilaments may be woven into a mesh belt comprising long longitudinal strands of polyester with shorter polyester filaments woven into the longitudinal strands to form cross members. The edges of such a belt may be heated to weld the cross members to the outer longitudinal
25 members. The monofilaments may be 1 to 3 millimeters in diameter and the apertures may be between 0.5 and 2 square centimeters. When mesh belt are used, automatic tracking of the belt is required to keep the belt from running off the belt supports. Mesh belt functioned very well when the oleophilic sieve process was used in the pilot plant but did not stand up to long duration testing. Cable wraps have
30 replaced mesh belts in more recent developments of the process.

“mineral particulate matter” usually refers to the mineral matter found in bitumen and may include titanium ore particles, zirconium ore particles, sand particles, silt particles and clay particles; and may include other components including in silver, gold, aluminum, calcium, iron, potassium, magnesium, sodium, silica, titanium and zirconium in measurable quantity. Particle sizes may vary between less than 2 microns and up to 1000 microns. Bitumen product obtained from separating a tailings pond sludge (fluid tailings) by means of an apertured oleophilic screen or sieve was found to be high in rutile ore mineral particulate matter, which is a premium ore of titanium.

10 **“multiple wraps of endless metal cable”** or **“multiple wraps of endless plastic rope”** refers to a revolvable endless belt without cross members formed from metal or plastic rope. Tracking is not required since the wraps are guided by grooves in rollers and/or by the spaces between hoops of apertured drum surfaces. However, when multiple wraps of single endless rope or cable are used, guide rollers are
15 required to prevent the wraps from running off a supporting drum or roller.

“multiple wrap endless cable” as used in reference to separations processing refers to a revolvable endless cable that is wrapped around two or more drums and/or rollers a multitude of times to form an endless belt having spaced cables and no cross members. Proper movement of the endless belt can be facilitated by at
20 least two guide rollers or guides that prevent the cable from rolling off an edge of the drum or roller and guide the cable back to the opposite end of the same or other drum or roller. Apertures of the endless belt are formed by the slits, spaces or gaps between sequential wraps. The endless cable can be a single wire, a wire rope, a plastic rope, a compound filament or a monofilament which is spliced together to form a
25 continuous loop, e.g. by splicing, welding, etc. As a general guideline, the diameter of the endless cable can be as large as 3 cm and as small as 0.01 cm or any size in between, although other sizes might be suitable for some applications. Very small diameter endless cables would normally be used for small separation equipment and large diameter cables for large separating equipment. A multiwrap endless cable belt
30 may be formed by wrapping the endless cable multiple times around two or more

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rollers or apertured drums. The wrapping is done in such a manner as to minimize twisting of and stresses in the individual strands of the endless cable. An oleophilic endless cable belt is a cable belt made from a material that is oleophilic under the conditions at which it operates. For example, a steel cable is formed from a multitude
5 of wires and the cross section of such a cable is not perfectly round but contains surface imperfections because of the warp of the individual wires. Bitumen captured by such a cable may at least partly fill the voids between the individual wires along the cable surface, and will remain captured there while the bulk of the bitumen is removed from the cable surface in a bitumen recovery zone. This residual bitumen
10 keeps the cable oleophilic even after the bulk of the bitumen has been removed from the cable, and this remaining bitumen serves as a nucleus for capturing more bitumen in a separation zone.

“oleophilic” as used in these specifications refers specifically to bitumen attracting. Most dry surfaces are bitumen attracting upon contact or can be made to
15 be bitumen attracting. A plastic rope, or a metal wire rope normally is bitumen attracting upon contact and will capture bitumen upon contact unless the rope is coated with a bitumen repelling coating. A plastic rope or metal wire rope that is coated with a thin layer of bitumen normally is oleophilic or bitumen attracting since this layer of bitumen will capture additional bitumen upon contact. A plastic rope or
20 metal wire rope will not attract bitumen when it is coated or partly coated with light oil since the low viscosity of the light oil will not provide adequate stickiness for the adhesion of bitumen to the rope. Similarly, a rope covered with a thin layer of hot bitumen will not be very oleophilic until the thin layer of bitumen has cooled down sufficiently to allow bitumen adhesion to the rope under the conditions of the claimed
25 methods.

“oil sand bitumen product of separation” as used herein refers to any bitumen product that results from processing an oil sand mixture by any method including sieving of the mixture. The oil sand mixture may be a slurry of oil sand and water, it may be the tailings of separating an oil sand slurry, it may be the middlings
30 of separating an oil sand slurry, it may be tailings pond sludge, it may be bitumen

froth that has resulted from separating an oil sand slurry, or it may be the bitumen in a bitumen in water emulsion obtained from processing deep oil sand deposits by means of steam injection or oil sand formation combustion.

5 **“oleophilic apertured wall”** refers to oleophilic sieve, to oleophilic apertured screen, to oleophilic mesh belt, or to oleophilic endless rope or wire rope cable formed into an apertured oleophilic belt by means of wrapping the cable multiple times around rollers or drums. When using oleophilic apertured walls to separate bitumen from an aqueous mixture, water and suspended hydrophilic solids pass through the apertures of the belt or through the slits between sequential wraps of the
10 oleophilic endless cable, whilst bitumen and oleophilic solids are captured by the oleophilic belt surfaces or cable wrap surfaces in a separation zone. The captured bitumen is subsequently removed from these surfaces in a bitumen removal zone to become the bitumen product of separation. Mesh belts were used in the prior art of the inventor, but in many cases mesh belts did not last very long in the presence of
15 abrasive sand. For that reason, mesh belts were replaced by endless plastic rope belts or metal wire rope belts, which made the technology more commercially viable. Alternately the endless belts may be made from multiple wraps or single wraps of endless monofilament material, such as polypropylene, nylon, polyester or similar materials, spliced to make each monofilament endless.

20 **“oversize solids”** refers to any solids that are larger in size than the linear distance between adjacent cable wrap surfaces and preferably refers to any solids that are in size about 10% of the linear distance between adjacent cable wrap surfaces or smaller. When such solids are abrasive, these may cause damage to the wraps. Therefore, in many cases oversize also includes abrasive sand that may damage cable
25 wraps. In case of a mesh belt, oversize was defined in relation to the size of the mesh apertures.

30 **“residence time”** refers to the time span taken for a mixture between entering and leaving a system, a process, a vessel or an apparatus. It is assumed that during this time span the desired separation, compaction, settling or processing has been achieved.

“recovery” and **“removal”** of bitumen as used herein have a somewhat similar meaning. Bitumen recovery generally refers to the recovery of bitumen from a bitumen containing mixture. Bitumen removal generally refers to the removal of adhering bitumen from the surfaces of a mesh belt or from the oleophilic wraps of endless cable. Bitumen is recovered from a mixture by an apertured oleophilic screen when bitumen is “captured” by the screen in a separation zone and adheres to the screen surfaces. Bitumen is stripped or removed from the screen surfaces in a bitumen removal zone. A bitumen recovery apparatus is an apparatus that recovers bitumen from a mixture.

“retained on” refers to association primarily via simple mechanical forces, e.g. a particle lying on a gap between two or more cables. In contrast, the term **“retained by”** refers to association primarily via active adherence of one item to another, e.g. retaining of bitumen by an oleophilic cable or adherence of bitumen coated balls to bitumen coated internal walls of an agglomerator. In some cases, a material may be both retained on and retained by an apertured oleophilic screen.

“roller” indicates a revolvable cylindrical member or a drum, and such terms are used interchangeably herein.

“separation zone” refers to a section along an apertured oleophilic screen. In a separation zone, bitumen adheres to the surfaces of the screen and aqueous phase generally passes through the apertures of the screen.

“tower packings” are light plastic extrusions, with large apertures, normally used to provide oleophilic surfaces in extraction towers. When used in rotating bitumen agglomerators, the tower packings may completely fill the agglomerator drum and the dispersion then flows through the apertures of the tower packings. Bitumen adheres to the oleophilic tower packing surfaces in increasing thickness until shear from the flowing dispersion strips enlarged bitumen from the packing surfaces. Jaeger Tri-Packs typically are spherical plastic tower packings that have a very high open area, and are very light. These tower packings are well suited for use in bitumen agglomerators when tumbling balls are not desired, or may be used as balls in a mixture of balls. A mixture of Jaeger Tri-packs and heavier balls may form a bed of

tumbling free bodies in an agglomerator drum, free bodies being bodies that will tumble in a rotating drum in the presence of a suspension containing bitumen particles. In that case Jaeger Tri-packs are considered to be balls.

5 **“screen”** refers to an apertured wall, sieve or cable belt. Apertures of a wall, of a screen or of a sieve are the holes or slits through which aqueous phase can pass.

“schematic view” refers to a simplified drawing showing only the pertinent features to explain its operation.

10 **“sieve”** refers to an apertured oleophilic screen and is used interchangeably with “screen” unless specifically stated to the contrary. However, a screen may also be used to remove oversize particulates and in that case may not be oleophilic and is not a sieve as defined in these specifications. In prior patents of the present inventor the term “sieve” referred specifically to mesh belts, to metal conveyor belts or to perforated metal drum walls from which bitumen product was scraped or removed. In the currently pending patent applications of the inventor the term “sieve” more
15 specifically refers to screens formed from multiple adjacent wraps of endless rope, since mesh belts, apertured drum walls and commercial metal conveyor belts were found to performed poorly or wore out during long term separation of bitumen from aqueous mixtures. For that reason the term “screen” is used in preference to “sieve” in these specifications to indicate the difference between current and prior art.

20 **“single wrap endless cable”** refers to an endless cable which is wrapped around two or more cylindrical members in a single pass, i.e. contacting each roller or drum only once. Single wrap endless cables do not require a guide or guide rollers to keep them aligned on the support rollers but may need methods to provide cable tension for each wrap. This is particularly so when sequential cable wraps are of the
25 exact same lengths. In that case the wraps preferably are made from from stretchable material, such as nylon, or the cable may be designed to be stretchable and provide suitable tension in each wrap. Single wrap endless cables may serve the same purpose as multiple wrap endless cables for separations. When multiple wrap endless cables are specified, single wrap endless cables may be used in stead unless specifically
30 excluded.

“sludge” as used herein refers to any mixture of fine solids in water and contains residual bitumen. In describing or claiming certain embodiments, the term sludge, fluid tailings, fine tailings, mature fine tailings, bitumen containing suspensions and mixture are used interchangeably, unless explicitly stated to the contrary. In the oil sands industry, sludge is a term that used to be reserved for a mixture of bitumen and dispersed solids in a continuous water phase in a mined oil sands tailings pond but more recently “fluid tailings”, “fine tails”, “fresh fine tails” or “mature fine tails” have come in vogue for political reasons and also to provide a distinction as to how long this sludge has resided in a tailings pond.

10 **“slurry”** as used herein refers to a mixture of solid particulates and bitumen particulates or droplets in a continuous water phase. In the oil sands industry, oil sand slurry is a term normally used to describe an oil sand ore that has been or is in the process of being digested with water to disengage bitumen from sand grains. A process aid normally is used when a slurry is produced for subsequent bitumen froth
15 flotation. When a slurry is produced for separation by an oleophilic sieve, a process aid may not be required, or a different process aid may be used.

“sparging” or **“sparged”** as used herein refers to the introduction of a gas, such as steam, carbon dioxide or other gas under pressure into a bitumen containing mixture or into fluid tailings or effluents through tubes, pipes, enclosure openings,
20 perforated pipes or porous pipes. The type of gas used for sparging normally is described in the specifications. When steam is the sparging gas it may be used to increase the temperature of bitumen to reduce its viscosity. Live steam may also serve to both heat bitumen and to add water to bitumen.

“substantially” refers to the complete or nearly complete extent or degree of
25 an action, characteristic, property, state, structure, item, or result. For example, an object that is “substantially” enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the
30 same overall result as if absolute and total completion were obtained. The use of

"substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result.

5 **"surface speed"** is the speed of movement of the surface of an apertured agglomerator outlet or is the speed of movement of an apertured oleophilic screen.

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

"wrapped" or **"wrap"** in relation to a monofilament, wire, rope or cable wrapping around an object indicates an extended amount of contact. Wrapping does
15 not necessarily indicate full or near-full encompassing of the object.

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

Concentrations, amounts, volumes, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be
25 interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 inch to about 5 inches" should be interpreted to include not only the explicitly recited values of about
30 1 inch to about 5 inches, but also include individual values and sub-ranges within the

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indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc. This same principle applies to ranges reciting only one approximate numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the
5 range or the characteristics being described.

Bold text in the present disclosure is provided for convenience only.

MORE DETAILED DESCRIPTION OF THE FIGURES

10 **Fig. 1.** Is a flow diagram of a typical commercial oil sands plant using a PSV (primary separation vessel) and a TORV (tailings oil recovery vessel). In this drawing the oil sand ore is mined and moved by large dump trucks to roller crushers where the ore is crushed to a size suitable for slurry transport. A cyclo feeder mixes the crushed
15 ore with water and air and introduces the resulting mixture into a pipeline for slurry transport and to condition the oil sand ore to convert it into a slurry by turbulent flow in the pipeline. Additional air may be introduced into the slurry along the pipeline. The amount of water added at the hydrocyclone is limited in order to produce a thick slurry that will contain entrained air. Flood water is then added to thin the aerated
20 slurry for suitable froth flotation in a PSV. Residence time in the PSV reportedly is about 45 minutes for most oil sand slurries. Bitumen froth is skimmed from the top. Bottoms and middlings from the PSV are pumped to the TORV for recovering some of the bitumen that would not float in the PSV. Bitumen froth rising to the top of the TORV is pumped to the PSV inlet and middlings from the TORV are hydrocycloned to yield additional bitumen froth that is returned to the TORV. TORV tailings and
25 hydrocyclone underflow are pumped through a slurry pipeline to a tailings pond for beach settling of coarse sand for building pond dykes and the resulting fluid tailings run off flow into the sedimentation area where these take a few years to settle before recycle water from the top of the pond can be used in the extraction plant. After settling the fines form thixotropic gels that will not dewater naturally.

Residence time in a TORV is not reported in current literature. It is reasonable to assume that total residence time in the PSV and the TORV is at least 70 minutes. Each commercial oil sands plant uses a different configuration but each uses very large separation vessels to encourage bitumen froth to rise to the top and to maximize bitumen froth recovery. Some use a PSC (primary separation cell) which has a steeper cone than a PSV and some use subaeration cells in place of a TORV. In subaerated cells, air is introduced into the middlings product of a PSV or PSC by means of rapidly rotating air spargers that introduce air into the bottom of these cells to scavenge for and float additional bitumen froth.

Pumps and sample ports are not shown in Figure 1 to keep it simple but clearly much control is required in a current commercial oil sand extraction plant to optimize the flow and composition in all the various pipeline flow loops. Figure 1 is only one of several variations of the Clark process in commercial use.

Fig. 2. is a general flow diagram for processing mined oil sand by bitumen agglomeration and screening. Several configurations are possible and one of these is illustrated in this Figure. As described in copending patent application CA 2,700,446 the equipment required for bitumen agglomeration and screening may be small enough to allow oil sand extraction closer to the mine face than is feasible with the huge vessels of the current commercial plants. In Figure 2, oil sand is mined and crushed and then enters a high speed ablation drum. The older commercial oil sands extraction plants use conditioning drums, which are very large slowly turning drums to condition oil sand with water, caustic soda and air to make a thick aerated slurry suitable for flooding, followed by flotation in a PSV. In contrast, the ablation drum of the referenced copending application has high throughput capacity, is much smaller and rotates fast in cateracting mode to form a diluted oil sand slurry that contains very little or no air and is ready for separation in a shorter time than is possible in the current commercial plants that required a thick aerated slurry.

The dilute oil sand slurry is coarse screened to remove rocks and coarse gravel and then is pumped to a confined path hydrocyclone that is disclosed in detail in

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compending patent application CA 2,638,550. This hydrocyclone features a confined path in the form of a coiled pipe upstream of the hydrocyclone body. The coiled pipe is provided with nozzles in the outside lane for fluid injection to drive dispersed bitumen particles from the outside lane to the inside lane for reporting to the

5 hydrocyclone overflow. The confined path hydrocyclone overflow enters a rotating agglomerator that features an apertured cylindrical wall that is partly covered with a revolving apertured oleophilic screen in the form of multiple adjacent cable wraps. In a separation zone debituminized slurry flows through the drum and screen apertures along the bottom of the agglomerator to become effluent whilst agglomerated

10 bitumen leaving the agglomerator through its apertured wall adheres to the screen cable wraps to be removed in a bitumen removal zone represented by two squeeze rollers above the agglomerator. This is the raw bitumen product of separation and contains some water and solids but specifically contains ultrafine minerals. In the current commercial processes the ultrafines end up in the settling portions of tailings

15 ponds and there form a thixotropic gell, which is the reason why current commercial fluid tailings after settling will not dewater in commercial tailings ponds. Unlike the current commercial plants that allow these ultrafines to report to the fluid tailings, the ability of agglomerating the ultrafines into the bitumen product prevents these gel forming ultrafines from entering tailings ponds, as described in compending patent

20 application CA 2,696,181.

The underflow of the confined path hydrocyclone provides a filter bed for the effluent leaving the agglomerator and allows water run off from the resulting tailings to return to the process for making more oil sand slurry. This water run off may be hydrocycloned to remove some of its solids before returning to the process, and the

25 underflow of this conventional hydrocyclone may also be filtered by the sand bed of the confined path hydrocyclone. One nice feature of bitumen screening is that the process is very tolerant of fines in the process water. The left over solid tailings contain between 20 and 25% water and this creates a demand for some fresh water for slurry preparation. During winter time this fresh water may be hot water to melt

30 frozen lumps of oil sand ore in the ablation drum.

Fig. 3A is a sectional view of a conditioning drum cut lengthwise. Feedstock (1) enters the drum (2) through a rotary seal type entrance (3) and flows into a bed (4) of balls (5) contained in the drum (2). The drum has endwalls (6 and 7) supported at one end by a rotary turn table (8) on a structural mount (14) which turn table allows passage of feedstock through its centre. The drum (2) is supported at the other end by a shaft (10) in a bearing in a large pillow block (9) on a structural mount (13). A sprocket (11) mounted on the shaft (10) is mechanically coupled to a gear motor (12) by a roller chain. The two end walls (6 and 7) are connected to each other by heavy bars (15) that prevent sagging of the drum due to the weight of the bed (4) of balls. A number of these bars (15) are mounted concentric with the feedstock (1) entrance (3) and their number and size are calculated to suitably strengthen the drum (2). Instead of a series of bars (15), a rigid central pipe (not shown) may be used, which contains a few holes to allow feedstock (1) to flow to the bed (4) of balls. The cylindrical wall (16) of the conditioning drum is comprised of a large number of hoops (17) that may be assembled from cut sections of steel plate or that may be rolled from flat bars. These hoops have an internal diameter, an external diameter and a thickness. In all cases the thickness of each hoop is smaller in size than the difference between the hoop outside diameter and inside diameter. That is the reason why these are called hoops instead of rings. In many cases the hoop thickness is less than one tenth of the difference between hoop outside diameter and inside diameter. For example, nominal 0.25 inch thick (6 mm), 4 inch wide (100mm) steel flat bars may be rolled into hoops that are 2 meters in inside diameter; the ends may be welded together, and the hoops (17) may be re-rolled to make them truly round. Each hoop is welded at its inside diameter to cross bars that are evenly spaced around the periphery of the drum (2) and these cross bars are attached to the end walls (6 and 7) of the drum (2) by means of attachment rings (201 and 202). In this manner the cylindrical wall (16) of the drum (2) is apertured, contains a bed (4) of balls (5) and allows exit from the drum for feedstock (1) after it has been processed. Oleophilic cable wraps (18) partly fill the spaces between adjacent hoops to partly block or reduce the size of the aperture openings of the drum and to capture bitumen phase. The workings of the drum and of

the cable wraps are explained in more details with Figure 4. A enlarged cross sectional view of a few hoops (17) welded to a cross bar (16) and with cable wraps (18) between hoops (17) is shown in **Fig. 3B**, which uses the same component numbers as Figure 3A. Again referring to Figure 3A, a flanged opening (20) is
 5 provided for the insertion or removal of balls (5) and the inside of the end wall (6) is kept smooth to prevent balls from getting caught in the flange opening (20). Splash baffles (21 and 22) may be provided under the drum. When the drum is short or when the cross bars (16) are heavy, concentric bars (15) or concentric pipe may not be required, since the cross bars (16) welded to each hoop (17) inside diameter, and
 10 fastened to the end walls will provide considerable strength and rigidity to the drum (2).

Fig. 4A is a cross sectional view across the width of the drum of Figure 3A and also shows revolving rollers and revolving cross bars covered by cable wraps. Each cable wrap (30) is in contact with many of the cross bars (31) Shown are the
 15 feedstock entry (32) and the main strengthening bars (33) that provide rigidity to the drum (34) and hoops (35) welded on the inside diameter (36) to cross bars (31) that keep the hoops properly aligned and spaced. Also shown are the splash baffles (37) and the flow of aqueous phase (38) out of the agglomerator in the separation zone (39). Shown also are the bitumen removal zone (40) consisting of two rollers (41 and
 20 42) that may be grooved and prevent any significant amounts of bitumen to pass by these rollers but causes the bitumen (43) to flow into a bitumen receiver (44) that has an exit pipe (45) for transporting the bitumen product away from the receiver (44) by means of a pump (not shown) Also shown are one of several nozzles (46) that may be used to spray water onto bitumen (not shown to keep the drawing simple) adhering to
 25 the cable wraps (47). The bitumen receiver (44) has optional baffles (48 and 49) to heat the rising bitumen on the moving cable wraps. This heating is illustrated by the electrical resistance symbol (50). Heating may be done by sparging live steam between these baffles ((48 and 49) into the rising bitumen. Couette flow of cold bitumen entering with the cable wraps into the space between the baffles (48 and 49)
 30 will force the heated biutmen upward into the bitumen receiver, as indicated by the

curved arrow at the top of the left baffle (48). One nice feature of the separator design of Figure 4A is that either or both rollers (41 or 42) may be cooled, for example by water flowing through the roller interiors to cool down warm cable wraps before these leave the bitumen removal zone to return to the separation zone for capturing
5 more bitumen.

A scraper blade (51) attached to the bottom receiver baffle (48) serves to scrape bitumen from the hoop (34) surfaces and transfer it to cable wraps (30) as these move upward to the bitumen removal zone (40). As described, the baffles (48 and 49) are placed close to the cable wraps (31) to cause couette flow of viscous
10 bitumen into the receiver (44) before this bitumen is contacted by live steam. The top baffle (49) may have edges adjacent to the outer cable wraps and may be angled and automatically adjusted with respect to distance to the cable wraps to enhance the desired couette flow of bitumen adhering to the cable wraps (30) and prevent spillage of bitumen. The force of gravity could cause warm excess bitumen to fall off the
15 wraps (31) or flow downward along the wraps but the baffles contain this excess bitumen and, with colder, more viscous bitumen behind it, cause it to flow upward into the receiver due to couette flow. Thus, bitumen leaving the hoops (35) of the rotating agglomerator (34) are relatively cold and will tend to fill the space between the baffles (48 and 49). Positioning of these two baffles (48 and 49) and control of
20 heating (50) therefore represent an important part of equipment optimization and adjustment.

Warm water or hot air may be provided instead of cold water from the nozzles (46) to remove superficial mineral matter from the captured bitumen before it is removed in the bitumen removal zone, and alternately to preheat the captured
25 bitumen. However, care must be taken not to wash warm bitumen down the rising cable wraps.

For an agglomerator rotating counter clockwise as in Figure 4A, feedstock (53) enters the agglomerator (34) through its central inlet (32) and is agglomerated by a bed (54) of balls to increase the size of bitumen particles dispersed in the feedstock
30 (53) by means of adhesion to oleophilic surfaces of the balls and subsequent

sloughing off of enlarged bitumen phase particles back into the mixture or for temporary storage in voids of the bed (54) of balls. Aqueous phase (38) mainly leaves through the left bottom quadrant (55) of the agglomerator wall, where the voids between wraps and hoops are not blocked by bitumen. Along the right bottom quadrant (56) of the agglomerator wall, bitumen being kneaded out of the ball voids due to the movement of the bed (54) of balls in the revolving agglomerator (34) will tend to fill the aperture voids between wrap and hoop surfaces (See Figure 3B for a close up sketch of the apertures) and will prevent or reduce the flow of aqueous phase (38) out of the agglomerator (34). Kneading by the bed (54) of balls will tend to cause bitumen phase to flow through the drum apertures in the right bottom quadrant (56) of the drum (34) and deposit a thick layer of bitumen (not shown) on the cable wraps for transfer to the bitumen removal zone (40). Splash baffles (37) may be replaced by a tank to collect the effluent for transport to storage or dewatering.

Fig. 4B illustrates a short section of the scraper (51) of Figure 4A. The scraper (67) has teeth (65) that fit between the hoops to more effectively scrape bitumen from the hoops and deposit it on the cable wraps moving towards the bitumen removal zone. Or in other words, the scraper of Figure 4B has adjacent slits (66) that accommodate adjacent hoops for proper transfer of bitumen from hoops to wraps.

Fig. 5A is similar to Figure 3A with two main differences. In Figure 5A the agglomerator has two compartments. The first compartment (70) receives the feedstock (71) and is filled with oleophilic tower packings (72) in a manner that these tower packings (72) are not free to tumble. From there the partly agglomerated feedstock passes through an apertured wall (73) into a second compartment (74) partly filled with a bed of tumbling balls (75). The cylindrical wall (76) of the second compartment (74) is similar in construction and operation as the apertured cylindrical wall of Figures 3 and 4 and is as described with these Figures. Another major difference is that the agglomerator end walls (77 and 78) have slewing rings (79) that are supported on rollers (80) on shafts in bearings that are driven by a motor (81). In Figure 3A the drum was supported by a mounted central bearing and by a vertical

central turn table bearing. When designing agglomerators supported by slewing rings, the endwalls normally are reenforced to prevent deformation. However, such reenforcement is not shown here for the sake of simplicity.

Fig. 5B is very similar to Figure 5A with the exception that the first compartment (90) is concentric with the second compartment (91) which two compartments are separated by a perforated cylindrical sheet (92) that increases the hold up of mixture in the first compartment for feedstock agglomeration by tower packings before entering the second compartment (91) for agglomerating by a bed of balls.

Figs. 5C illustrate the potential locations of three sets of rollers (80) that support the slewing rings of the rapidly rotating agglomerator. For simplicity of explaining the drawing, the rollers of Figures 5 A and 5B are positioned according to Figure 5C. However, the preferred position is shown by **Fig. 5D** which uses two bottom rollers (98 and 99) to support the slewing ring. The top roller (97) prevents the rapidly turning agglomerator from jumping off the bottom rollers (98 and 99)

Fig. 6A is an illustration of a catteracting bed (100) of balls in a drum (101) rotating at approximately 75 percent of critical drum rotation rate.

Fig. 6B is an isometric drawing of the drum (102) of Figure 5A, showing the unapertured portion (103) of the drum wall, the apertured portion (104) of the drum wall, the rollers of the bitumen removal zone (105), the apertured oleophilic screen (106) in the form of adjacent cable wraps, the feedstock entrance (107) and showing a baffle plate (108) for directing effluent. It does not show drum supports or drum drive.

Fig. 6C is an illustration of a revolvable oleophilic screen in the form of adjacent cable wraps (120) supported by grooved main rollers (121 and 122) and with cable guide rollers (123 and 124) that keep the endless cable from running off the main rollers (121 and 122). This concept was disclosed in detail in pending Canadian patent 2,638,596. The same type of endless cable, guide rollers, and adjacent cable wraps are used in the present invention. However, in the present invention one of the rollers is an apertured agglomerator drum and the other roller is one or both of the

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rollers of the bitumen removal zone. Since the concept of guide rollers to keep endless cables on rollers or drums has been described in detail in application 2,638,596 and is used in the present invention, there did not seem to be a need to explain this again. However, in all cases in the present invention a set of guide rollers
5 is required for each endless cable unless each cable wrap is an endless cable by itself. In that case, each revolving cable wrap remains permanently between two sequential hoops as it revolves from separation zone to bitumen removal zone and back. Then the endless wraps all must be the same in length, and/or the wraps must be made from a stretchable material, such as nylon or from stretchable cable or rope to provide
10 proper wrap movement between the two zones and to prevent wrap slippage.

Fig. 6D is a photographic image of a polyolefin Jaeger Tri-pack type of tower packing that is spherical and may also be used in conjunction with and be mixed with metal balls in a bed of tumbling balls provided that the bed of balls will not crush nor destroy the Tri-packs. Similar tower packings may be designed and
15 fabricated that are of stronger design, or made from stronger materials and may then be used as replacements for Jaeger Tri-packs to serve the purpose of reducing the density of a mixed bed of balls in an agglomerator.

Fig. 7. shows a comparison between the required size of a commercial PSC (primary separation cell) plus subaeration cells for recovering bitumen from 7000
20 metric tons of oil sand ore per hour, and the required size of bitumen agglomerators and apertured screens for processing the same amount of ore per hour with the same degree of bitumen recovery. A typical commercial oil sand extraction plant processing 7000 metric tons of mined oil sand uses a conical primary separation cell (PSC) that has a diameter of 30 meters and a height of 21 meters and a volume of
25 about 7900 cubic meters to process approximately 10,300 cubic meters of slurry per hour, resulting in a PSC residence time of 46 minutes. The middlings from the PSC are processed in banks of 8 subaeration flotation cells that have a combined volume of 1280 cubic meter. Assuming that 25 percent of the slurry flowing through the PSC volume are middlings, this will cause a flow of 2600 cubic meters of middlings per
30 hour through subaeration cells that have a combined volume of 1280 meters. The

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resulting residence time in the subaeration cells then becomes 30 minutes and the total residence time through the PSC and the subaeration cells is 76 minutes or more than an hour and a quarter based on these data. In comparison, separating the same feedstock by means of agglomeration and sieving may only take 2.1 minutes since the
5 flow rate is the same and the equipment volume is only 255 cubic meters.

Based on scale up calculations detailed in the previous pages, a 3 meter diameter, 36 meter long agglomerator with associated apertured screen rotating at 15 RPM is anticipated to separate 10,300 cubic meters of slurry per hour and with the same efficiency of bitumen recovery as the PSC and subaeration cells. Instead of
10 using a single 36 meter long agglomerator, two 18 meter long agglomerators may be used. This comparison is illustrated in Figure 7. This suggests that an oleophilic sieve is 36 times as fast as froth flotation, which is remarkable. Even if it turns out to be only 10 times faster, this difference will have a huge impact on the future of mined oil sands extraction.

15 Six meter diameter agglomerators may be used instead of 3 meter diameter agglomerators to reduce the width of the desired apertured screens, but then the RPM must be reduced to about 11 RPM to stay well below the cattering RPM. In that case two agglomerators may be used that are 6 meters in diameter and are 12 meters long. It is anticipated that increasing the drum diameter to 6 meters will allow a
20 reduction in the percentage ball fill of an agglomerator to achieve the same degree of agglomeration as compared with a 3 meter diameter agglomerator.

The scale up factors presented here will need to be tested in the field with very large equipment and will require major R&D funding. However, the potential of being able to reduce oil sand slurry processing time from about 76 minutes to 3 or
25 even 8 minutes will have a tremendous impact on the cost of commercial oil sand processing.

While these scale up calculations make eminent sense, it is obvious that very larger scale test work is required to verify these data. It is not very likely that such large scale up test work will be attempted soon with oil sand slurries since that
30 would interfere to a significant degree with the operation of a commercial oil sands

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plant. However, the same scale up test work may be done with tailings pond sludge, or fluid tailings, as these are now called. Millions of cubic meters of fluid tailings lay in waste in the existing commercial oil sand tailings ponds. Performing large size scale up test work on fluid tailings will in no measure interfere with the operation of a commercial oil sands extraction plant. Not only will it produce a significant amount of bitumen that perhaps may be converted to asphalt for road construction but it will also clean up the tailings ponds by capturing the ultrafines that are the bad actors which prevent dewatering of fluid tailings.

Since oil sand slurries, after oversize removal, can be separated by an agglomerator and associated apertured oleophilic screen with the same ease as fluid tailings, any scale up data obtained from processing fluid tailings may have direct application in commercial processing of oil sand slurries to produce bitumen from mined oil sand.

The average density of a bed of balls may vary from 1.5 gram per c.c. to 8 gram per c.c. depending on the feedstock composition, on the agglomerator diameter and on agglomerator ball loading. Normally the average density is less than 4 grams per cubic centimeter to get agglomerators away from heavy ball mill designs. The ball diameter may vary in size but the average ball diameter of a bed of balls normally is between 1 centimeter and 10 centimeters. The thickness of the hoops may vary from 3 centimeters to 0.2 centimeters but the preferred range is between 1.5 centimeters and 0.5 centimeters. The distance between two adjacent hoops may be between 10 centimeters and 1 centimeter depending on the diameter of the cable wraps selected to fit between the hoop surfaces and the thickness of the hoops but the preferred distance is between 6 centimeters and 1 centimeter.

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SUMMARY

Pilot plant test work with oleophilic sieves and bitumen agglomerators has been very successful. Mined high grade oil sand, medium grade oil sand, low grade oil sand, conventional middlings and tailings pond sludge or fluid tailings were separated

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in very simple equipment and achieved higher bitumen recovery than was possible by means of bitumen froth flotation in the current commercial oil sands plants that use the process invented by Karl Clark over 80 years ago. The present inventor joined the Alberta Research Council in 1961 while Karl was still employed there as a consultant.

5 As a result, he had access to and read all the research reports of Karl Clark, who died one year before the first commercial plant using the Clark process started oil sand processing. Kruyer was given permission to develop a process to overcome the problems that had surface after the Clark process had been commercialized. Instead of attempting to improve the Clark froth flotation process, he chose a different route

10 which involved sieving bitumen from suspensions. Only a few years prior to that, the Research Council of Alberta had given the Clark process to the industry for free. After a very successful start the Kruyer process was put on the shelf and the inventor was fired when he objected. The matter went to court for resolution and in a consent judgment the inventor was granted the right to continue development of his process

15 on his own. In the years that followed he improved the oleophilic sieve process and was able to achieve more efficient bitumen recovery and faster separation rates than was possible with the Clark process. One major benefit was the discovery that the tailings of agglomeration and sieving will dewater rapidly. This in contrast to the commercial Clark process that produces fluid tailings that, after settling for a few

20 years to 30 to 35 percent solids content, will not dewater naturally after that. Another significant discovery was that, while bitumen froth flotation of fluid tailings from tailings ponds was a failure, a suitable agglomerator and oleophilic sieve combination achieved very high bitumen recovery from such fluid tailings, and require very simple small equipment that featured high throughput. In other words, screening bitumen

25 from a suspension turned out to be more efficient and much faster than attaching air bubbles to bitumen particles and waiting for these bitumen particles to rise through an aqueous slurry of settling sand and solids.

Several patents were granted originally for this process, but these were based on the equipment that was developed in the pilot plant. For example, bitumen

30 agglomerators were patented that used perforated steel sheets for the apertured

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agglomerator cylindrical wall. While such patented agglomerators worked very well in the pilot plant, scaling these up to large commercial sizes became an engineering impossibility. These simply were not strong enough when extended to larger sizes. Similarly, endless mesh sieve belts were used in the pilot plant for separating
5 suspension that contained agglomerated bitumen, water and mineral particulates. These mesh belts worked remarkably well in the pilot plant but did not last for more than a few months, and would have not lasted very long in a continuous commercial plant. As a result, an extensive development program was entered into to make the process suitable for scale up to the sizes needed for a commercial oil sands plant.

10 As described, this technology uses a completely different approach, as compared to conventionally accepted methods, to separate bitumen from suspensions; and covers a very broad field of engineering. As a result, the many copending patent applications referred to in the present invention, together with this present invention, cover a very broad, new and potentially very profitable field of engineering.
15 Unfortunately, during the past 50 years, much time and money have been invested by industry and governments on improving parts of the Clark process, and this has resulted in many experts who are hesitant to look beyond the merits of the Clark process.

Thus, while many of the patents granted in the past had the objective of
20 improving the extraction of bitumen from aqueous suspensions on a pilot scale, the currently pending patent applications are dedicated to making the process commercially viable in a large scale industrial setting.

Of course, it is to be understood that the above described arrangements, and specific examples and uses, are only illustrative of the application of the principles of
25 the present invention. Thus while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications may be made without departing from the principles and concepts set forth herein.

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CLAIMS

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

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1. A method of agglomerating in an agglomerator and separating by oleophilic screening in a separation zone and removing bitumen from oleophilic screen surfaces in a bitumen removal zone a feedstock that contains bitumen phase particles dispersed in continuous aqueous phase, wherein

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- a) agglomerating occurs in a revolving agglomerator drum that has endwalls and cylindrical wall and feedstock entrance and agglomerated feedstock exit and is at least partly filled with oleophilic surfaces that temporarily collect bitumen phase particles from the feedstock in layers of increasing thickness until shear forces in the agglomerator slough off enlarged bitumen phase from said surfaces for subsequent oleophilic screening in the separation zone where at least part of the cylindrical wall is apertured and forms the agglomerated feedstock exit, wherein

15

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- b) the exit comprises equally spaced multiple adjacent circular hoops that each have an outside diameter and an inside diameter and a thickness and are attached at the inside diameter to rigid cross bars equally spaced along the inside diameter of the hoops to form the apertured cylindrical wall, wherein

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- c) the rigid cross bars of the apertured cylindrical wall are directly or indirectly attached to the end walls of the drum, wherein

- d) endless cable wraps are positioned between sequential hoops and contact the cross bars along the bottom of the apertured cylindrical wall to form the separation zone, wherein

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- e) each cable wrap in the separation zone only partly fills the space between the surfaces of each two sequential hoops to thereby allow

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aqueous phase to pass between cable wrap surfaces and hoop surfaces,
wherein

- 5 f) each cable wrap is wrapped around the apertured wall along at least the bottom half of the agglomerator in the separation zone and around part of one or more rollers above the agglomerator in the bitumen removal zone, wherein
- 10 g) in the separation zone aqueous phase leaving the agglomerator through the exit passes between cable wrap surfaces and hoop surfaces to become effluent of separation whilst enlarged bitumen phase leaving the agglomerator through the exit is captured by the cable wraps and is conveyed by the cable wraps to the bitumen removal zone where adhering bitumen is removed from the cable wraps to become bitumen product of separation.

- 15 2. A method as in Claim 1 wherein the feedstock is an oil sand slurry feedstock, an oil sand middlings feedstock, an oil sands tailings feedstock or an oil sand emulsion feedstock.
3. A method as in Claim 1 wherein a chemical reagent is added to the feedstock before or after it has entered the agglomerator.
- 20 4. A method as in Claim 1 wherein the oleophilic surfaces are the surfaces of balls that tumble inside the agglomerator which agglomerator turns at a rate less than 75 percent of the critical rotation rate of the agglomerator.
5. A method as in Claim 4 wherein the agglomerator turns at a rate less than 50 percent of the critical rotation rate of the agglomerator.
- 25 6. A method as in Claim 1 wherein the oleophilic surfaces are the surfaces of oleophilic tower packings.
7. A method as in Claim 4 wherein the balls are a mixture of metal balls and non metal balls.
- 30 8. A method as in Claim 7 wherein the non metal balls are spherical Jaeger Tri-packs or revised Tri-packs strong enough to tumble inside the agglomerator with heavy balls without breaking.

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9. A method as in Claim 1 wherein the oleophilic surfaces are the surfaces of a bed of balls that has an average ball density of less than 4 grams per cubic centimeter.
10. A method as in Claim 1 wherein the oleophilic surfaces are the surfaces of a bed of balls with average ball diameter larger than 1 centimeter.
11. A method as in Claim 1 wherein the oleophilic surfaces are the surfaces of a bed of balls with average ball diameter smaller than 10 centimeters.
12. A method as in Claim 1 wherein the agglomerator has two compartments wherein feedstock enters the first compartment that is filled with oleophilic tower packings through the entrance and flows from the first compartment into a second compartment that is partly filled with a bed of tumbling oleophilic balls after which agglomerated feedstock leaves the second compartment through the agglomerator exit.
13. A method as in Claim 1 wherein the cable wraps are wraps of plastic rope, metal wire rope, single wire or plastic monofilament.
14. A method as in Claim 1 wherein the agglomerator is driven.
15. A method as in Claim 14 where one or more of the rollers in the bitumen removal zone are driven to have a surface speed identical to the surface speed of the agglomerator to minimize surface wear.
16. A method as in Claim 1 wherein the rollers in the bitumen removal zone are both grooved to allow passage of moving wraps but cause shedding of bitumen from the cable wraps in the bitumen removal zone.
17. A method as in Claim 1 wherein one roller in the bitumen removal zone is grooved and another roller in the bitumen zone has a flexible surface to allow passage of moving wraps but cause shedding of bitumen from the cable wraps in the bitumen removal zone.
18. A method as in Claim 1 wherein scraper blades transfer adhering bitumen from hoop surfaces to cable wraps leaving the apertured agglomerator surface for subsequent removal from the wraps in the bitumen removal zone.

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19. A method as in Claim 1 wherein a fine spray of water is used to wash superficial mineral matter from bitumen on revolving cable wraps to remove superficial minerals before entering the bitumen removal zone.
- 20 A method as in Claim 1 wherein bitumen on cable wraps confined in an enclosure is heated and couette flow causes flow of confined bitumen into the bitumen removal zone.
21. An apparatus for agglomerating in an agglomerator and separating by oleophilic screening in a separation zone and removing bitumen from oleophilic screen surfaces in a bitumen removal zone a feedstock that contains bitumen phase particles dispersed in continuous aqueous phase, wherein
- a) the agglomerator is a revolving agglomerator drum that has endwalls has cylindrical wall has feedstock entrance and has agglomerated feedstock exit and can be at least partly filled with oleophilic surfaces that can temporarily collect bitumen phase particles from the feedstock in layers of increasing thickness until shear forces in the agglomerator slough off enlarged bitumen phase for subsequent oleophilic screening in the separation zone where at least part of the cylindrical wall is apertured and forms the agglomerated feedstock exit, wherein
- b) the exit comprises equally spaced multiple adjacent circular hoops that each have an outside diameter and an inside diameter and a thickness and are attached at the inside diameter to rigid cross bars equally spaced along the inside diameter of the hoops to form the apertured cylindrical wall wherein
- c) the rigid cross bars of the apertured cylindrical wall are directly or indirectly attached to the end walls of the drum, wherein
- d) endless cable wraps can be positioned between sequential hoops and contact the cross bars along the bottom of the apertured cylindrical wall to form the separation zone, wherein

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- e) each cable wrap in the separation zone only partly fills the space between the surfaces of each two sequential hoops, wherein
 - f) each cable wrap can be wrapped around the apertured wall along at least the bottom half of the agglomerator in the separation zone and around part of one or more rollers above the agglomerator in the bitumen removal zone, wherein
 - g) in the separation zone aqueous phase can leave the agglomerator through the exit and pass between cable wrap surfaces and hoop surfaces to become effluent of separation whilst enlarged bitumen phase can leave the agglomerator through the exit and be captured by the cable wraps conveyance by the cable wraps to the bitumen removal zone where adhering bitumen can be removed from the cable wraps to become bitumen product of separation.
22. An apparatus as in Claim 21 wherein the agglomerator can be safely driven at a rate greater than 25 percent of the critical rotation rate of the agglomerator.
23. An apparatus as in Claim 21 wherein the agglomerator can be safely driven at a rate greater than 50 percent of the critical rotation rate of the agglomerator
24. An apparatus as in Claim 21 wherein the agglomerator has two compartments wherein feedstock can enter the first compartment filled with oleophilic tower packings through the entrance and can flow from the first compartment into a second compartment partly filled with a bed of tumbling oleophilic balls after which agglomerated feedstock can leave the second compartment through the agglomerator exit.
25. An apparatus as in Claim 21 wherein the cable wraps are wraps of plastic rope, metal wire rope, single wire or plastic monofilament.
26. An apparatus as in Claim 21 wherein the rollers in the bitumen removal zone are both grooved.
27. An apparatus as in Claim 21 wherein one roller in the bitumen removal zone is grooved and another roller in the bitumen zone has a flexible surface.

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28. An apparatus as in Claim 21 wherein scraper blades are in contact with hoop surface for the purpose of transferring adhering bitumen from the rotating hoop surfaces to the revolving cable wraps before the wraps enter the bitumen removal zone.
- 5 29. An apparatus as in Claim 21 that can heat bitumen on the cable wraps before entering the bitumen removal zone.
30. An apparatus as in Claim 21 wherein the one or more rollers in the bitumen removal zone can be cooled to cool warm cable wraps leaving the bitumen removal zone and returning to the separation zone.
- 10 31. An apparatus as in Claim 21 wherein bitumen on the cable wraps is confined in a heated enclosure such that couette flow can cause movement of confined bitumen into the bitumen removal zone.
32. An apparatus as in Claim 31 wherein the enclosure is heated by steam.
33. An apparatus as in Claim 21 wherein the distance between sequential hoops is less than 6 centimeters and the diameter of each cable wrap is less than 4 centimeters.
- 15 34. An apparatus as in Claim 21 wherein the distance between sequential hoops is less than 2 centimeters and the diameter of each cable wrap is less than 1 centimeter.
- 20 35. An apparatus as in Claim 21 where the thickness of each hoop is less than 1.5 centimeters.
36. An apparatus as in Claim 21 where the thickness of each hoop is less than 0.5 centimeters.
- 25 37. An apparatus as in Claim 21 wherein the agglomerator is reinforced by a structural pipe between the agglomerator end walls concentric with the agglomerator axis said pipe having a few holes to allow feedstock to enter the agglomerator.
- 30 38. An apparatus as in Claim 21 wherein the agglomerator is reinforced by a number of structural rods between the agglomerator end walls placed in circumferential alignment with the agglomerator axis.

Application number / numéro de demande: 2707577

Figures: ~~5D~~ 6D

Pages: _____

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10ème étage)

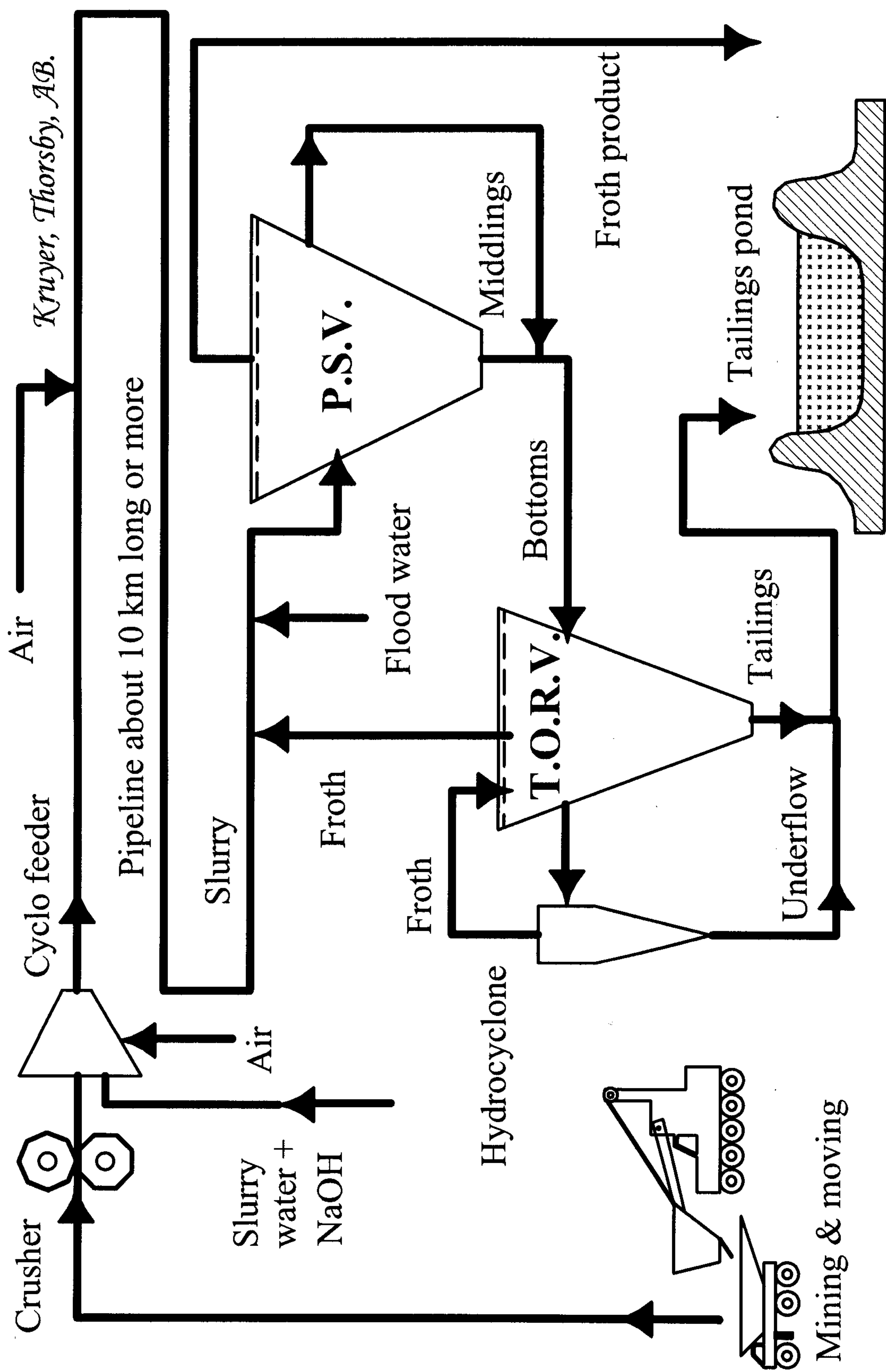


FIG. 1, A COMMERCIAL OIL SAND SEPARATION PLANT.

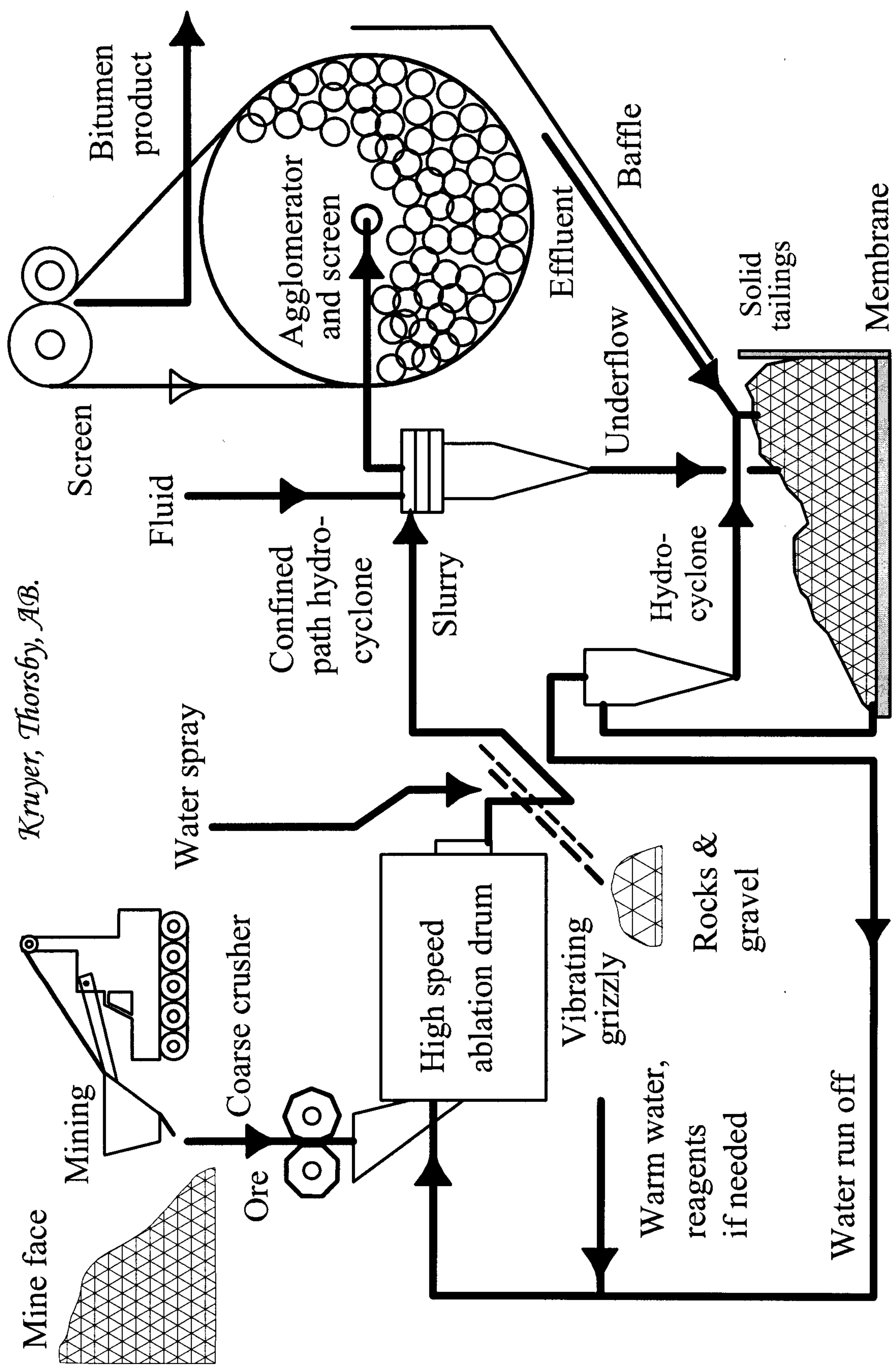


FIG. 2, GENERAL FLOW DIAGRAM OF BITUMEN SCREENING

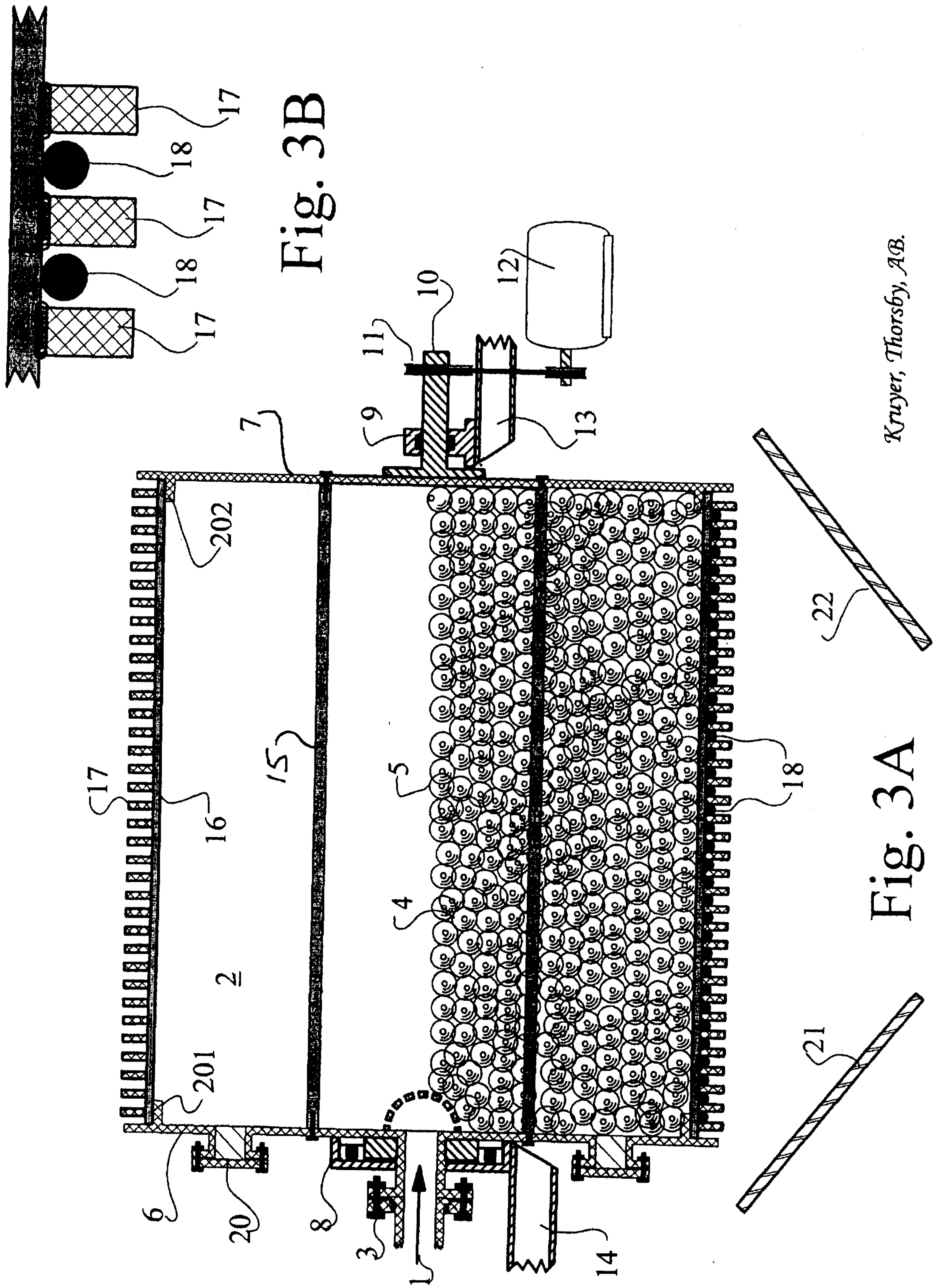


Fig. 3A

Fig. 3B

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Fig. 4B

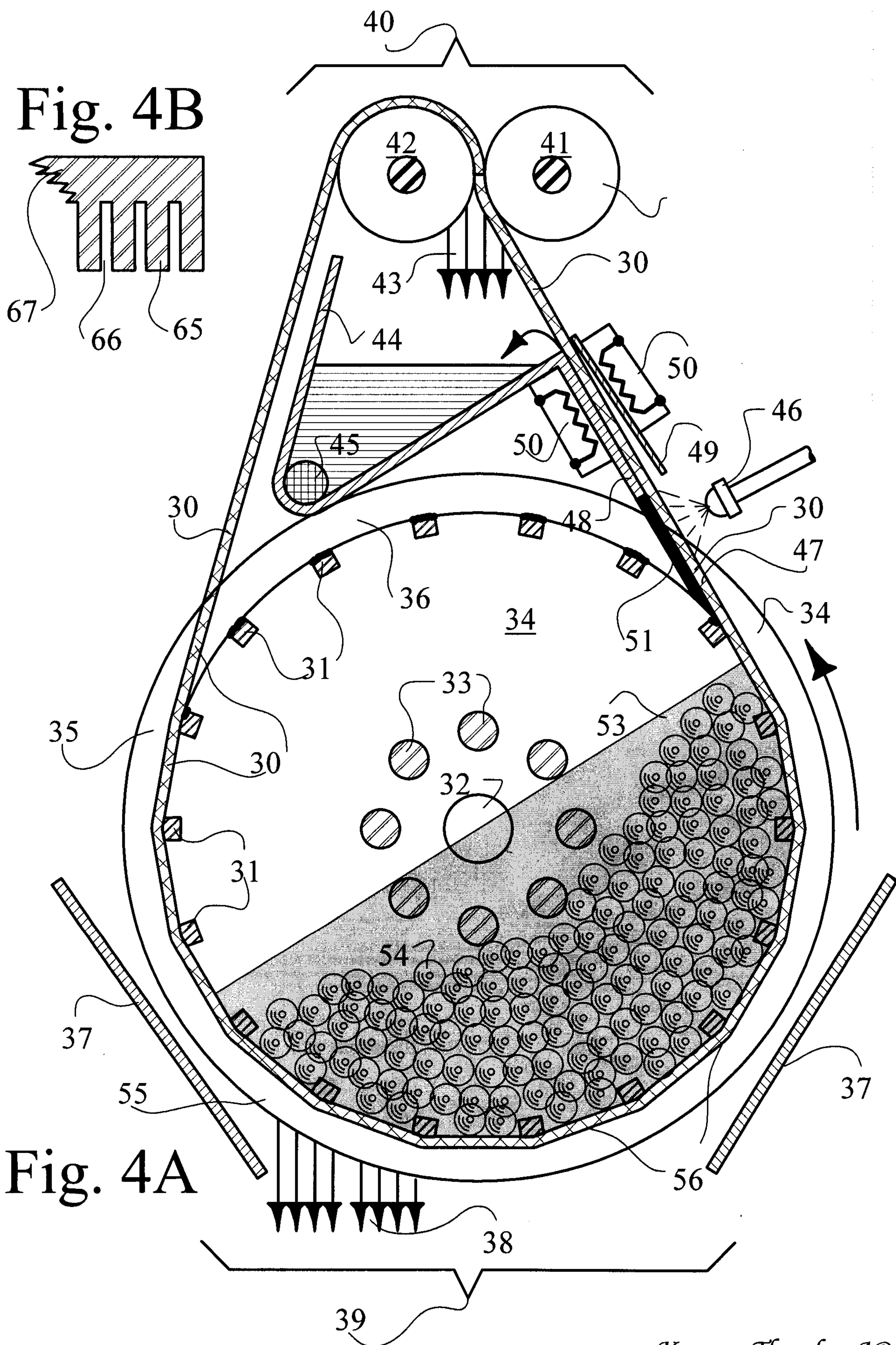


Fig. 4A

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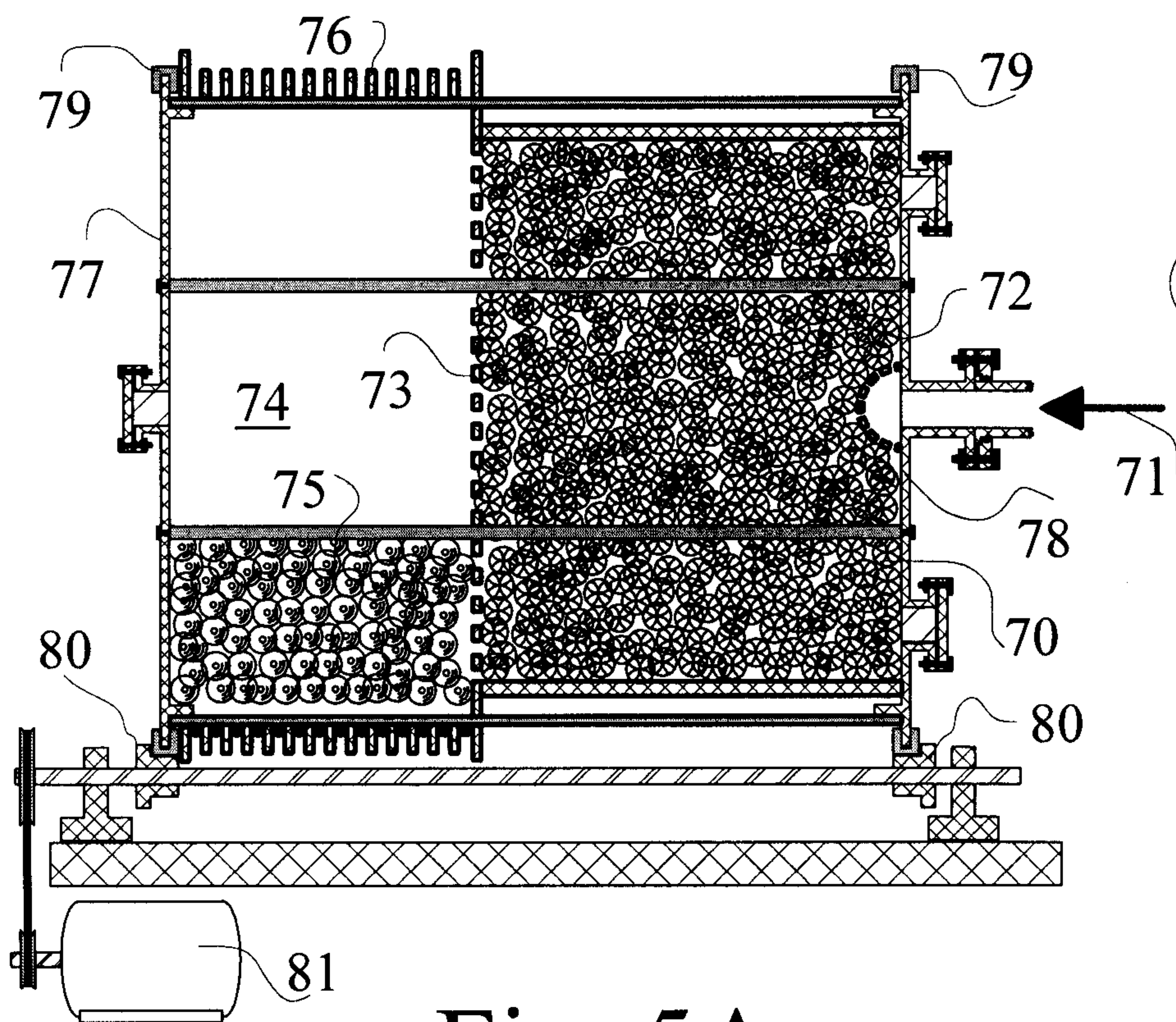


Fig. 5A

Fig. 5B

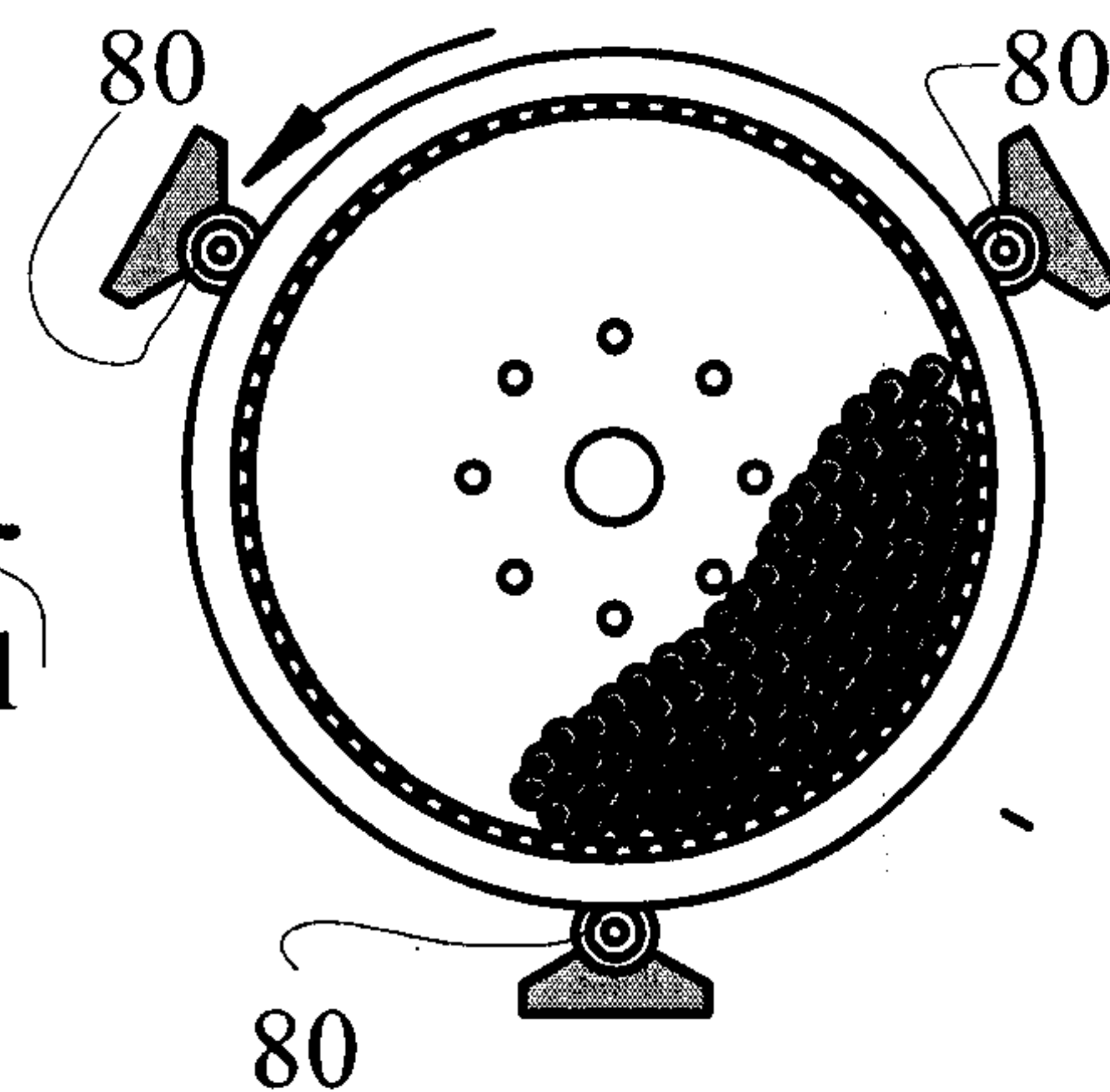


Fig. 5C

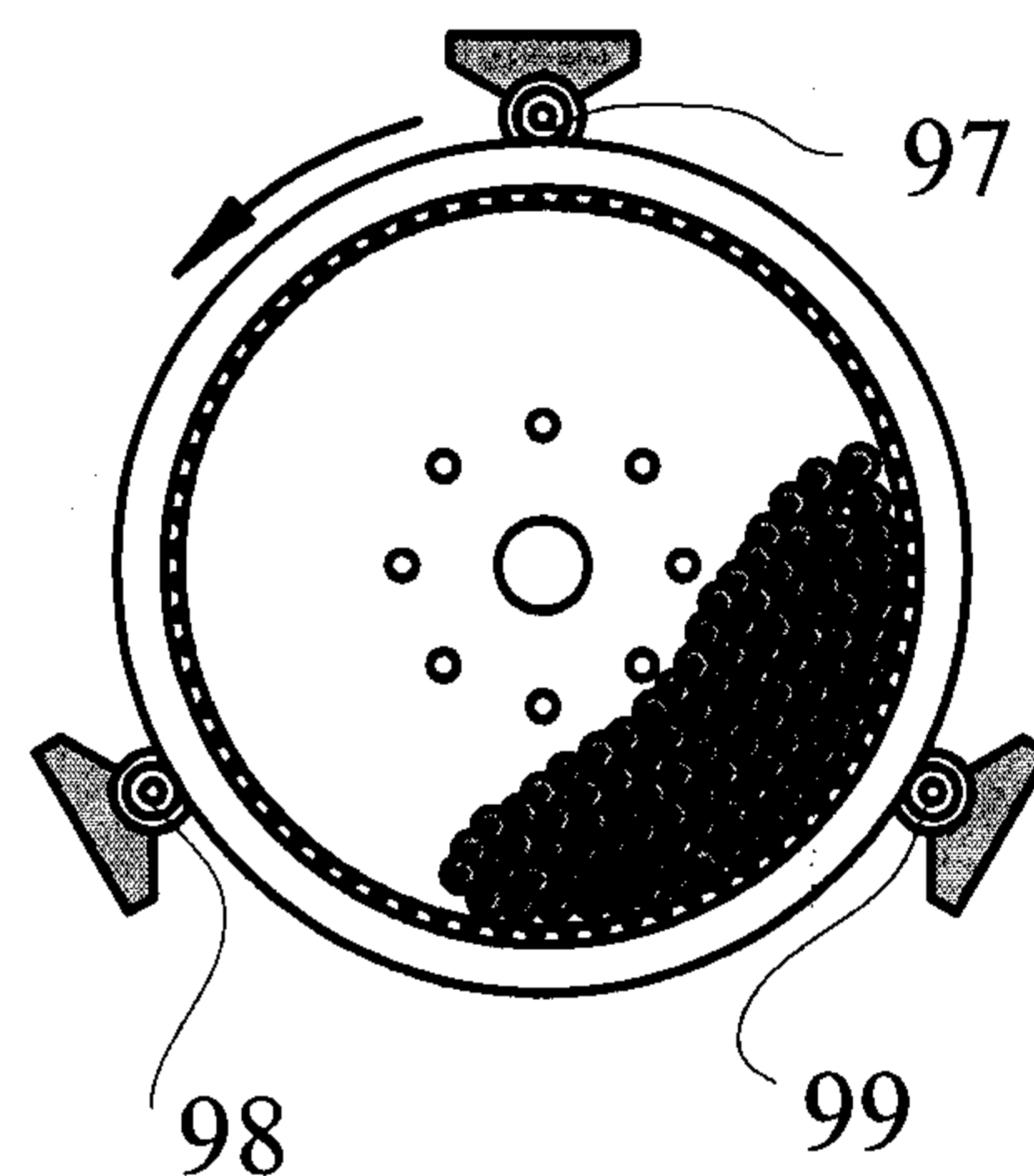
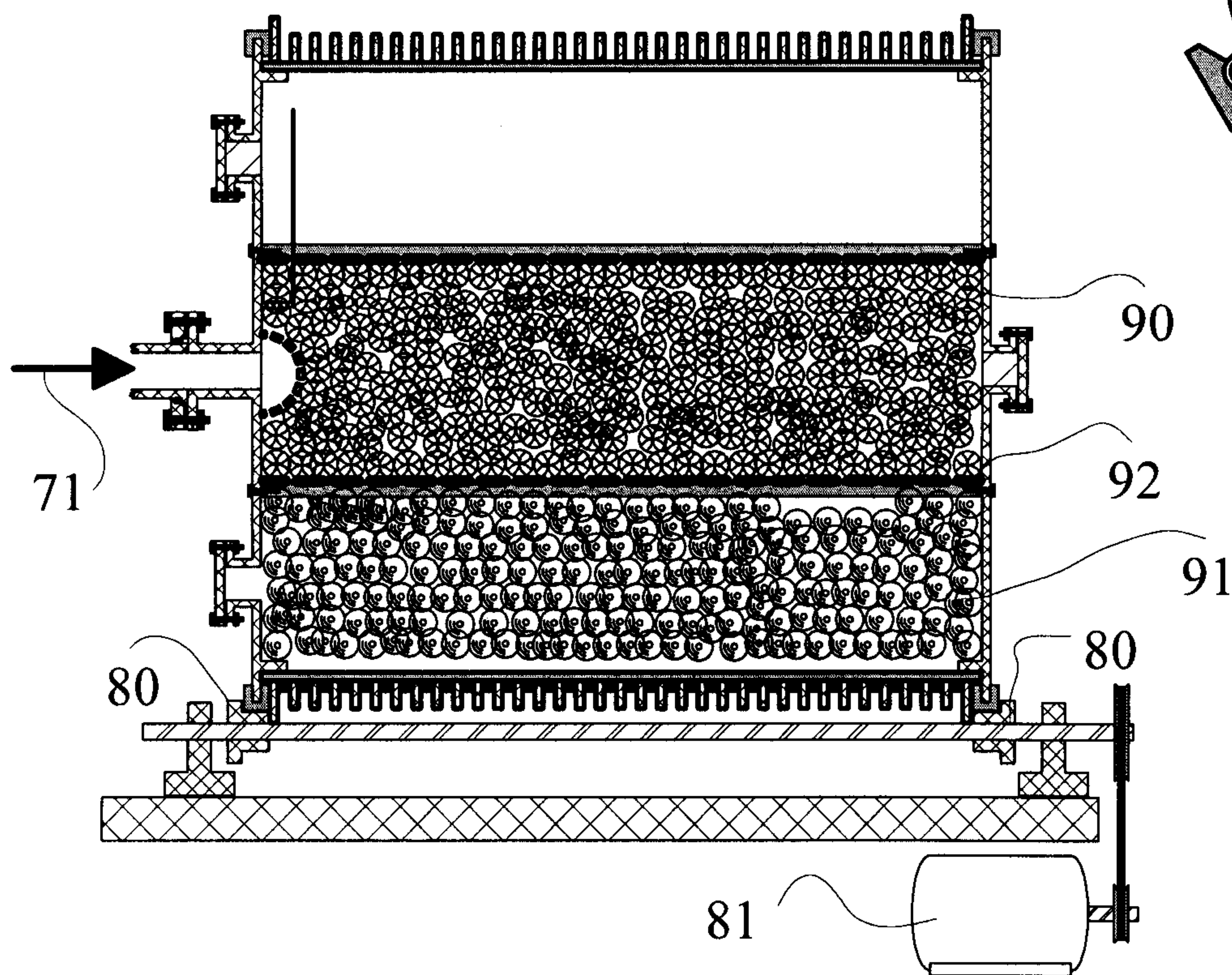
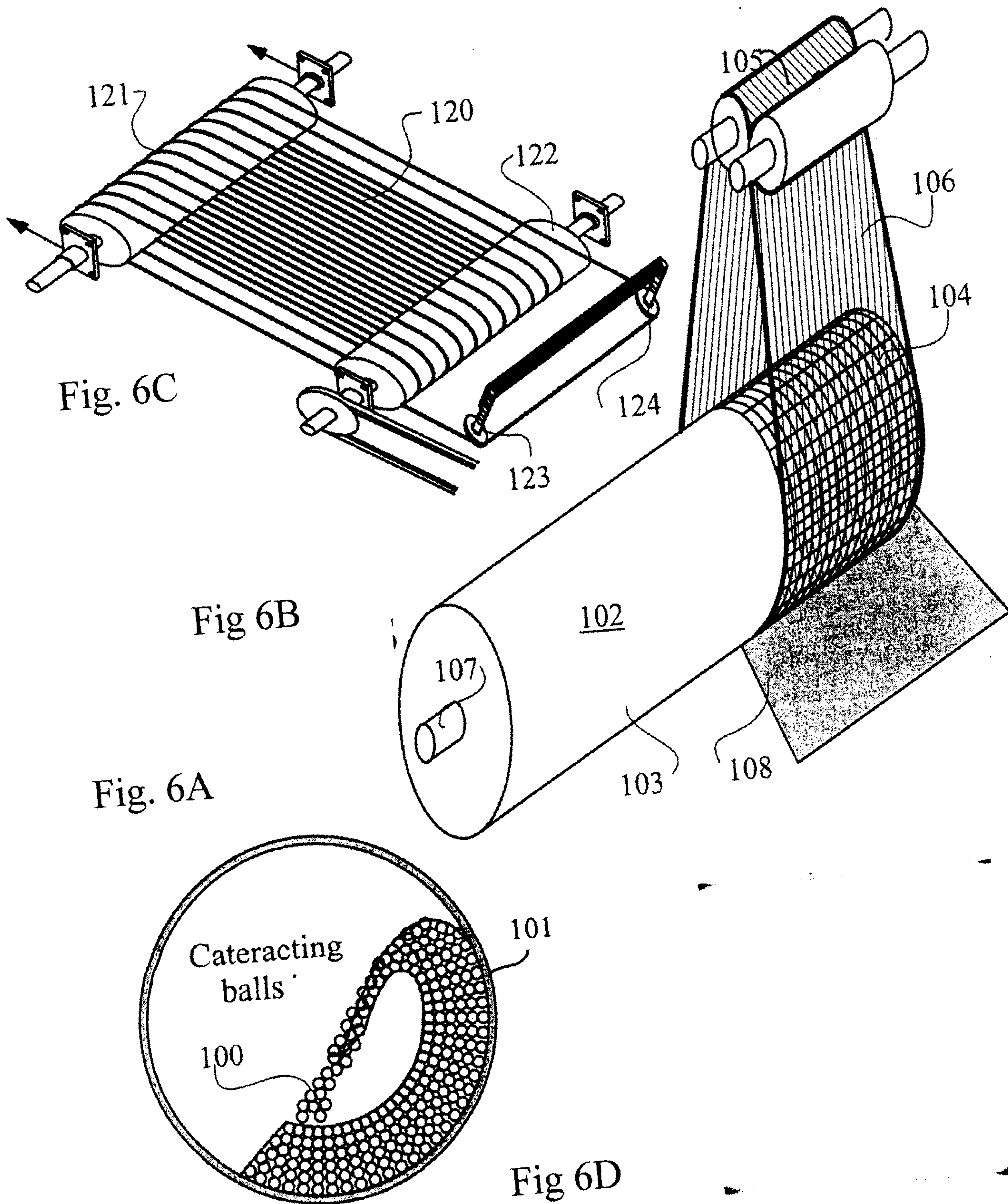


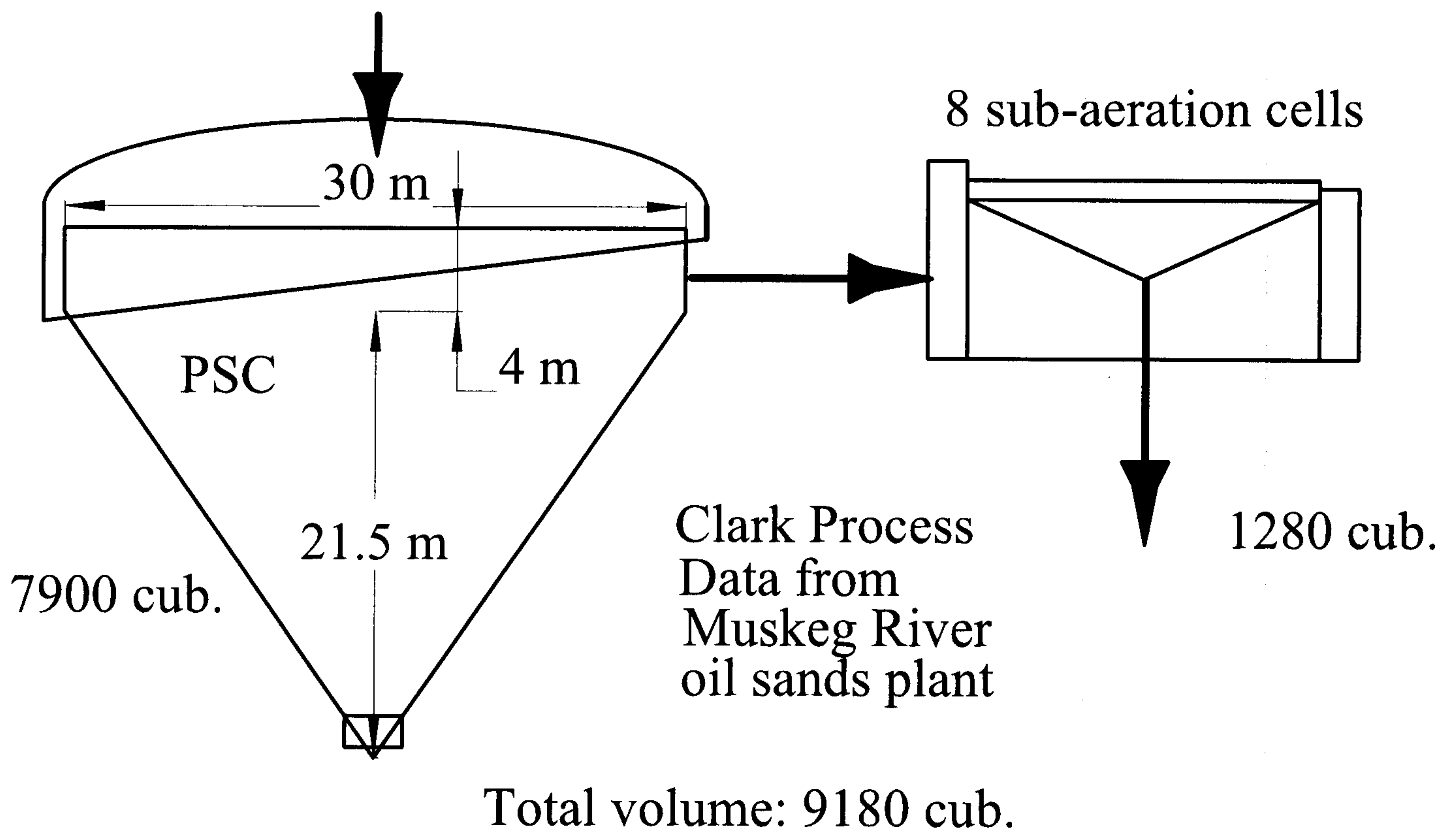
Fig. 5D



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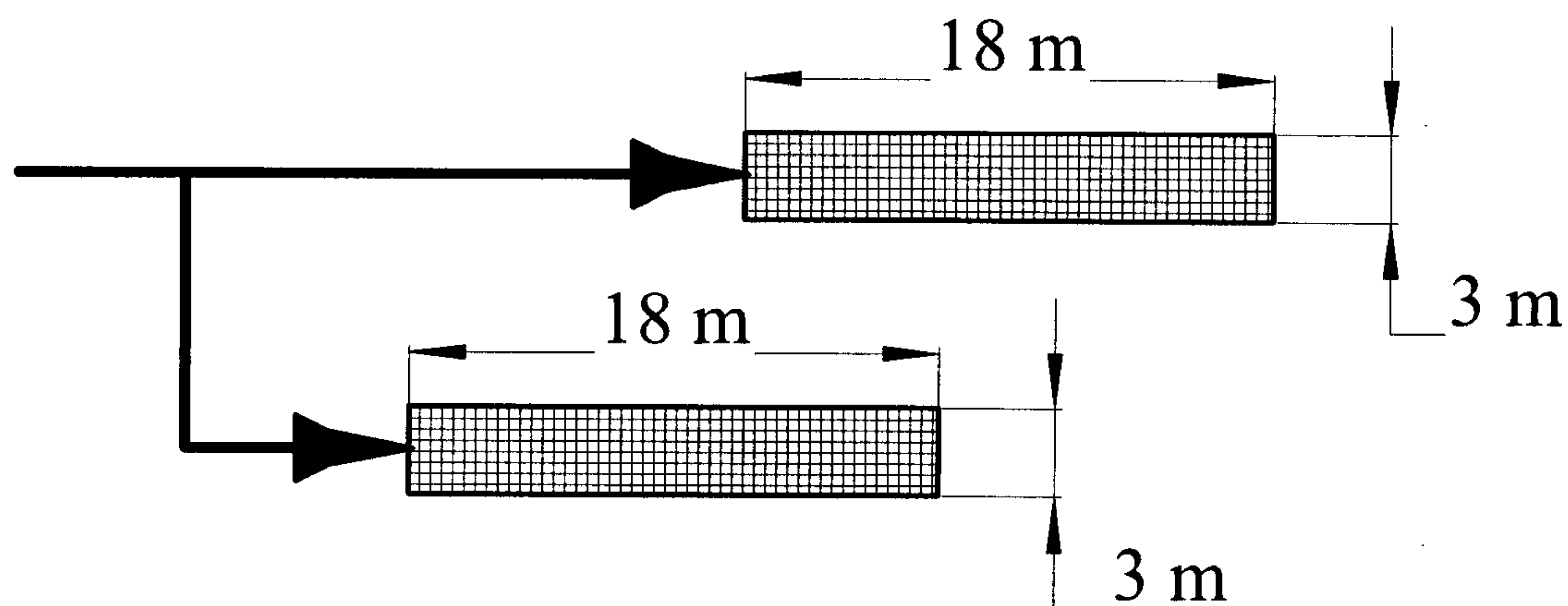


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----- 7000 metric tons of ore per hour ----- Fig. 7

Oleophilic Sieve Process



Two agglomerators that may achieve the same results.
Total volume: 255 cub.

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