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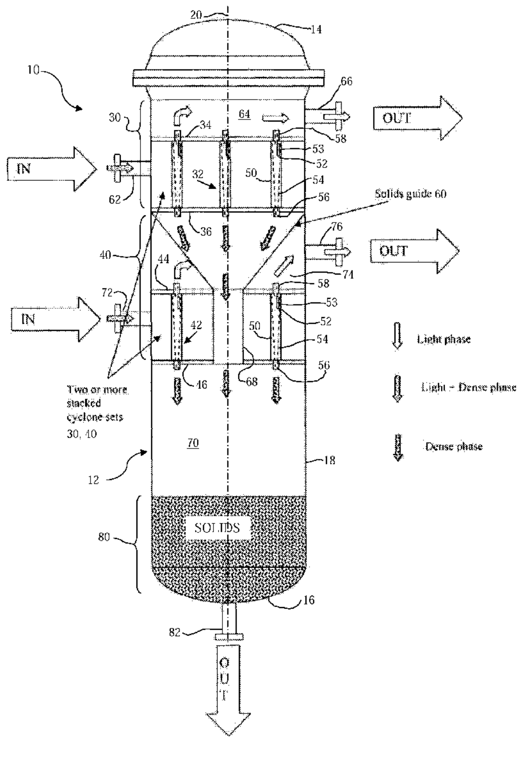
(54) Title: COMPACTED HYDROCYLONE APPARATUS IN VESSELS



(57) Abstract: A particular stacking configuration may be used for installing or orienting a plurality of hydrocyclones in a vessel in order to reduce vessel size and make process systems more compact at higher flow rates. Vessel size and footprint reduction may be achieved by stacking one or more hydrocyclone packs, modules or groups one above the other in a vertically oriented vessel.

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COMPACTED HYDROCYCLONE APPARATUS IN VESSELS

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BACKGROUND OF THE DISCLOSURE

[0001] The present disclosure relates to apparatus for improved arrangements or orientations of pluralities of hydrocyclones, and particularly relates, in one non-limiting embodiment, to vessels with orientations of pluralities or groups of hydrocyclones that reduce the total size and footprint of the vessel housing them.

[0002] Hydrocyclones are well known. They are devices to classify, separate or sort liquids and/or particles in a liquid mixture based on the densities of the liquids, or in suspension based on the densities of the particles. That is, a hydrocyclone may be used to separate solids from liquids or to separate liquids or fluids of different density. A hydrocyclone will normally have a cylindrical section at the top, where liquid is being fed tangentially, and a conical base. The angle, and hence length of the conical section, plays a role in determining operating characteristics.

[0003] A hydrocyclone often has two exits on the axis thereof in opposing directions: the larger on the underflow or accept and a smaller at the overflow or reject, for instance in the case of liquid-liquid deoiling hydrocyclones. For liquid-solid hydrocyclones, the liquid overflow/accept is the relatively larger exit and the solids underflow/reject is the relatively smaller exit. The underflow is generally the denser or thicker fraction, while the overflow is the lighter or more fluid fraction. Another way of understanding a typical hydrocyclone is that it includes an elongated tapered separation chamber of circular cross-section, which decreases in cross-sectional size from a large overflow and input end to an underflow end. An overflow or reject outlet for the lighter fraction is provided at the base of the conical chamber while the heavier underflow or accept fraction of the suspension exits through an axially arranged underflow outlet at the opposite end of the conical chamber. It will be appreciated that the terms “accept” or “reject” are relative and may be reversed depending on the relative density value of the components being separated.

[0004] Liquids and suspended particles are introduced into the chamber via one or more tangentially directed inlets. These are adjacent to the overflow end of the separation chamber to create a fluid vortex therein. The centrifugal forces created by this vortex throw denser fluids and particles in suspension outwardly toward the wall of the conical chamber, thus giving a concentration of denser fluids and particles adjacent thereto, while the less dense fluids are brought toward the center of the chamber. As the denser fluids and particles continue to spiral towards the small end of the conical chamber, the lighter fractions are forced to move by differential forces in the reverse direction towards the reject outlet. The lighter fractions are thus carried outwardly through the overflow outlet. The heavier particles continue to spiral along the interior wall of the hydrocyclone and eventually pass outwardly via the underflow outlet. Internally, centrifugal forces are generated by the rapid acceleration of the fluids through the inlet ports of the hydrocyclone. As noted, denser particles or fluids migrate towards the wall for eventual exit via the underflow, whilst the less dense particles and fluids migrate towards the core, remain in the liquid and exit at the overflow through a tube typically extending slightly into the body of the cyclone at the center. Finer particles will not migrate to the center unless they are less dense than the liquid, but they will move outwards more slowly and thus may not have time to escape the center core of liquid.

[0005] The fluid velocities within a hydrocyclone are high enough that the dynamic forces produced therein are sufficiently high to overcome the effect of any gravitational forces on the performance of the device. Hydrocyclones may therefore be arranged in various physical orientations without affecting performance. Hydrocyclones are commonly arranged in large banks of several dozen or even several hundred hydrocyclones with suitable intake, overflow, and underflow assemblies arranged for communication with the intake, overflow, and underflow openings respectively of the hydrocyclones.

[0006] Earlier separator systems involving large numbers of hydrocyclone separators commonly employed complex systems of intake, overflow, and underflow pipes or conduits which occupied a substantial amount of space and which required costly and complex support structures for the piping systems involved. It is desired to reduce the space occupied by hydrocyclone assemblies and provide a relatively compact arrangement, especially in the petroleum industry, where offshore platform applications and ship-based installations put a premium on space. A compact arrangement would also minimize the cost of the equipment and improve flow distribution to the hydrocyclone inlets.

[0007] Difficulties of conventional arrangements or configurations of hydrocyclones include the fact that vessel flow capacity may be limited by the practical handling diameter of the vessel internals. Further, the inlet nozzle size may be limited by the length of the hydrocyclones. Additionally, there is difficulty in sealing in other configurations where there are an increasing number of chambers within the vessel.

[0008] There is also loss of efficiency due to poor turndown. Turndown refers to the minimum flow through the vessel that may be achieved whilst still meeting performance. The efficiency of hydrocyclones diminishes as the flow reduces so there comes a point at which the performance will not meet specifications. While it varies from case to case, typically it occurs when the flow is from about 50% to about 75% of the vessel design flow. Flow is related to the number of hydrocyclone liners in service (where the liners are defined herein as the small, individual hydrocyclones). Easily isolatable compartments are desirable to enable improved turndown characteristics

[0009] It would be desirable if an apparatus were devised that could provide a configuration or design of a plurality of hydrocyclones that would permit smaller diameter vessels, which would thus have smaller footprints, *e.g.* to occupy less area on an offshore platform. Smaller diameter vessels would also dramatically reduce vessel costs in the amount of exotic materials required, *e.g.* stainless steel, duplex, or super duplex steels.

BRIEF SUMMARY OF THE DISCLOSURE

[0010] There is provided, in one non-restrictive form, a hydrocyclone separation assembly that includes a vessel, a first group or plurality of hydrocyclones within the vessel, and one or more additional groups or plurality of hydrocyclones within the vessel. Each of said hydrocyclones involves a tubular body with an inlet section having a first diameter and a separation section having a second diameter, where the first diameter is greater than the second diameter, where each separation section has an underflow nozzle, and where all underflow nozzles of the first group or plurality of hydrocyclones communicates with a first common guide. The subsequent plurality of hydrocyclones is similarly disposed in a generally parallel relation to one another and to the first plurality of hydrocyclones, as would be still further subsequent pluralities of hydrocyclones, if present. Correspondingly, each of said hydrocyclones in the additional groups or pluralities includes a tubular body with an inlet section having a first diameter and a separation section having a second diameter, where the first diameter is greater than the second diameter, where each separation section has an underflow nozzle, and where all underflow nozzles of the second group or plurality of cyclones communicates with a second common guide. The first common guide and the second common guide are in communication. The first common guide may be understood as channeling the more dense material to each additional guide, and then to a sump. In one non-limiting embodiment, the vessel is oriented vertically as are the hydrocyclones in the first and subsequent pluralities or groups.

[0011] Another non-limiting embodiment according to the present disclosure may include a hydrocyclone separation assembly comprising: a vessel configured to receive a first cassette and a second cassette; the first cassette with a first diameter comprising: a plurality of hydrocyclones, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter, where the first diameter is greater than the second diameter, where each separation section has an underflow nozzle, and where each underflow nozzle of the first plurality of hydrocyclones communicates with a first common guide; the second cassette with a second diameter comprising: a plurality of hydrocyclones, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter, where the first diameter is greater than the second diameter, where each separation section has an underflow nozzle, and where each underflow nozzle of the second plurality of hydrocyclones communicates with a second common guide, where the first common guide and the second common guide are in communication.

[0012] Another non-limiting embodiment according to the present disclosure may include a hydrocyclone separation assembly comprising: a vessel configured to receive a first cassette and a second cassette; the first cassette with a first diameter comprising: a plurality of hydrocyclones, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter, where the first diameter is greater than the second diameter, where each separation section has an underflow nozzle, and where each underflow nozzle of the first plurality of hydrocyclones communicates with a first common guide; the second cassette with a second diameter comprising: a plurality of hydrocyclones, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter, where the first diameter is greater than the second diameter, where each separation section has an underflow nozzle, and where each underflow nozzle of the second plurality of hydrocyclones communicates with a second common guide, where the first common guide and the second common guide are in communication.

BRIEF DESCRIPTION OF THE DRAWING

[0013] The Figure is a schematic, cross-section illustration of one non-limiting embodiment of a hydrocyclone illustrating two or more groups of hydrocyclones positioned one above the other.

[0014] It will be appreciated that the Figure is a schematic illustration that is not necessarily to scale or proportion, and, as such, some of the important parts of the disclosure may be exaggerated for illustration or emphasis.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0015] It has been discovered that hydrocyclones may be installed in a vessel in such a way that vessel size and footprint is reduced and the process system is more compact at higher flow rates. This vessel size reduction is accomplished by stacking one or more cyclone packs or groups above each other in a vessel. Features of this configuration include the following:

- The ability to pack more cyclones into a smaller diameter vessel, which increases the flow capacity for that vessel.
- Improvement in flow turndown characteristics by increasing the number of vessel chambers that may be isolated or selected.
- The incorporation of multiple chambers allows the use of smaller nozzles.
- More secure, simpler sealing may be provided between the chambers.
- A smaller number of vessels may be permitted for a particular process.

[0016] The problems addressed and improved upon by the design described herein include improving the vessel flow capacity previously considered limited by practical mechanical handling diameter of vessel internals. Additionally, sealing between chambers is simplified and improved. Further, in previous designs inlet nozzle size was limited by the length of the cyclones. Also, previous loss of efficiency due to poor turndown is improved.

[0017] In the present design, groups or modules (also called pluralities) of hydrocyclones (liners) are stacked one above the other in a single vessel. Having more than one stacked chamber in the vessel means that the number of liners in use, and thus the flow and the turndown, can be reduced by simply isolating one of the chambers. Two stacked chambers means that flow may be reduced to about 25% to about 38% of the design flow. Three stacked chambers means that flow may be reduced to about 16% to about 26% of the design flow if only one chamber is active. It will be appreciated that there may be as many stacked chambers of hydrocyclones as are practical and useful.

[0018] There are other, conventional ways of reducing the flow, including taking out individual liners and fitting in blanks, which requires opening up the vessels. Alternatively, a single layer may be divided into separate sections, *e.g.* like a slice of cake or segments. However, this method is difficult to seal between the chambers and is normally only restricted to two chambers. An advantage of the present method and design described herein is that it is relatively easy to seal between the chambers using O-ring seals. Further, there may be several chambers one stacked above the other.

[0019] Shown in the Figure is a schematic illustration of a hydrocyclone separation assembly **10** having a vessel **12** with a top **14**, bottom **16** and side wall **18**. While it is not necessary that vessel **12** be of cylindrical shape with a longitudinal axis **20**, it is expected that such a shape will be typical since it is conventional to fabricate and handle.

[0020] The particular hydrocyclone separation assembly **10** has a first chamber **30** and a second chamber **40**, although as previously noted, there may be more chambers present. Chamber **30** has a first plurality of hydrocyclones **32** within chamber **30** and vessel **12**, where the hydrocyclones **32** are in parallel relation to one another. It is expected that in most implementations the hydrocyclones **32** will also be in parallel relation to the longitudinal axis **20** of vessel **12**, which as shown in the Figure, are oriented vertically. While other orientations are certainly possible, it is expected that the vertical orientation shown will be the one most often implemented since it would occupy a minimum footprint on an industrial site, such as an offshore oil platform. In some embodiments, a chamber may be configured to have another chamber stacked above it. The chambers may be sized to have the same diameter or different diameters.

[0021] Similarly, chamber **40** has a second plurality of hydrocyclones **42** within chamber **40** and vessel **12**, where the hydrocyclones **42** are in parallel relation to one another. Again, it is expected that in most implementations the hydrocyclones **42** will also be in parallel relation to the longitudinal axis **20** of vessel **12**, and thus will also be in parallel relation to the first plurality of hydrocyclones **32**. In alternative embodiments, one or more of the hydrocyclones **32** and/or hydrocyclones **42** may be nonparallel in relation to the longitudinal axis **20** of vessel **12**. In some embodiments, hydrocyclones **32** may be nonparallel to hydrocyclones **42**. In some embodiments, the pluralities of hydrocyclones

32, **42** may be grouped into cassettes (not shown) that may be lowered into chambers in the vessel.

[0022] Each of the hydrocyclones **32** and **42** include a tubular body **50** with an inlet section **52** having an inlet **53** and a first diameter and a separation section **54** having a second diameter, where each separation section has an underflow nozzle **56**. Hydrocyclones **32** and **42** also each include an overflow outlet **58**. The hydrocyclones in the first plurality **32** may be the same as or different from the hydrocyclones in the second plurality **42**. The first plurality of hydrocyclones **32** is held in place at the upper ends thereof by upper support member **34** and at the lower ends thereof by lower support member **36**. The second plurality of hydrocyclones **42** is held in place at the upper ends thereof by upper support member **44** and at the lower ends thereof by lower support member **46**. These support members **34**, **36**, **44** and **46** may be generally flat plates with circular openings to accommodate the corresponding portion of the hydrocyclones **32**, **42**, where O-rings (not shown) seal between the support member and the hydrocyclone and prevent the passages of the mixtures or phases therebetween.

[0023] A mixture of a relatively lighter phase and a relatively denser phase is injected, pumped or otherwise transmitted under pressure into vessel **12** and first chamber **30** by first chamber inlet **62**. As shown in the Figure, the flow of the light phase is shown by white arrows, the flow of the dense phase is shown by the dark arrows (both after separation by the hydrocyclones **32** and **42**), where the mixture of the light and dense phases is shown by the gray arrows. After the mixture enters first chamber inlet **62**, it is injected into the first plurality of hydrocyclones **32** via inlets **53** and separated in the hydrocyclones **32** by the known process. Each underflow nozzle **56** of hydrocyclones **32** in the upper or first chamber **30** communicates with, empties or exits into a common first solids guide **60**, which is shown as a cross-section of a cone in the Figure. In the particular embodiment shown in the Figure, the first solids guide **60** channels or directs the dense phase or solids through a pipe or passageway **68** through and bypassing (no communication therewith) the center of second chamber **40** and communicates with common second solids guide **70**, which may simply have has its side wall as the side wall **18** of vessel **12**.

[0024] The light phase separated by the first plurality of hydrocyclones **32** exits overflow outlets **58** into common first overflow space **64** which in the Figure is in the upper part of first chamber **30**, and the light phase exits vessel **12** via first chamber outlet **66**.

[0025] Similar to the operation in first chamber **30**, another portion of the mixture of a relatively lighter phase and a relatively denser phase is injected, pumped or otherwise transmitted under pressure into vessel **12** and second chamber **40** by second chamber inlet **72**. After the mixture enters second chamber inlet **72**, it is injected into the first plurality of hydrocyclones **42** via inlets **53** and separated in the hydrocyclones **42** by the known process. Each underflow nozzle **56** of hydrocyclones **42** in the lower or second chamber **40** communicates with, empties, or exits into a common second solids guide **70**, which is shown as a cross-section of a cylinder in the Figure. The dense phase from both first chamber **30** and second chamber **40** may collect in sump solids collection area **80**, which may simply be the lowest portion of vessel **12** in the non-limiting embodiment shown in the Figure. Sump **80** may be drained or emptied by solids outlet **82**.

[0026] In turn, the light phase separated by the second plurality of hydrocyclones **42** exits overflow outlets **58** into common first overflow space **74** which in the Figure is in the upper part of second chamber **40** and below the conical first solids guide **60**, and the light phase exits vessel **12** via second chamber outlet **76**.

[0027] It will be appreciated that in most versions or embodiments of the hydrocyclone separation assembly **10** that many more hydrocyclones **32** and **42** may be used in the upper or first chamber **30** and lower or second chamber **40**, respectively, than are shown in the Figure. Only a few hydrocyclones **32** and **42** are illustrated for the sake of simplicity.

[0028] As shown in the Figure, the first plurality of hydrocyclones **32** and second plurality of hydrocyclones **42** may be in a parallel relation to longitudinal axis **20** of vessel **12**. Also, in one non-limiting embodiment, the first solids guide **60** and the second solids guide **70** may have their own central or longitudinal axes, respectively, which are not separately shown in the Figure because they are the same or coaxial with respect to each other and optionally also longitudinal axis **20** of the vessel **12**. These central or longitudinal axes of the first solids guide **60** and the second solids guide **70** may also be considered to be in a parallel relation to the longitudinal axis **20** of the vessel **12.**

[0029] It will be appreciated that the design and configuration of the hydrocyclones **32** and **42** in first and second chambers **30** and **40**, respectively, and the optional inclusion of more chambers containing more hydrocyclones, easily permits various of the cyclones in their respective chambers to be engaged or disengaged by the use of conventional valves (not shown) on the inlets **62** and **72**, respectively, and/or the respective outlets **66** and **76**.

[0030] For instance, for oilfield use, during the production life of an oil field, the amount of water produced with the oil increases with time. Thus, as the flow begins relative lower and increases over the years, the design and configuration described and illustrated makes it easier to match the number of hydrocyclones to the flow.

[0031] Having separate chambers (*e.g.* **30** and **40**) that may be isolated improves the flow turndown. The individual liners (*e.g.* **32** and **42**) are a fixed length and are mounted between the two plates in a vessel so that the nozzle diameter may be smaller than the length of the liner. The size of the nozzle that fits therefore limits the number of liners that may be put into a single layer in the vessel. A vessel stacked with groups or pluralities of cyclones, such as that described and shown, may contain more liners and handle more flow.

[0032] The hydrocyclone liner section of the vessel may be similar or smaller in volume to those conventionally used for the same flow volume. Vessel size is often more related to the amount of solids collected in the sump (*e.g.* **80**) under the hydrocyclones, and the time the operator requires between emptying the sump. Thus, it is expected that in most cases, the individual vessel will be a smaller diameter than conventional vessels that may handle the same flow rate, and thus provide a smaller footprint, but taller than such conventional vessels. Stacking the liners in chambers one above the other results in using less total number of vessels to handle the flow which may change over time. If the vessels are made from corrosion resistant materials such as stainless steel, duplex steel or super duplex steel (or other exotic steels), there can be a significant cost savings by using a vessel with an overall smaller diameter because of the full vessel diameter flanges or quick release closures and other components.

[0033] In practice, in one non-limiting embodiment during the construction of the hydrocyclone separation assembly, each group of hydrocyclones will be assembled outside of the vessel and dropped in as a cartridge assembly. Each cartridge assembly will have to seal against a ring welded to the wall of the vessel; therefore the outside diameter of each cartridge assembly will decrease from top to bottom in the vessel so they pass through the welded in seal rings for the ones above. This is not likely to be a large change in diameter, perhaps ¼" to ½" (0.6 to 1.3 cm) difference for each layer.

[0034] It may thus be readily seen that the design and configuration of liners in a vessel as described and illustrated herein may increase flow capacity, increase flow turndown and decrease equipment size, as well as improve the ability to adapt or change the number of liners on line in one or more vessel, as compared with conventional designs or configurations. The design and configuration herein will also save space and weight, which will be applicable for future applications of cyclones.

[0035] In the foregoing specification, the disclosure has been described with reference to specific embodiments thereof, and is expected to be effective in providing methods and apparatus that pack more hydrocyclones into a smaller diameter vessel to increase the flow capacity of that vessel. However, it will be evident that various modifications and changes may be made thereto without departing from the broader spirit or scope of the disclosure as set forth in the appended claims. Accordingly, the specification is to be regarded in an illustrative rather than a restrictive sense. For example, the hydrocyclones, solids guides, vessel shape and other component parameters may be changed or optimized from that illustrated and described, and even though certain additional features are not specifically identified or tried in a particular system, method or apparatus described herein, they would be anticipated to be within the scope of this disclosure. For instance, the materials, surfaces, coatings and treatments any of the described components and equipment would be expected to find utility and be encompassed by the appended claims. The configuration and method described and illustrated herein is expected to be useful regardless of liner type (*e g.* K, G, etc.).

[0036] The words “comprising” and “comprises” as used throughout the claims is to interpreted “including but not limited to”.

[0037] The present disclosure may suitably comprise, consist or consist essentially of the elements disclosed and may be practiced in the absence of an element not disclosed. For instance, in one non-limiting embodiment, the hydrocyclone separation assembly consists of or alternatively consists essentially of only two pluralities of hydrocyclones. In a non-restrictive alternative version the assembly consists of or consists essentially of three pluralities or chambers of hydrocyclones, although more pluralities or chambers may be used.

CLAIMS

What is claimed is:

1. A hydrocyclone separation assembly comprising:

a vessel;

a first plurality of hydrocyclones within the vessel, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter,

where the first diameter is greater than the second diameter,

where each separation section has an underflow nozzle, and

where each underflow nozzle of the first plurality of hydrocyclones communicates with a first common guide;

a second plurality of hydrocyclones within the vessel, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter,

where the first diameter is greater than the second diameter,

where each separation section has an underflow nozzle, and

where each underflow nozzle of the second plurality of hydrocyclones communicates with a second common guide, where the first common guide and the second common guide are in communication.

2. The hydrocyclone separation assembly of claim 1, wherein each of the first plurality of hydrocyclones is generally parallel to the other hydrocyclones of the first plurality of hydrocyclones; and each of the second plurality of hydrocyclones is generally parallel to the other hydrocyclones of the second plurality of hydrocyclones.

3. The hydrocyclone separation assembly of claim 2, wherein the hydrocyclones of the first plurality of hydrocyclones are generally parallel with the hydrocyclones of the second plurality of hydrocyclones.

4. The hydrocyclone separation assembly of claim 2 where the vessel is cylindrical with a longitudinal axis and the first plurality of hydrocyclones and the second plurality of hydrocyclones are in a parallel relation thereto.

5. The hydrocyclone separation assembly of claim 3 where the first common guide and the second common guide each have a central axis and are coaxial with respect to each other.

6. The hydrocyclone separation assembly of claim 4 where the central axes of the first and second common guides are in a parallel relation to the longitudinal axis of the vessel.

7. The hydrocyclone separation assembly of claim 5 where the vessel and the first and second common guides are coaxial.

8. The hydrocyclone separation assembly of claim 1 where the first diameter of the first plurality of hydrocyclones is the same as the first diameter of the second plurality of hydrocyclones, and where the second diameter of the first plurality of hydrocyclones is the same as the second diameter of the second plurality of hydrocyclones.

9. A hydrocyclone separation assembly comprising:
a vessel configured to receive a first cassette and a second cassette;
the first cassette with a first diameter comprising:
a plurality of hydrocyclones, each of the hydrocyclones comprising
a body with an inlet section having a first diameter and a separation section having a second diameter,
where the first diameter is greater than the second diameter,

where each separation section has an underflow nozzle, and

where each underflow nozzle of the first plurality of hydrocyclones communicates with a first common guide;

the second cassette with a second diameter comprising:

a plurality of hydrocyclones, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter,

where the first diameter is greater than the second diameter,

where each separation section has an underflow nozzle, and

where each underflow nozzle of the second plurality of hydrocyclones communicates with a second common guide, where the first common guide and the second common guide are in communication.

10. The hydrocyclone separation assembly of claim 9, wherein the first diameter of the first cassette and the second diameter of the second cassette are different.

11. The hydrocyclone separation assembly of claim 9, wherein each of the first plurality of hydrocyclones is generally parallel to the other hydrocyclones of the first plurality of hydrocyclones; and each of the second plurality of hydrocyclones is generally parallel to the other hydrocyclones of the second plurality of hydrocyclones.

12. The hydrocyclone separation assembly of claim 11, wherein the hydrocyclones of the first plurality of hydrocyclones are generally parallel with the hydrocyclones of the second plurality of hydrocyclones.

13. The hydrocyclone separation assembly of claim 11 where the vessel is cylindrical with a longitudinal axis and the first plurality of

hydrocyclones and the second plurality of hydrocyclones are in a parallel relation thereto.

14. The hydrocyclone separation assembly of claim 12 where the first common guide and the second common guide each have a central axis and are coaxial with respect to each other.

15. The hydrocyclone separation assembly of claim 13 where the central axes of the first and second common guides are in a parallel relation to the longitudinal axis of the vessel.

16. The hydrocyclone separation assembly of claim 14 where the vessel and the first and second common guides are coaxial.

17. The hydrocyclone separation assembly of claim 9 where the first diameter of the first plurality of hydrocyclones is the same as the first diameter of the second plurality of hydrocyclones, and where the second diameter of the first plurality of hydrocyclones is the same as the second diameter of the second plurality of hydrocyclones.

18. A hydrocyclone separation assembly comprising:
a vessel configured to receive a first cassette and a second cassette;
the first cassette with a first diameter comprising:
a plurality of hydrocyclones, each of the hydrocyclones comprising
a body with an inlet section having a first diameter and a separation section having a second diameter,
where the first diameter is greater than the second diameter,
where each separation section has an underflow nozzle, and
where each underflow nozzle of the first plurality of hydrocyclones communicates with a first common guide;
the second cassette with a second diameter comprising:

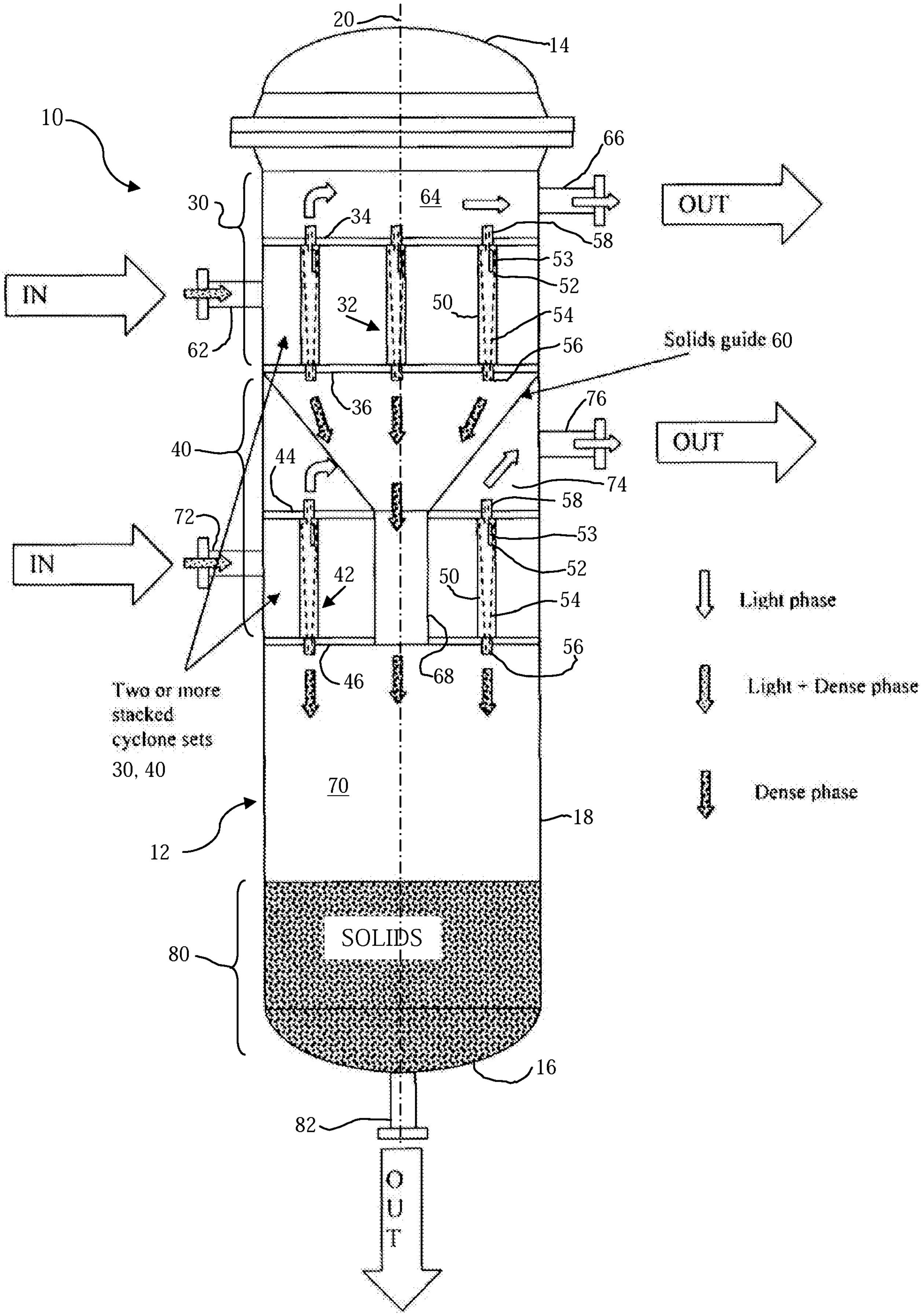
a plurality of hydrocyclones, each of the hydrocyclones comprising a body with an inlet section having a first diameter and a separation section having a second diameter,

where the first diameter is greater than the second diameter,

where each separation section has an underflow nozzle, and

where each underflow nozzle of the second plurality of hydrocyclones communicates with a second common guide, where the first common guide and the second common guide are in communication.

19. The hydrocyclone separation assembly of claim 18 where the vessel is cylindrical with a longitudinal axis and the first plurality of hydrocyclones and the second plurality of hydrocyclones are in a parallel relation thereto, and where the first common guide and the second common guide each have a central axis in parallel relation to the longitudinal axis of the vessel and are coaxial with respect to one another and the vessel.



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Solids guide 60
36
76
40
OUT
44
74
72
58
53
IN
42
50
52
54
56
46
68
Two or more stacked cyclone sets 30, 40
Light phase
Light + Dense phase
Dense phase
70
18
12
SOLIDS
80
16
82
OUT

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 10/39483

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 21/26; B04C 11/00; B04C 5/00 (2010.01)
USPC - 209/725; 209/720; 210/512.3; 210/512.1;
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B01D 21/26; B04C 11/00; B04C 5/00 (2010.01)
USPC - 209/725; 209/720; 210/512.3; 210/512.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - B01D 21/26; B04C 11/00; B04C 5/00 (2010.01)
USPC - 209/725; 209/720; 210/512.3; 210/512.1 Patents and NPL (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (US Pat, PgPub, EPO, JPO: classification, keyword), GoogleScholar;
Search terms used: hydrocyclon, separate, sort, cyclon, centrifuge, centripetal, compact, plurality, parallel, stack, set, array, nozzle, jet, underflow

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007/0202027 A1 (WALKER et al.) 30 August 2007 (30.08.2007), Figure; para [0011], [0015], [0022], [0023], [0026], [0028]	1-19
Y	US 2005/0040119 A1 (KULBETH) 24 August 2005 (24.08.2005), para [0039], [0073]	1-19
A	WO 2007/096612 A2 (HOPPER) 30 August 2007 (30.08.2007), entire document	1-19
A	US 2003/0168391 A1 (TVEITEN) 11 September 2003 (11.09.2003), entire document	1-19

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 July 2010 (30.07.2010)	11 AUG 2010

Name and mailing address of the ISA/US	Authorized officer:
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