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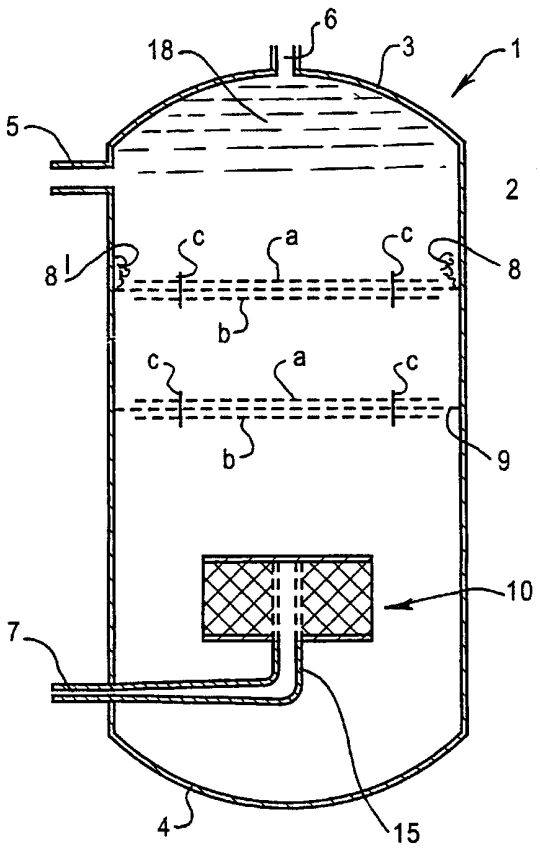
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[Continued on next page]

(54) Title: SEPARATION OF LIQUIDS



(57) Abstract: The present invention provides an apparatus for separation of oil and water from mixtures thereof, the apparatus comprising: a vessel for providing separation; an inlet for liquid to be separated within the vessel; an upper outlet from the vessel for separated oil; a lower outlet for separated water providing a downward flow within the vessel; and separation means disposed between the upper outlet and lower outlet including at least one fibre mat extending across the flow path within the vessel.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

SEPARATION OF LIQUIDS

The present invention relates to an apparatus for the separation of mutually immiscible liquids and to a process for separation of liquids using the apparatus. The apparatus and process will be described with reference to separation of water and oil from mixtures thereof. The term oil is herein used to refer to water immiscible liquids which may be in the form of silicones or organic liquids such as hydrocarbons, lubricants and waxes.

Background Art

With the advent of stricter environmental standards, there is a need for highly efficient methods of separating oil and water from mixtures of the two which occur, for example in the bilge water of a naval vessel. Internationally agreed standards require that mixtures be separated to reduce the oil content of the water to less than 15 ppm. It is presently very difficult to achieve these standards, particularly for viscous high density oils such as bunker oil which may be used to fuel cargo vessels.

A number of separators are being produced for oil-water separation, for example Provisional Application No. PP9623 which uses gravity separation and PCT/AU96/00307 which uses filtration to separate oil/water mixtures.

Frequently, gravity separation devices (primary separators) are used in tandem with filtration devices (polishers) to achieve the necessary degree of oil water separation.

Problems which frequently arise with filtration devices (polishers) include:

- Pressure build-up as the oil load in the filter increases, particularly for viscous oils
- Limited oil holding capacity in the filter, since all retained oil is held up in the interstitial space of the filter. This results in unsteady performance which diminishes over time.

- High costs and difficult procedures associated with the replacement of oil cartridges.

International application PCT/AU96/00307 discloses an apparatus which provides separation of oil water mixtures by pumping the mixture through a filter. While the apparatus provides efficient separation of oils, the present inventors have found that the efficiency is reduced when heavy oils are present in significant amounts. We have found that heavy oils tend to clog the filter making separation less efficient.

Summary of the Invention

The present invention provides an apparatus for separation of oil and water from mixtures thereof, the apparatus comprising:

a vessel for providing separation;

an inlet for liquid to be separated within the vessel;

an upper outlet from the vessel for separated oil;

a lower outlet for separated water providing a downward flow within the vessel; and

separation means disposed between the upper outlet and lower outlet including at least one fibre mat extending across the flow path within the vessel.

The apparatus may further include a filter assembly downstream from the fibre mat.

The fibre mat typically includes an oleophilic fibre. The fibre may be a synthetic fibre or natural fibre of plant or animal origin provided it has an oleophilic character. Preferred fibres are greasy wool and kapok, a silky fibre obtained from a number of tropical plants and which is also known as Java cotton. We have found that oleophilic fibres such as greasy wool and kapok may become fragile when they absorb oil. We therefore prefer to use a mat formed of oleophilic fibre and a structural fibre. The structural fibre is generally inert in the sense that it maintains its integrity in the presence of oil.

The structural fibre is preferably an oil resistant plant fibre for example sisal or oil resistant synthetic fibre such as nylon. The mat may be formed of a woven or non-woven aggregate of the fibres.

It may be advantageous to provide an oleophilic surface treatment to one or more fibre types, using methods known to the art. Fluoropolymers which may be partly fluorinated or perfluorinated polymers may be used as surface treatments. It may be advantageous to provide fibres which are biodegradable. It is advantageous to provide a loosely interwoven mat of fibres which is permeable to water at low pressures, but which also presents a high surface area of oleophilic fibre to the percolating aqueous stream.

The apparatus of the invention will generally include a plurality of fibrous mats extending across the vessel and vertically spaced from each other. They may be disposed approximately horizontally. The first of the fibre mats is preferably spaced below the inlet by at least half the internal diameter of the vessel. When used, a second mat is preferably spaced below the first mat by at least one quarter of the internal diameter of the vessel and most preferably by at least one half the internal diameter.

The fibre mat is preferably retained between a pair of supporting perforated plates which may be retained together by fastening means. The perforated plates are preferably formed of a rigid material such as metal or plastic. In a preferred embodiment of the invention the perforated plates are spaced from the wall of the vessel or provided with apertures at the peripheral edge to provide discontinuous spacing from the wall. In this embodiment the plates are preferably supported by radially extendible support means adapted to engage the wall or other support means. The radially extendible support means may be adjustable threaded rods directed outward so as to engage the wall when extended. The mat or mats are preferably of size larger than the vessel diameter to provide bunching of the mat adjacent the side wall of the vessel. We have found that the bunching adjacent the wall aids removal of the portion of the oil which tends to migrate downward adjacent the wall. Preferably the periphery of the mat is

downwardly deformable so that its contact with the wall can be breached if the mat becomes clogged with oil to thereby provide pressure relief. Where a number of mats are present clogging and subsequent breach of contact with the side wall creates a current which we have found to improve the coalescence of oil on the mat below the clogged mat.

Preferably the diameter of the perforated metal or plastic discs in the mat assembly is 0.5 – 1.5cm less than the inner diameter of the vessel. Preferably the diameter of the circular section of woven mat sandwiched between the perforated metal or plastic discs is 1 – 2cm greater than the inner diameter of the vessel. When the mat assembly is inserted into the vessel and pushed down against the spider support, the outer rim of the woven mat is pushed upwards against the inner walls of the vessel.

The inlet for the mixture to be separated is above the upper mat. The upper mat is generally sufficiently spaced from the top of the vessel to provide a head space for collection of separated oil. The size of the head space, the point of entry of the mixture be separated and rate of flow allow collection of a layer of oil adjacent the top. Preferably the layer remains undisturbed to allow removal of the separated oil.

Turbulent flow sufficient to produce significant mixing of separated oil layer is to be avoided.

The uppermost mat is typically spaced from the top of the vessel by a distance of at least half the greatest dimension of a longitudinal section of the upper part of the vessel. We generally find it convenient to use a generally cylindrical vessel with its axis approximately vertical and in such a case the upper mat is spaced from the top by at least half the diameter and preferably is spaced by about the diameter of the vessel. The spacing between the mats may change depending on the influent flow rate.

The inlet for the mixture to be separated may be located in the top wall of the vessel or the side wall or may extend from the top or side wall to deliver the mixture to a level below or partly below the layer of collected oil.

The outlet for the less dense component of the mixture to be separated (generally oil) is preferably located at or adjacent the top of the vessel.

It is believed that the entry of oily water into the upper chamber (ie. The chamber formed by the top of the vessel and the uppermost woven fibre mat extending across the vessel) causes a swirling fluid motion in the upper chamber. When oil droplets make contact with the woven fibre mat, the droplets merge with and/or coalesce onto the fibre mat. As more oil is deposited on the mat, the swirling fluid motion assists in dislodging large coalesced oil drops, causing them to float at the top of the vessel. In this way, significantly more oil can be removed from water than can be held in the interstitial region of the mat.

We have found that in many cases build up of oil on the mat does not significantly reduce the efficiency of separation even though there is a tendency for oil to break through the mat. Without wishing to be bound by theory we believe that coalescence of oil particles in the mat facilitates easy gravity separation. Although oil may pass through the mat it is generally in the form of relatively large particles or portions which are easily separated and rise into the mat. The apparatus thus tends to equilibrate when the mat becomes saturated so that oil periodically breaks through as large particles which rise upward and return into the mat. Oil may rise from the mat to collect at the top of the vessel.

The mat is generally constructed of a material which facilitates wicking of oil to distribute oil within the mat. This allows oil to accumulate in the mat and increases the size (and hence ease of separation) of globules which pass below the mat when it is saturated.

When the oil is relatively light such as diesel or number 2 fuel oil it establishes an equilibrium after the mat has become saturated so that oil continually breaks through below the mat and rises to be reassociated with the mat. The net loss of oil from the mat is therefore from oil rising above the mat to the oil reservoir which accumulates at the top of the vessel.

As the grade of oil to be separated becomes heavier a more significant back pressure is produced when the mat becomes saturated. This can significantly reduce the efficiency of separation. We have found that for relatively heavy oils such as Number 6 fuel oil or bunker oil the operation of the separator is improved if the upper mat is treated with a light oil such as diesel oil prior to or during operation. If the separator is to be used for extended periods in separating heavy oil the efficiency of operation may be maintained by introducing a light oil below the mat such that it rises into the mat to reduce back pressure. In this embodiment the light oil may be introduced continuously to maintain efficient operation or may be introduced periodically in response to an increase in back pressure or other feed back.

The apparatus of the invention may include a filter assembly down stream from the one or more fibre mats. The filter assembly may include a housing having a downstream portion in fluid communication with the lower outlet and a fibrous filter mass or alternatively the filter may be downstream of the outlet. The apparatus preferably provides radial flow through the filter mass to said downstream portion. The filter assembly preferably has upper and lower walls and an annular pervious wall extending between the upper and lower walls and about which fibrous filter material is provided. The lumen of the annular pervious wall may be connected to the lower outlet by a conduit. The fibrous filter mass may be formed of interwoven structural and oil absorbent fibres.

The apparatus may include a probe including an oil detecting surface responsive to a change between immersion of the surface in water and immersion of the surface in oil. The oil detecting surface may be spaced from the top of the vessel so that when the volume of oil is increased to the

desired maximum the probe oil detecting surface is changed from a condition of immersion in substantially water to immersion in substantially oil and is operatively connected to produce an outlet of oil from the vessel. The probe may detect the change in condition from immersion in water to immersion in oil by means of electroconductivity.

The invention will now be described with reference to the attached drawings.

In the drawing:

Figure 1 is a side sectional view of a first embodiment of a separation apparatus in accordance with the invention; and

Figure 2 is a sectional view of the filter assembly (10) of the apparatus of Figure 1.

Figure 3 is a side sectional view of a second embodiment of a separation apparatus of the invention.

As shown in Figure 1 and Figure 3 the filter assembly (1) embodying the invention comprises housing consisting of a cylindrical side wall (2), a top wall (3) and a bottom wall (4). The separation apparatus (1) is provided with an inlet (5) for the mixture to be separated in the side wall (3). An outlet (6) for the lighter liquid such as hydrocarbon is provided in the top wall (3) and the outlet (7) for the heavier component such as water is provided in the side wall (2) closer to the bottom wall (4) of the separation apparatus (1), two filter mats (8,9) extend across the vessel and are each formed of an oil absorbent natural fibre such as kapok or greasy wool fibre and a structural fibre which is preferably a plant fibre such as sisal. The mats are of an open weave such that when the mats are saturated with oil there is not a substantial increase in back pressure of type which would disturb the flow of the mixture to be separated.

The mats (8,9) are retained within the vessel by an assembly comprising opposed upper and lower plates (a,b) which are urged together with the mat (8,9) therebetween by fastening means (c). The mats (8,9) have an extended diameter larger than the inside of the vessel and when inserted

into the vessel produce bunching of the peripheral edge (8') adjacent the vessel wall (2). The plate assembly (a,b) is spaced from the vessel wall and supported against the vessel wall by support means comprising a plurality of extendible wall engaging means (not shown).

In the embodiment of Figure 1 there is provided downstream of the mats a filter apparatus comprising a cylindrical filter assembly (10) which is more clearly shown in Figure 2.

The filter assembly (10) has an impervious upper wall (11) and impervious lower wall (12) and a pervious cylindrical sleeve (13) extending between the upper wall (11) and lower wall (12). The lumen of the cylindrical sleeve (13) is connected to the water outlet (7) via conduit (15). The filter assembly (10) has an absorbent filter mass (16) of an oil absorbent natural fibre such as greasy wool. The fibre mass (16) may be formed of an open weave of greasy wool and structural fibre such as a plant fibre and may be wound about the cylindrical pervious sleeve (13). A less dense filter material (17) such as glass wool or the like may be provided about the filter mass (16).

Oily water mixture enters the separation apparatus via inlet (5) and flows through the open weave mats (8,9) which provide primary separation within the separation apparatus (1). The oleophilic fibre component of the mats becomes swollen with oily material causing droplets of oil to coagulate and to rise above the mats into a head space (18). Once sufficient oil has collected in the head space (18) it may be delivered from the separation apparatus via the outlet for the lighter liquid (6). The filter assembly (10) located down stream of the mats (8,9) provides a flow radially inward through the filter mass of the natural fibre (16) to the perforated sleeve (13) from which it passes to the outlet for the heavier liquid (7). The filter assembly may be removable to facilitate periodic cleaning.

The separation apparatus of the invention may be operated under ambient pressure or may be subject to pressure or partial vacuum.

In a further embodiment the head-space (18) of the separation apparatus is provided with oil detection means operable to initiate delivery of liquid from the head-space once sufficient volume of oil has been collected.

In the embodiment as shown in Figure 3 the apparatus is provided with a header tank (19) which is in fluid communication with the vessel (1) via conduit (20). Header tank (19) when filled with water allows a back pressure to be applied to enable oil to be delivered from upper outlet (6) during or after operation of the apparatus. A final scavenging mat may be placed inside the header tank.

The conduit (20) preferably extends from the header tank adjacent the bottom (21) to the vessel (2) adjacent the bottom (4). The tank (19) may be provided with upper water outlet (22) provided with antisyphon value (23) and water drain value (24) adjacent the bottom (21). An oil drain value (25) may also be provided.

The separation apparatus of the invention may be operated at flow rates of the order of up to 10 cubic meters per hour or even higher to enable the oil concentration in the discharge liquor to be reduced to less than 15 ppm.

The apparatus of the invention may be used to remove oil from bilge water or it may be used to remove oil from water contaminated by an oil slick.

Example 1

An oil/water separator (polisher) according to this invention was provided in the form specified in Figure 1. In particular

- the diameter of the vessel was 300mm
- the height of the vessel was 1,200mm
- the woven fibre mat was "Grabol", a product comprising interwoven structural and oleophilic vegetable fibre manufactured by Fibertex Pty Ltd of Revesby, Sydney Australia

- the first fibre mat assembly was located 300mm from the top of the vessel
- the second fibre mat assembly was located 400mm from the top of the vessel
- the fibrous filter mat in the filter housing was "Grabol"
- the composition of the influent stream was 150ppm diesel, balance water
- the flow rate of the influent stream was 18 litres per minute
- a total volume of 5,000 litre of influent liquor was passed through the vessel at the above flow rate
- the operating pressure did not change during the operating period
- the effluent from the polisher was monitored using a Shimadzu oil content meter and was found to be less than 2ppm for the entire operating period. In confirmation of this result, the effluent samples at all times were visually clear of surface oil film
- 625ml of free diesel was found in the top of the polisher vessel after the operating period had expired
- 125ml of diesel was found in the uppermost woven fibre mat after the operating period had expired
- only trace amounts of diesel were found in the lower woven fibre mat and in the fibrous fibre mass associated with the filter housing
- the vessel could be rejuvenated simply by replacing the uppermost fibrous mat.

The separation apparatus of the invention is particularly suited to removal of oil at concentrations up to 15,000 ppm and in cases where concentrations are significantly higher it may be used in series with a preliminary separation apparatus.

Example 2

The procedure of Example 1 was repeated using a mixture of bunker oil and water. The bunker oil was dispersed as fine droplets produced by the action of a pump. Bunker oil was present at a concentration of 150 ppm. Prior to commencement of the operation of the polisher the upper mat was

soaked in diesel oil. Operation of the polisher was improved by the presence of diesel oil in the upper mat.

When the mat was not soaked in diesel there was a tendency for the mat to produce a build up of pressure during operation as the mat became saturated with viscous oil.

Example 3

This example describes an externally located filter assembly downstream from the vessel containing one or more fibre mats.

A cylindrical filter housing which was 20 cm tall and had a diameter of 12 cm was taken from a Cuno Pacific Microwynd filter assembly as supplied by Cuno Pacific of Melbourne Australia. The hollow cylindrical fibre supplied with the filter assembly was stripped to reveal the pervious hollow cylindrical core, and the core was wrapped three times around with a Grabol sheet 4.5 mm thick. The "Grabol" wound filter was sealed into the filter assembly using an acrylic copolymer sealant (Brand name "All-clear") provided by Selleys, Melbourne Australia.

The direction of fluid flow in the above filter assembly was from the outside of the hollow cylinder to the inside.

An influent stream comprising 9.6 ppm diesel oil in water was passed through the filter at a flow rate of 2.5 litres/minute and monitored for 22 hours. The filter effluent at all times contained less than 2 ppm oil.

It is to be understood that the invention described hereinabove is susceptible to variations, modifications and/or additions other than those specifically described and that the invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the above description.

Claims:

1. The present invention provides an apparatus for separation of oil and water from mixtures thereof, the apparatus comprising:

a vessel for providing separation;

an inlet for liquid to be separated within the vessel;

an upper outlet from the vessel for separated oil;

a lower outlet for separated water providing a downward flow within the vessel; and

separation means disposed between the upper outlet and lower outlet including at least one fibre mat extending across the flow path within the vessel.

2. An apparatus according to claim 1 wherein the fibre mat includes an oleophilic fibre component.

3. An apparatus according to claim 2 wherein the oleophilic fibre component comprises one or more fibres selected from the group of oleophilic vegetable fibres and wool.

4. An apparatus according to claim 2 wherein the oleophilic fibre includes one or more fibres selected from the group consisting of wool, kapok, java cotton, fibres treated to provide an oleophilic surface.

5. An apparatus according to claim 2 wherein the fibre mat further includes an inert structural fibre.

6. An apparatus according to claim 4 wherein the structural fibre is selected from inert fibres sisal, nylon, modified or unmodified cellulose and mixtures thereof.

7. An apparatus according to claim 1 wherein the total volume of fibre mat within the vessel is less than 10% of the vessel volume.

8. An apparatus according to claim 6 wherein the total volume of fibre mat within the vessel is less than 5% of the vessel volume.

9. An apparatus according to claim 2 wherein the mat is retained between opposed perforated plates.

10. An apparatus according to claim 7 wherein the dimensions of the malt are greater than the inner diameter of the vessel and the mat is bunched adjacent the vessel wall.

11. An apparatus according to claim 7 or claim 8 wherein the periphery of the opposed plate is spaced from the vessel wall producing bunching of the periphery of the plate and the vessel wall.

12. An apparatus according to claim 2 further including a filter downstream of the one or more fibre mats.

13. An apparatus according to claim 10 wherein the filter includes an annular pervious wall extending between an upper and a lower filter wall wherein fibrous filter material is provided about the annular pervious wall and includes one or more fibres selected from the group consisting of nylon, oleophilic vegetable fibres, wool and inert structural fibres.

14. An apparatus according to claim 11 wherein the fibrous filter material includes an oleophilic fibrous material.

15. An apparatus according to claim 2 including a plurality of fibrous mats vertically spaced from one another within the vessel.

16. An apparatus according to claim 1 including a first mat spaced below the inlet by at least half the internal diameter of the vessel.

17. An apparatus according to claim 16 wherein the apparatus further includes a second mat spaced below said first mat by at least one quarter of the internal diameter of the vessel.

18. An apparatus according to claim 1 wherein the vessel includes a headspace for collection of oil and a probe located within the vessel headspace operable to actuate delivery of oil from the upper outlet of the vessel when a predetermined maximum volume of oil is reached.

19. An apparatus according to claim 14 wherein the probe includes a detection surface operable to produce an outlet of oil from the vessel in response to a change in condition from immersion of the surface in substantially oil to immersion in substantially water.

20. A process for separating oil and water from mixtures thereof comprising:

feeding the mixture to the inlet of an apparatus according to claim 1;

providing outlet for a water phase below the inlet to thereby cause the mixture to pass through the mat extending across the vessel to produce coalescence of oil on the mat to form a layer of oil above the mat; and

providing an outlet for oil adjacent the top of the vessel.

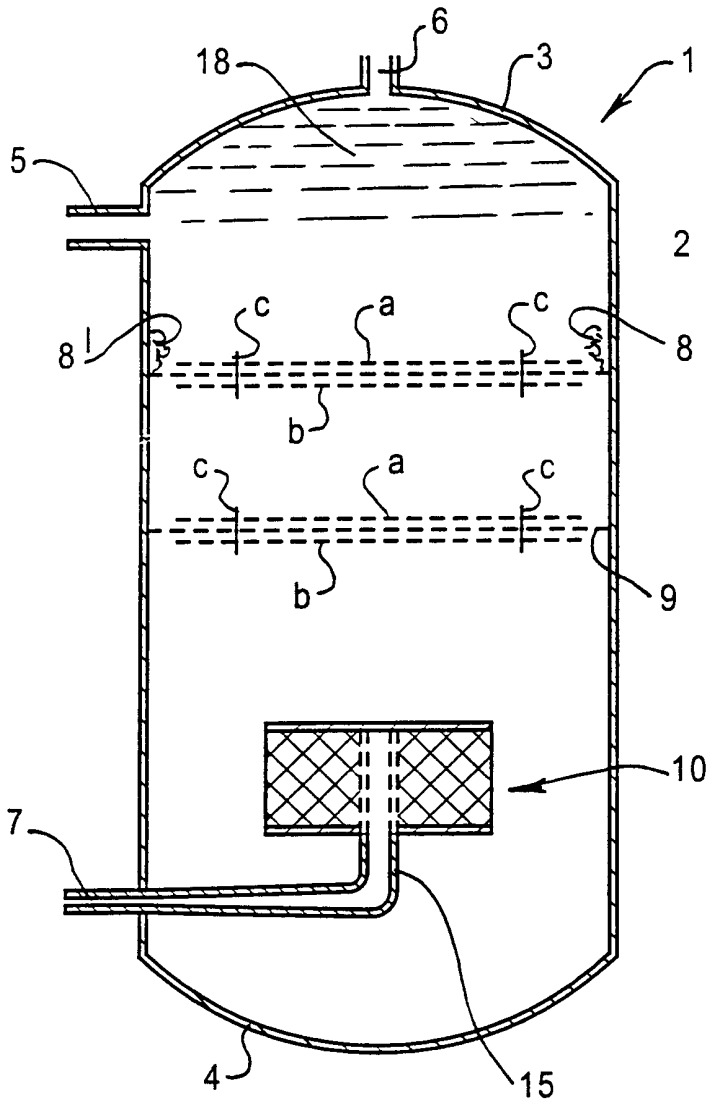


FIG 1

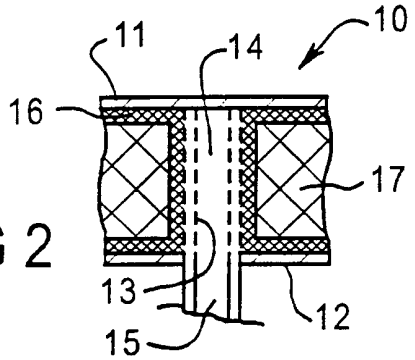


FIG 2

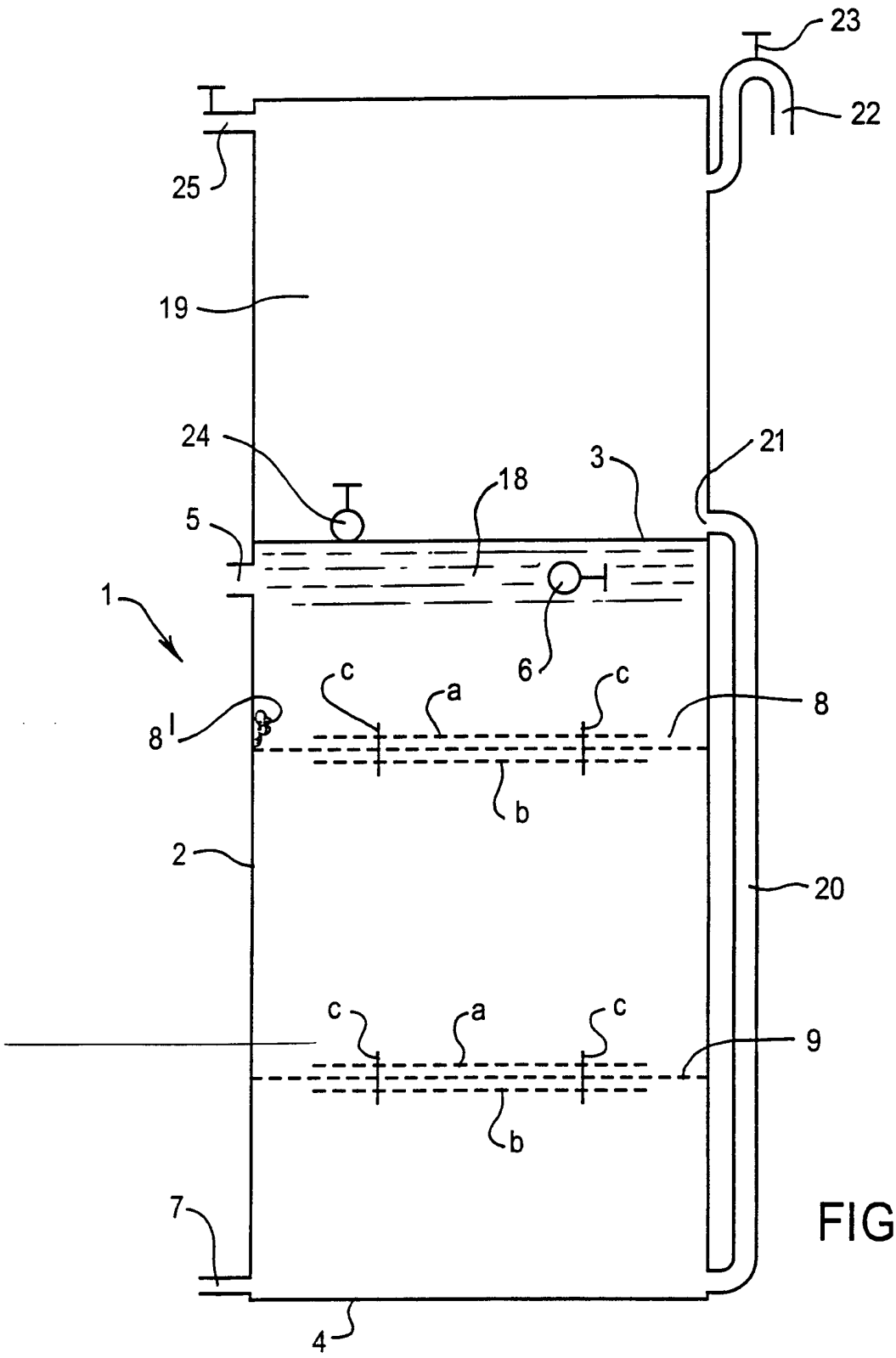


FIG 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/01221

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: B01D 017/02, 17/032

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[7] AS ABOVE

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent WPAT: IPC[7] as above and mesh+ or mat+ or perforat+ or +woven+ or knit+ or laced+ or fibr+ or fiber+ or filter+ or oleo+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1535160 A (Sakaguchi) 6 December 1978 Whole Document	
A	US 4240908 A (Swain et al) 23 December 1980 Whole Document	
A	US 4191651 A (Cheysson et al) 4 March 1980	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* 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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
31 October 2000	8 NOV 2000 8 NOV 2000
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer DAVID K. BELL Telephone No : (02) 6283 2309

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU00/01221

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2026886 A (Machinefabriek Geurtsen Deventer B. V.) 13 February 1980 Whole document.	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/01221

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
GB	1535160	US	4151087				
US	4240908	NONE					
US	4191651	BE	864141	CA	1122538	DE	2805672
		ES	467226	FR	2381550	GB	1601671
		HK	166/82	IT	1092787	JP	53121266
		LU	79094	NL	7801989		
GB	2026886	DE	2928869	DK	3232/79	FR	2432330
		IT	1124146	JP	55111806	NL	7808075
		NO	792377	PL	217473	US	4261820
		YU	1858/79				

END OF ANNEX