

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization

International Bureau



(10) International Publication Number

WO 2016/110394 A1

(43) International Publication Date

14 July 2016 (14.07.2016)

(51) International Patent Classification:

B01J 8/00 (2006.01) C10G 49/00 (2006.01)  
B01J 8/04 (2006.01)

Lyngby (DK). CENNI, Roberta; Ellebakken 33, 3460 Birkerød (DK).

(21) International Application Number:

PCT/EP2015/080405

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date:

18 December 2015 (18.12.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

PA 2015 00004 5 January 2015 (05.01.2015) DK

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,

(71) Applicant: HALDOR TOPSØE A/S [DK/DK]; Haldor Topsøes Allé 1, 2800 Kgs. Lyngby (DK).

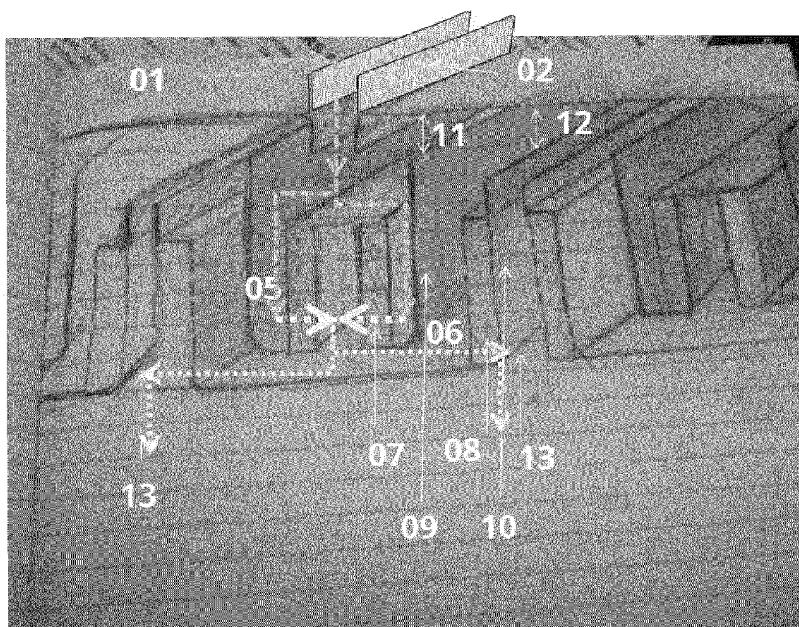
(72) Inventors: ZAHIROVIC, Emir; Rentemestervej 19 D, 2400 Copenhagen NV (DK). RISBJERG JARLKOV, Klaus; c/o Haldor Topsøe A/S, Nymøllevej 55, 2800 Kgs.

[Continued on next page]

(54) Title: FILTRATION TRAY FOR CATALYTIC CHEMICAL REACTOR

Fig. 3

(57) Abstract: A particle separation system for a catalytic chemical reactor.





LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

— *of inventorship (Rule 4.17(iv))*

**Published:**

— *with international search report (Art. 21(3))*

**Declarations under Rule 4.17:**

- *as to the identity of the inventor (Rule 4.17(i))*
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

## Filtration tray for catalytic chemical reactor

### FIELD OF THE INVENTION

5 This invention relates to a chemical reactor with filtration tray. The reactor can be a down-flow gas and liquid catalytic reactor which includes vertically superimposed packed beds of particulate catalytic material. This type of reactor is used in the petroleum and chemical processing industries for carrying out various catalytic reactions, such as sulphur and nitrogen conversion  
10 (HDS/HDN); hydrogenation of: olefins (HYD) and aromatics (hydrodearomatisation - HDA), metals removal (hydrodemetallisation - HDM), oxygen conversion (hydrodeoxygenation - HDO) and hydrocracking (HC). Alternatively, the reactor is a radial converter, where elements of the decks have to be fixed to the reactor. This reactor has a radial flow crossing a packed bed of catalytic  
15 material and it is typically used in the petroleum and chemical processing industries for carrying out catalytic reactions such catalytic reforming and ammonia synthesis.

### BACKGROUND OF THE INVENTION

20 Particle separation and classification are well explored needs of the chemical, pharmaceutical, mineral and food industries. While particle classification in industrial processes may be required to improve the quality of a certain product, particle separation may be necessary to purify a fluid stream or to avoid  
25 problems to process equipment.

30 Sometimes particles are intentionally present in the process stream. This is for example the case of heterogeneous catalysis in liquid phase. In other cases the presence of particles is unintentional. This is for example the case of some refineries streams like shale crudes, various intermediate process streams, or effluents from slurry bed reactors. Particles may have various origins: they may

be part of the original feedstock and other reactant streams or they may be generated in and collected from process equipment, for example as erosion and corrosion products. Particles may have organic nature, like char, coke and gums, or inorganic nature, like salts, debris or corrosion and erosion as iron components, or debris of catalyst particles. Also, they may contain living impurities as bacteria. Shape and size may also vary greatly – from sphere to flakes, from millimetres to a few microns or less. If the particles are unwanted in the downstream process, a filter, or other suitable particle separation technology known in the art, removes large part of these particles prior to sensitive equipment. However, in certain processes, the problem may appear or become more severe over time, for example when erosion and corrosion are involved. Sometimes, installing a particle removing equipment as an independent unit operation prior to sensitive equipment is not possible in practice.

15

One specific example of problems generated by particles may be seen in hydroprocessing. The feed to a hydroprocessing reactor is sometimes laden with particles. When the feed is introduced into the reactor, most particles accumulate on the inert and/or on the catalyst packed beds, plugging the bed.

20

The consequent rapid increase in pressure drop is responsible of increased power requirement for compression. When the pressure drop across the reactor exceeds the maximum pressure that the system may deliver, reactors require skimming of the affected layers of the packed bed to continue operations. A frequency of once every 5-6 months for skimming is not uncommon. Skimming at a frequency higher than the schedule of the regular turnaround may be a source of significant profitability loss for the unit and the refinery.

25

A characterization of the particles affecting a reacting system may not be available. In a hydroprocessing reactor, the type of particles depends upon the specific crude and/ or process related issues (rust, salts, gums, etc.). On-stream collection of the particles is typically not available. Thus, particle characterization relies on post-mortem analyses. These are often affected by large uncertainties due to particle agglomeration and oxidation.

30

US2009177023 discloses a filtration tray for a fixed bed reactor with a co-current down-flow of gas and liquid.

The device can trap plugging particles contained in the liquid feed supplying a reactor functioning in gas and liquid co-current down-flow mode using a specific distributor tray comprising a filtration medium. The device is of particular application to the selective hydrogenation of feeds containing acetylenic and dienic compounds.

US 20090177023 describes a device which can trap plugging particles contained in the liquid feed supplying a reactor functioning in gas and liquid co-current down-flow mode using a specific distributor tray comprising a filtration medium. The device is of particular application to the selective hydrogenation of feeds containing acetylenic and dienic compounds.

EP0358923 discloses a process and an apparatus for purifying a raw gas originating from the gasification of solids. In a process and apparatus for purifying raw gas from solids gasification, containing granular and dusty solids particles, a solution is to be found, by means of which solids particles of any size are largely removed from the raw gas before entry to downstream cooling devices. This is achieved when the raw gas is passed in a first purification stage from the gasification zone in a straight line in the direction of a gas-holding space, whereby the granular solids particles are precipitated at the bottom of the gas-holding space and then, in a second purification stage, the partially purified raw gas is laterally deflected from the gas-holding space and undergoes a change to a velocity reduced by a factor of at least 3 and, after a further gas deflection, is passed substantially in the vertical direction through a solids filter, where the dusty solids particles are removed from the raw gas.

In spite of the above mentioned known art, a need exists for a reactor with a particle separator to ensure prolonged effective operation of the reactor despite any particle impurities in the inlet fluid stream to the reactor.

5      SUMMARY OF THE INVENTION

The present invention describes a novel particle separation system that combines sedimentation with filtration. In particular, the system includes various filtration sections with overfill systems to maximize particle capture while 10 keeping the pressure drop constant and limiting the liquid load across the system. With some modifications, the present invention may be used to selectively separate particles of certain shapes.

15      The filtration tray of this invention allows the gas to flow from the entry point, through slots, to downstream the filtering section, substantially unhindered by the filters.

According to this invention, the filtration tray comprises a number of basins for the collection of the liquid. Some basins are interconnected. One, several or all 20 the walls of the basins are made of a filtering medium. The filtering medium may be composite. When the liquid pours in the one basin, initially the liquid will permeate through the fresh filtering medium. The liquid may permeate directly downstream the filtration tray, or to a new filtration basin. As the filtering medium in any of the basins progressively plugs by the accumulating particles, 25 the liquid level raises and fresh sections of the filtering medium are exposed to the liquid stream.

A critical feature of the invention is that the basins walls function as overfill gates. When a filtering wall of a containing basins progressively plugs, the 30 liquid level raises. Eventually the liquid level achieves the same height of the gate and liquid flows unhindered to a new basin. The open passage in connection with the overfill gates (slot) is designed such to create a certain

pressure drop, which is the maximum pressure drop across the tray. This shall be higher than the sum of the pressure drops across all the fresh filtering sections that the liquid has to permeate through to flow downstream the filtration tray.

5

Initially, the liquid flows across one or several filtering wall and it is led downstream the filtration tray without accumulating in any basin. Concomitantly with the progressive plugging of the filtering media, the level of the liquid in the affected basin increases until the liquid raises above the overfill gate and spills into the adjacent basin. The process continues until the last basin is filled and the liquid spills over the last gate and downstream the filtration tray. Thereby, the maximum pressure drop across the filtration tray has a limit.

10

The use of overfill gates to offer new filtration sections to the process allows to limit the total height of the liquid column on the tray. This feature is important as tall liquid columns in such a system have a few drawbacks:

15

- a) They are heavy. Designing the tray to withstand big weights adds design complication and material. Consequently, the cost of the tray increases;
- b) Tall liquid columns occupy a tall section of the reactor space. Normally, as much as possible of the reactor space is needed for the reactions and it is occupied by the catalyst. Reducing the space available for the catalyst typically implies shorter cycle lengths at a given product quality.

20

25

The gas flows directly from the entry point to the last slot and exits the filtration tray together with the liquid. The last slot is retrofitted with a technology for the dispersion of the liquid and gas throughout all the catalyst / grading surface.

30

The method of this invention includes at least one basin for the sedimentation of large and heavy scale particles prior to the filtration basins.

Prior sedimentation is necessary to avoid that scale particles with a large surface quickly plug the filters.

5 Depending upon the characteristics of the scale particles, the filtering media may be composite. One method to manufacture the filtering media is for example to construct a crate with at least two walls made of a screen type material, like wired mesh, printed pattern, or others, and to fill it with catalyst or inert particles. The use of catalyst material is interesting in certain  
10 embodiments, where the filtration tray may be used to favor certain chemical reactions. The screen material has to be fine enough to prevent the catalyst or inert material to exit the crate and large enough to allow the passage of the liquid through it. In the simplest construction method of the filtration tray, the two screens face each other and are perpendicular to the flow. There are however  
15 embodiments where the geometries are arranged differently and include angles towards the liquid flow or the options that the screens do not face each other. As the catalyst or inert shall be changed after each cycle, the crates have at least one removable side. In one embodiment, the removable side is perpendicular to the flow. By this method, the inert and / or catalyst  
20 material that fill the crate may be layered in layers of various types. In certain systems, this feature is beneficial to improve the effectiveness of separation without excessive increase of pressure drop. The removable side of the crate can be conveniently fixed and fastened to the crate by means of quick releases,  
25 which are systems for fixing and fastening that can be opened and closed in minutes and without the use of tools.

The invention can be performed with filtering media of different type and nature. For example they can be made of porous monolithic structures that may be composite.

The slot that allows the gas and liquid to flow downstream are retrofitted with a dispersion system that allows the mixture to spread uniformly on the downstream packed bed without the need of an additional distribution tray.

5      FEATURES OF THE INVENTION

1. A particle separation system for a catalytic chemical reactor, wherein the particle separation system comprises a plurality of filtration sections comprising overfill systems, thereby enabling particle capture while keeping the pressure drop over the separation system constant and limiting the liquid load across the system, wherein the particle separation system comprises at least one filtration tray comprising a number of basins with basin walls for collection of liquid, thereby combining sedimentation and filtration.

10     2. A particle separation system according to feature 1, wherein a plurality of the basins are interconnected in series of upstream and downstream basins.

15     3. A particle separation system according to any of the preceding features, wherein at least one of said basin walls comprises a filtering medium.

20     4. A particle separation system according to feature 3, wherein said filtering medium comprises a composite.

25     5. A particle separation system according to any of the features 3-4, wherein an upstream basin is enabled to let liquid permeate through the filtering medium either downstream the filtration tray or to a downstream basin until said filtering medium is plugged by accumulating particles.

30     6. A particle separation system according to any of the features 3-5, wherein the liquid level of an upstream basin rises when the filtering medium of said tray progressively plugs, thereby exposing downstream basins to the liquid stream, whereby the basin walls function as overfill gates.

7. A particle separation system according to feature 6, wherein an open passage downstream the overfill gate is adapted to have a pressure drop which is higher than the sum of the pressure drops of all serially interconnected basins with unplugged filtering medium in a filtration tray.

8. A particle separation system according to any of the preceding features, further comprising at least one initial sedimentation basin upstream the trays for large and heavy scale particles.

10 9. A particle separation system according to any of the preceding features, wherein the trays are constructed as crates comprising at least two walls made of a screen type material.

15 10. A particle separation system according to feature 9, wherein the screen type material comprises catalyst or inert material, or catalyst and inert material.

20 11. A particle separation system according to feature 10, wherein the screen type material is adapted to allow passage of liquid, while preventing the catalyst or inert material to pass through it.

12. A particle separation system according to any of the features 9-11, wherein the two screens face each other and are oriented perpendicular to a fluid flow.

25 13. A particle separation system according to any of the features 9-12, wherein the crates have at least one removable side for service.

14. A particle separation system according to feature 13, wherein the removable side is fastened by means of quick releases.

30 15. Use of a particle separation system according to any of the preceding features for hydroprocessing.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further illustrated by the accompanying drawings showing  
5 examples of embodiments of the invention.

Fig. 1 shows a schematic drawing of the assembly,

Fig. 2 shows the path of the gas throughout the all cycle length of the filtration  
10 tray. Substantially all gas separates from the mixture and, passing from slot 1  
(11) and slot 2 (12), reaches downstream through the exit channel (13). Slot 1  
and slot 2 are dimensioned such to define a certain pressure drop in the  
filtration basins. The design pressure drop depends upon the physical  
properties of the liquid; the mechanical properties of the filtering media 1 (07)  
15 and 2 (08) (including porosity and thickness); the size and other characteristics  
of the scale particles to be separated, the height of the overfill gate 1 (09) and  
gate 2 (10),

Fig. 3 shows the path of the liquid at time 0. Substantially all liquid is separated  
20 from the mixture upon pouring on the sedimentation basin 1 (01). The coarser  
scale particles stay on the sedimentation basin, while the liquid carrying the fine  
particles flows over the overfill gate (02) into the filtration basin 1 (05). The liquid  
permeates across the filtration medium 1 (07), which separates the fine  
particles, and flows into the filtration basin 2 (06). The liquid flows across the  
25 filtration medium 2 (08), which in this case does not perform any substantial  
action, since most of the particles were separated in the filtration medium 1. The  
liquid flows through the exit channel downstream,

Fig. 4 shows the path of the liquid when the particle collecting capacity of the  
30 filtering medium 1 (07) is exhausted. The liquid level raises above the overfill  
gate 1 (09) and escapes through the slot 1 (11). The liquid pours into the

filtration basin 2 (06), and it permeates through the filtration medium 2 (08). The liquid flows through the exit channel downstream,

5 Fig. 5 shows the path of the liquid when the particle collecting capacities of both the filtering medium 1 (07) and 2 (08) are exhausted and the filtration tray has concluded its cycle length. The liquid level raises above the overfill gate 2 (09) and escapes through the slot 2 (12). Subsequently, it flows through the exit channel downstream. Particles are now still transported with the liquid. Fig. 5 shows an isometric view of the sedimentation basin 1 and sedimentation overfill 10 gate 1 in one of the embodiment,

Fig. 6 shows the same of Fig. 5 with the liquid on the sedimentation basin,

15 Fig. 7 shows an isometric view of the filtration section, showing one embodiment of the sedimentation basin 2 (03) the sedimentation overfill gate 2 (04) the filtration basin 1 (05) and the filtration basin 2 (06),

Fig. 8 shows another isometric view of the filtration section, and

20 Fig. 9 shows another embodiment of the filtration media. In this embodiment there are filtration media on all walls of the filtration basins.

#### Position numbers

25 01 Sedimentation basin 1.  
02 Sedimentation overfill gate 1  
03. Sedimentation basin 2.  
04 Sedimentation overfill gate 2  
05. Filtration basin 1.  
30 06. Filtration basin 2.  
07. Filtering media.1  
08. Filtering media 2.

- 09. Overfill gate 1
- 10. Overfill gate 2
- 11. Slot 1.
- 12. Slot 2.
- 5 13. Exit channel

**Claims**

1. A particle separation system for a catalytic chemical reactor, wherein the particle separation system comprises a plurality of filtration sections comprising overfill systems, thereby enabling particle capture while keeping the pressure drop over the separation system constant and limiting the liquid load across the system, wherein the particle separation system comprises at least one filtration tray comprising a number of basins with basin walls for collection of liquid, thereby combining sedimentation and filtration.

10

2. A particle separation system according to claim 1, wherein a plurality of the basins are interconnected in series of upstream and downstream basins.

3. A particle separation system according to any of the preceding claims, wherein at least one of said basin walls comprises a filtering medium.

4. A particle separation system according to claim 3, wherein said filtering medium comprises a composite.

20 5. A particle separation system according to any of the claims 3-4, wherein an upstream basin is enabled to let liquid permeate through the filtering medium either downstream the filtration tray or to a downstream basin until said filtering medium is plugged by accumulating particles.

25 6. A particle separation system according to any of the claims 3-5, wherein the liquid level of an upstream basin rises when the filtering medium of said tray progressively plugs, thereby exposing downstream basins to the liquid stream, whereby the basin walls function as overfill gates.

30 7. A particle separation system according to claim 6, wherein an open passage downstream the overfill gate is adapted to have a pressure drop which is higher

than the sum of the pressure drops of all serially interconnected basins with unplugged filtering medium in a filtration tray.

8. A particle separation system according to any of the preceding claims, further comprising at least one initial sedimentation basin upstream the trays for large and heavy scale particles.

9. A particle separation system according to any of the preceding claims, wherein the trays are constructed as crates comprising at least two walls made of a screen type material.

10. A particle separation system according to claim 9, wherein the screen type material comprises catalyst or inert material, or catalyst and inert material.

11. A particle separation system according to claim 10, wherein the screen type material is adapted to allow passage of liquid, while preventing the catalyst or inert material to pass through it.

12. A particle separation system according to any of the claims 9-11, wherein the two screens face each other and are oriented perpendicular to a fluid flow.

13. A particle separation system according to any of the claims 9-12, wherein the crates have at least one removable side for service.

14. A particle separation system according to claim 13, wherein the removable side is fastened by means of quick releases.

15. Use of a particle separation system according to any of the preceding claims for hydroprocessing.

Fig. 1

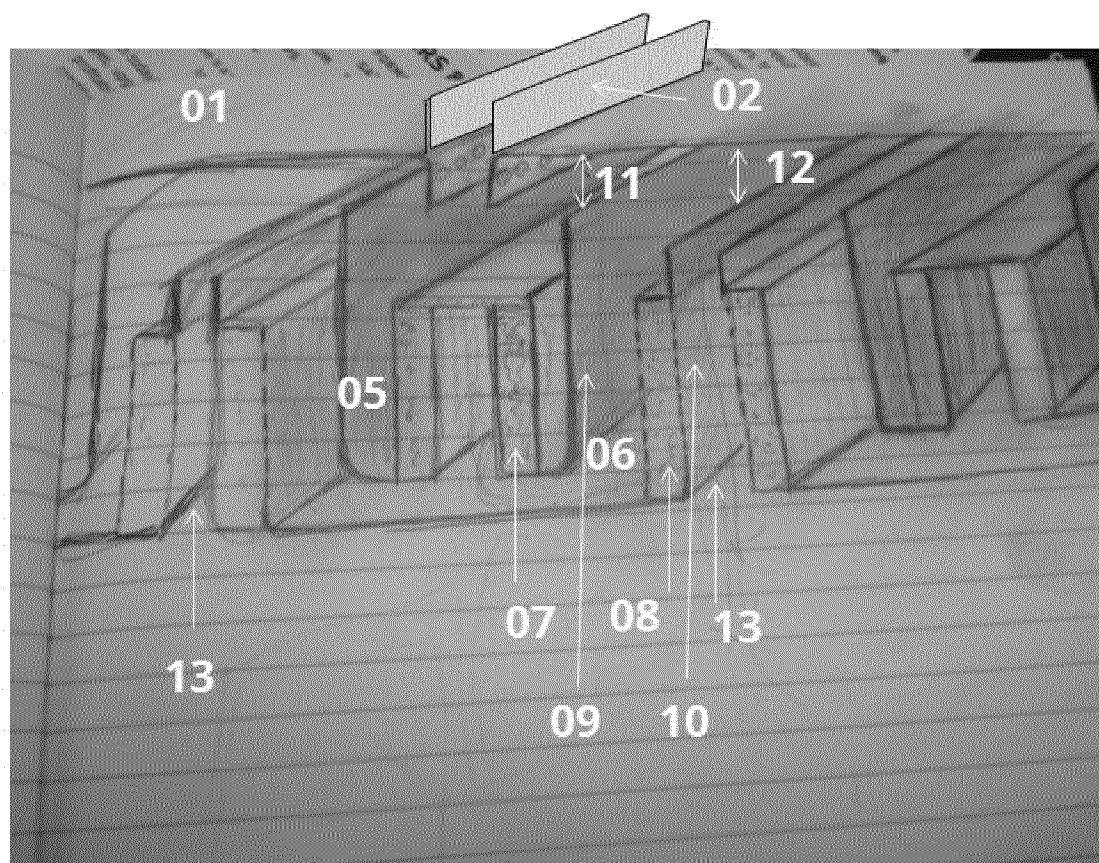


Fig. 2

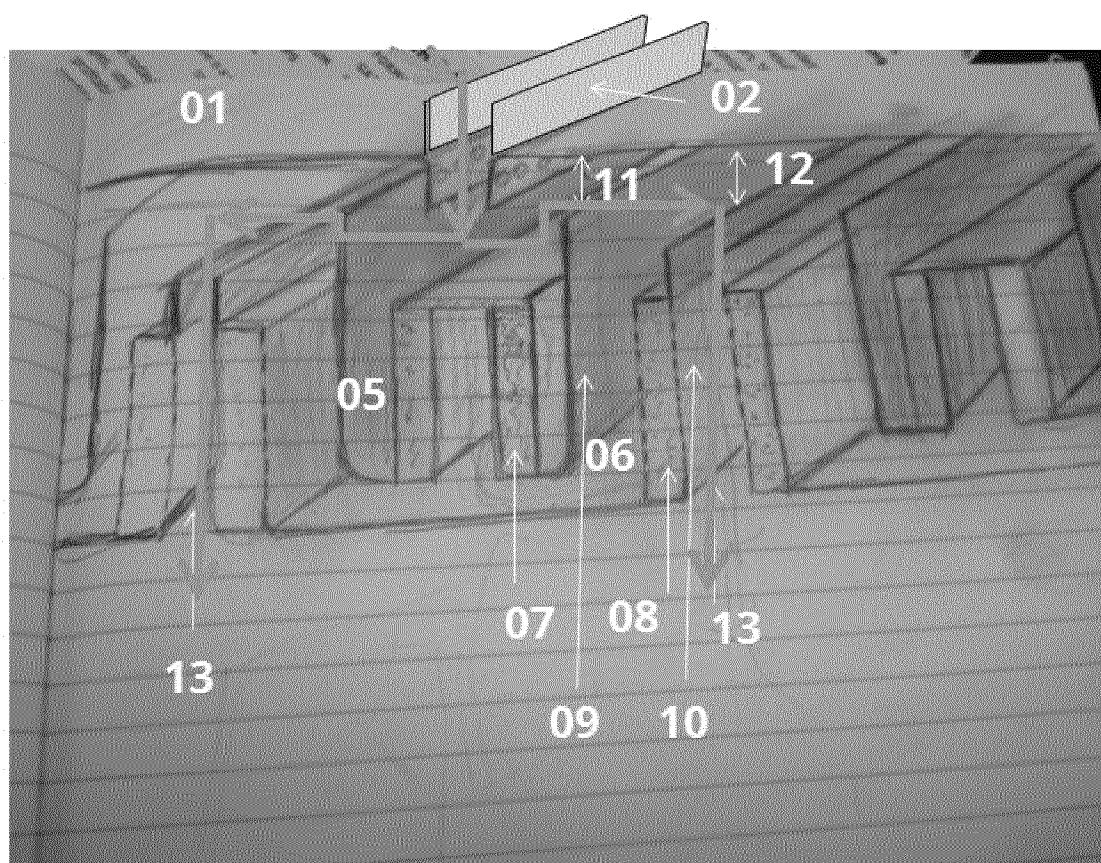


Fig. 3

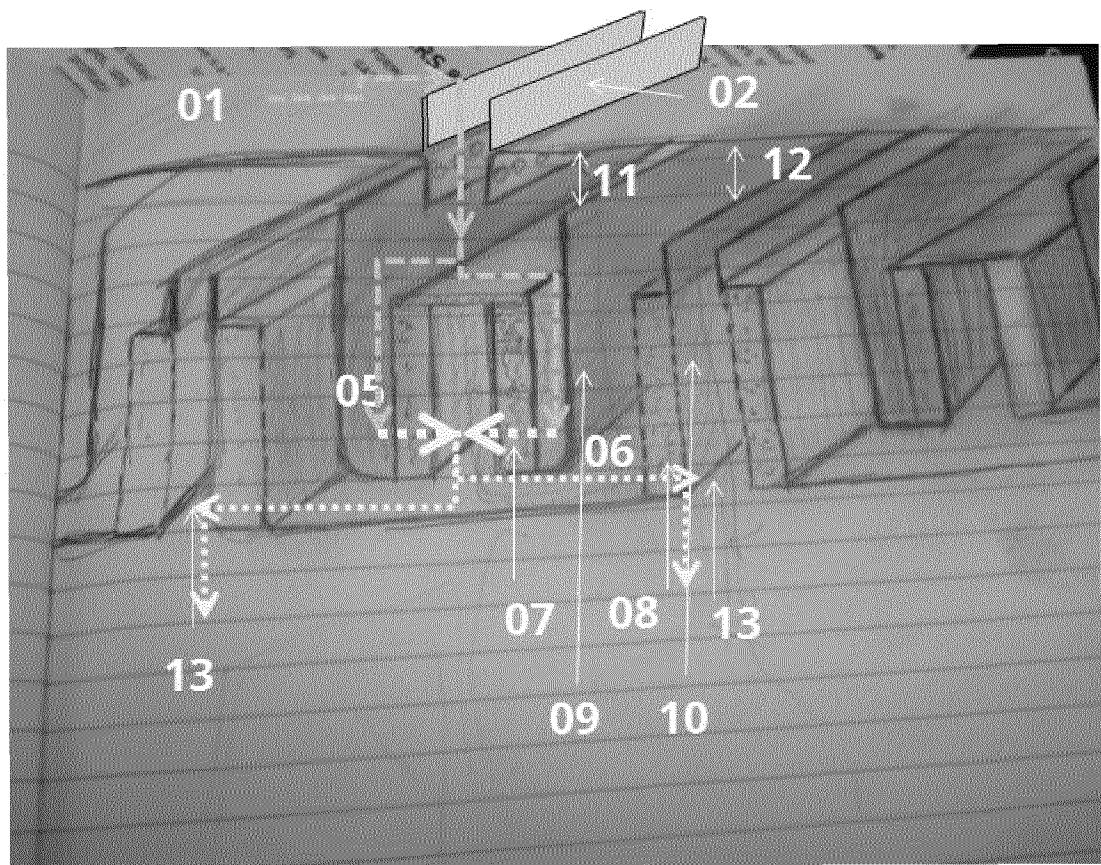


Fig. 4

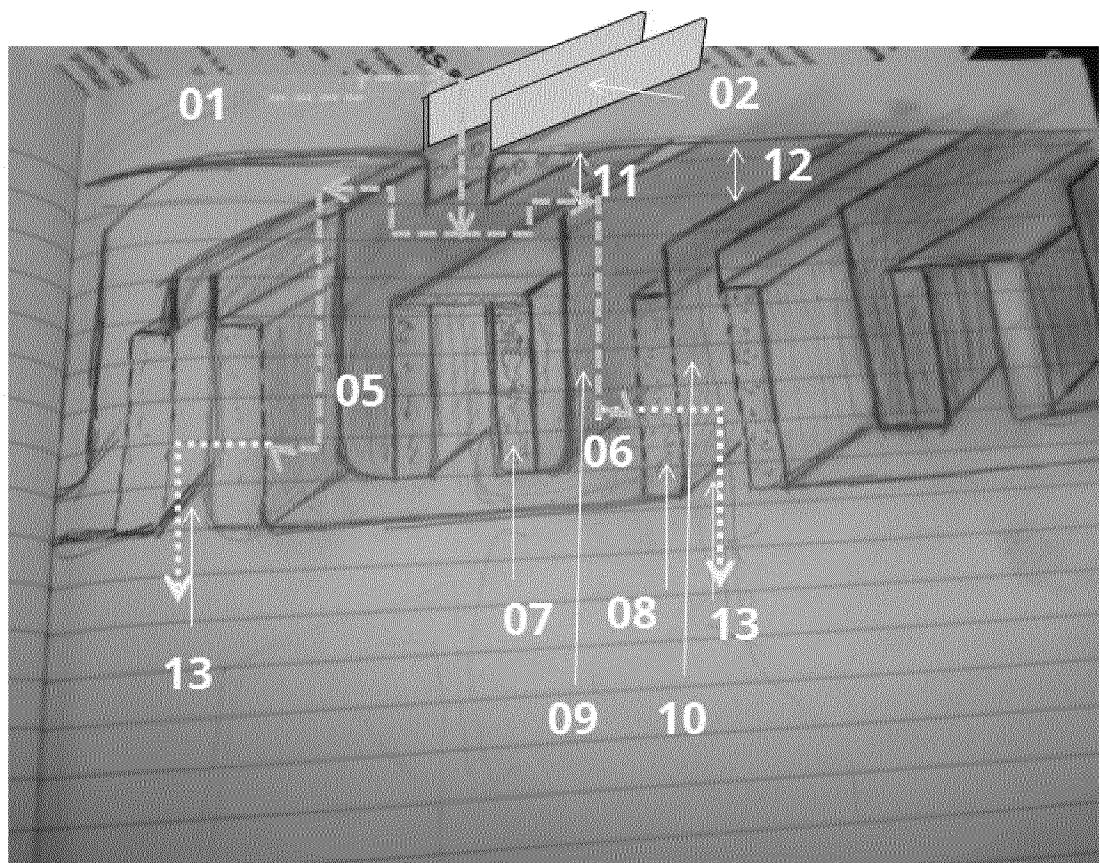


Fig. 5

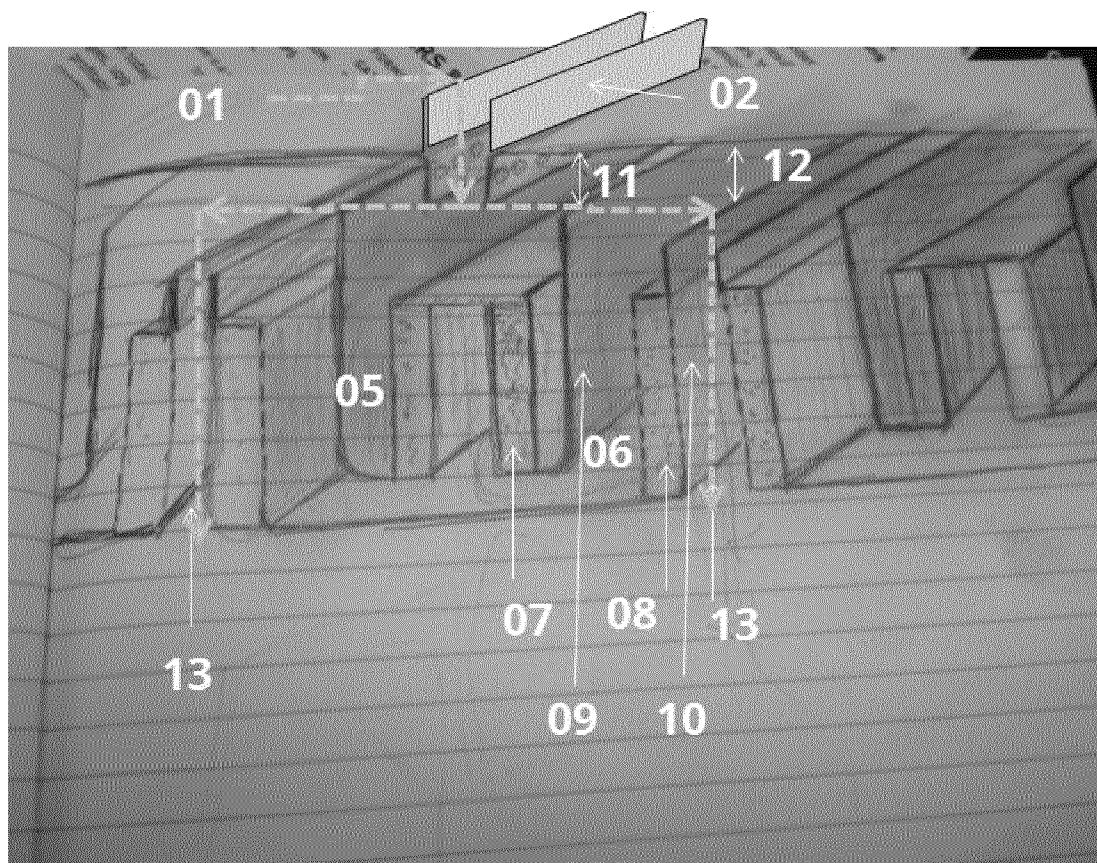


Fig. 6

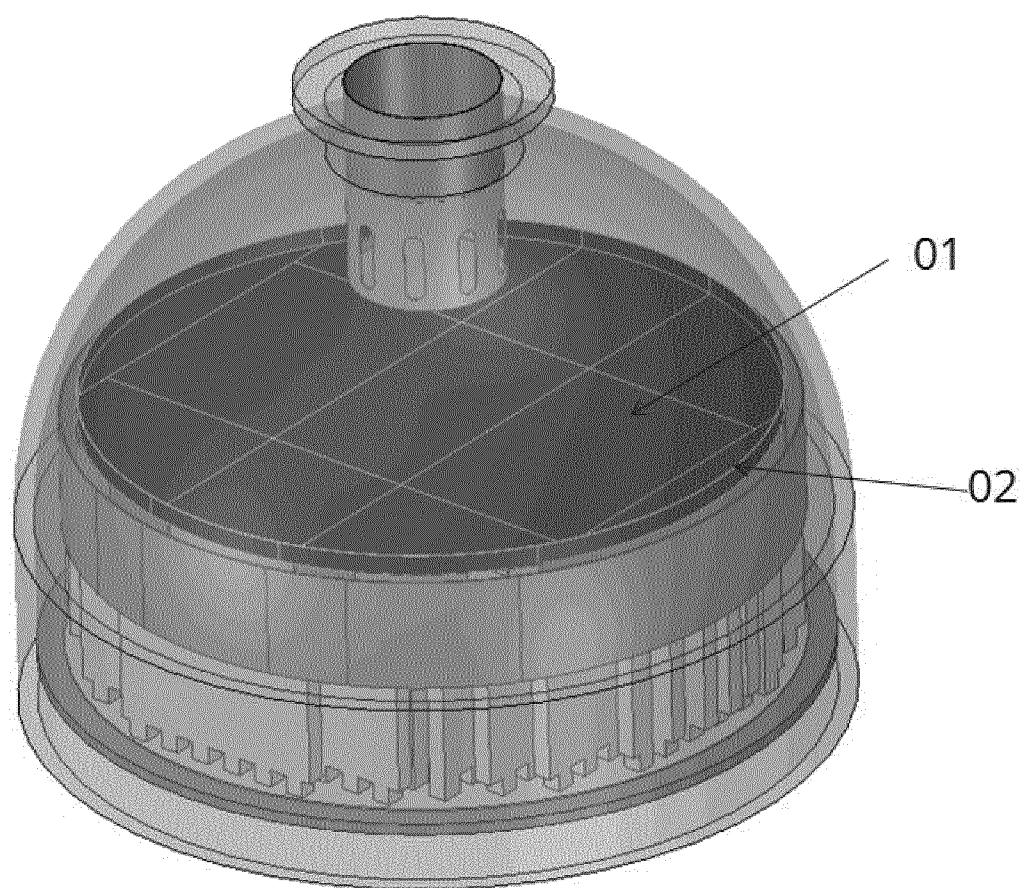


Fig. 7

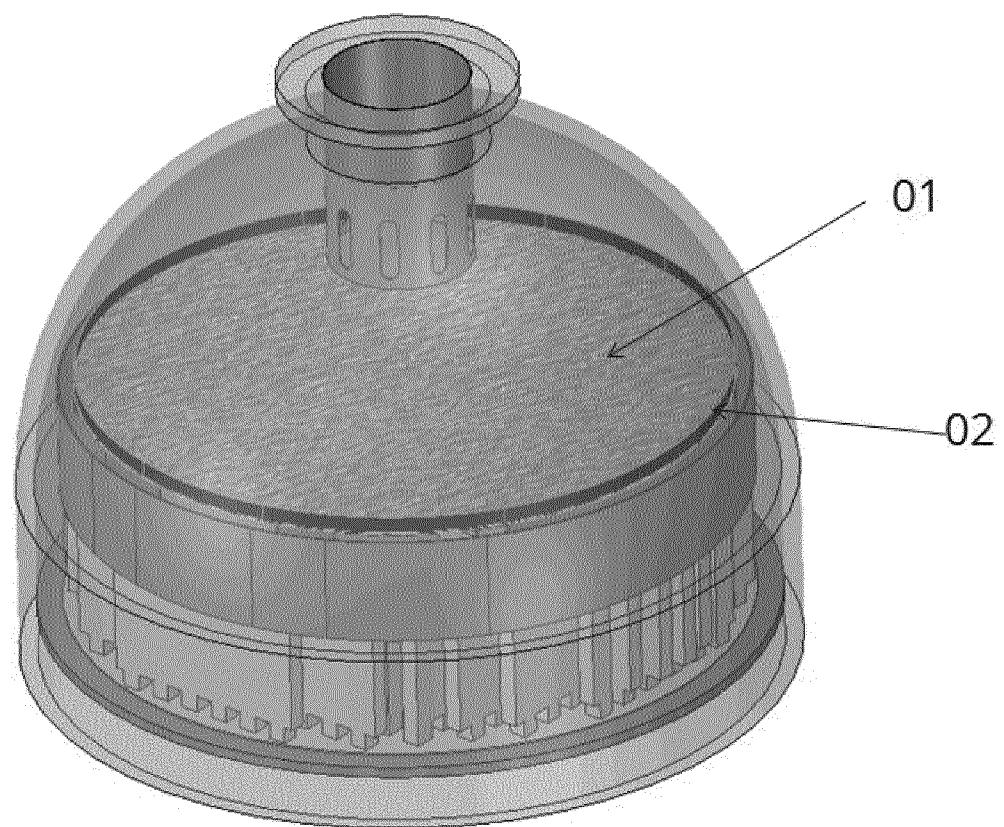


Fig. 8

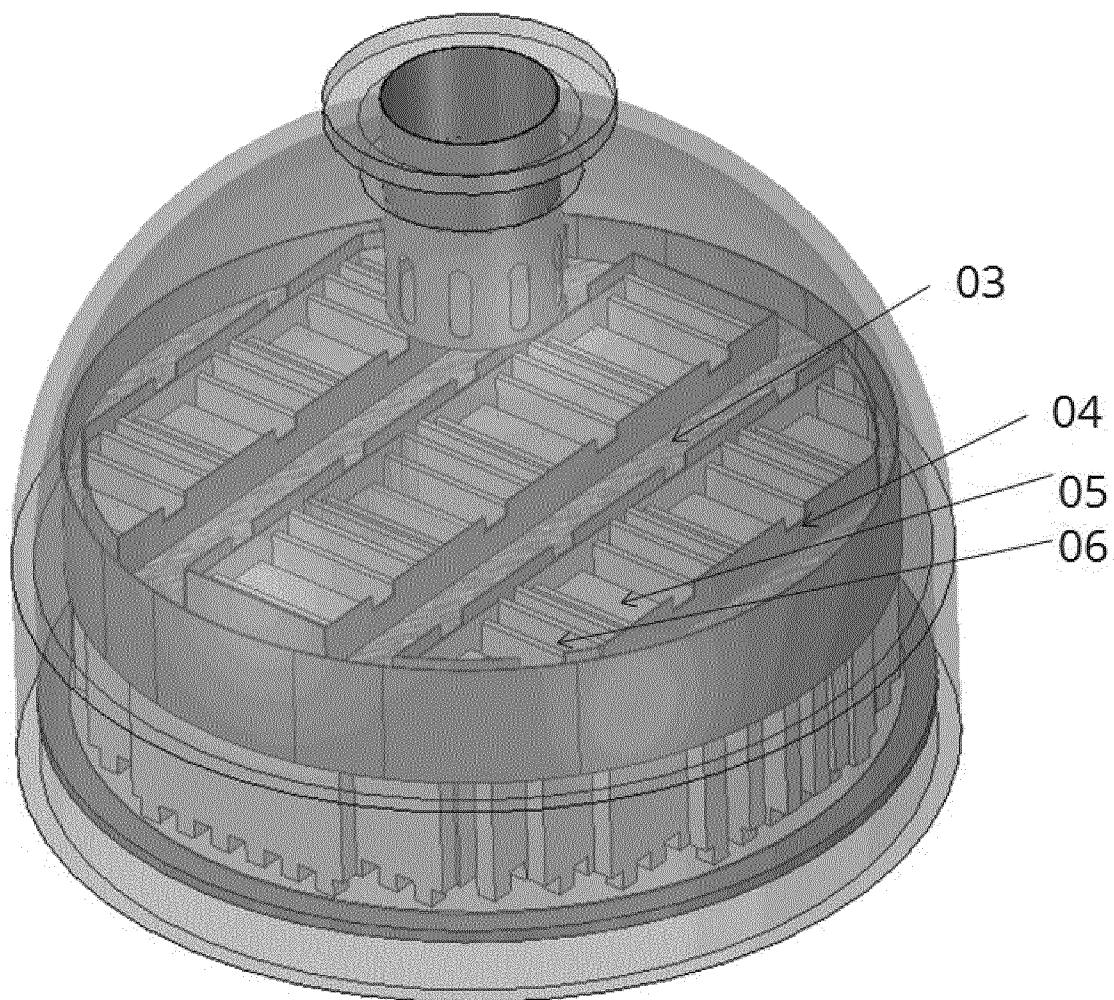


Fig. 9

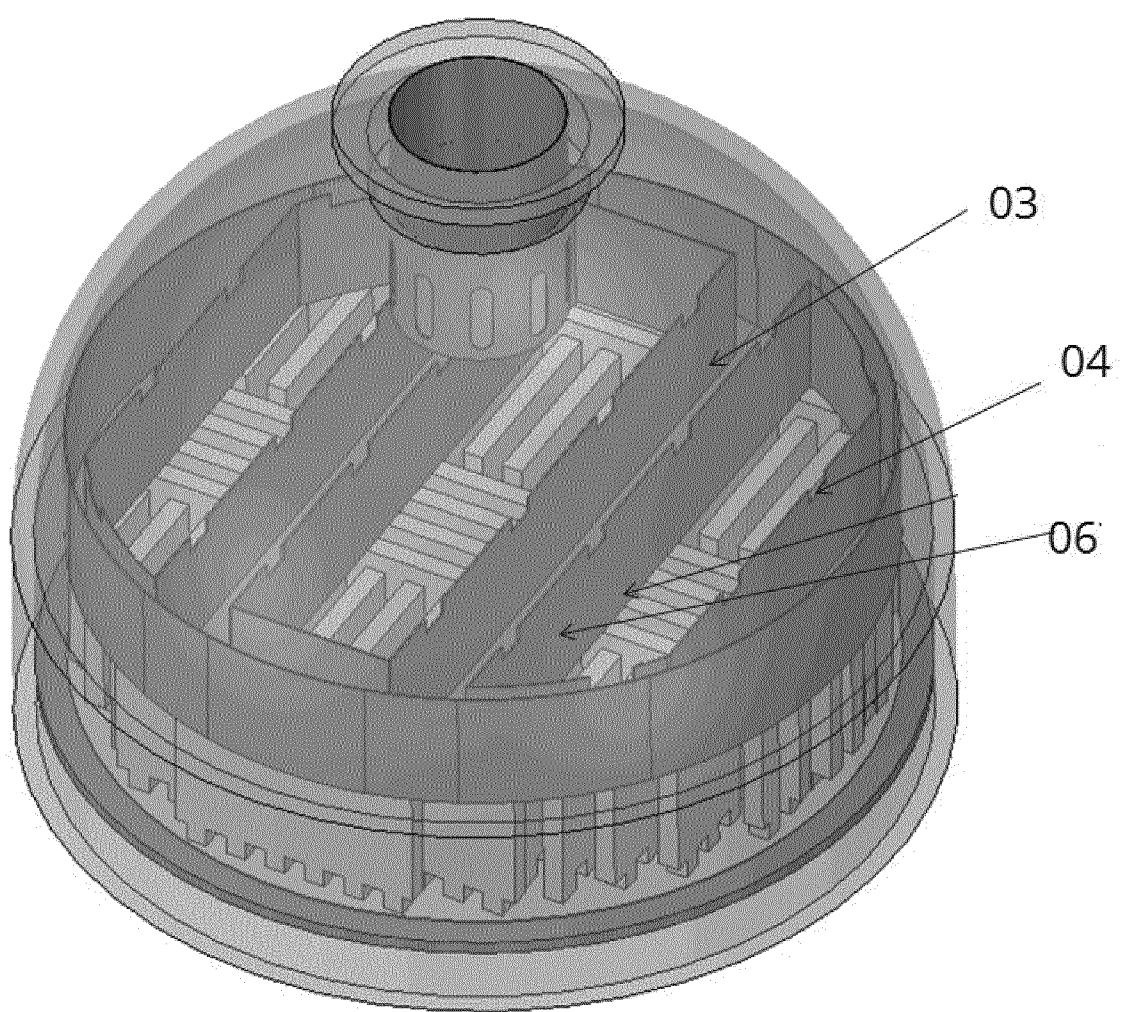
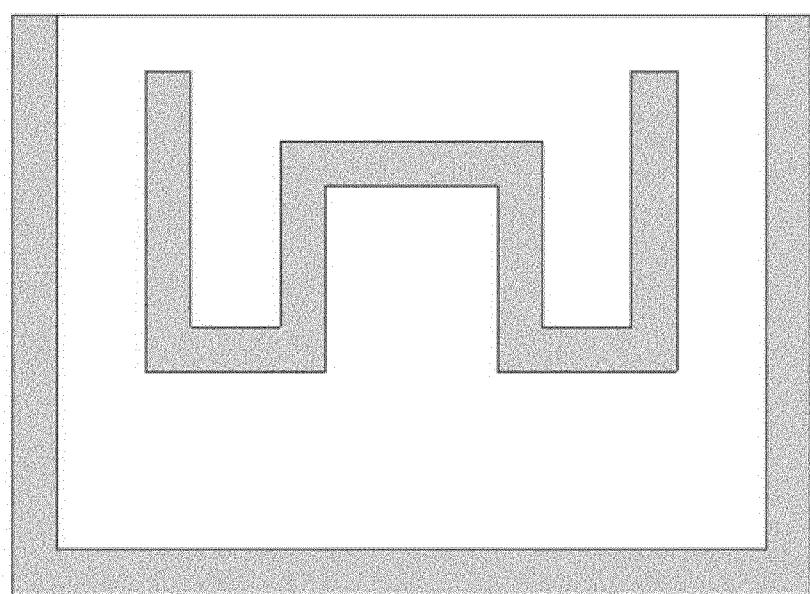


Fig. 10.



# INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2015/080405

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. B01J8/00 B01J8/04 C10G49/00  
ADD.

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
B01J C10G

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

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

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/177023 A1 (KOUDIL ABDELHAKIM [FR] ET AL) 9 July 2009 (2009-07-09) paragraphs [0094] - [0104] claims 1,14 figure 1 -----	1-15
X	US 5 855 741 A (KOCH DAVID H [US] ET AL) 5 January 1999 (1999-01-05) column 12, line 1 - column 13, line 36 column 14, line 55 - column 15, line 39 figures 1,2,7-11 -----	1-14
X	US 3 888 633 A (GROSBOLL MARTIN P ET AL) 10 June 1975 (1975-06-10) column 1, lines 7-12 column 3, lines 41-47 column 3, line 55 - column 5, line 51 figures 1-4 ----- -/-	1-15

Further documents are listed in the continuation of Box C.

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  6 April 2016	Date of mailing of the international search report  14/04/2016
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Baumlin, Sébastien

**INTERNATIONAL SEARCH REPORT**

International application No
PCT/EP2015/080405

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 146 189 A (FREDERICK KUNREUTHER ET AL) 25 August 1964 (1964-08-25) column 3, line 27 - column 4, line 49 figures 1-3 -----	1-14
1		

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/080405

Patent document cited in search report	Publication date	Patent family member(s)			Publication date
US 2009177023	A1	09-07-2009	BR	PI0615044 A2	26-04-2011
			CN	101287813 A	15-10-2008
			EP	1922391 A1	21-05-2008
			FR	2889973 A1	02-03-2007
			JP	5069238 B2	07-11-2012
			JP	2009505819 A	12-02-2009
			KR	20080038196 A	02-05-2008
			US	2009177023 A1	09-07-2009
			US	2013064727 A1	14-03-2013
			WO	2007023225 A1	01-03-2007
<hr/>					
US 5855741	A	05-01-1999	US	5855741 A	05-01-1999
			US	6110326 A	29-08-2000
<hr/>					
US 3888633	A	10-06-1975	NONE		
<hr/>					
US 3146189	A	25-08-1964	DE	1192625 B	13-05-1965
			FR	1320032 A	08-03-1963
			GB	944188 A	11-12-1963
			NL	272129 A	04-12-1961
			US	3146189 A	25-08-1964
<hr/>					