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(54) Title: PROCESS AND APPARATUS FOR SEPARATING PARTICLES OF A CERTAIN ORDER OF MAGNITUDE FROM A SUSPENSION

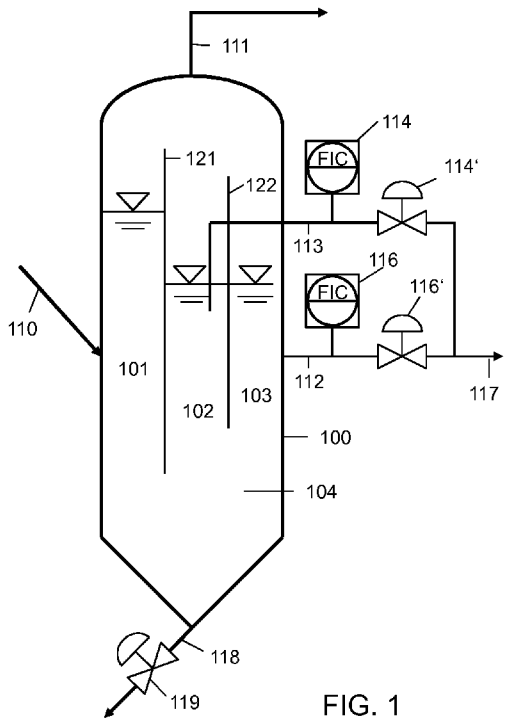


FIG. 1

(57) Abstract: The invention comprises a process and a plant for separating a suspension C from a suspension A, wherein the fraction of particles P_c in the suspension C, which have a diameter smaller than a defined limit grain diameter, is greater than in the suspension A by at least the factor of 2. The suspension A (110) is introduced into a container (100) extending from the bottom to the top and a suspension B (118) is withdrawn from the container as a first partial stream, whose fraction of particles with a diameter greater than the defined limit grain diameter is increased with respect to suspension A. Due to the fact that suspension C is withdrawn from the container in a second partial stream (112, 113) above the first partial stream (118), in that the flow velocity of the suspension C is greater than the sinking velocity of the particles P_c contained therein, an effective separation can be achieved.

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Process and Apparatus for Separating Particles of a Certain Order of Magnitude from a Suspension

The invention relates to a process and an apparatus for separating a suspension C from a suspension A, wherein the fraction of particles P_C in the suspension C, which are smaller than a defined limit grain diameter, is greater than in the suspension A by at least the factor of 2, wherein the suspension A is introduced into a container extending from the bottom to the top and wherein a suspension B is withdrawn from the container, whose fraction of particles with a diameter greater than the defined limit grain diameter is increased with respect to suspension A.

Suspension is understood to be a heterogeneous substance mixture of a liquid and solids finely dispersed therein. When a suspension is allowed to stand in a container, the solids slowly sink to the bottom and form a sediment when the solids have a greater density as compared to the pure liquid. The supernatant liquid is decanted and the solids thus can be separated from the liquid. The smaller a particle the smaller its density difference to the liquid, and the higher the viscosity of the liquid the more slowly the sedimentation proceeds. Shape and structure of the particles also influence the sedimentation. The sedimentation can be accelerated by centrifuges.

Substance properties of a suspension, above all the particle size and the distribution of the particle size, can be determined e.g. by an ultrasonic attenuation spectroscopy. In this process an ultrasonic wave runs through the suspension, wherein the intensity of this wave is attenuated. The amount of the attenuation is dependent on substance properties, the concentration of the particles and the size of the suspended particles. By connections and dependencies, in particular by corresponding calibration, distributions of particles in heterogeneous systems

can be determined. What is difficult, however, is the targeted separation of particles of a certain size.

A separation of particles of different mean diameters can be achieved in principle in so-called rising chambers. As described for example in DD 293 065, a gas for this purpose is introduced into a solid bed from below, wherein the flow velocity of the gas is adjusted such that it entrains particles up to a certain size, while other particles exclusively are slightly fluidized or not lifted at all. By varying the gas velocity, particles of different diameters thus can be separated. Varying separation quantities can be achieved by using several rising chambers which are separately approached by gas from below.

US 8,603,343 B2 describes a process for the separation of particles from a suspension, in which the separation of particles and a clear liquid is achieved by a special arrangement in a decanter.

It now is the object of the present invention to separate particles, in particular of the same density, of a certain order of magnitude from a suspension. In particular, there should be found a process and an apparatus which also allows to process suspensions in which gas mixtures or gas-suspension mixtures are present.

This object is solved by a process with the features according to claim 1. For this purpose, a suspension A is introduced into a container extending preferably vertically from the bottom to the top. To the top in the sense of the invention means that the bottom of the container is formed such that it has the shortest distance to the earth's surface, whereas all further parts, the side walls, lid, etc. are further away from the earth's surface. The bottom can be flat, but also be chosen with an inclination or formed rounded.

From this container, a suspension B, which is characterized in that it has a partical fraction P_B with a certain first mean particle diameter, is discharged via a discharge conduit. The particles P_B for at least 80 wt-%, preferably for at least 90 wt-%, particularly preferably for at least 95 wt-% contain particles whose diameter is larger than a defined limit grain diameter.

According to the invention, a suspension C is withdrawn via a discharge conduit in a second partial stream, which is characterized in that the fraction of particles which are smaller than a defined limit grain diameter is greater than in the suspension A by at least the factor of 2, preferably by at least the factor of 5, particularly preferably by at least the factor of 10. This partial stream is withdrawn above the first partial stream (suspension B).

Fraction in the sense of the invention is understood to be the weight of the specific particles in relation to the weight of all particles. The fraction P_C in the suspension C therefore is the total weight of all particles with a diameter smaller than the defined limit grain diameter divided by the total weight of all particles contained in the suspension C.

By withdrawing the second partial stream (suspension C) above the first partial stream (suspension B) through the discharge conduit, a flow is obtained within the container. At the same time, the force of gravity acts on all particles contained in the suspension, whereby the same move towards the bottom at a sinking velocity which is dependent on the respective particle mass and hence the individual particle diameter. Favorably, the flow resulting from the withdrawal of the suspension C vectorially is directed differently with respect to the direction of action of the gravitation. The larger particles, which due to their weight and hence also their larger particle diameter sink to the bottom, thus separate from those particles in which the sinking velocity is smaller than the flow velocity. Since here the different sinking velocity of the particles in the suspension in

dependence on the diameter is utilized and particles sinking down very slowly are withdrawn by a flow, small particles can be separated from larger ones. By varying the discharge flow for the suspension C, particles with different properties can be withdrawn.

In particular, the particles themselves have a comparable density and a comparable material composition, respectively. By the process according to the invention, a size-dependent separation thus can be made. In principle, however, it also is conceivable to use this process for separating particles with the same size, but different density, from each other, wherein these density differences for example can result from different material compositions.

In this process, it is particularly favorable that other than in usual sedimentations the process can be carried out continuously, so that introduction and withdrawal of the suspensions is effected such that the filling quantity of the container remains approximately constant.

In particular, the invention is suitable for liberating suspended catalysts from fine grain whose defined limit grain diameter has a value between 10 and 50 µm, preferably between 15 and 30 µm.

Preferably, the stream fed into the container as suspension A has a solids concentration of 1 to 60 wt-%, preferably 20 to 50 wt-%.

The invention in particular also is suitable for removing particles of a certain size from a gas-suspension mixture. Preferably, the gas dispersed in the suspension therefore is separated in the container by outgassing, which in the most simple form is accomplished in that the filling level in the contains is adjusted such that above the filling level a gas layer is present, into which the gas can outgas.

Outgassing is positively influenced by the suspension not standing completely in the container.

In an advantageous aspect, a pressure of more than 10 bar, preferably more than 20 bar and particularly preferably of 25 to 35 bar exists in the container. Hence, the use of this process also is quite suitable for higher process pressures in the chemical industry, whereas in centrifuges considerable safety measures are necessary in this pressure range due to the large kinetic energy of the fast rotating rotors. In addition, centrifuging under excess pressure technically is very complex and therefore involves high costs.

Preferably, suspension A flows into the container due to a hydrostatic pressure gradient, which means that the apparatus preferably is arranged such that the pressure difference between the point of withdrawal of suspension stream A and the point of feedback of suspension B has an amount which effects a sufficient flow through the apparatus, but does not lead to an avoidable abrasion at the technical equipment or the flowing particles. When withdrawal and feedback take place from and into the same container, this driving force can be adjusted by the vertical distance between the points of withdrawal and feedback. A suitable throttle which is installed into the supply conduit of the suspension A and/or the discharge conduit of the suspension B likewise can positively influence the flow velocity of the suspension and the filling level in the apparatus, but is not required in principle for the invention.

On the other hand, it also is conceivable to pump in suspension A, so as to achieve a greater flexibility with regard to the arrangement of the entire plant.

The invention furthermore also comprises an apparatus for separating particles of a certain mean diameter from a suspension A with the features of claim 7. Such apparatus comprises a container, at least one feed conduit for the sus-

pension A into the container, and at least one outlet for a suspension B with a particle fraction P_B, in which at least 80 wt-%, preferably at least 90 wt-%, and particularly preferably at least 95 wt-% of the particles have a diameter which is greater than a defined limit grain diameter. According to the invention, such apparatus also includes a discharge conduit for a suspension C which contains a particle fraction P_C, in which the weight fraction of particles which are smaller than a defined limit grain diameter is greater than in the suspension A by at least the factor of 2, preferably by at least the factor of 5, particularly preferably by at least the factor of 10.

This discharge conduit leads to a connected equipment, preferably a container, in which a pressure exists which is smaller than the pressure in the apparatus. This pressure gradient preferably is the driving force for the flow. Alternatively, this flow also can be produced by a pump or by another method for increasing the pressure in the apparatus or for decreasing the pressure in the connected equipment. The flow velocity of the suspension C in the apparatus thus generated is greater than the sinking velocity of the particles P_C contained therein.

Preferably, the container in its total height extends from the bottom to the top, wherein the outlet for the suspension B as measured from the bottom or the lowest point of the container maximally is arranged at a height of 20 % of the total height. Preferably, the outlet for the suspension B is located at the lowest point of the container, so that all sunken particles can be removed from the container.

Preferably, the discharge conduit for the suspension C is located above the outlet for the suspension B. As a result, the particles not yet withdrawn can be separated by the resulting discharge flow, whereas larger and hence heavier particles sink to the bottom and hence leave the region of the container from which the suspension C is withdrawn.

Nevertheless, however, it also is conceivable to form the container with large width and provide the discharge conduit for suspension C opposite the supply conduit of suspension A. Via the path to be covered from the inlet to the outlet heavy particles then also would sink to the bottom, whereas light particles are discharged by the flow at the opposite outlet tube for the suspension C.

Preferably, the container includes at least one partition wall by which two chambers not completely separated from each other are obtained. Preferably, the feed conduit for suspension A opens into the first chamber and the discharge of suspension C is located in another chamber. It thereby is ensured that there is no flow short-circuit between feed and discharge conduit, but all particles remain in the system long enough, so that heavier particles can sink to the bottom.

It is particularly favorable when the chambers are open in the lower region. Lower region in the sense of the invention refers to the fact that the partition walls do not directly adjoin the bottom of the container. This is particularly favorable, as the particles thus forcibly sink down from the feed conduit due to the arrangement of the partition wall, wherein preferably the heavier particles sink down completely and thus can be separated from the lighter particles discharged with the outgoing flow.

Particularly preferably, the feed conduit opens into the first chamber in which entrained gas escapes from the suspension by outgassing and is discharged through a gas outlet.

A particularly favorable aspect of the invention provides three chambers, so that two partition walls are present. The first chamber includes the supply conduit for the suspension A, whereas the two other chambers each include a discharge conduit for the suspension C. This has the advantage that by valves in the discharge conduits one of the separation chambers each can be excluded from the

withdrawal, so that different quantities of suspension C can be withdrawn from the container without the flow velocity in the remaining separation chamber(s) and thus also the mean diameter of the withdrawn particles being changed.

It is preferred particularly when the cross-sectional area of the second chamber relative to the cross-sectional area of the third chamber has a ratio which lies between 1:0.2 to 1:5 and preferably is 1:2, wherein the cross-sectional area preferably extends parallel to the bottom. There are obtained three different possible withdrawal quantities, namely the withdrawal from the smaller chamber, the withdrawal from the larger chamber and the withdrawal from both chambers. This system also can be transferred to an even larger number of chambers.

What is also favorable is a conical bottom, as it prevents an actual settling of particles (sedimentation), in particular when the discharge conduit for the suspension B is provided at the lowest point of the bottom.

The invention also comprises the use of the apparatus for separating deactivated catalyst from a product stream of a Fischer-Tropsch synthesis. In a Fischer-Tropsch synthesis, synthesis gas which substantially is a mixture of hydrogen and carbon monoxide is converted to longer-chain hydrocarbon chains. This reaction for example is carried out in so-called bubble column reactors. The synthesis gas here is passed through a suspension of catalyst particles and hydrocarbons formed in the process, whereby a fluidization or slurry of the catalyst particles is caused. On the catalyst, a large part of the synthesis gas used is converted to the longer-chain hydrocarbons, wherein these hydrocarbons are present both in gaseous and in liquid form. After leaving the reactor, non-converted synthesis gas is separated from the gaseous product stream and again supplied to the reactor.

The metallic catalysts used for this process, substantially cobalt or iron, are applied onto the surface of carrier particles of e.g. aluminum oxides. In the following, these systems are referred to as catalyst particles. The catalyst particles are fluidized by the ascending bubbles and additional devices in the reactor and distributed within the reactor management such that a rather uniform catalyst concentration is present over the entire height and the cross-section of the reactor. Inevitably, mechanical loads of the catalyst particles also occur due to shocks of the particles among each other and by friction/collision of the particles with the internal fittings of the reactor, such as heat exchanger, device for gas distribution, devices for product separation, and others. Additional loads are produced by pressure fluctuations and evaporation of reaction products in the pores of the catalyst particles. In the long run, these mechanical loads produce catalyst fragments.

It has now been found that the mechanisms which lead to the mechanical degradation of the catalyst particles equally concern all particles. Hence, the actual size of the catalyst particles in relation to the mean size of the used catalyst particles is a measure of how long the respective catalyst particles have already been present in the system. The longer the individual catalyst particles have been used already, the smaller they are, since they were exposed to the load in the system for a correspondingly longer time. The finest particles thus are those particles which are subject to most of the degradations and thus have been in the reactor for the longest time. Due to this long use, the smallest particles hence also have the least chemical activity. The removal of the finest and oldest particles and the replacement of the removed catalyst by fresh catalyst hence serves the maintenance of the reactivity of the reaction mixture.

Thus, the idea underlying the invention also consists in separating the small particles continuously or at regular intervals and thus in removing inactive catalyst from the system. New, active catalyst then likewise must be filled up. A

uniform catalyst activity of the plant hence can be ensured. In the ideal case it even is possible to completely avoid downtimes for the exchange of catalyst and to operate the plant over many years with a continuously exchanged catalyst. The reactivity of the mixture of hydrocarbons and catalyst in the described reactor thus is maintained in commercial operation.

In Fischer-Tropsch reactions, the catalyst fraction discharged with the product so far usually is isolated and discarded or recirculated completely. A targeted withdrawal of mostly fine and/or deactivated particles does not occur.

Further features, advantages and possible applications of the invention can also be taken from the following description of the drawing. All features described and/or illustrated form the subject-matter of the invention per se or in any combination, independent of their inclusion in the claims or their back-reference.

In the drawing:

Fig. 1 shows a schematic representation of a plant according to the invention,

Fig. 2 shows a schematic representation of a Fischer-Tropsch process according to the prior art, and

Fig. 3 shows a schematic representation of a Fischer-Tropsch process according to the invention.

Fig. 1 schematically shows the apparatus according to the invention for separating fine particles from the entire stream.

The container 100 used here includes a feed conduit 110 via which a suspension A is introduced into the container. Through the partition walls 121 and 122, which do not extend down to the bottom, three chambers 101, 102 and 103 are obtained, wherein the feed conduit 110 opens into the chamber 101.

Process gas possibly contained in the suspension A here exits via the indicated surface of the suspension and can be discharged via conduit 111. The remaining suspension is backed up. Both downstream chambers 102 and 103 have two different sizes in which the ratio of the cross-sectional area of the chamber 102 relative to the cross-sectional area of the chamber 103 is 1:2.

Via the conduits 112 and 113, the suspension C which contains the particles P_C, in which the weight percentage of particles which are smaller than a defined limit grain diameter is greater than in the suspension A by at least the factor of 2, can be withdrawn from the chambers 102 and 103. The flow rate of suspension C can be controlled via the control device 114 and the associated valve 114' or via the control device 116 and the associated valve 116'. Via the withdrawal of the stream of suspension C a flow velocity in the chambers 102 and 103 can be applied. With increasing particle size the sinking velocity of particles increases. When the sinking velocity of the particle is greater than the flow velocity in the separation chambers 102 and 103, the particle is discharged via conduit 118 as suspension B which contains the particles P_B by using the control device 119, in which suspension at least 80 wt-% of the particles have a diameter which is greater than a defined limit grain diameter. When the particle, however, is smaller and its sinking velocity therefore is smaller than the flow velocity obtained in the separation chambers 102 and 103 through the discharge conduits 112 and 113, the particle is discharged there via conduit 112 or 113.

With the selection of the used chambers for separation, namely only the smaller chamber, only the larger chamber or both chambers in parallel, the quantity of

the discharged suspension can be varied without the flow velocity in the chamber and hence the size of the discharged particles being changed thereby. The constructional determination of the cross-sectional area for the chambers is effected corresponding to the targeted limit grain size, i.e. that particle size which is to be discharged. Further factors to be considered here are the density differences between the solids and the surrounding liquid.

According to the invention, the claimed process proceeds with particular separation sharpness when a constant level of the liquid is ensured in the two chambers 102 and 103. This is the only way to ensure that the particles in the chambers 102 and 103 must pass a sufficiently quiet zone and thus sinking velocity and flow velocity actually compete with each other and there is no discharge of larger particles at individual points due to locally larger flow velocities.

According to the invention, the process can be operated both continuously and alternately. It can also be advantageous to multiply such plant, to use reactors operated in parallel for generating the suspension A, so that the apparatus according to the invention alternately is charged by several reactors. In principle, it also is conceivable that several streams jointly enter into the apparatus according to the invention.

It also can be expedient to control the pressure in the container by supplying nitrogen. This nitrogen, which for example can originate from a waste gas treatment, can then be discharged again via conduit 111.

Fig. 2 shows the integration of a plant known from the prior art in a Fischer-Tropsch synthesis.

From the two bubble column reactors 11 and 11' connected in parallel a continuous process stream is withdrawn and discharged via the conduits 2 and 2'. The

withdrawal of this stream can be metered via the control device 4 and 4', respectively. The conduits 2 and 2' then open into conduit 3, via which the collected stream is guided into a heat exchanger 5 and into a storage tank 14.

The heat exchanger medium is supplied and discharged again via the conduit 13, 13'. In the storage tank 14, the pressure is controlled in a waste gas treatment by supplying nitrogen with elevated pressure and possibly by discharging nitrogen via conduit 6.

Via conduit 7, the suspension is supplied from the storage tank to a centrifuge 15 for separating the contained solids.

The light phase separated there is supplied to the treatment of the contained Fischer-Tropsch products by means of conduit 8. The light phase is supplied to a cooling device 16 via conduit 9. The suspension subsequently can be disposed of or be reprocessed in a non-illustrated way.

For a process management according to Figure 2, Table 1 shows specific parameters of individual streams which are divided onto the two reactors 11 and 11' and each have a total mass flow of 3565 kg/h each. Particles with a grain size of 25 µm are removed.

Table 1: Stream composition with a process design acc. to Fig. 2.

	2, 2'	3	7	9	8
Mass flow of all particles (kg/h)	1069.6	7130	7130	4750	2380
Temperature (°C)	234	234	150	148	148
Pressure (bar(g))	10	10	9.5	0.2	0.2
Mass flow of the particles below the limit grain size (kg/h)	38.5	77	77	75.9	1.1
Mass flow of the particles above the limit grain size (kg/h)	1031	2062	2062	2061.9	0.1

Fig. 3 shows the integration of an apparatus according to the invention in a Fischer-Tropsch synthesis. The gaseous products obtained again are largely discharged from the bubble column reactors 11 and 11' via conduits 1 and 1'.

Via conduits 110 and 110', a continuous product stream which contains liquid hydrocarbons, catalyst particles and in part also gaseous hydrocarbons is withdrawn and supplied to the container 100 and 100', respectively. This container 100, 100' is designed as shown in Fig. 1.

In the container 100 and 100' the gas contained in the inflowing product initially is separated and via conduits 111 and 111' combined with the waste gas from the bubble column reactor 11, 11' in conduit 1, 1' and discharged.

Via conduits 118 and 118', in which a non-illustrated control device 119, 119' is provided, the suspension B, which contains a particle fraction P_B in which at least 80 wt-% of the particles have a diameter which is greater than a defined limit grain diameter, gets back into the bubble reactor 11, 11'.

One or more partial streams with the suspension C, which contains a particle fraction P_C in which the weight percentage of particles which are smaller than a defined limit grain diameter is greater than in the suspension A by at least the factor of 2, are discharged from the container 100, 100' in a controlled manner via conduit 112, 112' and/or 113, 113' and fed into the common conduit 3 via conduit 2, 2'. The further configuration corresponds to the one explained in Fig. 2.

Table 2 describes the stream composition for the incorporation of the invention in a Fischer-Tropsch process as shown in Fig. 3. A total mass flow of wax and particles of 53526 kg/h each is charged to the two reactors 11 and 11', in order to remove particles with a grain size of 25 µm and smaller from the system.

Table 2: Stream composition with a process design acc. to Fig. 3.

	110, 110'	113	2	3	7	9	8
Mass flow of all particles (kg/h)	16058	3509	5168	10336	10336	331	10005
Temperature (°C)	234	234	234	234	150	148	148
Pressure (bar(g))	32	10	10	10	9.5	0.2	0.2
Mass flow of the particles below the limit grain size (kg/h)	578	26.1	38.5	77	77	72.3	4.7
Mass flow of the particles above the limit grain size (kg/h)	15480	26.1	38.5	77	77	72.3	4.7

List of Reference Numerals

1 - 3	conduit
4, 4’	control device
5	heat exchanger
6 - 9	conduit
11, 11’	bubble column reactor
13	conduit
14	storage tank
15	centrifuge
16	cooling device
100, 100’	container
101 - 103	chamber
104	lower region
110 - 113’	conduit
114 - 114”’	control device
116 - 116”’	control device
117, 118	conduit
119	control device
121, 122	partition wall

Claims

1. A process for the separation of a suspension C from a suspension A, wherein the fraction of particles P_C in the suspension C, which have a diameter smaller than a defined limit grain diameter, is greater than in the suspension A by at least the factor of 2, wherein the suspension A is introduced into a container extending from the bottom to the top and wherein a suspension B is withdrawn from the container, whose fraction of particles with a diameter greater than the defined limit grain diameter is increased with respect to suspension A, **characterized in** that the suspension C is withdrawn from the container in a second partial stream above the first partial stream due to the fact that the flow velocity of the suspension C is greater than the sinking velocity of the particles P_C contained therein.

2. The process according to claim 1, **characterized in** that the process is carried out continuously and with stationary operating conditions.

3. The process according to claim 1 or 2, **characterized in** that the defined limit grain diameter has a value between 10 and 50 µm.

4. The process according to any of the preceding claims, **characterized in** that the suspension A contains a gas.

5. The process according to claim 4, **characterized in** that the gas in the container is separated by outgassing and subsequently is withdrawn.

6. The process according to any of the preceding claims, **characterized in** that a pressure of more than 10 bar exists in the container.

7. The process according to any of the preceding claims, **characterized in** that suspension A flows into the container due to an applied or a hydrodyamic flow.

8. An apparatus for separating a suspension C from a suspension A, wherein the weight percentage of particles P_C in the suspension, which are smaller than a defined limit grain diameter, is greater than in the suspension A by at least the factor of 2, comprising a container (100), at least one feed conduit (110) for the suspension A into the container (100) and at least one outlet (118) for a suspension B, whose fraction of particles with a diameter greater than the defined limit grain diameter is increased with respect to suspension A, **characterized in** that a discharge conduit is provided for a suspension C, wherein by at least one device (114, 114', 116, 116') a flow is applied such that the flow velocity of the suspension C is greater than the sinking velocity of the particles P_C contained therein, and wherein at least one discharge conduit (112, 113) for the suspension C is arranged above the outlet (118) for the suspension B.

9. The apparatus according to claim 8, **characterized in** that the container (100) with its entire height cylindrically extends from its bottom to the top.

10. The apparatus according to claim 8 or 9, **characterized in** that by at least one partition wall (121, 122) the container (100) is divided into at least two chambers (101, 102, 103) not completely separated from each other.

11. The apparatus according to claim 10, **characterized in** that the chambers (101, 102, 103) are open in the lower region (104).

12. The apparatus according to any of claims 10 or 11, **characterized in** that the feed conduit (110) opens into the first chamber (101) in which gas escapes from the suspension by outgassing and can be withdrawn through a conduit

(111) and that at least one discharge conduit (112, 113) is provided for the suspension C in the region of at least one other chamber (102, 103).

13. The apparatus according to any of claims 10 to 12, **characterized in** that three chambers (101, 102, 103) are provided, wherein into one chamber (101) the feed conduit (110) for the suspension A opens and into the two other chambers (102, 103) discharge conduits (112, 113) for the suspension C are provided.

14. The apparatus according to claim 13, **characterized in** that the horizontal cross-sectional area of the second chamber relative to the horizontal cross-sectional area of the third chamber has a ratio of 2:3.

15. Use of the apparatus according to any of claims 8 to 14 for separating catalyst fine grain from a product stream of a Fischer-Tropsch synthesis.

16. Use of the apparatus according to any of claims 8 to 14 for separating deactivated catalyst from a product stream of a Fischer-Tropsch synthesis.

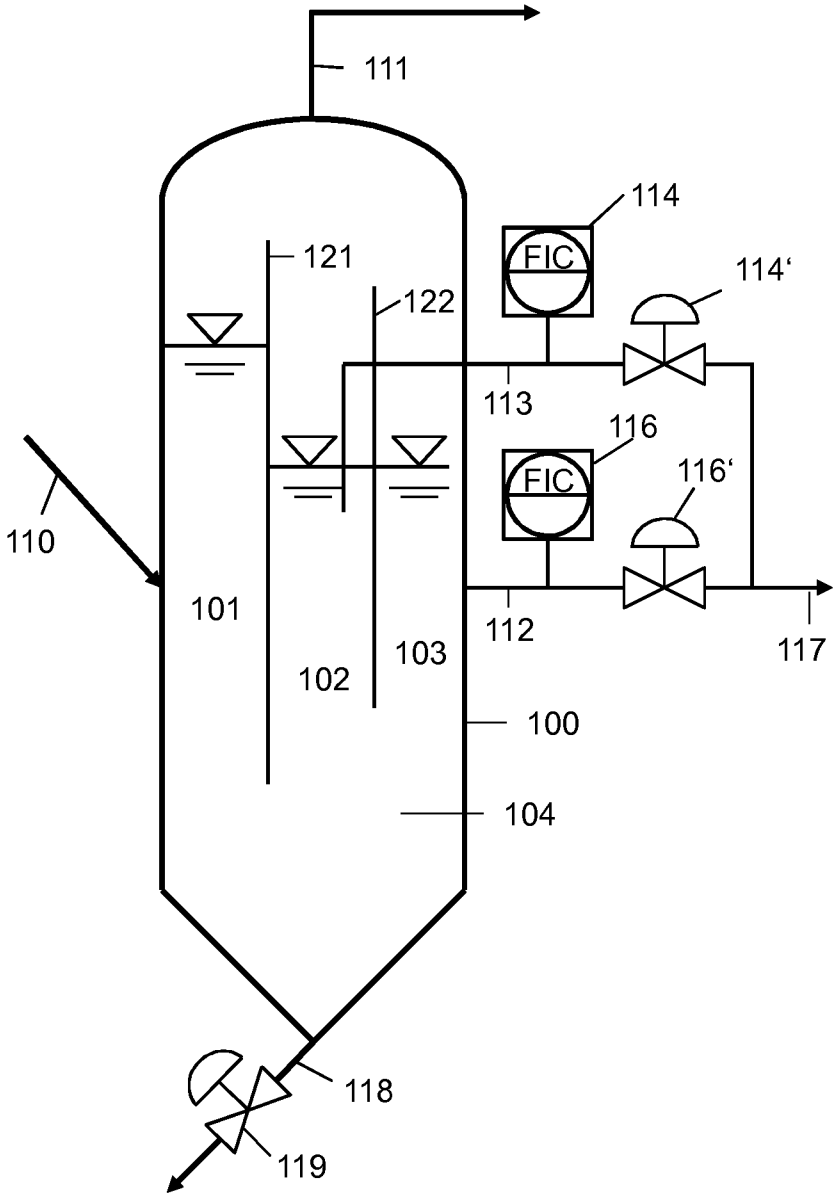

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114
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118
119

FIG. 1

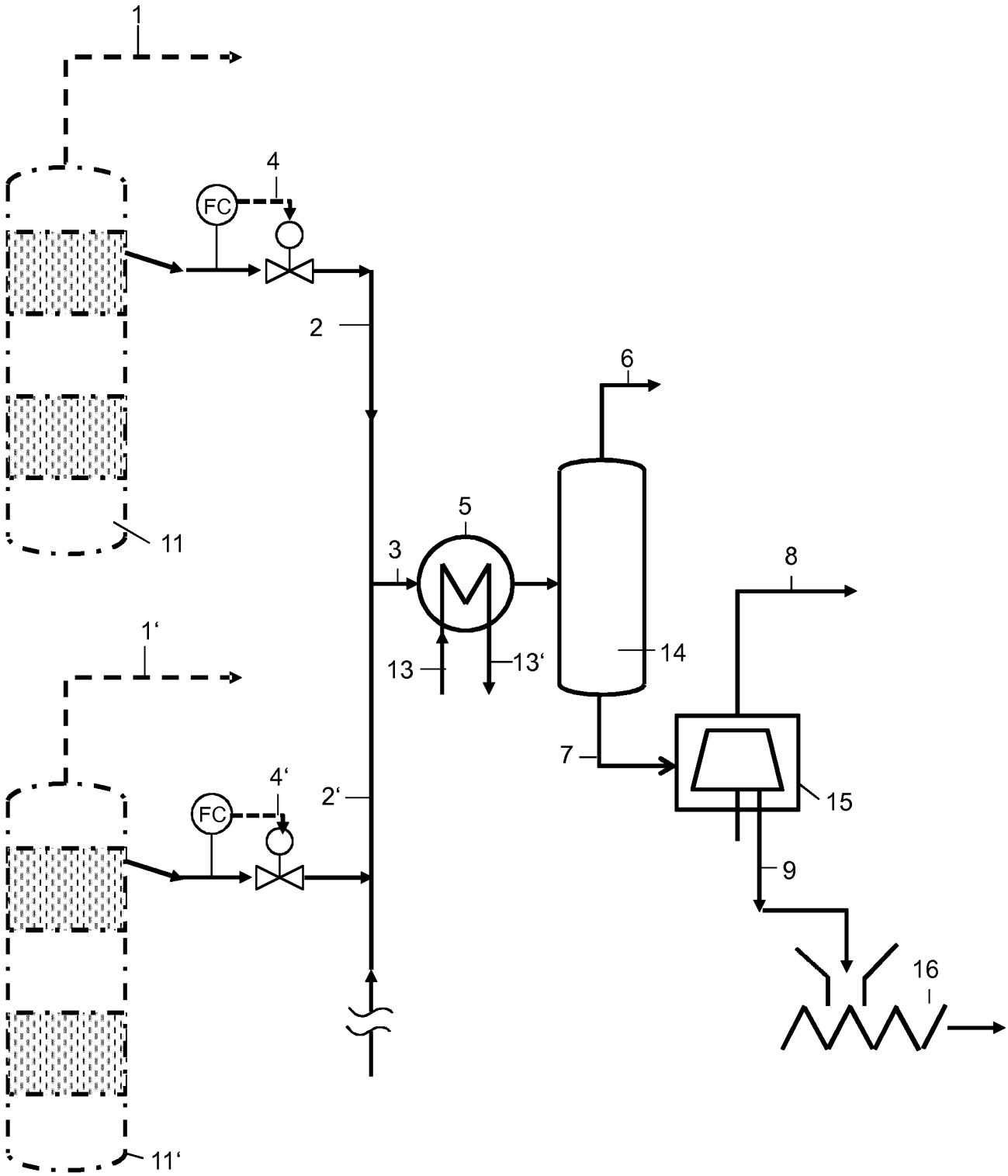


FIG. 2

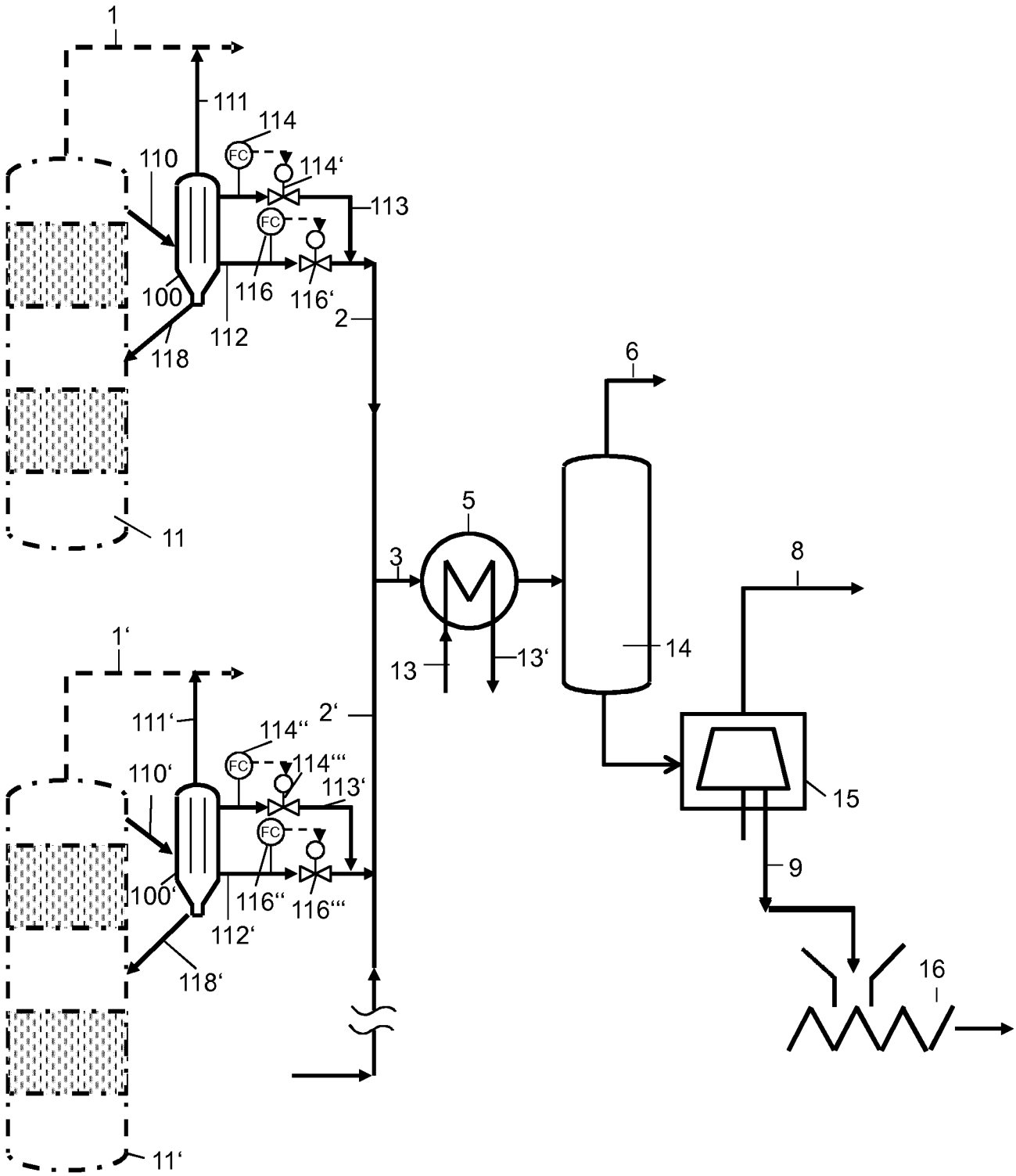

1
111
114
FC
114'
110
113
FC
100
116
116'
2
112
118
6
11
5
3
8
1'
13
13'
14
111'
114"
2'
FC
114'"
110'
113'
FC
100'
116"
116'"
15
9
112'
118'
16
11'

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/071863

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D21/00 B01D21/24 B01J8/00 B01J38/72 B03B5/62
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)
B03B B01D B01J

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.
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A	paragraph [0030] - paragraph [0041]; figures 1-3	13,14

X	US 2004/171702 A1 (ODUEYUNGBO OLUWASEYI A [US] ET AL) 2 September 2004 (2004-09-02)	1-12,15, 16
A	paragraph [0055] - paragraph [0089]; figures 2-6	13,14

X	WO 2014/156890 A1 (JAPAN OIL GAS & METALS JOGMEC [JP]; INPEX CORP [JP]; JX NIPPON OIL & E) 2 October 2014 (2014-10-02) the whole document	1-9,15, 16

X	US 5 770 629 A (DEGEORGE CHARLES W [US] ET AL) 23 June 1998 (1998-06-23)	1-12,15, 16
A	column 5 - column 6; figure 1	13,14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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
7 December 2016	22/12/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Roider, Josef

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/071863

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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