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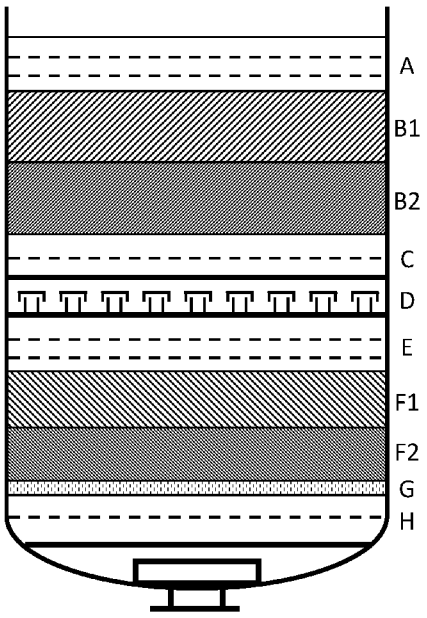
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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

(54) **Title:** REACTOR LOADING FOR EFFICIENT FLOW DISTRIBUTION

[Fig. 1]



(57) **Abstract:** The present disclosure relates to a reactor having an inlet above an outlet, containing a catalyst bed comprising multiple layers of material, in the following order from inlet to outlet, a first layer of material providing a flow resistance corresponding to a pressure drop per meter of dpm_1, a second layer providing a flow resistance corresponding to a pressure drop per meter of dpm_2, wherein the combined height of the first layer and the second layer is at least 4 m, wherein the height of the second layer is at least 0.5 m, wherein the pressure drop per meter of the second layer dpm_2 is at least 20% above the pressure drop per meter of the first layer dpm_1, and wherein the first layer, the second layer and optionally the third layer are supported by a single catalyst support. This has the associated benefit of providing an active redistribution of liquid flow, without the requirement of internals, except the single catalyst support under the multiple layers of catalyst.

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Description

Title of Invention: Reactor loading for efficient flow distribution

Technical Field

[0001] The present disclosure relates to the field of chemical engineering, and specifically to efficient management of flows in large fixed-bed reactors, such as trickle bed reactors.

Background Art

[0002] To ensure maximum employment of reactor volume in a catalytic reactor, efficient distribution of reactants and thermal energy is required, especially for large reactors.

[0003] Commonly mechanical equipment such as charge distributors are installed to redistribute the feed, product and energy, but such equipment is costly and takes up reactor space.

Summary of Invention

[0004] To enable efficient distribution of reactant and efficient use of reactor volume we propose loading catalytically active materials, such that a local resistance to flow, and thus a pressure drop, is created, in order to force increased radial distribution of flow. This resistance of flow is provided by having a reactor zone in which the flow resistance is lower, e.g. by smaller catalyst particles. As the flow enters the region of more resistance, radial diffusion will increase and the flow will be redistributed, such that the radial variation of composition and temperature is reduced.

Technical Problem

[0005] In a chemical reaction the availability of reactant, temperature and thermal energy defines the extent of reaction.

[0006] In many industrial applications, some or all reactants are typically in the liquid phase, and a suitable catalyst is required to facilitate the desired chemical reactions. In order to ensure that the reactants come into contact with the catalyst efficiently and uniformly, a liquid distributor is often used to distribute the reactants evenly across the catalyst bed.

[0007] A common reactor design is a vertical, cylindrical reactor, filled with catalytic particles, in which liquids and gases react. Commonly liquid reactants will enter at the top of such a reactor and exit at the bottom, while gaseous reactants may be either in co-flow or counter-flow. Theoretically, the distribution is uniform, due to the random loading of multiple small particles, but in practice, inflow or loading characteristics may result in regions with higher reaction, and even blockages, which may further increase the lack of uniformity in the reaction, by local conditions causing deposition of solids on the catalyst surfaces, hindering flows.

[0008] To minimize such maldistribution, it is common practice to redistribute the flowing gas and liquid at regular intervals, for example by providing the reactor with one or more mechanical redistribution trays along the cylinder axis. Such a tray will however take up reactor volume, and thus reduce the conversion capacity of the reactor, and therefore it is desirable to provide such redistribution, without sacrificing reactor volume.

[0009] The evaluation of redistribution is commonly made by evaluation of temperature gradients in a reactor, since temperature measurements are inexpensive and with rapid response, and for exothermal reactions the temperature measurement also reflects maldistribution and uneven reactivity.

[0010] US 3,732,078 discloses redistribution of reactor flow by a deflector followed by large size solid particles and evaluates the effect by evaluation of bulk catalyst performance.

[0011] US 9,732,774 follows a similar approach, in which a reactor comprises processing zones and a redistribution zone, in which the processing zones are illustrated as comprising large, high void, materials, and the effect is tested by distribution of water flow in a reactor.

[0012] Evaluation of such redistribution methods using an open redistribution zone made on reactors in operation have shown that the temperature variation across the reactor is unsatisfactorily high, and a way of enabling a lower radial temperature variation are desired.

Definitions

[0013] In the following a cylindrical catalytic reactor shall be construed as a mechanical unit having a central substantially cylindrical part positioned with a

substantially vertical axis, at least one inlet and one outlet position, and containing an amount of catalyst particles and optionally mechanical elements and non-catalytic particles. The substantially cylindrical part may be configured with upper and lower ends at which the inlet and outlet may be positioned. The ends may be dome shaped and the reactor may typically be prepared for elevated pressure up to several MPa. The reactor may have additional inlet and outlets commonly positioned at the perimeter of the cylinder. The reactor size may commonly be from 3 m diameter to 5 m diameter and the height may be from 10 m to 40 m or more.

[0014] The reactor may receive a one phase liquid or gaseous flow or it may be receiving or producing a two phase flow of liquid and gas.

[0015] If the reactor flow is a two phase flow the reactor may be of the type called trickle bed reactor in which a liquid and a gas are flowing in the same direction.

[0016] In the reactor multiple sensors may be positioned, especially temperature sensors. The radial temperature span is the maximum difference of temperature between sensors positioned at substantially same vertical (axial) position. The axial temperature span between different vertical positions is commonly calculated from the difference between two average values each determined at the similar vertical positions.

[0017] The invention is mainly of relevance for a redistribution in a bulk catalyst zone. A bulk catalyst is defined as a catalyst having less than 50% of the pore volume as measured by mercury intrusion porosimetry in macropores having a diameter above 100 nm.

[0018] Flows in cylindrical reactors may commonly be driven by an axial-adjective component and a radial-diffusive component. Axial-adjective flow shall be understood as flow from inlet to outlet along the cylinder axid of the reactor and driven by adjective forces. Radial-diffusive flow shall be understood as flow substantially orthogonal to the axial-adjective flow driven by diffusion and deflection of axial-adjective flow.

Solution to Problem

[0019] A typical trickle bed reactor, such as hydrotreating and hydrocracking reactors in which a liquid oil commonly reacts with gaseous hydrogen in the presence of

solid catalysts, may have a diameter of 3-5 m and a height of 40 m, but smaller and larger dimensions may also be found. For efficient operation, catalyst material is loaded in individual beds, with mechanical internal equipment facilitating mixing and gas/liquid contacting between the beds.

[0020] As mentioned, large reactor beds may cause poor bottom bed distribution occurring from axial flow phase separation. A design practice without long bed heights would eliminate this issue, but practical considerations, such as revamping existing plants, may cause a need for deviation from this practice.

[0021] To minimize the consequences of such large reactor beds, flow redistribution is desired. While the approach of distributing the flow by allowing open passages and guiding flow directions is tempting, the theory of trickle bed flow regimes must be considered to identify a working solution, and open passages will contribute minimally to distribution. The transport in a cylindrical trickle bed reactor will be axial-advective from top to bottom, driven by inlet pressure and gravity and radial-diffusive from center towards the reactor perimeter. The related Peclet number (Pe) for axial-advective-to-radial-diffusive transport is close to 12 for both gas and liquid at the typical Reynolds number (>10) in a hydrotreating or hydrocracking reactor.

[0022] To calculate the ratio of bed height (L) to bed diameter (L_d), the ratio between the two values is calculated from the Peclet number:

[0023] $$\frac{L}{L_d} = \sqrt{\frac{Pe}{4}} = \sqrt{\frac{12}{4}} = \sqrt{3} = 1.73$$

[0024] A redistribution zone which would provide full redistribution across a bed with diameter of 3 m, would thus require 3*1.73=5,2 m zone height. While the shape and orientation of particles may alter this ratio and the required zone height slightly, it will not have a redistribution effect of significance.

[0025] On the other hand, if a material with higher pressure drop is used, the forces of the increased pressure drop will cause the radial-diffusive transport to increase and the Peclet number to decrease, such that the full redistribution across a bed having a diameter of 3 m would require a lowering of the zone height required. Furthermore, by using such a low void material, the catalytically active volume in the reactor would not be reduced. If the top layer of the bed has a slightly higher

void than otherwise desired, and the lower layer has a lower void, this may even be accomplished without suffering an increase in pressure drop across the full bed.

[0026] A loading of catalyst layers with low pressure drops above catalyst layers with higher pressure drops is known from the so-called hold-down top layer above catalytic materials, where it serves a crude redistribution purpose as well as the purpose of avoiding lift of the fine catalyst particles. Hold-down layers are fulfilling a purely mechanical function and are commonly inert balls. In addition, grading at the inlet of catalytic reactors may also commonly be loaded with large particles above smaller particles. The objective of the grading is to collect impurities in the feed, including metals in organo-metallic compounds. Therefore, such a grading catalyst will have some catalytic activity, and in addition it will be designed for capturing solid material with minimal effect on the process. The grading catalyst will be a porous material which is dominated by large pores, in which metals may be deposited, and in addition a large particle size will also allow for depositing of impurities between the particles, without blocking the flow. Common pore sizes of such grading materials will be at least 50 % of the pore volume as measured by mercury intrusion porosimetry in macropores having a diameter above 100 nm. Common grading catalyst particle size will be above 5 mm (3/16”). A grading catalyst loading, will typically be characterized by one or more of the following involve catalysts having a significant pore volume in large pores, such as 50 % of the pore volume in pores having a radius above 500 Å, multiple small catalyst layers, each being less than 2000 mm and catalytically active materials of varying activity, such as a metal content differing by more than 20% between neighboring layers. Such a grading catalyst loading may be considered as not being a part of the present disclosure.

[0027] The present invention is related to the bulk catalyst of a process, which is smaller than the grading, such as less than 5 mm or 3 mm. Furthermore, the bulk catalyst may commonly have a minimum variation of activity and composition, such as metal content varying by less than 50 %, or less than 20%, or even being substantially identical. As the invention is especially relevant for hydrocracking processes, which are at risk of thermal runaway in the case of maldistribution, the catalyst may contain zeolite or other materials active in hydrocracking.

[0028] A practical consideration when considering catalysts of different sizes is the activity. For many processes the smaller catalyst particles result in higher practical activity, since the transport of reactants inside catalysts is not a limiting factor. Therefore, use of large particles may have a moderate reduced effect on overall activity. However, if the effect of the invention is obtained by a layer of material, moderately larger than commonly applied, followed by a layer, moderately smaller than commonly applied, the decreased activity of the first layer may be compensated by the second layer, such that the total activity and pressure drop will remain similar to that of a commonly designed catalyst loading.

Advantageous Effects of Invention

[0029] A first aspect of the present disclosure relates to a reactor having an inlet above an outlet, containing a catalyst bed comprising multiple layers of material, in the following order from inlet to outlet, a first layer of material providing a flow resistance corresponding to a pressure drop per meter of dpm_1, a second layer providing a flow resistance corresponding to a pressure drop per meter of dpm_2, wherein the combined height of the first layer and the second layer is at least 4 m, wherein the height of the second layer is at least 0.5 m, wherein the pressure drop per meter of the second layer dpm_2 is at least 20% above the pressure drop per meter of the first layer dpm_1, and wherein the first layer, the second layer and optionally further layers are supported by a single catalyst support.

[0030] This has the associated benefit of providing an active redistribution of liquid flow, without the requirement of internals, except the single catalyst support under the multiple layers of catalyst. The presented first and second layers are not excluding additional layers above, between or below the first and second layers in the catalyst bed, and additional catalyst beds and internals may also be present in the reactor.

[0031] A second embodiment of the present disclosure relates to a reactor of the first embodiment further comprising a third layer of porous material providing a flow resistance corresponding to a pressure drop per meter dpm_3, positioned below the second layer, wherein the material of the third layer comprises a porous refractory support and a catalytical active metal, wherein the pressure drop per

meter of the second layer is at least 20% above the pressure drop per meter provided by the third layer.

[0032] This has the associated benefit of providing an intermediate layer for redistribution, in between two layers with less total pressure drop.

[0033] A third embodiment of the present disclosure relates to the reactor of a previous embodiment wherein the material of the first layer, the material of the second layer or the material of the third layer if present, such as the material of multiple of these layers or all of these layers comprises a porous refractory support and a catalytical active metal.

[0034] This has the associated benefit of the redistribution being provided by materials supporting the catalytic reaction.

[0035] A fourth embodiment of the present disclosure relates to a reactor of a previous embodiment, wherein the shape of the reactor is substantially that of a vertical cylinder, with a ratio between the height of the first layer and the diameter being less than 4:1.

[0036] This has the associated benefit of providing a zone 1 within which the distribution is sufficient.

[0037] A fifth embodiment of the present disclosure relates to a reactor of a previous embodiment claim, wherein the shape of the reactor is substantially that of a vertical cylinder, with a ratio between the combined height of the first layer, the second layer and if present the third layer of porous material and diameter being more than 4:1, such as 5:1 or 6:1.

[0038] This has the associated benefit of enabling the efficient redistribution in a reactor bed, which is higher than traditional design limitations.

[0039] A sixth embodiment of the present disclosure relates to a reactor of a previous embodiment wherein shape of the reactor is substantially that of a vertical cylinder, with a ratio between the combined height of the first layer, the second layer and if present the third layer of porous material and diameter being less than 10:1, such as 8:1 or 7:1.

[0040] This has the associated benefit of enabling the efficient redistribution in a high reactor bed, which is within practical size limitations.

[0041] A seventh embodiment of the present disclosure relates to a reactor of a previous embodiment, wherein at least 50% of the porous material of at least one of the first layer, the second layer and if present the third layer, has an average dimension along the shortest axis being 0.1 mm, 0.5 mm, 1 mm to 3 mm or 5 mm and an average dimension along the longest axis relative to the average dimension along the shortest axis being from 1:1 to 20:1.

[0042] This has the associated benefit of such porous materials being well suited as catalysts. Alternative ratios may be at least 1.5:1 or 2:1. It may also be below the upper limit of 5:1, 10:1 or 15:1.

[0043] An eighth embodiment of the present disclosure relates to a reactor of a previous embodiment, wherein at least 50% of the porous material of at least one, such as multiple or all of the first layer, the second layer and if present the third layer if present, has a shape being quadrolobe, trilobe, ring shaped or cylindrical.

[0044] This has the associated benefit of such porous materials being well suited as catalysts, with a good local distribution of gas and liquid, reactants and products.

[0045] A ninth embodiment of the present disclosure relates to a reactor of a previous embodiment, wherein at least 50% of the porous material of at least one, such as multiple or all of the first layer, the second layer and if present the third layer, is an extruded material.

[0046] This has the associated benefit of such extruded materials being produced in a cost effective way.

[0047] A tenth embodiment of the present disclosure relates to a reactor of a previous embodiment, wherein the weight concentration of each catalytically active metal of the material of zone 1 and the material of zone 2 or if present zone 3 differs by less than 20% of the total weight concentration of catalytically active metals, but the size or shape is different between the zones.

[0048] This has the associated benefit of the reactor bed having a single catalytical functionality, while still supporting efficient distribution.

[0049] An eleventh embodiment of the present disclosure relates to a reactor of a previous embodiment, wherein the catalytically active metal of the material of

zone 1 and the material of zone 2 or if present zone 3 is active in hydrocracking, and optionally containing a zeolite or a molecular sieve.

[0050] As the invention is especially relevant for hydrocracking processes, which are at risk of thermal runaway in the case of maldistribution, the catalyst may contain zeolite or other materials active in hydrocracking.

[0051] A further aspect of the present disclosure relates to a method of flow redistribution in a fixed bed reactor having a liquid inlet above a liquid outlet, comprising the steps of providing a first layer of material positioned above a second layer of material in a single bed support by a single catalyst support, wherein the combined height of said first layer of catalyst and said second layer of catalyst is at least 4 m, wherein the height of the second layer is at least 0.5 m, wherein the pressure drop per meter over said second layer of material is at least 20% higher than the pressure drop per meter over said first layer of material.

[0052] This has the associated benefit of providing an active redistribution of liquid flow, without the requirement of internals, except the single catalyst support under the multiple layers of catalyst.

Brief Description of Drawings

[0053] [Fig.1] shows an example of the catalyst loading of a reactor according to the invention.

[0054] [Fig.2] shows an example of the catalyst loading of a reactor according to the invention.

[0055] [Fig.3] shows an example of the catalyst loading of a reactor according to the prior art.

[0056] Fig.4 shows the thermal performance of two beds in a reactor according to the invention.

Fig.1

[0057] [Fig.1] shows an example of the catalyst loading of the lower section of a reactor according to the invention. At the top is a void section, followed by a layer of inert material (A) to hold down lower layers, and ensure initial distribution. The combined height of A is 300 mm. Below this layer are two layers of active hydrocracking catalyst B1 and B2. B1 is 5500 mm of 1/8” trilobe shaped

extrudates and the estimated pressure drop over B1 is 0.08 bar/m. B2 is 5500 mm of 1/16" cylinder shaped extrudates having an estimated pressure drop of 0.15 bar/m. To retain the extrudates layer C of 150 mm inert ceramic balls are positioned on a catalyst support holding all of layers A, B1, B2 and C and positioned above a quench section receiving cool hydrogen with a bubble cap mixing zone and a void zone (here in total 370 mm, and commonly less than 500 mm). Below the mixing zone are two further inert layers totaling 300 mm; a layer of inert tablet shaped material to hold down lower layers, and ensure initial distribution and a layer of a further inert material for distributing the flow further and capturing impurities. Below these layers are two layers of a further active hydrocracking catalyst F1 and F2. F1 is 5500 mm of 1/8" trilobe shaped extrudates having an estimated pressure drop of 0.12 bar/m and F2 is 5500 mm of 1/12" quadrolobe extrudates having an estimated pressure drop of 0.18 bar/m. After this a layer (G) of 1350 mm hydrotreatment finishing catalyst (1/20" trilobe) is positioned, before the hold up layers of H, 1200 mm of three different sizes of inert ceramic balls positioned on a catalyst support.

Fig.2

[0058] [Fig.2] shows an example of the catalyst loading of the lower section of a reactor according to the invention. At the top is a void section, followed by a layer of inert material (A) to hold down lower layers, and ensure initial distribution. The combined height of A is 300 mm. Below this layer are three layers of active hydrocracking catalyst B1, B2 and B3. B1 is 4000 mm of 1/8" trilobe shaped extrudates and the estimated pressure drop over B1 is 0.08 bar/m. B2 is 3000 mm of 1/16" cylinder shaped extrudates having an estimated pressure drop of 0.15 bar/m. B3 is 4000 mm of 1/8" trilobe shaped extrudates and the estimated pressure drop over B1 is 0.08 bar/m. To retain the extrudates layer C of 150 mm inert ceramic balls are positioned on a catalyst support holding all of layers A, B1, B2 and C and positioned above a quench section receiving cool hydrogen with a bubble cap mixing zone and a void zone (here in total 370 mm). Below the mixing zone are two further inert layers totaling 300 mm; a layer of inert tablet shaped material to hold down lower layers, and ensure initial distribution and a layer of a further inert material for distributing the flow further and capturing impurities. Below these layers are two layers of a further active hydrocracking catalyst F1,

F2 and F3. F1 is 4000 mm of 1/8" trilobe shaped extrudates having an estimated pressure drop of 0.12 bar/m, F2 is 3000 mm of 1/12" quadrolobe extrudates having an estimated pressure drop of 0.18 bar/m and F3 is 4000 mm of 1/8" trilobe shaped extrudates having an estimated pressure drop of 0.12 bar/m. After this a layer (G) of 1350 mm hydrotreatment finishing catalyst (1/20" trilobe) is positioned, before the hold up layers of H, 1200 mm of three different sizes of inert ceramic balls positioned on a catalyst support.

[0059] Compared to the embodiment of Fig.1, this embodiment, may have an added complexity in the added layer, but the pressure drop will be lower, and the intermediate redistribution may provide a more uniform flow, throughout the three layers as a whole.

Fig.3

[0060] [Fig.3] shows an example of the catalyst loading of the lower section of a reactor according to the prior art. At the top is a void section, followed by a layer of inert material (A) to hold down lower layers, and ensure initial distribution. The combined height of A is 300 mm. Below this layer is a single layer of active hydrocracking catalyst B. B is 11000 mm of 1/12" trilobe shaped extrudates and the estimated pressure drop over B is 0.1 bar/m. To retain the extrudates layer C of 150 mm inert ceramic balls are positioned on a catalyst support holding all of layers A, B1, B2 and C and positioned above a quench section receiving cool hydrogen with a bubble cap mixing zone and a void zone (here in total 370 mm). Below the mixing zone are two further inert layers totaling 300 mm; a layer of inert tablet shaped material to hold down lower layers, and ensure initial distribution and a layer of a further inert material for distributing the flow further and capturing impurities. Below these layers are two layers of a further active hydrocracking catalyst F. F is 11000 mm of 1/10" trilobe shaped extrudates having an estimated pressure drop of 0.14 bar/m. After this a layer (G) of 1350 mm hydrotreatment finishing catalyst (1/20" trilobe) is positioned, before the hold up layers of H, 1200 mm of three different sizes of inert ceramic balls positioned on a catalyst support.

Fig.4

[0061] Fig.4 shows the thermal performance of two beds in a reactor according to the invention, both active in exothermal hydrocracking. The reactor contains smaller beds above the two major beds; an 11m hydrocracking bed (B; B1+B2) and an 11m hydrocracking bed (F; F1+F2). The two hydrocracking beds are configured as presented in Fig.1, with (B1) 5500 mm of a 1/8" trilobe hydrocracking catalyst above (B2) 5500 mm of a 1/16" cylinder hydrocracking catalyst in the first bed and with (F1) 5500 mm of a 1/8" trilobe hydrocracking catalyst above (F2) 5500 mm of a 1/12" quadrolobe hydrocracking catalyst in the second bed. For the first bed the average axial temperature increase is 27°C and the pressure drop 2.66 Bar; distributed as 0.93 Bar over B1 (0.08 Bar/m) and 1.74 Bar over B2 (0.16 Bar/m) while for the second bed the average axial temperature increase is 25°C and the pressure drop is 3.32 Bar; distributed as 1.30 Bar over F1 (0.12 Bar/m) and 2.01 Bar over F2 (0.18 Bar/m).

[0062] On the Y-axis of Fig.4, the radial temperature span in °C across the reactor is shown (dT_{rad}) and on the X-axis the ratio (dT_{rad}/dT_{ax}) between the radial temperature span in °C (dT_{rad}) across the reactor and the axial temperature span in °C (dT_{ax}) across the bed in %. Open symbols show the daily values for the first bed (C) and closed symbols show the daily values for the second bed (I). In both cases an initial stabilization period has been omitted, and the following 140 days are shown.

Examples

[0063] A hydrocracking reactor was loaded according to the scheme of Fig.1 and the radial temperature deviation of XX°C shown in Fig.4 was observed over a 140 day period for bed C. Similarly, the radial temperature deviation of XX°C for a loading scheme for bed I as shown in Fig.1, is depicted in Fig.4.

[0064] It can be seen that for bed C, the average radial temperature span is 4.3°C, which is 16% of the axial temperature increase and similarly for bed I, the average radial temperature span is 8.0°C, which is 32% of the axial temperature increase. Both of these values correspond to satisfactory distribution, and the current radial temperature span is about half of the previous performance, as indicated by two ellipses. The previous performance was obtained in a reactor loaded with an intermediate redistribution layer, and the redistribution was not

considered satisfactory, while the total pressure drop over each bed was slightly lower.

[0065] The results of the example show that by forcing a moderate increase in pressure drop, by use of smaller particles, it is possible to support a better flow and temperature distribution in a reactor bed, with more stable operation, and potentially increased catalyst lifetime.

Patent Literature

[0066] PTL1: US 3,732,078

[0067] PTL2: US 9,732,774

Claims

[Claim 1] A reactor having an inlet above an outlet, containing a catalyst bed comprising multiple layers of material, in the following order from inlet to outlet, a first layer of material providing a flow resistance corresponding to a pressure drop per meter of dpm_1, a second layer providing a flow resistance corresponding to a pressure drop per meter of dpm_2, wherein the combined height of the first layer and the second layer is at least 4 m, wherein the height of the second layer is at least 0.5 m, wherein the pressure drop per meter of the second layer dpm_2 is at least 20% above the pressure drop per meter of the first layer dpm_1, and wherein the first layer, the second layer and optionally further layers are supported by a single catalyst support.

[Claim 2] The reactor of claim 1 further comprising a third layer of porous material providing a flow resistance corresponding to a pressure drop per meter dpm_3, positioned below the second layer, wherein the material of the third layer comprises a porous refractory support and a catalytical active metal, wherein the pressure drop per meter of the second layer is at least 20% above the pressure drop per meter provided by the third layer.

[Claim 3] The reactor of claim 1 or 2 wherein the material of the first layer, the material of the second layer or the material of the third layer if present, such as the material of multiple of these layers or all of these layers comprises a porous refractory support and a catalytical active metal.

[Claim 4] The reactor of any preceding claim, wherein the shape of the reactor is substantially that of a vertical cylinder, with a ratio between the height of the first layer and the diameter being less than 4:1.

[Claim 5] The reactor of any preceding claim, wherein the shape of the reactor is substantially that of a vertical cylinder, with a ratio between the combined height of the first layer, the second layer and if present the third layer of porous material and diameter being more than 4:1, such as 5:1 or 6:1.

[Claim 6] The reactor of any preceding claim wherein shape of the reactor is substantially that of a vertical cylinder, with a ratio between the combined

height of the first layer, the second layer and if present the third layer of porous material and diameter being less than 10:1, such as 8:1 or 7:1.

[Claim 7] The reactor of any preceding claim, wherein at least 50% of the porous material of at least one of the first layer, the second layer and if present the third layer, has an average dimension along the shortest axis being 0.1 mm, 0.5 mm, 1 mm to 3 mm or 5 mm and an average dimension along the longest axis relative to the average dimension along the shortest axis being from 1:1 to 20:1.

[Claim 8] The reactor of any preceding claim, wherein at least 50% of the porous material of at least one, such as multiple or all of the first layer, the second layer and if present the third layer, has a shape being quadrolobe, trilobe, ring shaped or cylindrical.

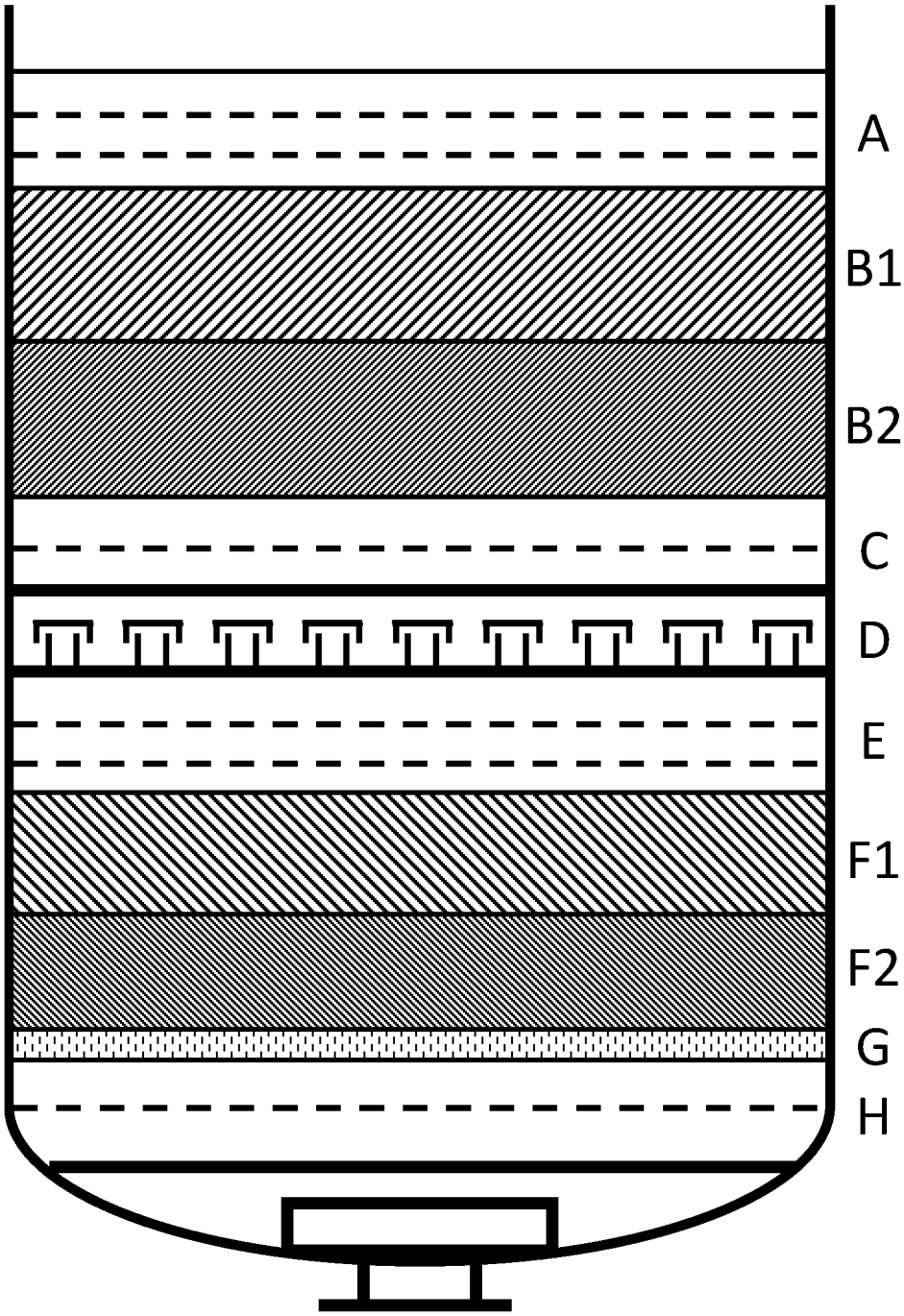
[Claim 9] The reactor of any preceding claim, wherein at least 50% of the porous material of at least one, such as multiple or all of the first layer, the second layer and if present the third layer, is an extruded material.

[Claim 10] The reactor of any preceding claim, wherein the weight concentration of each catalytically active metal of the material of the first layer, the material of the second layer and if present the material of the third layer differs by less than 20% of the total weight concentration of catalytically active metals, but the size or shape is different between the zones.

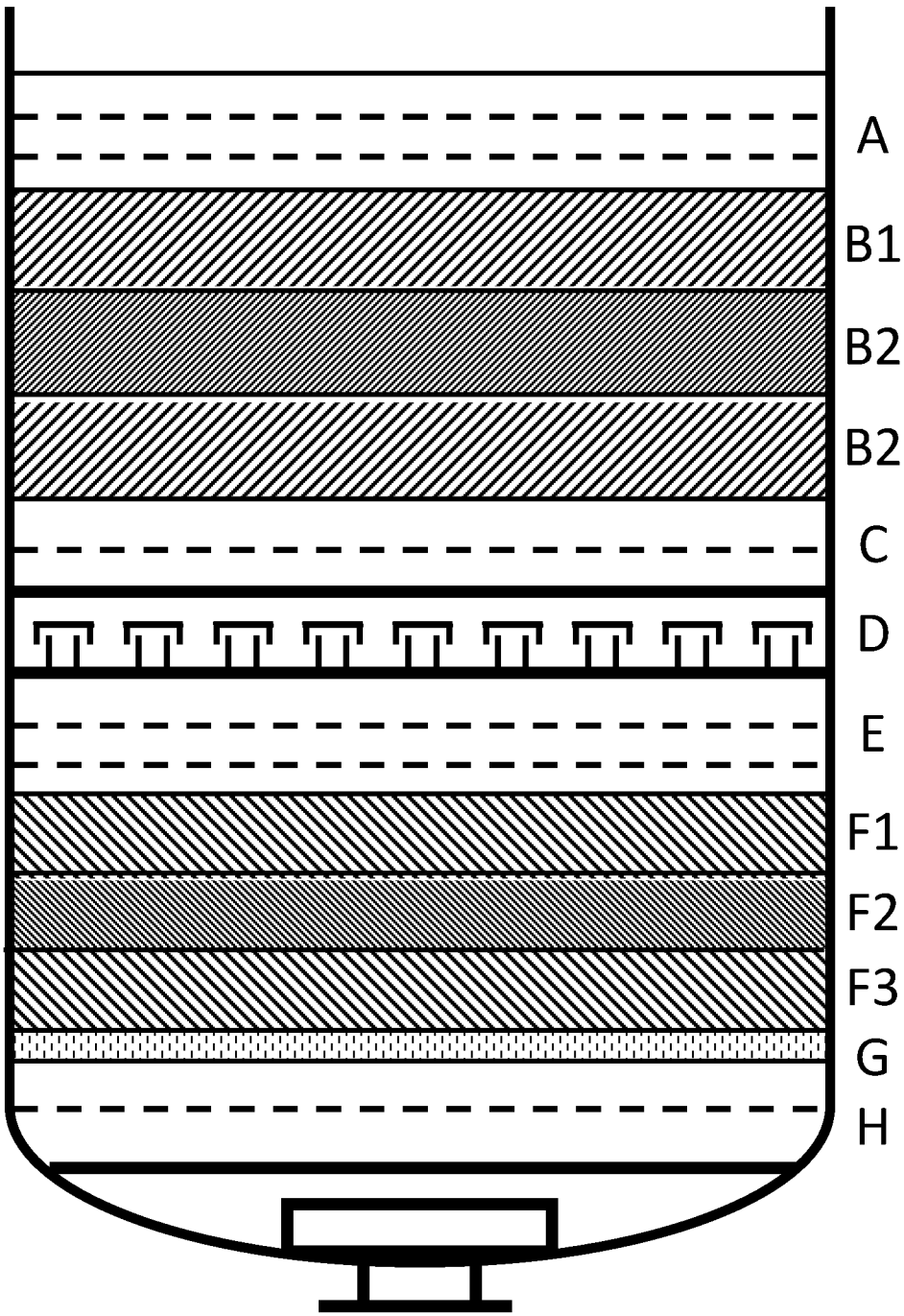
[Claim 11] The reactor of any preceding claim, wherein the catalytically active metal of the material of zone 1 and the material of zone 2 or if present zone 3 is active in hydrocracking, and optionally containing a zeolite or a molecular sieve.

[Claim 12] A method of flow redistribution in a fixed bed reactor having a liquid inlet above a liquid outlet, comprising the steps of providing a first layer of material positioned above a second layer of material in a single bed support by a single catalyst support, wherein the combined height of said first layer of material and said second layer of material is at least 4 m, wherein the height of the second layer is at least 0.5 m, wherein the pressure drop per meter over said second layer of material is at least 20% higher than the pressure drop per meter over said first layer of material.

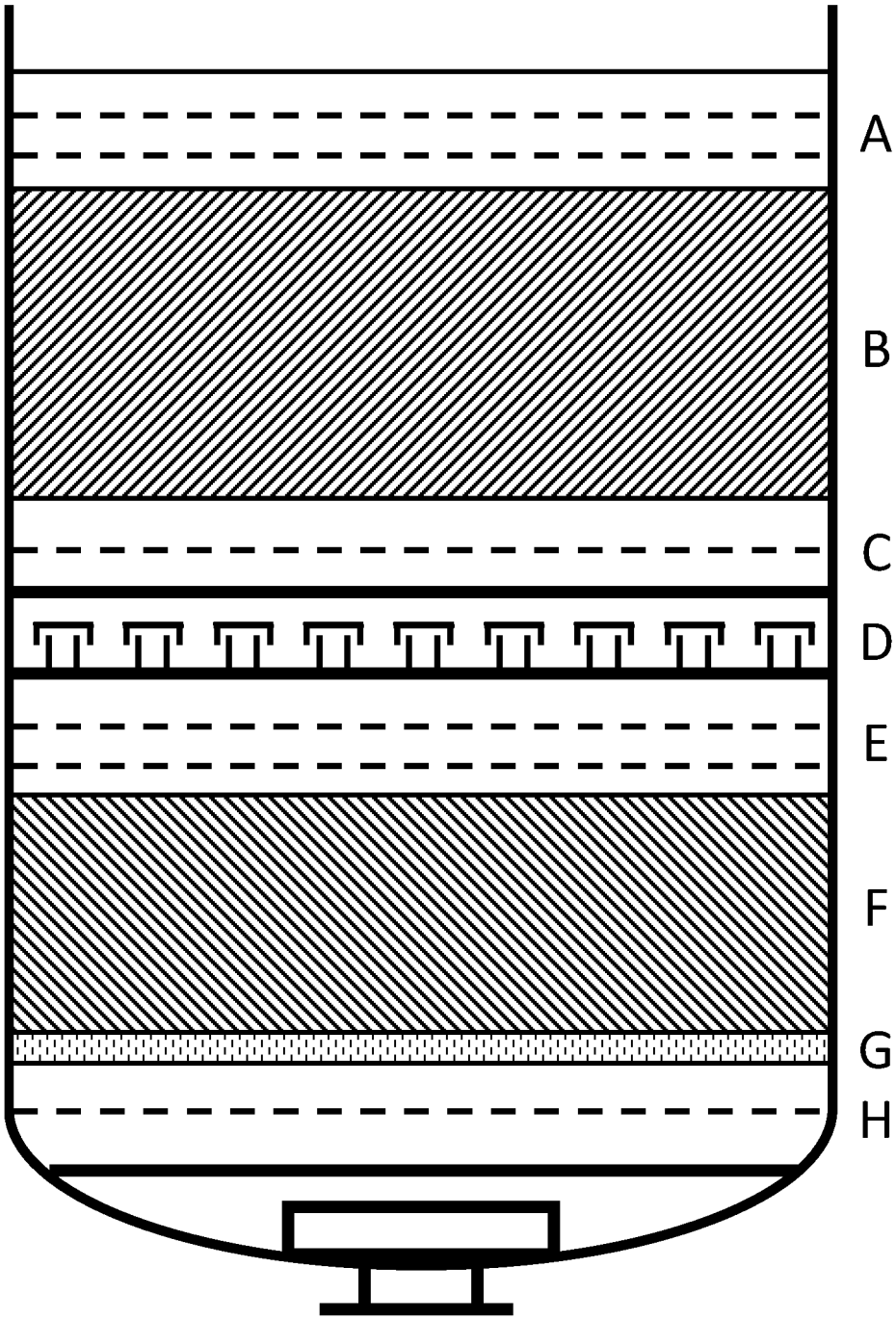
[Fig. 1]



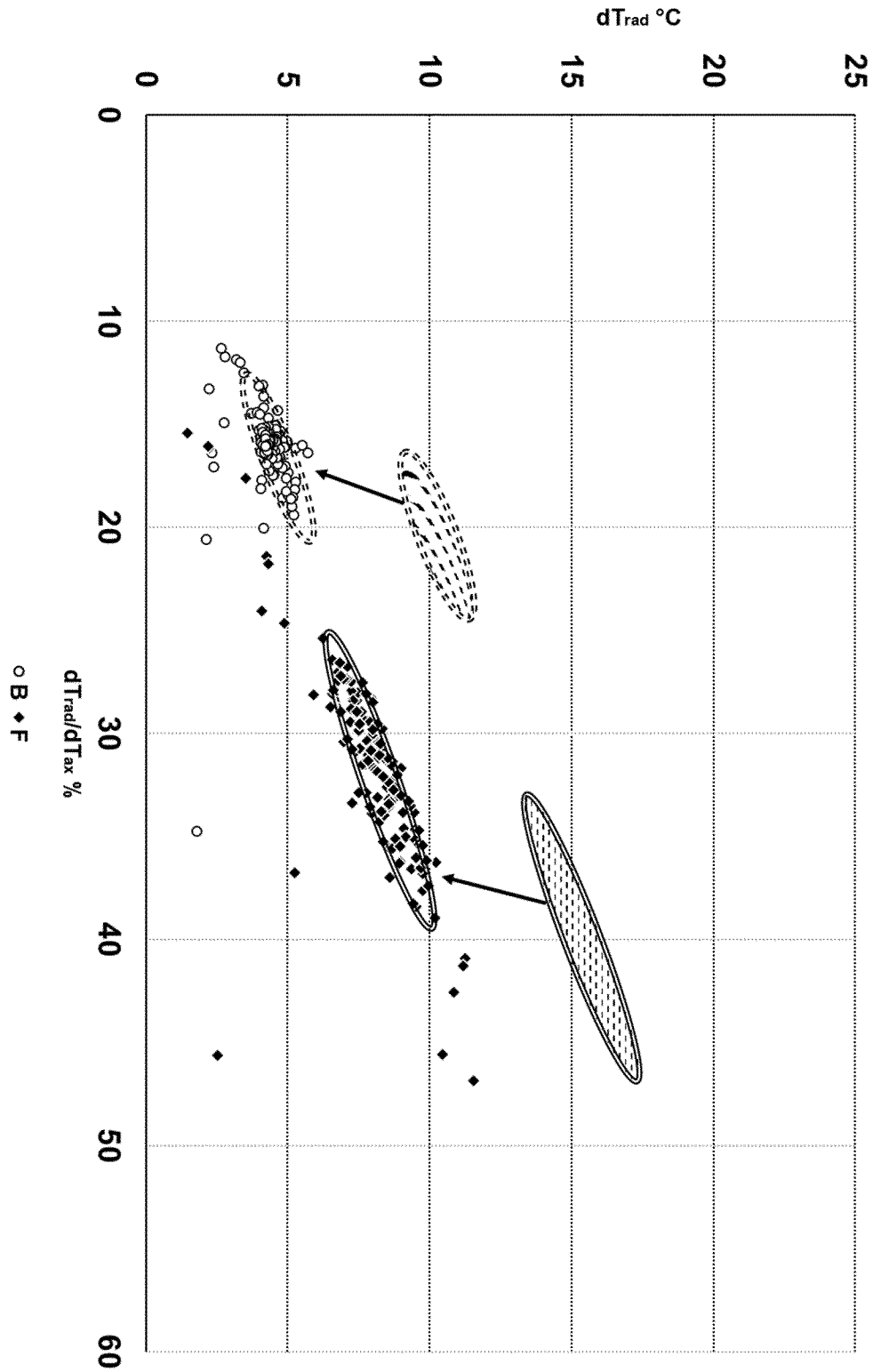
[Fig. 2]



[Fig. 3]



[Fig. 4]



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/069066

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01J8/02 B01J8/04 B01J19/30
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

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 2018/008952 A1 (GLOVER JOHN N [US] ET AL) 11 January 2018 (2018-01-11) paragraphs [0033], [0038], [0041] - [0043]; claims; figures	1-12
A	US 2019/217283 A1 (GLOVER JOHN N [US]) 18 July 2019 (2019-07-18) paragraphs [0008], [0011], [0079], [0085]; claims; figures	1-12
A	US 2010/209315 A1 (NIKNAFS HASSAN S [US] ET AL) 19 August 2010 (2010-08-19) paragraphs [0015], [0023], [0032]; claims; figures	1-12

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

[x] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 October 2024	28/10/2024

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	Serra, Renato

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2008/164625 A1 (NIKNAFS HASSAN S [US] ET AL) 10 July 2008 (2008-07-10) paragraph [0013]; claims; figures	1-12

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