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(54) Title: REACTIVE FLOW STATIC MIXER WITH CROSS-FLOW OBSTRUCTIONS

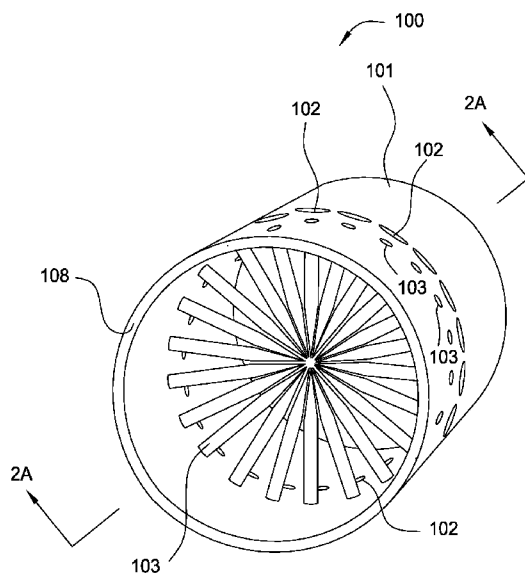


FIG. 2B

(57) Abstract: Embodiments of the present invention relate to a mixing apparatus. Particularly, embodiments of the present invention provide a mixing apparatus for mixing fluid components such as phosgene and amine during a highly reactive chemical reaction. One embodiment provides a mixing conduit (100) comprising a cylindrical sidewall (101) defining an inner volume, wherein one or more jets are formed through the cylindrical sidewalls and connect to the inner volume and one or more flow obstructions (103) disposed in the inner volume, wherein each flow obstruction is positioned upstream from an associated aperture (102).



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REACTIVE FLOW STATIC MIXER WITH CROSS-FLOW OBSTRUCTIONS

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention relate to a mixing apparatus for mixing fluid components, such as the mixing of phosgene and amine in a reactive chemical process.

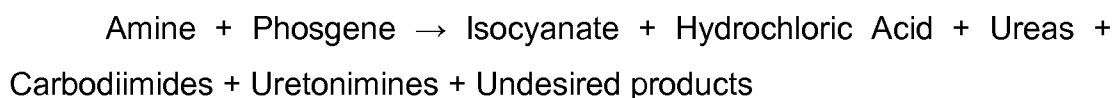
Description of the Related Art

[0002] The field of conventional mixing devices can be roughly divided into two main areas: dynamic or mechanical mixers and static mixers. Dynamic or mechanical mixers rely on some type of moving part or parts to ensure the desired or thorough mixing of the components. Static mixers generally have no prominent moving parts and instead rely on flow profiles and pressure differentials within the fluids being mixed to facilitate mixing. The current disclosure is mostly directed to a static mixer but could also be used in combination with dynamic mixers.

[0003] Isocyanates are molecules characterized by $\text{N}=\text{C}=\text{O}$ functional groups. The most widely used isocyanates are aromatic compounds. Two aromatic isocyanates are widely produced commercially, namely, toluene diisocyanate (TDI) and methylene diphenyl diisocyanate (MDI). Isocyanates may be reacted with polyols to form polyurethanes. Major polyurethane applications are rigid foams, which are good insulators and are heavily used in appliance, automotive and construction businesses; and flexible foams which may be used in mattresses and furniture applications. In addition aliphatic isocyanates such as hexamethylene diisocyanates are also widely produced and used in special applications such as abrasion and UV resistant coatings.

[0004] Mixing is important in isocyanate production. The isocyanate product quality and yield are dependent on a multistep chemical reaction network. In the first step of the process, two continuous streams of reactants (amine and phosgene) are mixed. Secondary reactions like the reaction between phosgenation products

and amine to form ureas and other urea derivatives ultimately reduce the quality of the product composition. While the production of isocyanates is desired, secondary reactions lead to the creation of undesired products. Some of these secondary reactions are believed to create products such as ureas and urea derivatives like carbodiimides, and uretonimines. The overall chemical reaction can be depicted as follows:



[0005] While many known and unknown factors control the quality of the principal reaction, an increase of the ratio of phosgene to amine, a dilution of amine in a solvent, or an improved mixing minimizes the formation of undesired by-products. Some of the undesired byproducts may be solids and may be associated with fouling in process equipment.

[0006] Consequently, mixer designs with improper mixing can result in lower overall yield of the desired product or can generate a product that clogs or fouls the reactor system leading to down time and/or increased maintenance costs.

[0007] Figure 1 schematically illustrates phosgene concentration within a static mixer of the prior art. Figure 1 illustrates a partial sectional view of a cylindrical conduit 3 where a phosgene flow 1 goes from the left to the right and an amine flow 2 is injected into the phosgene flow 1 from a jet 4 formed through the cylindrical conduit 3. As amine traverses and reacts with the phosgene, principal and secondary reactions occur. A circle 5, which is located at the distance L where amine flow 1 enters, illustrates a region on the downstream side of the jet 4 where the phosgene concentration is relatively low (near zero). Because phosgene and amine reactions are exothermic, the regions surrounding circle 5 have increased temperature. The low concentration of phosgene and increased temperature promote the formation of undesirable secondary reactions and production of by-product.

[0008] It would be desirable to have a static mixer that improves phosgene and amine mixing thus limiting the production of undesired by-products.

SUMMARY OF THE INVENTION

[0009] Embodiments of the present invention relate to a static mixing apparatus that can be used alone or in combination with dynamic mixers.

[0010] One embodiment of the static mixing apparatus provides a mixing conduit comprising a cylindrical sidewall defining an inner volume, wherein one or more jets are formed through the cylindrical sidewalls to the inner volume and one or more flow obstructions are disposed in the inner volume, wherein each flow obstruction is aligned upstream from an associated aperture to improve the cross flow with respect to jet penetration, and jet mixing and reduce backmixing in the mixing conduit.

[0011] Another embodiment of the present invention provides a static mixer comprising one or more fluid receiving conduits defining one or more outer walls of an annular chamber and a mixing conduit of the present invention disposed in a first conduit to define at least an inner wall of the annular chamber, wherein the annular chamber is in fluid communication with the one or more jets of the mixing conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0013] Figure 1 schematically illustrates phosgene concentration within a static mixer of prior art used in mixing phosgene and amine.

[0014] Figure 2A is a partial sectional view of a mixing conduit for a static mixer according to one embodiment of the present invention.

[0015] Figure 2B is a perspective view of the mixing conduit of Figure 2A.

[0016] Figure 3 is a sectional view of a static mixer according to one embodiment of the present inventions.

[0017] Figures 4A-4D schematically illustrate various embodiments of mixing conduits having obstructions mounted at different configurations.

[0018] Figures 5A-5G schematically illustrate various embodiment of obstructions for using in a mixing conduit such that the shape of the obstructions in radial direction further streamlines the cross-flow according to embodiments of the present invention.

[0019] Figures 6A-6D schematically illustrate various mechanisms for mounting obstructions in a mixing conduit according to embodiments of the present invention.

[0020] Figures 7A-7B schematically illustrate a mixing conduit with various configurations near a center axis according to embodiments of the present invention.

[0021] Figure 7C illustrates mounting of flow obstructions on a torpedo shaped central obstruction.

[0022] Figures 8A-8C schematically illustrate various mixing conduits having a central disk coupled to flow obstructions in vane like shapes directing the cross-flow according to embodiments of the present invention.

[0023] Figure 9 schematically illustrates a mixing conduit with multiple rows of obstructions according to one embodiment of the present invention.

[0024] Figures 10A-10D schematically illustrate mixing conduits having complex jets designs according embodiments of the present invention.

[0025] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

[0026] Embodiments of the present invention relate to a static mixing apparatus for mixing components, in applications with or without chemical reactions, where mixing is rate-limiting step and may cause undesired product formation. Particularly, embodiments of the present invention provide a mixing apparatus for mixing fluid components such as phosgene and amine during a highly reactive chemical reaction.

[0027] Static mixers of the present invention are designed to provide rapid mixing in industrial reactive processes, such as the reaction of MDA with phosgene to form MDI. Embodiments of the present invention provide static mixers that enable the phosgene to engulf the amine stream and minimize secondary reactions. The energy used to mix the fluid comes from the pressure drop in a mixing device. Static mixers of the present invention improve jet mixing process which enables increased production rates while maintaining reasonable pressure drop and improving product quality.

[0028] Embodiments of the present invention create a velocity profile in a first flow, typically a main cross-flow, as the first flow passes through a conduit and intersects with a second flow injected into the conduit by one or more jets formed through the conduit. In one embodiment, the velocity profile in the first flow is made by one or more flow obstructions placed upstream in the conduit. The one or more flow obstructions direct the first flow, such as phosgene, around the second flow, such as amine. The flow obstructions minimize the phosgene-deficient regions close to the amine jets and let the phosgene better engulf the amine stream.

[0029] One embodiment of the present invention provides a static mixer having a conduit with at least one aperture formed through a circumference of the conduit, and at least one obstruction disposed in the conduit upstream to the at least one aperture. During mixing, a first flow component flows through the conduit passing the at least one obstruction then encounters a second flow entering the conduit through the associated at least one aperture.

[0030] Figure 2A is a partial sectional view of a mixing conduit 100 for a static mixer according to one embodiment of the present invention. Figure 2B is a perspective view of the mixing conduit 100 of Figure 2A.

[0031] The mixing conduit 100 comprises a cylindrical sidewall 101 defining an inner volume 107. A first flow 105 is configured to enter the inner volume 107 from an inlet end 108 of the mixing conduit 100. The mixing conduit 100 has a central axis 106.

[0032] A plurality of apertures 102 are formed through the cylindrical sidewall 101 around a circumference of the mixing conduit 100. The plurality of apertures 102 are configured to inject a second flow 104 to the inner volume 107 of the mixing conduit 100. In one embodiment, the plurality of apertures 102 are evenly distributed around the circumference of the mixing conduit 100.

[0033] Figure 2A shows that each aperture 102 has a tapered shape. The tapered shape of the apertures 102 create a velocity profile in the second flow 104 as the second flow 104 enters the mixing conduit 100 so that the second flow 104 can penetrate closer to the central axis 106. However, other designs of the aperture 102 may also be used. U.S. Patent Application No. 11/658,193, filed July 7, 2005, published as US Publication 2008/0087348, having a least partial common inventorship and directing to a static mixer having tapered apertures, is incorporated herein by reference.

[0034] The mixing conduit 100 further comprises a plurality of spokes 103 disposed between the plurality of apertures 102 and the inlet end 108 of the mixing conduit 100. Each of the plurality of spokes 103 is aligned with an associated aperture 102 to create a flow obstruction in the first flow 105 before the first flow reaches the associated apertures 102.

[0035] In one embodiment, the plurality of spokes 103 are inserted into the mixing conduit 100 through the cylindrical sidewall 101. Each spoke 103 may have an inner end 103₁ and an outer end 103₂. The inner end 103₁ is smaller than the outer end 103₂ so that after the inner end 103a enters the mixing conduit 100 by

penetrating the cylindrical sidewall 101, the outer end 103₂ plugs the opening to seal the mixing conduit 100. Because each spoke 103 is directly aligned with an associated aperture 102, the spoke 103 creates a first flow velocity decrease upstream of the entrance of the second flow 104 from each aperture 102, therefore, allowing the second flow 104 to penetrate deeper inside the inner volume 107 and improving mixing.

[0036] Various factors may be adjusted to improve mixing according to the processing condition. For example, the distance 109 between the apertures 102 and the spokes 103, the size of each spoke 103, mounting angle of the spokes 103, the length of each spoke 103, the shape of the spoke 103, the design of the associated aperture 102, can be adjusted.

[0037] During mixing, the first flow 105 enters the mixing conduit 100 from the inlet end 108 and encounters the plurality of spokes 103. The plurality of spokes 103 mask the second flow 104 downstream from the cross-flow of the first flow 105 and increase the velocity of the first flow 105 in the spaces between the second flow from the apertures 102.

[0038] Figure 3 is a sectional view of a static mixer 150 according to one embodiment of the present. The static mixer 150 defines a cross-flow chamber formed by a second-flow conduit 155 attached within a first-flow conduit 153 having a longitude axis 156. A mixing conduit 100, as shown in Figure 2A, is disposed in the first-flow conduit 153 so that the mixing conduit 100 is co-axial with the first-flow conduit 153 and the plurality of apertures 102 fluidly connect the second-flow conduit 155 and the inner volume 107 of the mixing conduit 100. The mixing conduit 100 defines at least an inner wall of the annular chamber formed by conduit walls 154 and 155, wherein the annular chamber is in fluid communication with the one or more jets of the mixing conduit 100. The mixed flow 157 exits through an outlet end 158 of the first-flow conduit 153 co-axial with mixing conduit 100.

[0039] The mixing conduit 100 isolates the first-flow conduits 153 from the second-flow conduit 155 so that the second flow 104 can only mix with the second flow 105 via the plurality of apertures 102 in the mixing conduit 100. The first flow

105 enters the mixing conduit 100 from the inlet end 152 of the first-flow conduit 153, passes the plurality of spokes 103, then mixes with the second flow 104 entering the mixing conduit 100 from the second conduit 155 through the plurality of apertures 102. The mixed flow 157 exits the mixing conduit 100 through the outlet end 158. In one embodiment the flow area within first-flow conduit 153 may be varying to impart, for example a reducing and expanding flow profile.

[0040] It should be noted that the mixing conduit 100 may be used with other mixing devices. Various mixing conduits may be used with a static mixer of the present invention.

[0041] Figures 4A-4D schematically illustrate various embodiments of mixing conduits having various obstructions mounted at different angles.

[0042] Figure 4A illustrates a mixing conduit 100a similar to the mixing conduit 100 of Figure 2A. The mixing conduit 100a having a plurality of spokes 103a mounted parallel to a plane 110 that is perpendicular to the central axis 106 of the mixing conduit 100a. Figure 4B illustrates a mixing conduit 100b having a plurality of spokes 103b mounted at an angle α relative to the plane 110. The ends of the plurality of spokes 103b are angled towards the downstream direction. Figure 4C illustrates a mixing conduit 100c having a plurality of spokes 103c mounted at an angle β relative to the plane 110. The ends of the plurality of spokes 103d are angled towards the upstream direction. Figure 4D illustrates a mixing conduit 100d having a plurality of curved spokes 103d mounted relative to the plane 110. The plurality of spokes 103d are angled towards the upstream direction at the outer region of the conduit 100d and angled towards the downstream direction near the center of the conduit 100d. The angled orientation in conjunction with the shape of the obstructions can further provide improved cross-section interaction between the first flow and the second flow.

[0043] Figures 5A-5G schematically illustrate various embodiments of spokes for using in a mixing conduit according to embodiments of the present invention. Each Figure 5A-5G includes a sectional view and a top view of a spoke. Figure 5A illustrates a spoke 203a having a circular crosssection and a partially tapered end.

Figure 5B illustrates a spoke 203b having an oval cross-section and a partially tapered end without a head. Figure 5C illustrates a spoke 203c having a triangular cross-section. Figure 5D illustrates a spoke 203d having a diamond shaped cross-section. Figure 5E illustrates a spoke 203e having a diamond cross-section (kite shaped) without any tapered end. Figure 5F illustrates a spoke 203f having a tear-drop shaped cross-section and a fully-tapered shape. Figure 5G illustrates a spoke 203g having an oval cross-section and the spoke 203f is larger at an inner end than an outer end.

[0044] Figures 6A-6D schematically illustrate various mechanisms for mounting obstructions in a mixing conduit according to embodiments of the present invention. In Figure 6A, the spokes 103 are simply inserted into the sidewall 101 of the mixing conduit 100 and secured therein. The spoke 103 has an increased diameter on the one end (103b) attached to mixing conduit 100 in Figure 2A to prevent it from being moved into the mixing conduit 100. In Figure 6B, the plurality of spokes 103 are coupled to a center ring 111 inside the mixing conduit 100. The center ring 111 holds the plurality of spokes 103 in place. In one embodiment, the center ring 111 may be a center plate as shown in Figure 7B. In Figure 6C, two concentric center rings 111, 112 inside the mixing conduit 100 are used to secure the plurality of spokes 103. In Figure 6D, a retaining ring 113 disposed outside the sidewall 101 is used to prevent the spokes 103 from popping out of the mixing conduit 100.

[0045] Figures 7A-7C schematically illustrate mixings conduit with various configurations near a center axis according to embodiments of the present invention.

[0046] Figure 7A illustrates a mixing conduit 200a having a plurality of spokes 203 positioned upstream to a plurality of apertures 202. The spokes 203 do not reach a central axis 206 of the mixing conduit 200a leaving a circular gap 210 near a center region in the mixing conduit 200a. There is no obstruction to cross-flow 205 near the center of the mixing conduit 200a.

[0047] Figure 7B illustrates a mixing conduit 200b having a disk 211 secured to the plurality of spokes 203 near the center of the mixing conduit 200b. A side view of the mixing conduit 200b is shown in Figure 8A. The disk 211 not only secures the

spokes 203 but also provides additional obstructions to the cross flow 205. The obstruction from the disk 211 further increases the velocity of the cross flow 205 because of reduced cross-sectional area in the mixing conduits 200b. The disk 211 also creates a deficit of the cross flow 205 near the central axis 206 to improve mixing in the situations when the flow from aperture 202 cannot reach the central axis 206. In one embodiment, a retaining ring 213 is disposed outside a cylindrical wall 201 of the mixing conduit 200b for securing the spokes 203.

[0048] Figure 7C illustrates a mixing conduit 200c having a streamlined axial flow obstruction or a torpedo 212 secured to the plurality of spokes 203 near the center of the mixing conduit 200c. The torpedo 212 may have a cylindrical middle section and tapered ends. The torpedo 212 provides the same function as the disk 211 in Figure 7B. Additionally, the torpedo 212 also provides obstruction along a longitude of the mixing condition 200c so that the effect of obstructions from the spokes 203 and torpedo 212 extends further downstream. Detailed description of the torpedo design may be found in U.S. Patent Application No. 12/725,262 filed on March 16, 2010, by at least a partial common inventorship, which is incorporated herein by reference.

[0049] Figures 8A-8C schematically illustrate various mixing conduits having a central disk coupled to obstructions according to embodiments of the present invention. When a central disk, such as disk 211 in Figures 8A and 7B, is used, various spokes may be used to provide a tailored function. In Figure 8A, straight spokes 203₁ with tapered shape are coupled to the disk 211 in the mixing conduit 200_b. In Figure 8B, curved vanes 203₂ are used in a mixing conduit 200_c. In Figure 8C, expanding and contracting vanes 203₃ are used in a mixing conduit 200_d. These vanes act as flow directors and can be designed to provide an advantageous velocity profile.

[0050] Figure 9 schematically illustrates a mixing conduit 300 with complex obstructions according to one embodiment of the present invention. Two or more sets of spokes may be used in the mixing conduit 300. As shown in Figure 9, two sets of spokes 303a, 303b are disposed upstream to a plurality of apertures 302

formed through sidewall 301 of the mixing conduit 300. In one embodiment, each spoke 303a, 303b may be aligned with the perspective aperture 302. In another embodiment, the spokes 303a, 303b may be such that the spokes are not exactly aligned with respect to each other. In further embodiments, the sets of spokes vary in shape and/or dimension.

[0051] Embodiments of spokes described above may be used in combination of various aperture designs. Figures 10A-10D schematically illustrate mixing conduits having complex jets according to embodiments of the present invention.

[0052] Figure 10A schematically illustrates a sectional view of a mixing conduit 400a having a plurality of spokes 403 positioned upstream to two sets of apertures 402a, 402b. The aperture 402a is positioned upstream to the apertures 402b, which may be used to cool and or dilute the second flow with a solvent or with components in main flow. A cross flow 405 will be mixed with two sets of jet stream 411, 412 from the apertures 402a, 402b respectively at different longitudinal locations. The plurality of spokes 403 provide obstructions to both sets of apertures 402a, 402b.

[0053] Figure 10B schematically illustrates a sectional view of a mixing conduit 400b having a plurality of spokes 403 positioned upstream to two sets of apertures 402c, 402d. The apertures 402c are formed inside the apertures 402d. Jet stream 413 from the apertures 402c may have different flow rate than jet stream 414 from the aperture 402d, which may be used to cool and or dilute the second flow with a solvent or with components in main flow. A cross flow 405 will be mixed with two sets of jet stream 413, 414 at substantially the same longitudinal locations. The plurality of spokes 403 provide obstructions to both sets of apertures 402c, 402d.

[0054] Figure 10C schematically illustrates a sectional view of a mixing conduit 400c having a plurality of spokes 403 positioned upstream a plurality of apertures 402e relatively angled to a plane 410 perpendicular to the central axis 406 of the mixing conduit 400c.

[0055] Figure 10D schematically illustrates a sectional view of a mixing conduit 400d having a plurality of spokes 403 positioned upstream to two sets of apertures 402e, 402f. The mixing conduit 400d is similar to the mixing conduit 400a except the apertures 402e and 402f are tilted at different angles.

[0056] Detailed description of other jets that may be combined with obstructions described herein may be found in U.S. Patent Application No. 12/725,266 filed on March 16, 2010, by at least a partial common inventorship, which is herein incorporated by reference.

Example

[0057] Embodiments of the present inventions are used in mixing phosgene as the first flow with amine as the second flow as in MDI production process. The static mixer's performance is determined by the level of undesirable by-products, such as uretoneimines, and the pressure losses in the static mixer. In one embodiment, the second flow comprises at least one of methylene diphenyl diamine, toluene diamine, and hexamethylene diamine. Mixing conduits with flow obstructions according to embodiments of the present invention modifies velocity profiles in the first flow such that an amount of ureas, carbodiimides, and uretonimines formed are less than in a method where no obstructions are disposed in the inner volume. A comparison of performance of several mixers is given in Table 1.

[0058] For the mixers showing in Table 1, the number, size and shape of the amine jets were held constant. Option 1 represents the prior art with no upstream flow obstruction, as shown in Figure 1. Option 2 represents the mixer shown in Figure 7B. Option 2 reduces the undesired by-product, uretonimine, with only a slight change in the pressure loss of the cross-flowing phosgene stream compare to option 1. Option 3 represents the design shown in Figure 7A. Option 3 has less improvement in uretonimine levels but the change in pressure drop is also smaller. Option 4 is the spike mixer shown in Figures 2A-2B. Option 4 results in a higher reduction in uretonimine compared with the previous Options 2 and 3. Option 5 represents the design shown in Figure 7C. Option 5 gives both the lowest

uretonimine but also has the greatest phosgene pressure drop due to the dominant obstruction of the central cross- flow.

Table 1. Relative Comparison of Selectivity and Pressure Drop

	Option 1	Option 2	Option 3	Option 4	Option 5
	No Obstruction	Disc with Spokes	Spokes	Tapered Spokes	Spokes Annulus
Relative uretonimine	1	0.89	0.96	0.88	0.80
Amine pressure drop	1	1.02	1.00	1.01	1.00
Phosgene pressure drop	1	1.10	1.04	1.08	1.23

[0059] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof.

What is claimed is:

1. A mixing conduit, comprising:
a cylindrical sidewall defining an inner volume, wherein one or more jets are formed through the cylindrical sidewalls and connect to the inner volume; and
one or more flow obstructions disposed in the inner volume, wherein each flow obstruction is aligned upstream from an associated aperture.
2. The mixing conduit of claim 1, wherein the one or more jets comprise a plurality of apertures formed along a circumference of the cylindrical sidewall, and the one or more flow obstructions comprises a plurality of spokes inserted into the inner volume along the circumference of the cylindrical sidewall.
3. The mixing conduit of claim 2, wherein each spoke has a section in the shape of one of a circle, oval, triangle, diamond, non-symmetrical diamond, or tear-drop.
4. The mixing conduit of claim 2 or claim 3, wherein each spoke is tapered having a large end coupled to the cylindrical sidewall and a small end near a central axis of the mixing conduit.
5. The mixing conduit of any one of claims 2-4, wherein the plurality of spoke are coupled to a disk substantially concentric to the cylindrical sidewall.
6. The mixing conduit of any one of claims 2-4, wherein the plurality of spokes are coupled to one or more rings substantially concentric to the cylindrical sidewall.
7. The mixing conduit of any one of claims 2-4, wherein the plurality of spoke are coupled to a torpedo disposed along a central axis of the mixing conduit.
8. The mixing conduit of any one of claims 1-7, wherein each jet comprises a tapered aperture having a large opening outside the mixing conduit and a small opening inside the mixing conduit.

9. The mixing conduit of any one of claims 1-7, wherein an additional jet is disposed adjacent each of the plurality of jets downstream on a longitudinal axis of the cylindrical sidewall.
10. The mixing conduit of any one of claims 1-7, wherein each jet comprises two apertures disposed concentrically.
11. The mixing conduit of any one of claims 1-10, wherein each jet comprises an aperture tilted at an angle relative to a plane perpendicular to a longitudinal axis of the mixing conduit.
12. The mixing conduit of anyone of claims 1-11, wherein the one or more obstructions are mounted at an angle relative to a plane perpendicular to a longitudinal axis of the mixing conduit.
13. A static mixer comprising:
one or more fluid receiving conduits defining one or more outer walls of an annular chamber; and
a mixing conduit of any one of claims 1-12 disposed in a first conduit defining at least an inner wall of the annular chamber, wherein the annular chamber is in fluid communication with the one or more jets of the mixing conduit.
14. A method for mixing comprising:
flowing a first flow along a longitude of the mixing conduit of any one of claims 1-13, wherein the one or more obstructions of the mixing conduit are upstream to the one or more jets of the mixing conduit; and
flowing a second flow through the one or more jets of the mixing conduit of any one of claims 1-13.
15. The method of claim 14, wherein the first flow comprises phosgene and the second flow comprises amines.

16. The method of claim 15, wherein the second flow comprises at least one of methylene diphenyl diamine, toluene diamine, and hexamethylene diamine.

17. The method of any one of claims 13-16, wherein the one or more flow obstructions disposed in the inner volume modifies velocity profiles in the first flow such that an amount of ureas, carbodiimides, and uretonimines formed are less than in a method where no obstructions are disposed in the inner volume.

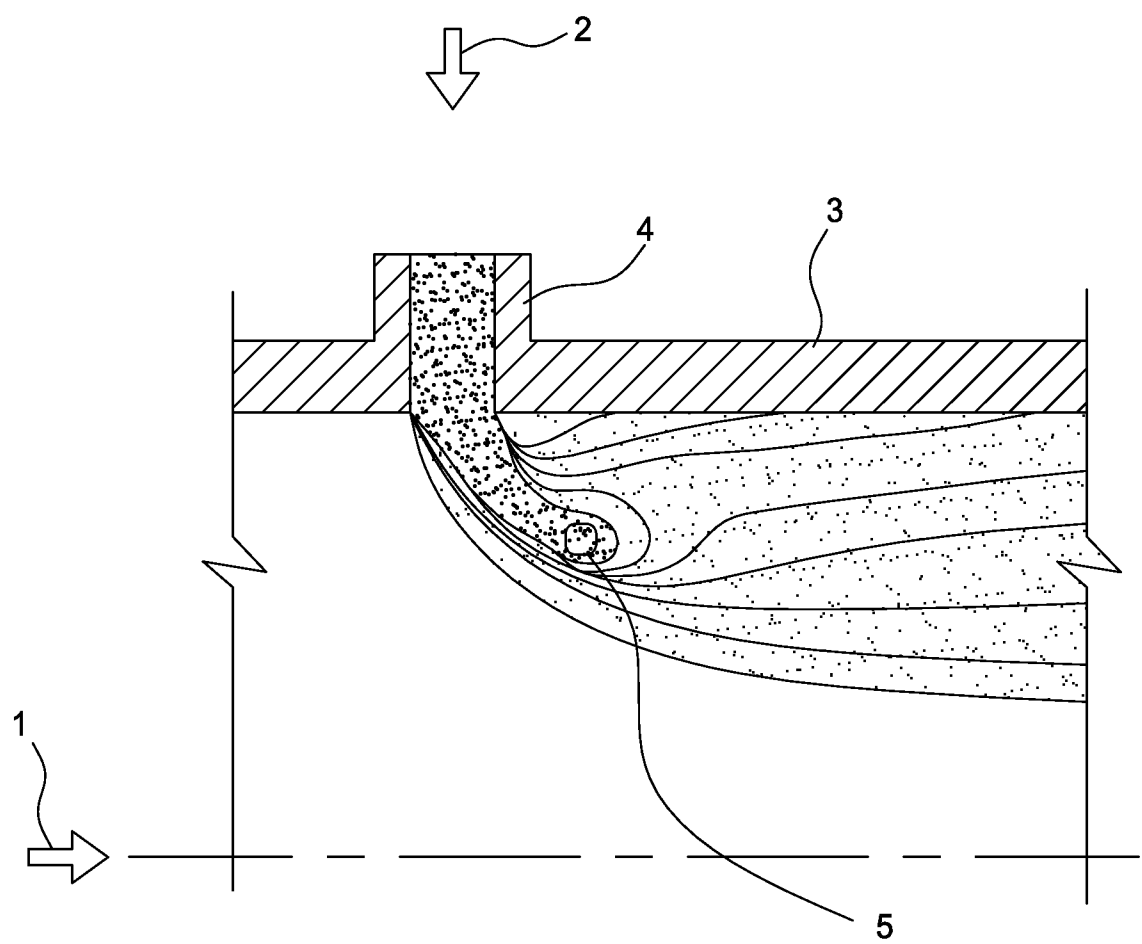


FIG. 1
(PRIOR ART)

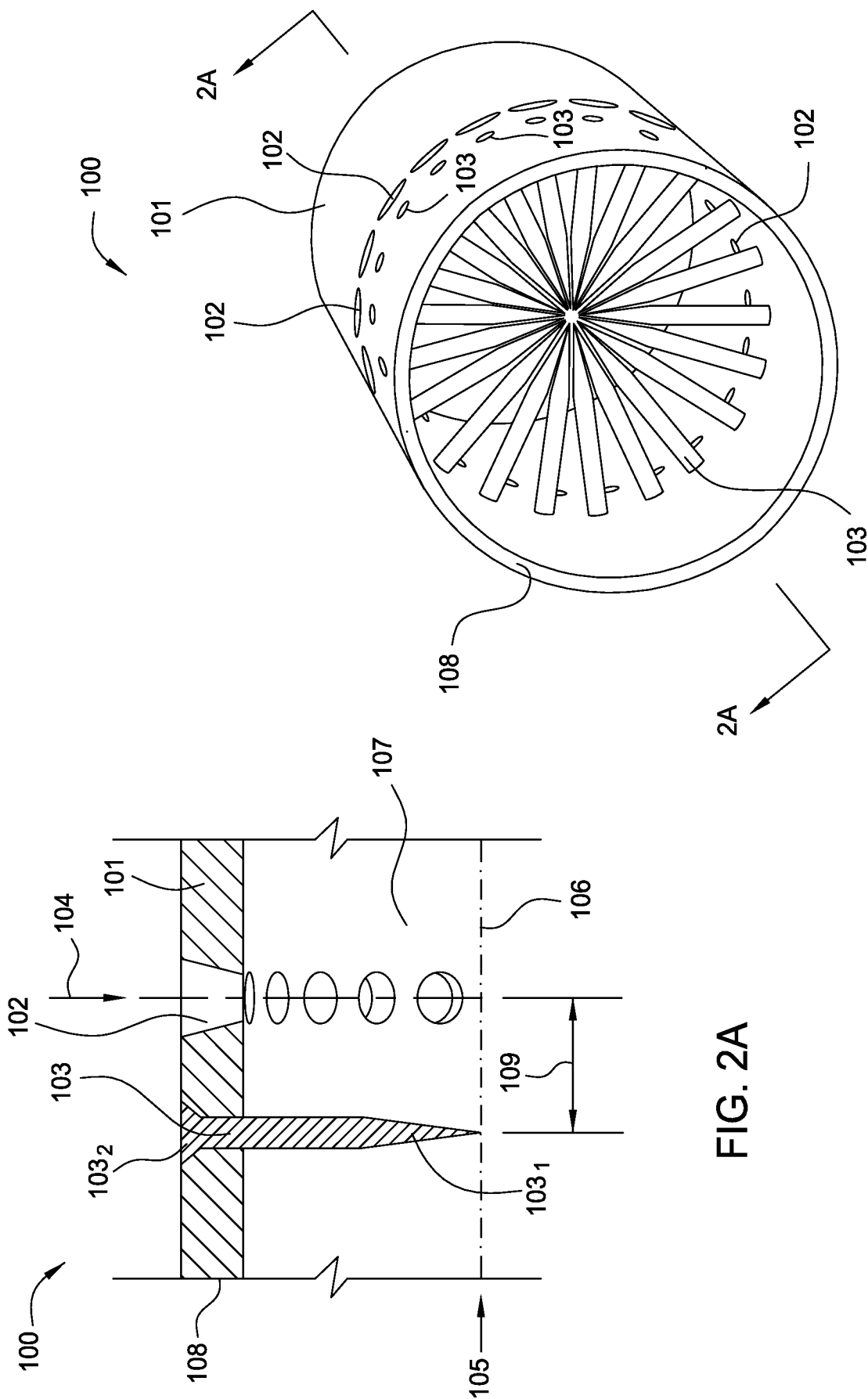


FIG. 2B

FIG. 2A

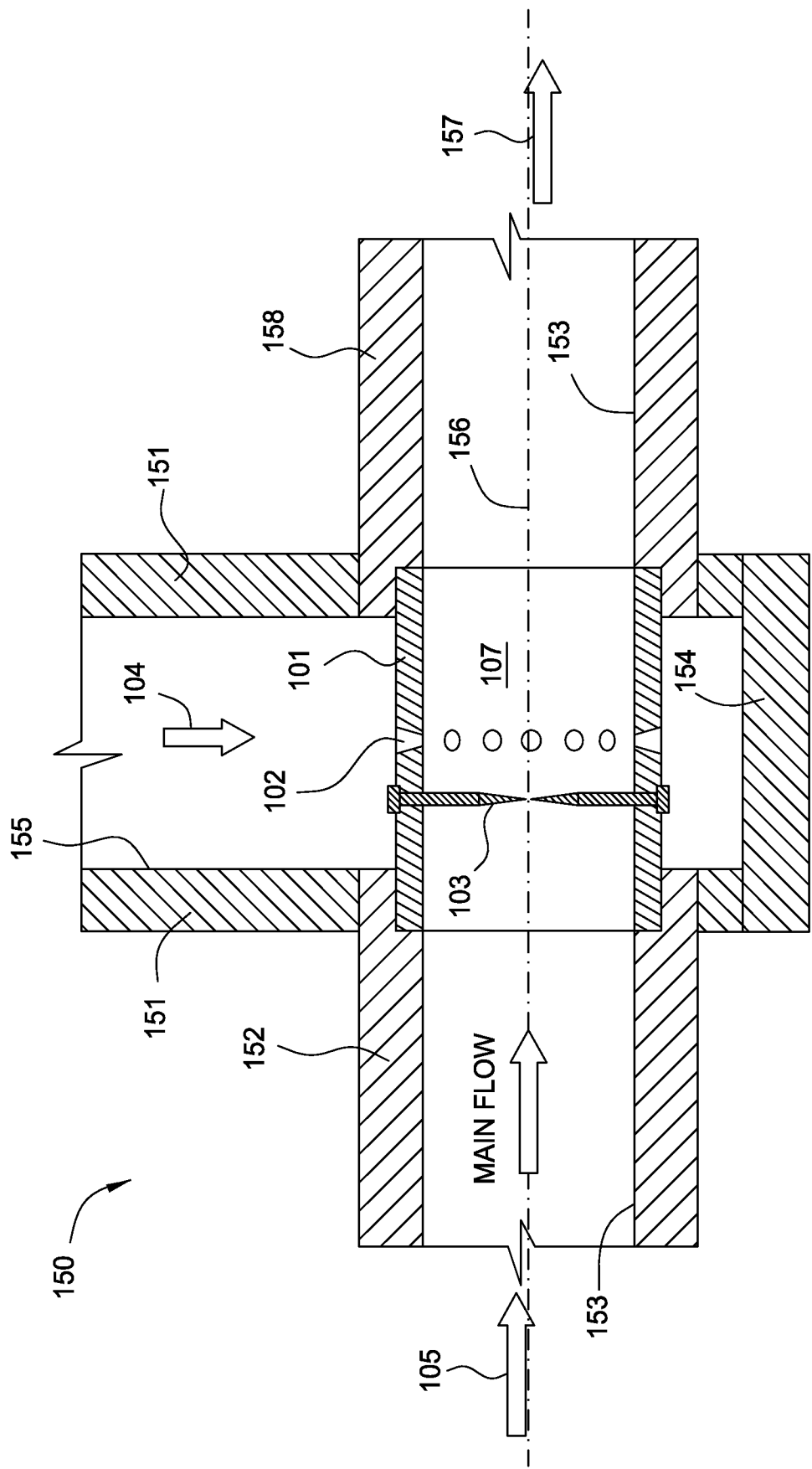
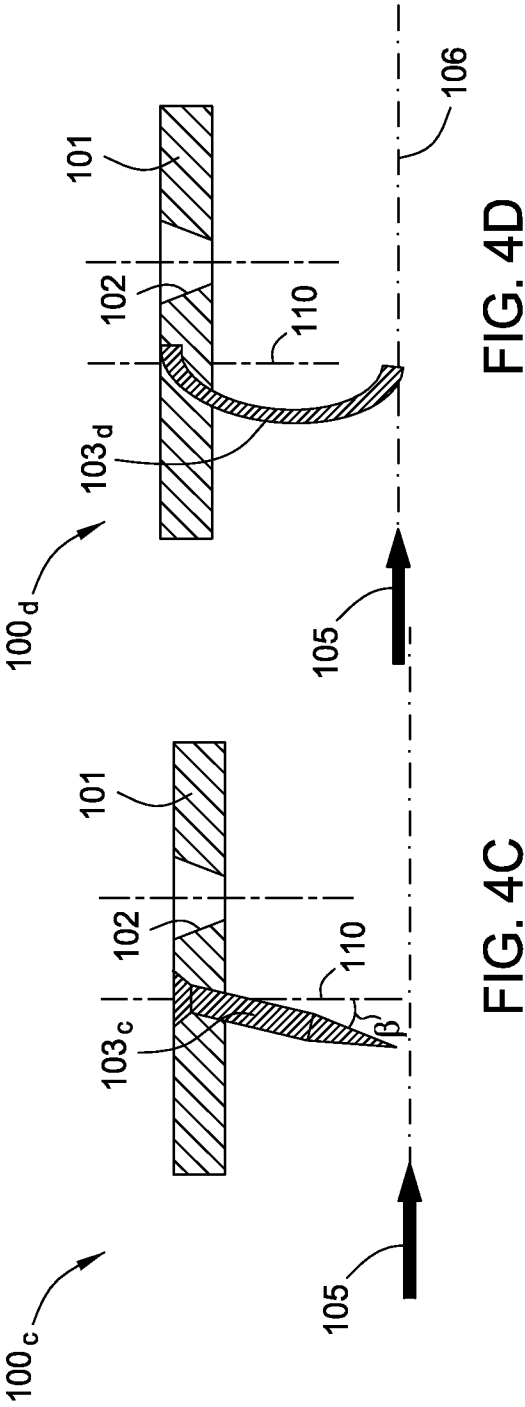
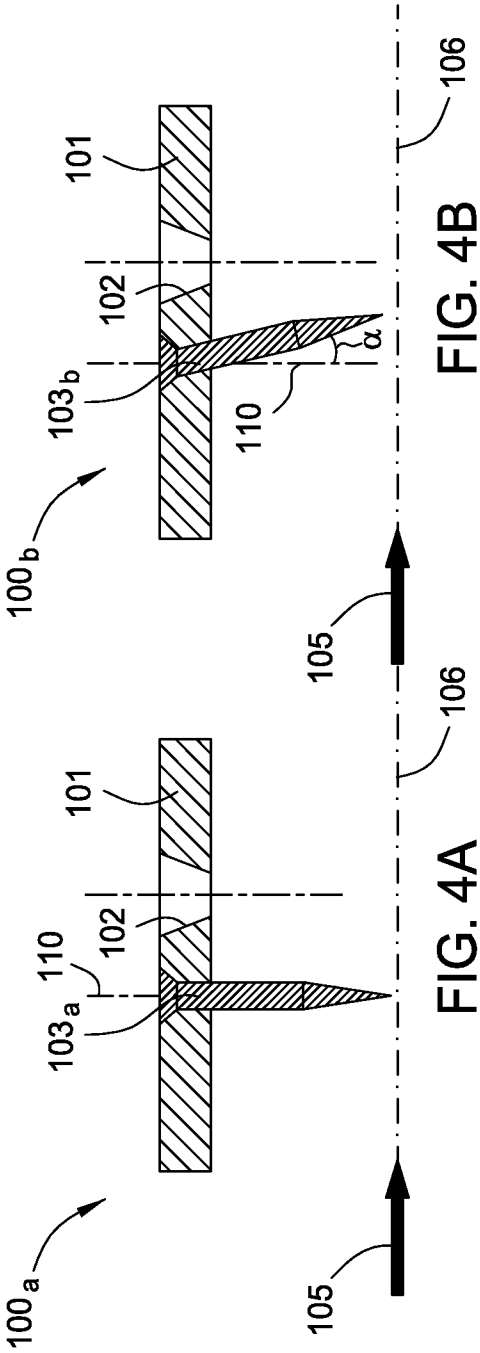


FIG. 3



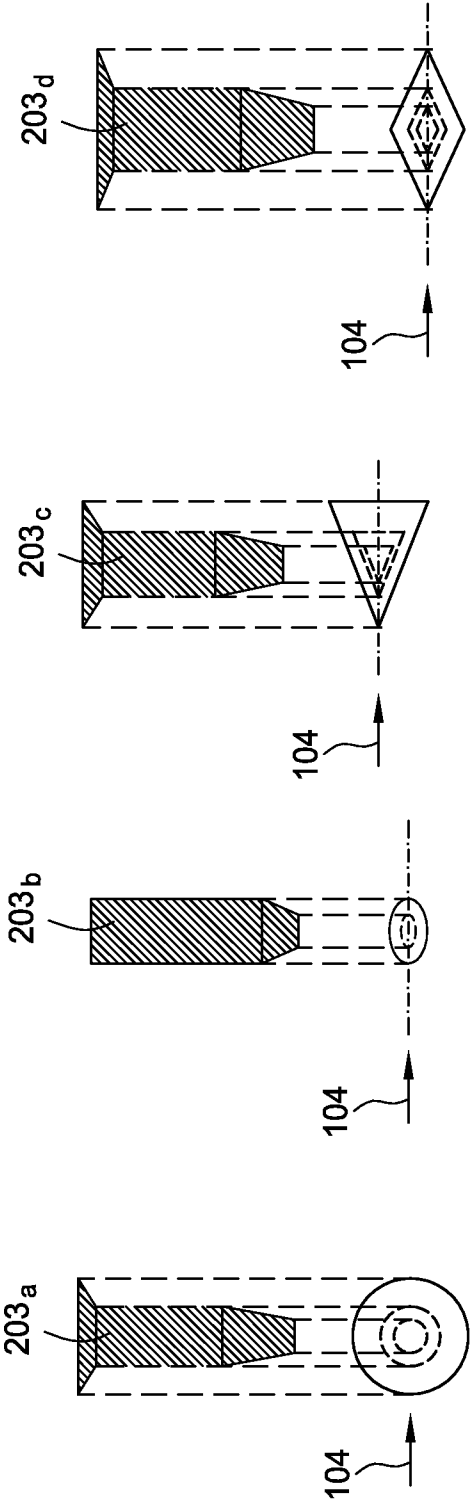


FIG. 5A

FIG. 5B

FIG. 5C

FIG. 5D

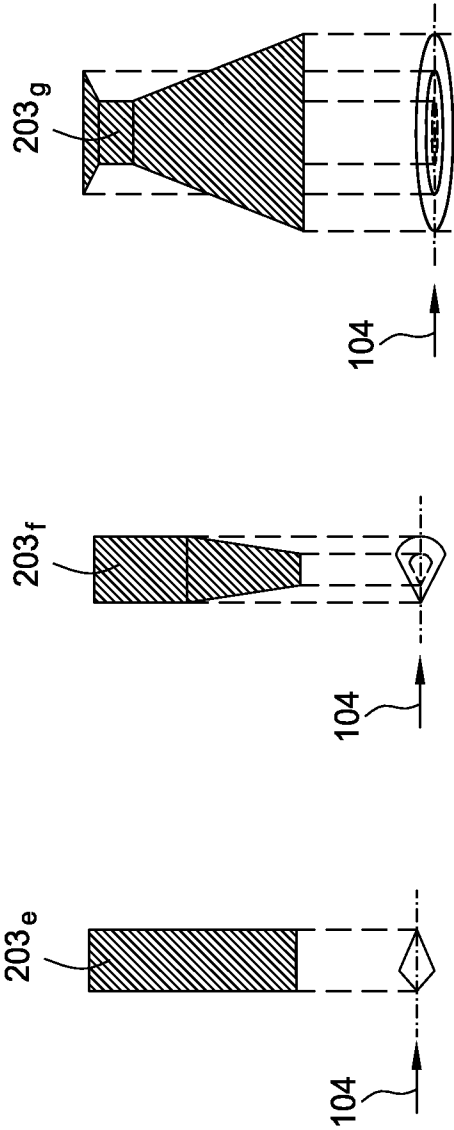
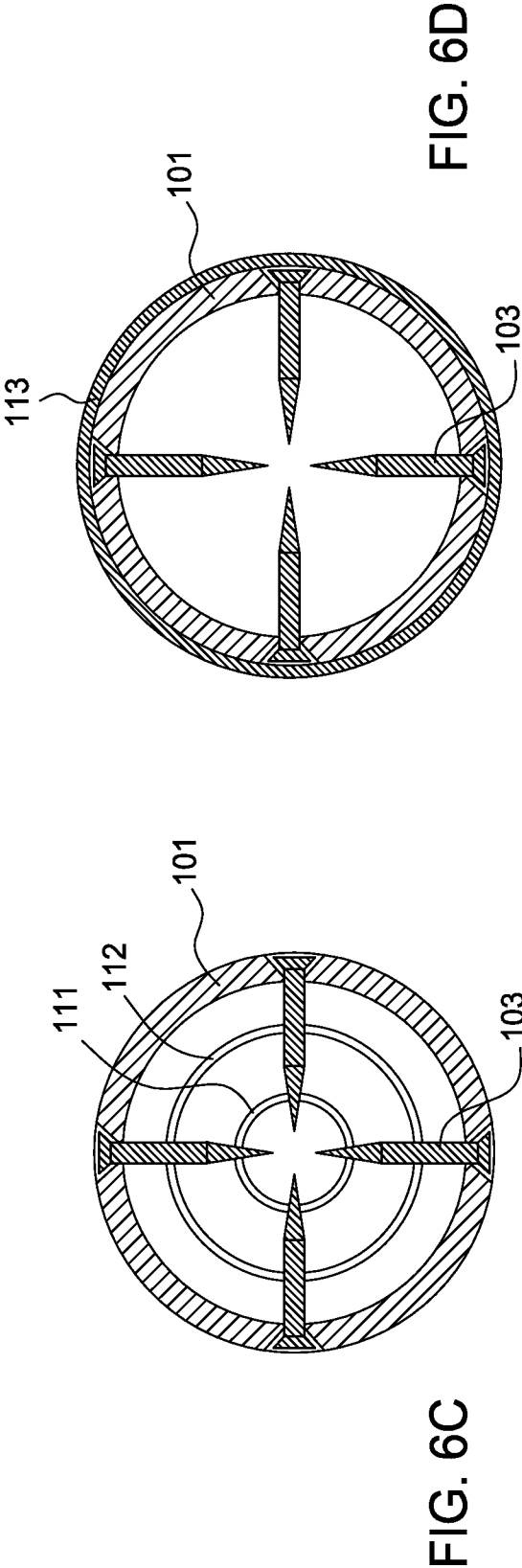
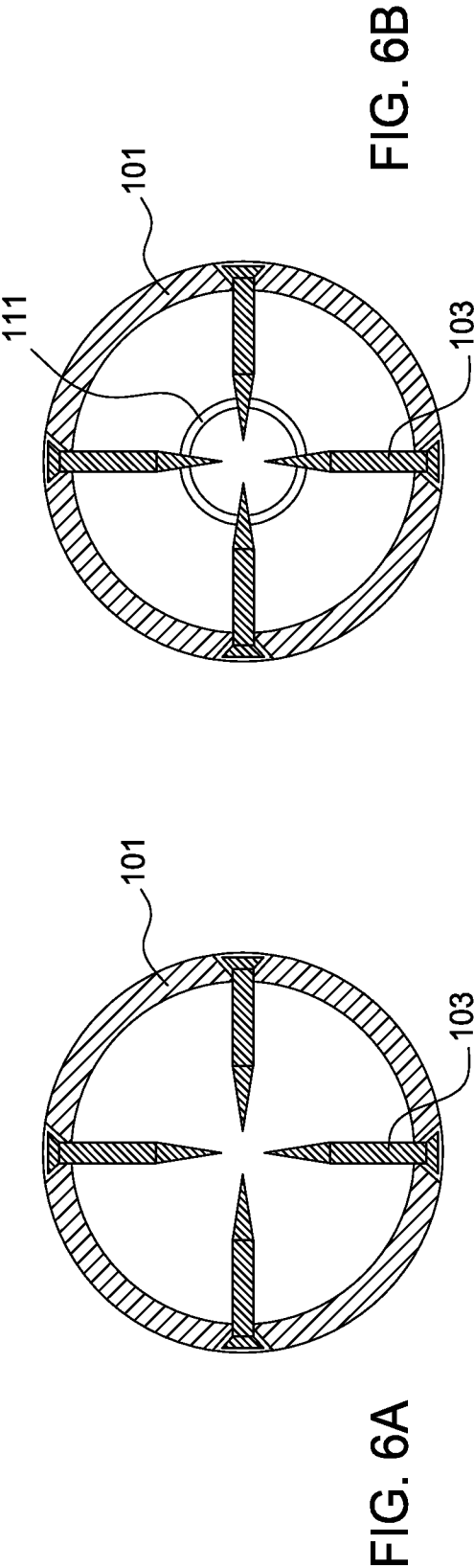


FIG. 5E

FIG. 5F

FIG. 5G

FIG. 5H



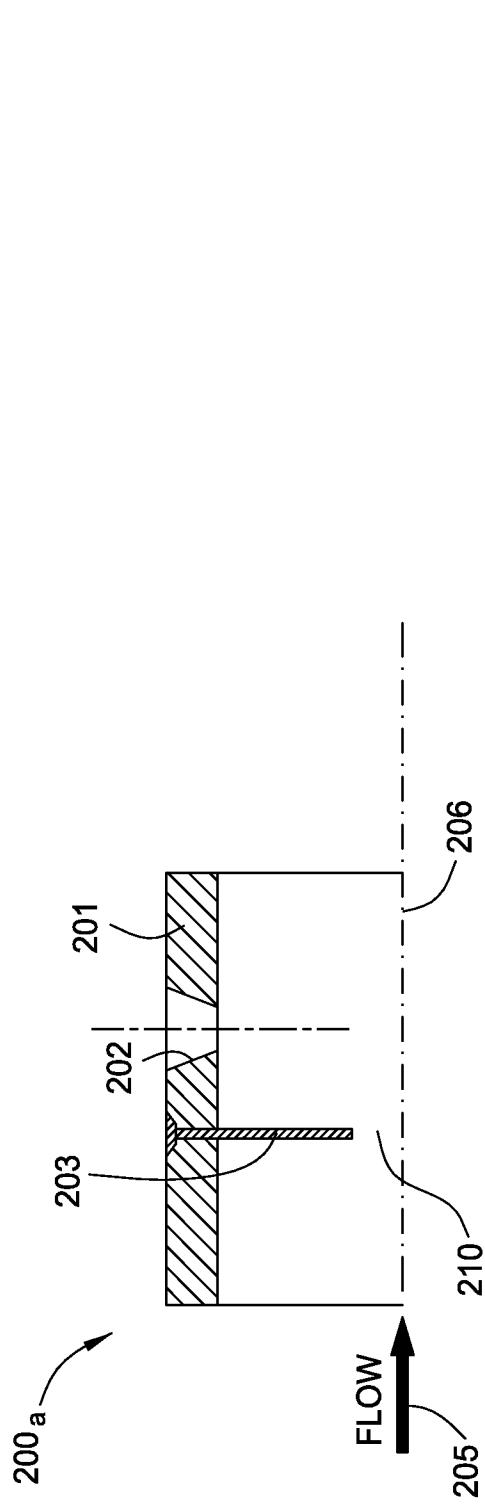


FIG. 7A

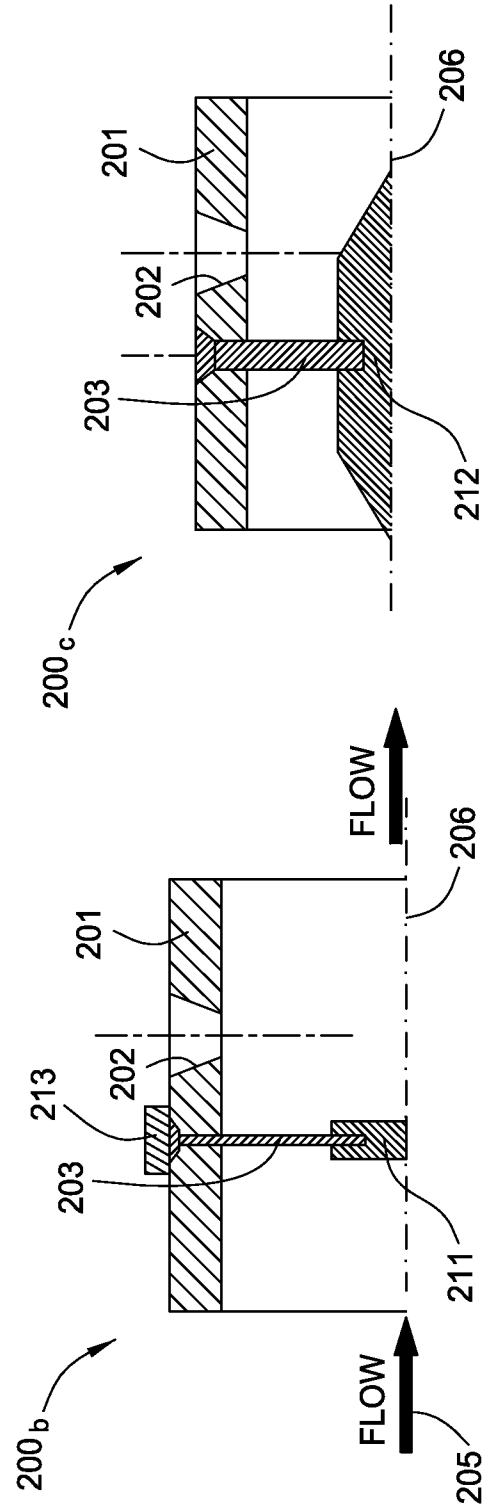


FIG. 7B

FIG. 7C

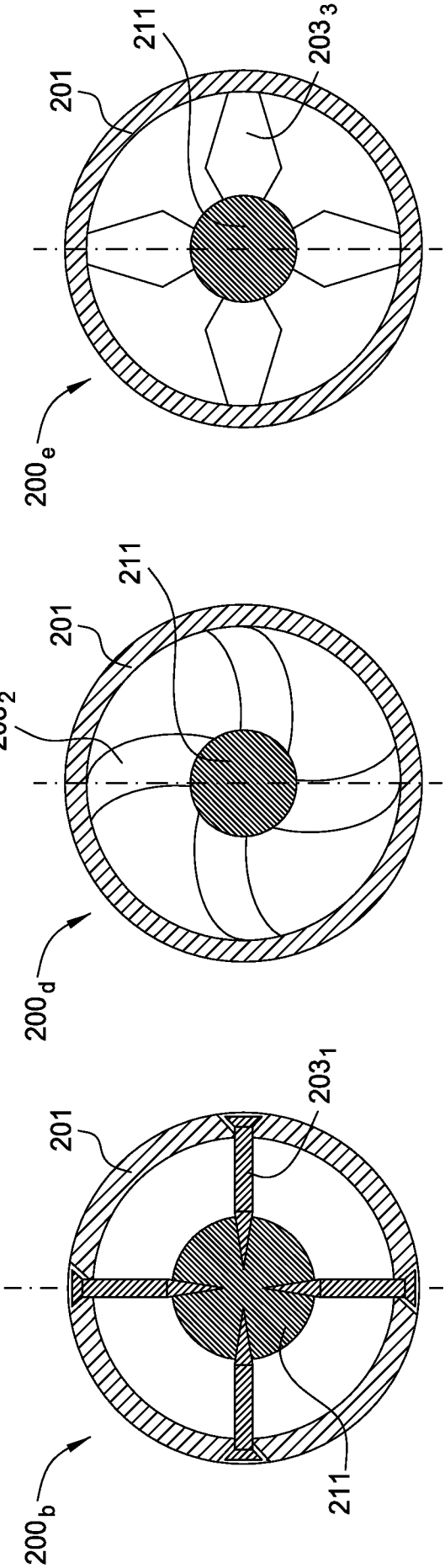
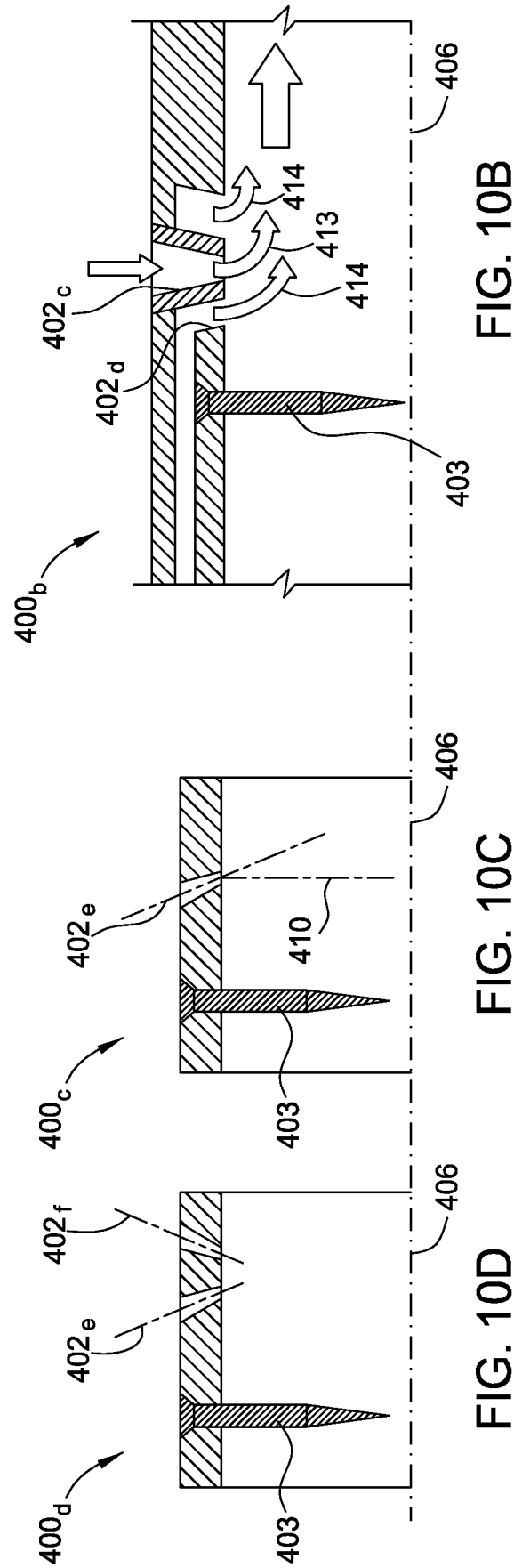
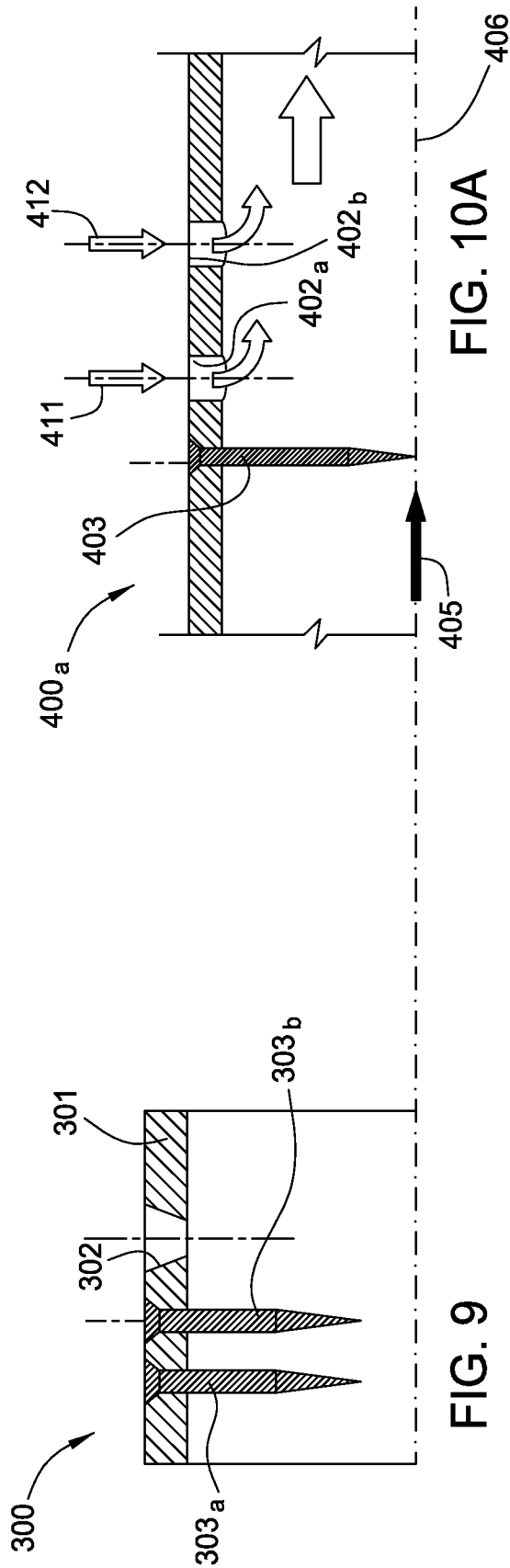


FIG. 8C

FIG. 8B

FIG. 8A



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/053583

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01F5/04 B01F5/06 C07C263/10
ADD. B01J19/24

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)
B01F

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 practical, search terms used)

EP0-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	EP 1 716 918 A1 (HITACHI LTD [JP]; HITACHI HIGH TECH CORP [JP]; BABCOCK HITACHI KK [JP]) 2 November 2006 (2006-11-02)	1,2,4-6, 11-14
Y	paragraph [0001] paragraph [0028] - paragraph [0033] paragraph [0059] - paragraph [0061] figures 1-2B,4,8-9B	3
X	US 4 981 368 A (SMITH CHARLES R [US]) 1 January 1991 (1991-01-01)	1,2,4-6, 11-14
Y	column 1, line 6 - line 23 column 10, line 7 - line 50 figure 6	3
	----- -/--	



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

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

14 December 2011

Date of mailing of the international search report

24/02/2012

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Real Cabrera, Rafael

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/053583

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6, 11-14

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/053583

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2004/057334 A1 (WILMER JEFFREY ALEXANDER [US] ET AL) 25 March 2004 (2004-03-25) figures 5-7	3 1,2,4-6, 11-14
Y A	----- WO 2008/000616 A2 (SULZER CHEMTECH AG [CH]; MOSER FELIX [CH]; SULZER WORLITSCHKEK SABINE []) 3 January 2008 (2008-01-03) figures	3 1,2,4-6, 11-14
Y A	----- US 2007/177452 A1 (AROSSI ABDELWAHAB [GB]) 2 August 2007 (2007-08-02) figures 2a-4c	3 1,2,4-6, 11-14

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 11-14

Mixing conduit comprising spokes having a specific cross section or having tilted jets.

1.1. claims: 1-6, 12-14

Mixing conduit comprising spokes having a specific cross section.

1.2. claim: 11

Mixing conduit having tilted jets.

2. claim: 7

Mixing conduit comprising spokes coupled to a torpedo.

3. claim: 8

Mixing conduit comprising jets being fed by a tapered aperture.

4. claim: 9

Mixing conduit comprising additional jets.

5. claim: 10

Mixing conduit comprising jets with two concentric apertures.

6. claims: 15, 16

Method for mixing phosgene and amines.

7. claim: 17

Method for minimizing formation of ureas, carbodiimides and uretonimines.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/053583

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2004022462 A2	18-03-2004
