

AN APPARATUS FOR MIXING AT LEAST TWO LIQUIDS

FIELD OF INVENTION

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The present invention relates to an apparatus for mixing at least two liquids and a method for assembling the apparatus.

BACKGROUND

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Mixing liquids in a channel can be carried out with mixers having impellers producing a flow pattern within the channel to achieve the desired results. These impellers are typically configured to generate various types of flow patterns within the channel, such as, for example, straight-blade turbine radial flow, pitched-blade turbine mixed flow, hydrofoil impeller axial flow, and so forth.

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Unfortunately, the use of impellers to carry out mixing leads to several issues. One of the issues relates to the power consumption of the impellers. Substantial amounts of power are consumed when using the impellers, and this increases the cost of carry out the mixing. In addition, the cost to maintain the operability of the impellers is also substantial, and this also increases the cost to carry out the mixing.

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Moreover, practical inefficiencies of the impellers also cause the mixing by the impellers to be inconsistent, which is undesirable.

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Alternatively, mixing liquids in the channel can also be carried out with static mixers which rely on principles of flow division using at least one mixing element. However, the at least one mixing element is typically in a form which is not easily fabricated and/or arranged in configurations which are complicated.

The present invention aims to solve the issues mentioned in the preceding paragraphs.

SUMMARY

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In a first aspect, there is provided an apparatus for mixing at least two liquids. The apparatus includes a circular cylindrical channel for passage of the at least two liquids; a first planar mixing element of a semi-oval shape with a first arcuate edge and a first straight edge; and a second planar mixing element of a semi-oval shape with a second arcuate edge and a second straight edge. It is preferable that the first mixing element and the second mixing element are non-coplanar, with a first normal axis of the first mixing element being at a first acute angle to the cylindrical channel and a second normal axis of the second mixing element being at a second acute angle to the cylindrical channel. The first normal axis and the second normal axis are preferably divergent to each other. The apparatus can further include at least one injector located upstream from the first mixing element and the second mixing element for

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introducing at least one liquid into the cylindrical channel.

Each of the first acute angle and the second acute angle may be between 45° to 65° . The first acute angle and the second acute angle may be identical, and each of the first acute angle and the second acute angle is 56° . The first acute angle and the second acute angle affect a pressure drop in the cylindrical channel, and/or a coefficient of variance at a pre-determined distance downstream from the first mixing element and the second mixing element.

Each of the first mixing element and the second mixing element may include at least one opening. At least one parameter of the at least one opening affects a pressure drop in the cylindrical channel, the at least one parameter being, for example, size, shape, location and so forth. The at least one opening is defined by a shape selected from, for example, a sector of an oval, a circle, a polygon, an ellipse and so forth.

Preferably, the first arcuate edge and the second arcuate edge are mounted in contact with an inner surface of the cylindrical channel. Each of the first mixing element and the second mixing element preferably has a thickness of at least 4.5 mm.

The first and second mixing elements may be formed from a single panel made of either a metal or a fibre-reinforced plastic. The first and the second mixing elements may be joined to each other.

The single panel may be either being cut to two separate pieces or cut and twisted in a manner whereby the two halves are joined together at a centre portion of the panel.

In a second aspect, there is provided a method for assembling an apparatus for mixing at least two liquids. The method includes positioning a first and a second planar mixing element in a circular cylindrical channel; and mounting the first and the second mixing elements in contact with an inner surface of the cylindrical channel. It is preferable that the first mixing element and the second mixing element are non-coplanar, where a first normal axis of the first mixing element is at a first acute angle to the cylindrical channel and a second normal axis of the second mixing element is at a second acute angle to the cylindrical channel. The first normal axis and the second normal axis are preferably divergent to each other. The method may further include mounting at least one injector at a location along the cylindrical channel upstream from the first mixing element and the second mixing element.

Each mixing element may include at least one opening. It is preferable that at least one parameter of the at least one opening affects a pressure drop in the cylindrical channel, the at least one parameter being selected from, for example, size, shape, location and so forth. The at least one opening is defined by a shape selected from, for example, a sector of an oval, a circle, a polygon, an ellipse and so forth.

Each of the first acute angle and the second acute angle may be between 45° to 65° . The first acute angle and the second acute angle may be identical, and each of the first acute angle and the second

acute angle is 56° . The first acute angle and the second acute angle affect a pressure drop in the cylindrical channel, and/or a coefficient of variance at a pre-determined distance downstream from the first mixing element and the second mixing element.

- 5 The first and second mixing elements may be formed from a single panel made of either a metal or a fibre-reinforced plastic. The first and the second mixing elements may be joined to each other.

The single panel may be either being cut to two separate pieces or cut and twisted in a manner whereby the two halves are joined together at a centre portion of the panel.

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DESCRIPTION OF FIGURES

- In order that the present invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative example only preferred embodiments of the present invention, the description being with reference to the accompanying illustrative figures.

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Figure 1 shows a top view of mixing elements used in an apparatus of the present invention.

Figure 2 shows a side view of the apparatus of the present invention.

Figure 3 shows a front view of the apparatus of the present invention.

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Figure 4 shows a path line plot for the apparatus of the present invention at maximum flow conditions.

Figure 5 shows a velocity vector plot at 1m downstream from the mixer elements at maximum flow conditions.

Figure 6 shows a path line plot for the apparatus of the present invention at minimum flow conditions.

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Figure 7 shows a velocity vector plot at 1m downstream from the mixer elements at minimum flow conditions.

Figure 8 shows a plot of pressure drop against flow velocity for the apparatus of the present invention.

Figure 9 shows a plot of coefficient of variance against flow velocity for the apparatus of the present invention.

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Figure 10 shows sampling locations in the apparatus of the present invention for determining a coefficient of variance.

Figure 11 shows a front view of an alternative embodiment of the apparatus of the present invention.

Figure 12 shows a process flow for a method to assemble the apparatus of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

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The present invention relates to an apparatus for mixing at least two liquids, whereby the apparatus does not include any moving parts and requires minimal maintenance. The apparatus also enables a method for mixing two liquids. The apparatus is able to mix the at least two liquids with minimal pressure loss in a mixing channel and is able to carry out consistent mixing of the at least two liquids.

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Referring to Figures 1 to 3, there is provided an apparatus 20 for mixing at least two liquids. The apparatus 20 includes a circular cylindrical channel 21 for passage of the at least two liquids. The cylindrical channel 21 can be of a diameter between 0.1m to 5m.

5 The apparatus 20 includes a first planar mixing element 22 of a semi-oval shape with a first arcuate edge 26 and a first straight edge 28. The first mixing element 22 also includes a first opening 30 at a trailing portion 32 of the first mixing element 22. It should be appreciated that "at" means "around the region of". In addition, the apparatus 20 includes a second planar mixing element 24 of a semi-oval shape with a second arcuate edge 34 and a second straight edge 36. The second mixing element 24
10 also includes a second opening 38 at a trailing portion 40 of the second mixing element 24. It should be appreciated that "at" means "around the region of". The trailing portions 32, 40 of the elements 22, 24 are sections of the elements which are furthest away from an inlet 69 of the apparatus 20. Furthermore, the first planar mixing element 22 and the second planar mixing element 24 may also have one other opening at their leading edges 33 and 41 respectively. It should be appreciated that "at" means "around
15 the region of".

A mid-portion 42 of the second straight edge 36 of the second mixing element 24 may be joined to a mid-portion 44 of the first straight edge 28 of the first mixing element 22. It should be appreciated that even though Figure 1 shows that the first mixing element 22 and the second mixing element 24 are two
20 separate items, it is also possible for the first mixing element 22 and the second mixing element 24 are formed from a single panel, whereby the panel is oval shaped and is divided into two halves and twisted in a manner whereby the two halves are joined together at a centre portion of the panel. Alternatively, the oval shape panel is cut into two separate halves and joined together at a centre portion of the panel. The first mixing element 22 and the second mixing element 24 are made from either a metal or fibre-
25 reinforced plastic like isophatalic polyester. Each of the first mixing element 22 and the second mixing element 24 has a thickness of at least 4.5 mm. The first arcuate edge 26 and the second arcuate edge 34 are configured to be mounted in the cylindrical channel 21 such that the first mixing element 22 and the second mixing element 24 are secured to the cylindrical channel 21.

30 The apparatus 20 can further include at least one injector 70 located upstream from the first mixing element 22 and the second mixing element 24 for introducing at least one liquid into the cylindrical channel 21. It should be appreciated that the performance of the apparatus 20 can be optimized by varying a protruding length of the at least one injector 70, and a position/orientation of the at least one injector 70 with respect to the mixing elements 22, 24.

35 In the apparatus 20, the first mixing element 22 and the second mixing element 24 are non-coplanar, the first mixing element 22 being mounted in a manner where a first normal axis 23 of the first mixing element 22 is at a first acute angle 60 to the cylindrical channel 21 and a second normal axis 25 of the second mixing element 24 is at a second acute angle 62 to the cylindrical channel 21. The first angle 60
40 and the second angle 62 can be identical. Each of the first angle 60 and the second angle 62 is between

45° to 65°. Each of the first angle 60 and the second angle 62 can be 56°. It should be noted that the first normal axis 23 and the second normal axis 25 are divergent to each other for both upstream and downstream faces of the first mixing element 22 and the second mixing element 24. Furthermore, there is no mirror symmetry in the apparatus 20.

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As shown in Figures 1 and 3, the first opening 30 and the second opening 38 are each defined by a shape of a sector of an oval. The shape of the openings 30, 38 can also be, for example, circular, polygonal, elliptical and so forth. It should be appreciated that at least one parameter, such as, for example, a location, size, shape and so forth of the first opening 30 and the second opening 38 affects a pressure drop in the cylindrical channel 21. In addition, the first angle 60 and the second angle 62 affect at least one of a pressure drop in the cylindrical channel, and a coefficient of variance (CoV) at a pre-determined distance downstream from the first mixing element 22 and the second mixing element 24. Thus, it should be appreciated that the location, size and shape of the first opening 30 and the second opening 38 and the first angle 60 and the second angle 62 affects a performance of the apparatus 20.

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Referring to Figure 11, there is shown a front view of an alternative embodiment of the apparatus 20. In the alternative embodiment, the first mixing element 22 and the second mixing element 24 do not have openings and each of the first mixing element 22 and the second mixing element 24 is of a semi-oval shape with a portion removed at the respective trailing edges 32, 40. In this regard, the respective trailing edges 32, 40 and a wall of the circular cylindrical channel 21 define a third opening 29 and a fourth opening 37. It should be appreciated that the third opening 29 and the fourth opening 37 only appear to be openings from the front view. The third opening 29 and the fourth opening 37 are merely portions in the circular cylindrical channel 21 which are not blocked by the first mixing element 22 and the second mixing element 24 respectively.

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The following section will describe simulations carried out to demonstrate the desired performance characteristics of the apparatus 20.

Computational fluid dynamics (CFD) simulation is employed as a tool to confirm and optimize the performance parameters of the apparatus 20 under different operating flow conditions, particularly, a pressure drop across the mixing elements 22, 24 and a CoV at three meters downstream of the mixing elements 22, 24. The CFD simulation is performed by creating a full-scale computational model of the apparatus 20 complete with the at least one injector 70. The inputs to the simulation include types of fluids, specified flow rates of a main flow as well as the specified flow rates of the chemicals being injected into the main flow.

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The turbulence in the flow caused by the mixing elements and associated uncertainty of turbulence effect on the mixing process have been considered. Correspondingly, the Kepsilon turbulent model has been employed in the numerical simulation to address the issues caused by the turbulence in the flow.

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In this simulation, the apparatus 20 is designed to perform inline mixing of water with Chemical A and Chemical B under the following operating conditions in Table 1:

Component	Major flow	Minor flow-1	Minor flow-2	Mixture
Fluid	Water	Chemical A	Chemical B	
Flowrate (m ³ /hr)	3103 - 31030	0.55	0.025	3104 - 31031
Viscosity (cP)	1	1	25-40	1
Density (kg/m ³)	1030	1200	1250	1030
Pressure (barg)	3.5	5.5	5.5	3.5
Temperature (deg.C)	26.0 – 36.0	26.0 – 36.0	26.0 – 36.0	26.0 – 36.0
Pipe Diameter (mm)	2200	25	25	2200

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Table 1

It is desirable if the apparatus 20 is able to conform to the following parameters:

- CoV at 3m downstream of mixer elements 22, 24 $\leq 5\%$
- 10 - Pressure drop across the mixer elements 22, 24 ≤ 0.102 bar

During the simulation, the properties of fluid flow are solved by one set of the following conservation equations of mass and momentum, namely:

- 15 a. Mass balance equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i} (\rho u_i) = S_m$$

- 20 where ρ and u_i are a density and a velocity of fluid respectively, and S_m represents mass. This source term is zero in the solution domain for this simulation.

- b. Momentum balance equation

$$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i$$

where p is the static pressure, g_i is the gravity acceleration which introduces the buoyancy force with the density variation, and the stress tensor τ_{ij} is given by,

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$$\tau_{ij} = \left[(\mu + \mu_t) \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) \right] - \frac{2}{3} \mu \frac{\partial u_i}{\partial x_i} \delta_{ij}$$

where μ and μ_t are molecular viscosity and eddy viscosity respectively.

- 10 Furthermore, as mentioned in a preceding paragraph, turbulence in flow is taken into consideration for the eddy viscosity, μ_t . For this purpose, standard k- ϵ two equations model have been used to estimate the turbulence kinetic energy (k) and dissipation (ϵ). Hence, the turbulent eddy viscosity, μ_t is defined as follows:

$$\mu_t = C_\mu \rho k^2 / \epsilon$$

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where C_μ is the model constant.

- Figure 2 also denotes boundary conditions of the CFD simulation. The mixing elements 22, 24 and the cylindrical channel 21 are considered as no-slip walls while a main inlet 69 is located around the at least one injector inlet 70. An outlet 71 is defined at four times of a diameter of the cylindrical channel 21 downstream from the mixing elements 22, 24. In this CFD simulation, there are four injectors located upstream from the mixing elements 22, 24, and the flow direction from the main inlet 69 is defined as parallel to a Z-axis as shown in Figure 2.

- 25 With regard to the pressure drop analysis, two planes were created before and after the mixing elements 22, 24 to obtain the pressure readings. The pressure drop across the mixing elements 22, 24 is then obtained by subtracting an averaged pressure at the two planes.

- With regard to the CoV analysis, a third plane was created at three metres away from the mixing elements 22, 24 to obtain the relevant data. Figure 10 shows sampling locations for calculating the CoV in the cylindrical channel 21. The CoV is defined as the ratio of the standard deviation (σ) to the mean (μ) of the scattered data:

$$CoV = \frac{\sigma}{\mu}$$

Table 2 below shows all the results obtained from the CFD simulation (labeled in Table 2 as "predicted" values) on the performance of the apparatus 20. It shows that the pressure drop and the CoV values are able to meet the desired performance criteria.

	Desired Pressure Drop (bar)	Actual Pressure Drop (bar)	Desired CoV	Actual CoV
100% Flow	0.102	0.102	0.05 @ 3m	0.03955 @ 3m
75% Flow	0.102	0.064774	0.05 @ 3m	0.04210 @ 3m
25% low	0.102	0.007146	0.05 @ 3m	0.04283 @ 3m
min Flow	0.102	0.0011	0.05 @ 3m	0.04357 @ 3m

Table 2

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Referring to Figures 4 and 6, path line plots at maximum and minimum flow conditions respectively are shown. It can be seen that good mixing is achieved at the downstream of the apparatus 20 in both cases. A significant swirling effect created by the mixing elements 22, 24 is clearly visible. The swirling effect can also be known as a spiral or helical effect with respect to a main axis of the cylindrical channel 21. This significant swirling effect in the flow leaving the mixing elements 22, 24 provides desirable mixing of the at least two liquids downstream of the mixing elements 22, 24.

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Furthermore, referring to Figures 5 and 7, transverse velocity vector plots (at a location 1m downstream from the mixing elements 22, 24) at maximum and minimum flow conditions respectively are shown. A swirling effect in a transverse plane is taking place across an entire cross-section of the cylindrical channel 21 is clearly visible. This swirling effect in the transverse plane in the flow leaving the mixing elements 22, 24 provides desirable mixing of the at least two liquids downstream of the mixing elements 22, 24.

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Referring to Figure 8, there is also shown a plot of pressure drop against flow velocity for the apparatus 20. It can be observed that the greater the main flow velocity, the greater the pressure drop across the mixing elements 22, 24. However, referring to Figure 9 which shows a plot of CoV against flow velocity for the apparatus 20, it can be observed that the greater the main flow velocity, the lower the CoV at the

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third plane at three metres away from the mixing elements 22, 24. Thus, it can be observed that the apparatus 20 is able to keep within desired parameters in relation to both pressure drop and CoV for a range of main flow velocities.

5 It is appreciated that the apparatus 20 is able to carry out the mixing of at least two liquids within desired parameters in relation to both pressure drop and CoV for a range of main flow velocities without employing any moving parts and without consuming power. Thus, the apparatus 20 is robust without needing maintenance for any moving parts. Moreover, the two mixing elements 22, 24 do not take up a substantial length in the circular cylindrical channel 21, and a low CoV is maintained at a short distance
10 from the two mixing elements 22, 24. Furthermore, the low CoV also indicates that the mixing carried out by the apparatus 20 is consistent and repeatable, which is desirable for mixing apparatus. As such, the apparatus 20 will not take up a substantial length in a facility where it is installed, and is able to be deployed in facilities with space constraints. It should be appreciated that the performance of the apparatus 20 can be optimized by varying a positioning of the two mixing elements 22, 24, and/or by
15 including openings in the two mixing elements 22, 24.

Referring to Figure 12, there is provided a method 100 for assembling an apparatus for mixing at least two liquids similar to the apparatus 20 as described in the preceding paragraphs. The method 100 includes positioning a first 22 and a second 24 planar mixing element in a circular cylindrical channel 21
20 (102) and mounting the first 22 and the second 24 mixing elements in contact with an inner surface 19 of the cylindrical channel 21 (104). The first mixing element 22 and the second mixing element 24 can be formed from a single panel, whereby the panel is oval shaped and is cut, and twisted in a manner whereby the two halves are joined together at a centre portion of the panel. Alternatively, the oval shape panel is cut into two separate halves. The first mixing element 22 and the second mixing element 24 are
25 made from either a metal or fibre-reinforced plastic like isophatalic polyester.

The first mixing element 22 and the second mixing element 24 are non-coplanar, the first mixing element 22 being mounted in a manner where a first normal axis 23 of the first mixing element 22 is at a first acute angle 60 to the cylindrical channel 21 and a second normal axis 25 of the second mixing element
30 24 is at a second acute angle 62 to the cylindrical channel 21. The first angle 60 and the second angle 62 can be identical. Each of the first angle 60 and the second angle 62 is between 45° to 65° . Each of the first angle 60 and the second angle 62 can be 56° . It should be noted that the first normal axis 23 and the second normal axis 25 are divergent to each other. In addition, the first angle 60 and the second angle 62 affect at least one of a pressure drop in the cylindrical channel, and a coefficient of variance
35 (CoV) at a pre-determined distance downstream from the first mixing element 22 and the second mixing element 24.

Each mixing element 22, 24 can include at least one opening. At least one parameter of the at least one opening affects a pressure drop in the cylindrical channel, the at least one parameter being, for example,

size, shape, location and the like. The at least one opening is defined by a shape selected from, for example, a sector of an oval, a circle, a polygon, an ellipse and so forth.

5 Finally, the method 100 further includes mounting at least one injector 70 at a location along the cylindrical channel 21 upstream from the first mixing element 22 and the second mixing element 24.

It is appreciated that the method 100 produces an apparatus which is able to carry out the mixing of at least two liquids within desired parameters in relation to both pressure drop and CoV for a range of main flow velocities without employing any moving parts and without consuming power.

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Whilst there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

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CLAIMS

1. An apparatus for mixing at least two liquids, the apparatus including:
a circular cylindrical channel for passage of the at least two liquids;
5 a first planar mixing element of a semi-oval shape with a first arcuate edge and a first straight edge; and
a second planar mixing element of a semi-oval shape with a second arcuate edge and a second straight edge;
wherein the first mixing element and the second mixing element are non-coplanar, a first normal
10 axis of the first mixing element being at a first acute angle to the cylindrical channel and a second normal axis of the second mixing element being at a second acute angle to the cylindrical channel, with the first normal axis and the second normal axis being divergent to each other, and
wherein a mid-portion of the first straight edge of the first planar mixing element is joined to a
15 mid-portion of the second straight edge of the second planar mixing element.
2. The apparatus of claim 1, wherein each of the first mixing element and the second mixing element includes at least one opening.
3. The apparatus of claim 2, wherein at least one parameter of the at least one opening is
20 configured to keep a pressure drop in the cylindrical channel within desired performance criteria, the at least one parameter being selected from a group of: size, shape, and location.
4. The apparatus of claim 2, wherein the at least one opening is defined by a shape selected from a group consisting of: a sector of an oval, a circle, a polygon and an ellipse.
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5. The apparatus of any one of claims 1 to 4, wherein the first arcuate edge and the second arcuate edge are mounted in contact with an inner surface of the cylindrical channel.
6. The apparatus of any one of claims 1 to 5, wherein each of the first mixing element and the
30 second mixing element has a thickness of at least 4.5 mm.
7. The apparatus of any one of the claims 1 to 6, wherein each of the first acute angle and the second acute angle is between 45° to 65° .
8. The apparatus of claim 7, wherein each of the first acute angle and the second acute angle is
35 56° .
9. The apparatus of any one of claims 1 to 6, wherein the first acute angle and the second acute angle are identical.
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10. The apparatus of any one of claims 1 to 9, wherein the first acute angle and the second acute angle are configured to keep at least one of: a pressure drop in the cylindrical channel, and a coefficient of variance at a pre-determined distance downstream from the first mixing element and the second mixing element within desired performance criteria.

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11. The apparatus of any one of claims 1 to 10, further including at least one injector located upstream from the first mixing element and the second mixing element for introducing at least one liquid into the cylindrical channel.

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12. The apparatus of any one of claims 1 to 11, wherein the first and second mixing elements are formed from a single panel made of either a metal or a fibre-reinforced plastic.

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13. The apparatus of claim 12, wherein the single panel is either being cut to two separate pieces or being cut and twisted in a manner whereby the two halves are joined together at a centre portion of the panel.

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14. A method for assembling an apparatus for mixing at least two liquids, the method including: positioning a first and a second planar mixing element in a circular cylindrical channel; and mounting the first and the second mixing elements,

wherein the first mixing element and the second mixing element are non-coplanar, a first normal axis of the first mixing element being at a first acute angle to the cylindrical channel and a second normal axis of the second mixing element being at a second acute angle to the cylindrical channel, with the first normal axis and the second normal axis being divergent to each other, and

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wherein a mid-portion of a first straight edge of the first planar mixing element is joined to a mid-portion of a second straight edge of the second planar mixing element.

15. The method of claim 14, wherein each mixing element includes at least one opening.

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16. The method of claim 15, wherein at least one parameter of the at least one opening is configured to keep a pressure drop in the cylindrical channel within desired performance criteria, the at least one parameter being selected from a group of: size, shape, and location.

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17. The method of claim 15, wherein the at least one opening is defined by a shape selected from a group consisting of: a sector of an oval, a circle, a polygon and an ellipse.

18. The method of any one of claims 14 to 17, wherein the first mixing element and the second mixing element are mounted in contact with an inner surface of the cylindrical channel.

19. The method of any one of claims 14 to 18, wherein each of the first acute angle and the second acute angle is between 45° to 65° .

20. The method of claim 19, wherein each of the first acute angle and the second acute angle is 56° .

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21. The method of any one of claims 14 to 18, wherein the first acute angle and the second acute angle are identical.

22. The method of any one of claims 14 to 21, wherein the first acute angle and the second acute angle are configured to keep least one of: a pressure drop in the cylindrical channel, and a coefficient of variance at a pre-determined distance downstream from the first mixing element and the second mixing element within desired performance criteria.

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23. The method of any one of claims 14 to 22, further including mounting at least one injector at a location along the cylindrical channel upstream from the first mixing element and the second mixing element.

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24. The method of any one of claims 14 to 23, wherein the first and the second mixing elements are made from either a metal or a fibre-reinforced plastic.

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25. The method of any one of claims 14 to 24, wherein the first and second mixing elements are formed from a single panel made of either a metal or a fibre-reinforced plastic.

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26. The method of claim 25, wherein the single panel is either being cut to two separate pieces or being cut and twisted in a manner whereby the two halves are joined together at a centre portion of the panel.