

HEAT EXCHANGER

FIELD OF THE INVENTION

The field of the invention relates to heat exchangers.

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BACKGROUND

Heat exchangers are known. Heat exchangers typically take a fluid such as a gas stream and convey that fluid through a structure having a device which operates to change the temperature of the fluid. Although such heat exchangers exist, they each have their own shortcomings. Accordingly, it is desired to provide an improved heat exchanger.

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SUMMARY

According to a first aspect, there is provided a heat exchanger for a reagent stream, comprising: an inlet conduit configured to receive the reagent stream; an inlet manifold fluidly coupled with the inlet conduit; and a plurality of heat exchange chambers fluidly coupled with the inlet manifold, wherein the inlet manifold has a static impeller structure configured to separate the reagent stream into a plurality of separated reagent streams and to direct each of the plurality of separated reagent streams to a corresponding one of the plurality of heat exchange chambers.

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The first aspect recognizes that a problem with existing heat exchangers is that they can be less efficient than desired, leading them to occupy more space than desired. Accordingly, a heat exchanger is provided. The heat exchanger may be for a reagent stream or other gas stream. The heat exchanger may comprise an inlet conduit, channel duct. The inlet conduit may be configured to receive the reagent stream. The heat exchanger may comprise an inlet manifold or structure. The inlet manifold may be fluidly coupled with the inlet conduit. The inlet manifold may receive the reagent stream. The heat exchanger may comprise a plurality of heat exchange chambers or cavities. The heat exchange chambers may be fluidly coupled with the inlet manifold. The inlet manifold may

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have a static, fixed or stationary impeller structure, or a ridged or ribbed dome structure. The static impeller structure may be configured to separate or divide the reagent stream into a plurality of separated reagent streams. The static impeller structure may direct or guide each of the plurality of separated reagent
5 streams to a corresponding or associated one of the plurality of heat exchange chambers. In this way, the reagent stream can be split into multiple separated streams, each of which is provided to a separate heat exchange chamber which can efficiently perform the required temperature change on the reagent stream. Providing the static impeller structure helps to improve the flow characteristics of
10 the separated reagent streams, with minimal back pressure. This helps to provide a compact heat exchanger with improved performance.

The static impeller structure may be shaped and/or configured to present a plurality of leading edges or upstanding ridges facing towards a major flow
15 direction of the reagent from the inlet conduit. The plurality of leading edges may be positioned to separate or divide the reagent stream into the plurality of separated reagent streams within the inlet manifold. Again, this provides for a compact arrangement for conveniently splitting the reagent stream.

20 The plurality of leading edges may extend radially from a central axis aligned with the major flow direction. Hence, the leading edges may extend with a radial component outwards from a centreline of the direction of flow of the reagent stream from the inlet conduit. This separates and distributes the reagent stream, providing a compact arrangement.

25 The plurality of leading edges may extend radially from the central axis to define a spiral structure facing towards the major flow direction. Hence, the leading edges may spiral radially outwards from the central axis. This causes the separated reagent streams to also spiral radially outwards from the central axis.

30 The plurality of leading edges may extend radially from the central axis to define a helical structure facing towards the major flow direction.

The plurality of leading edges may be positioned to redirect flow of the reagent stream from the major flow direction along the central axis to a radial flow direction for each of the plurality of separated reagent streams. Hence, the
5 leading edges may change the direction of flow from axial to having a radial flow component.

The static impeller structure may be shaped and/or configured to impart or cause a rotational flow about the radial flow direction to each of the plurality of
10 separated reagent streams. Accordingly, the static impeller structure may serve to rotate the flow of each separated reagent stream.

The plurality of leading edges may be provided by connected vanes defined by a continuous surface.

15 Each heat exchange chamber may comprise a swept inlet cavity. Each swept inlet cavity may be configured to receive an associated or corresponding one of the plurality of separated reagent streams in the radial flow direction. The swept inlet cavity may redirect that separated reagent stream to flow in a direction
20 parallel to the central axis. Accordingly, the swept inlet cavity may realign the direction of flow of each of the separated reagent stream to return to being along the central axis.

The swept inlet cavity may be shaped as a double offset structure.

25 The swept inlet cavity may enlarge along a direction of flow of that separated reagent stream. This helps to slow each separated reagent stream.

The swept inlet cavity may transition or change from a generally circular cross-
30 section to a generally rectangular cross-section along a directional flow of that separated reagent stream.

Each heat exchange chamber may comprise an elongate portion downstream of the swept inlet cavity. The elongate portion may have a generally rectangular cross-section.

- 5 Each rectangular cross-section may extend generally radially and tangentially to the central axis. This arranges each elongate portion to enable them to be positioned in a compact arrangement whilst still providing required space outside the elongate portion.
- 10 The elongate portion may comprise a solid insert or member defining a plurality of conduits or channels configured to divide the separated reagent stream. This helps to increase the surface area between the separated reagent stream and the elongate portion to improve heat exchange.
- 15 The elongate portion may comprise a planar or flat external surface. The external surface may be configured and/or shaped to receive a heating/cooling device.

- The elongate portion may comprise a pair of opposing planar external surfaces, each configured to receive a heating/cooling device. Accordingly, each elongate portion may receive a pair of heating/cooling devices. Alternatively, each elongate portion may receive a single heating/cooling device.

- The heating/cooling device may comprise a Peltier device.

- 25 Each elongate portion may extend along a plane which is angularly offset from circumferentially adjacent elongate portions. Again, this helps to improve the compactness of the heat exchanger since rather than extending fully radially, which would narrow the space between adjacent elongate portions at their
- 30 radially innermost approach, providing the angular offset increases the space between adjacent elongate portions.

Each heat exchange chamber may be at least partially nested within a circumferentially adjacent heat exchange chamber. Again, this helps to improve the compactness of the heat exchanger.

- 5 The heat exchanger may comprise an outlet manifold fluidly coupled with the plurality of heat exchange chambers. The outlet manifold may have a further static impeller structure configured to combine the plurality of separated reagent streams into a combined reagent stream and to direct the combined reagent stream to a fluidly coupled outlet conduit.

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The further static impeller structure may be shaped to present a corresponding one of a plurality of vane surfaces positioned to combine each of the plurality of separated reagent streams into the combined reagent stream. The plurality of vane surfaces may extend to trailing edges facing away from a major flow

- 15 direction of the combined reagent stream.

The plurality of trailing edges may extend radially from a central axis aligned with the major flow direction.

- 20 The plurality of trailing edges may extend radially from the central axis to define a spiral structure facing away from the major flow direction.

The plurality of trailing edges may extend radially from the central axis to define a helical structure facing away from the major flow direction.

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The plurality of trailing edges may be positioned to redirect flow from a radial flow direction of each of the plurality of separated reagent streams to the major flow direction of the combined reagent stream along the central axis.

- 30 The static further impeller structure may be shaped to impart a rotational flow about the major flow direction of the combined reagent stream.

The plurality of vane surfaces may comprise a plurality of connected vane surfaces defined by a continuous surface.

Each heat exchange chamber may comprise a swept outlet cavity configured to
5 receive one of the plurality of separated reagent streams in the direction parallel to the central axis and to redirect that separated reagent stream to flow in the radial flow direction.

The swept outlet cavity may be shaped as a double offset structure.
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The swept outlet cavity may narrow along a direction of flow of that separated reagent stream.

The swept outlet cavity may transition from a generally rectangular cross section
15 to a generally circular cross section along a direction of flow of that separated reagent stream.

The inlet conduit may extend along the central axis and each elongate portion may extend in a direction parallel to the central axis.
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The outlet conduit may extend along the central axis.

The inlet conduit and the outlet conduit may be inline, positioned on the central axis.
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According to a second aspect, there is provided a method, comprising: receiving a reagent stream at an inlet conduit; conveying the reagent stream from the inlet conduit to an inlet manifold fluidly coupled with the inlet conduit; and separating the reagent stream into a plurality of separated reagent streams with a static
30 impeller structure and directing each of the plurality of separated reagent streams to a corresponding one of a plurality of heat exchange chambers.

The method may comprise shaping the static impeller structure to present a plurality of leading edges facing towards a major flow direction of the reagent from the inlet conduit and positioning the static impeller structure to separate the reagent stream into the plurality of separated reagent streams.

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The method may comprise positioning the plurality of leading edges to extend radially from a central axis aligned with the major flow direction.

10 The method may comprise positioning the plurality of leading edges to extend radially from the central axis to define a spiral structure facing towards the major flow direction.

15 The method may comprise positioning the plurality of leading edges to extend radially from the central axis to define a helical structure facing towards the major flow direction.

The method may comprise positioning the plurality of leading edges to redirect flow of the reagent stream from the major flow direction along the central axis to a radial flow direction for each of the plurality of separated reagent streams.

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The method may comprise shaping the static impeller structure to impart a rotational flow about the radial flow direction to each of the plurality of separated reagent streams.

25 The plurality of leading edges may be provided by connected vanes defined by a continuous surface.

The method may comprise receiving one of the plurality of separated reagent streams in the radial flow direction and to redirecting that separated reagent stream to flow in a direction parallel to the central axis with a swept inlet cavity.

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The swept inlet cavity may be shaped as a double offset structure.

The swept inlet cavity may enlarge along a direction of flow of that separated reagent stream.

- 5 The swept inlet cavity may transition from a generally circular cross section to a generally rectangular cross section along a direction of flow of that separated reagent stream.

- 10 Each heat exchange chamber may comprise an elongate portion downstream of the swept inlet cavity, the elongate portion having a generally rectangular cross section.

- 15 The method may comprise positioning each rectangular cross-section to extend generally radially and tangentially to the central axis.

The method may comprise dividing the separated reagent stream with a solid insert defining a plurality of conduits within the elongate portion.

- 20 The method may comprise receiving a heating/cooling device on a planar external surface of the elongate portion.

The method may comprise receiving a heating/cooling device on each of a pair of opposing planar external surfaces of the elongate portion.

- 25 The heating/cooling device may comprise a Peltier device.

The method may comprise positioning each elongate portion to extend along a plane which is angularly offset from circumferentially adjacent elongate portions.

- 30 The method may comprise at least partially nesting each heat exchange chamber within a circumferentially adjacent heat exchange chamber.

The method may comprise positioning the inlet conduit to extend along the central axis and each elongate portion to extend in a direction parallel to the central axis.

- 5 The method may comprise coupling an outlet manifold with the plurality of heat exchange chambers and combining the plurality of separated reagent streams into a combined reagent stream and directing the combined reagent stream to a fluidly coupled outlet conduit with a further static impeller structure.
- 10 The method may comprise shaping the further static impeller structure to present a corresponding one of a plurality of vane surfaces positioned to combine each of the plurality of separated reagent streams into the combined reagent stream, the plurality of vane surfaces extending to trailing edges facing away from a major flow direction of the combined reagent stream.
- 15 The method may comprise positioning the plurality of trailing edges to extend radially from a central axis aligned with the major flow direction.
- The method may comprise positioning the plurality of trailing edges to extend
- 20 radially from the central axis to define a spiral structure facing away from the major flow direction.
- The method may comprise positioning the plurality of trailing edges to extend
- 25 radially from the central axis to define a helical structure facing away from the major flow direction.
- The method may comprise positioning the plurality of trailing edges to redirect flow from a radial flow direction of each of the plurality of separated reagent streams to a major flow direction of the combined reagent stream along the
- 30 central axis.

The method may comprise shaping the static further impeller structure to impart a rotational flow about the major flow direction of the combined reagent stream.

5 The plurality of vane surfaces may comprise a plurality of connected vane surfaces defined by a continuous surface.

The method may comprise receiving one of the plurality of separated reagent streams in the direction parallel to the central axis and redirecting that separated reagent stream to flow in the radial flow direction with a swept outlet cavity.

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The swept outlet cavity may be shaped as a double offset structure.

The swept outlet cavity may narrow along a direction of flow of that separated reagent stream.

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The swept outlet cavity may transition from a generally rectangular cross section to a generally circular cross section along a direction of flow of that separated reagent stream.

20 The method may comprise positioning said inlet conduit to extend along said central axis and each elongate portion to extend in a direction parallel to said central axis.

25 The method may comprise positioning said outlet conduit to extend along said central axis.

The method may comprise positioning said inlet conduit and said outlet conduit to be inline, positioned on said central axis.

30 Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be

combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

Where an apparatus feature is described as being operable to provide a function,
5 it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described further, with
10 reference to the accompanying drawings, in which:
Figure 1 is an isometric view of a heat exchanger according to one embodiment;
Figure 2 is an inlet end view of the heat exchanger of Figure 1;
Figure 3 is an outlet end view of the heat exchanger of Figure 1;
Figure 4 is an isometric view of a heating/cooling device;
15 Figure 5 is an isometric view of the heat exchanger of Figure 1 with the heating/cooling devices omitted;
Figure 6 is a side view of the heat exchanger of Figure 5;
Figures 7 and 8 are sectional end views of the heat exchanger of Figure 5 showing the static impeller in more detail;
20 Figure 9 is a sectional isometric view of the heat exchanger of Figure 5 showing the static impeller in more detail;
Figures 10 and 11 are a sectional isometric views of the heat exchanger of Figure 5 showing the swept inlet in more detail; and
Figure 12 is a sectional isometric views of the heat exchanger of Figure 5
25 showing the elongate portion in more detail.

DESCRIPTION OF THE EMBODIMENTS

Before discussing the embodiments in any more detail, first an overview will be provided. Some embodiments provide for a compact and efficient heat
30 exchanger. Typically, the heat exchanger is produced using additive manufacturing techniques. The heat exchange has an inlet which receives a gas stream and an inline outlet which provides the gas stream at a different

temperature. An inlet manifold splits the received gas stream and conveys this to a number of heat exchange chambers. A dome-like or static impeller-like structure is used to split the received gas stream and direct each split gas stream into an associated heat exchange chamber which operates to change the

5 temperature of the split gas streams. The dome-like or static impeller-like structure has a number of protrusions, ribs, ridges or leading edges which act on the received gas stream and split it into separated gas streams. Having a number of heat exchange chambers arranged in parallel improves the performance of the heat exchanger. Splitting the gas stream into separate gas

10 streams helps to reduce flow rates through the heat exchange chambers and increase their dwell time. The dome-like or static impeller-like structure helps to rotate the separate gas streams entering the heat exchange chambers. The heat exchange chambers are orientated both radially and tangentially to enable the heat exchange chambers and their heating/cooling devices to be closely packed

15 together to reduce footprint size. The split gas streams exhausted by the heat exchange chambers are conveyed to a downstream outlet manifold. A further static impeller structure is used to combine the split gas streams and convey the combined gas stream into the outlet. The further static impeller structure helps to rotate the combined gas stream to improve mixing and reduce any temperature

20 gradient across the combined gas stream.

Heat Exchanger – General Configuration

FIG. 1 is an isometric view and FIG 2. is an end view of a heat exchanger 10 for changing a temperature of a reagent stream according to one embodiment. The

25 heat exchanger 10 comprises an inlet conduit 20. The inlet conduit 20 is generally cylindrical, having a generally circular cross-section extending from an inlet aperture 25. The inlet conduit 20 extends along an axial direction A-A. The inlet conduit 20 coupled with a downstream inlet manifold 30. The inlet manifold 30 has a single, generally circular cross-section inlet aperture and a plurality (in

30 this embodiment, 5) of generally rectangular cross-section outlets. The inlet manifold 30 couples with 5 downstream heat exchange chambers 40. The heat exchange chambers 40 each comprise a swept inlet cavity 50 located

downstream of the inlet manifold 30, an elongate portion 60 which fluidly couples downstream with the associated swept inlet cavity 50, a swept outlet cavity 70 fluidly coupled downstream of an associated elongate portion 60. The elongate portion 60 carries a pair of Peltier devices 110 for changing the temperature of the reagent stream. The elongate portion 60 extends along the axial direction A-A. The inlet manifold 30 is shaped to separate the reagent stream into 5 separated reagent streams, each provided to an associated heat exchange chamber 40. This helps to improve the overall performance of the heat exchanger 10 since each heat exchange chamber 40 only needs to deal with a portion of the overall reagent stream – which helps to reduce the overall length of the heat exchanger 10. The swept inlet cavities 50 and the swept outlet cavities 70 are shaped to position the elongate portions 60 and their associated Peltier devices 110 to be nested closely together - which helps to improve the radial compactness of the heat exchanger 10. The heat exchange chambers 40 fluidly couple with a downstream outlet manifold 80. The outlet manifold 80 has a plurality (in this embodiment, 5) of generally rectangular cross-section inlets and a single, generally circular cross-section outlet aperture. The outlet manifold 80 is shaped to combine the 5 separated reagent streams into a combined reagent stream. The outlet manifold 80 fluidly couples with a downstream outlet conduit 90. As can be seen in more detail in FIG 3, the outlet conduit 80 is generally cylindrical, having a generally circular cross-section extending to an outlet aperture 95. The outlet conduit 80 extends along the axial direction A-A. This arrangement provides for an inline device where the inlet conduit 20 and the outlet conduit 90 are aligned axially along the axial direction A-A.

As can be seen in more detail in FIGS. 4 to 6, the elongate portion 60 has a generally rectangular cross-section and has a pair of generally planar, opposing major surfaces 100A, 100B. A Peltier device 110 is located on each of the major surfaces 100A, 100B. Each Peltier device 100 is also elongate with a generally rectangular cross-section and has a major surface 120A which is planar and shaped and configured to fit with the major surfaces 100A, 100B.

Inlet Manifold

FIGS. 7 to 9 are sectional views showing internal features of the inlet manifold 30. The inlet manifold 30 comprises a structure which is shaped to split the flow received from the inlet conduit 20 along the axial direction A-A into five separate streams, each of which is then directed into its associated swept inlet cavity 50. In particular, the inlet manifold has a static impeller structure 130 having five sets of vanes 140A, 140B, each defining five leading edges 150 which face towards the major direction of flow of the reagent stream received through the inlet conduit 20. The leading edges 150 are configured to extend radially from the axial direction A-A. The leading edges 150 split the reagent stream into 5 separated reagent streams. The vanes 140A, 140B provide surfaces which scoop each separated reagent streams and direct their flow into the swept inlet cavities 50.

Heat Exchange Chambers

FIGS. 10 to 12 are a sectional isometric views showing the heat exchange chambers 40 in more detail. As can be seen in FIGS. 10 and 11, the shape of the swept inlet cavities 50 downstream of the static impeller 130 becomes more rectangular in cross-section towards the elongate portion 60. Hence, the inlet manifold 30 and the swept inlet cavities 50 take a reagent stream having a generally circular cross-section and splits this into five separated reagent streams having a generally rectangular cross-section. The elongate portion 60 has its major surfaces 100A, 100B positioned to extend generally radially with respect to an elongate axis A-A of the heat exchanger 10 but with an angular offset to orientate each elongate portion 60 to a more tangential position in order to prevent excessive narrowing of the radially-innermost space between adjacent elongate portions 60 to enable the Peltier devices 110 to be located in place. In particular, a radially-innermost edge 65 of each elongate portion 60 is positioned on a circumference extending around the axial direction A-A. Each elongate portion 60 is then orientated to extend generally radially from that position. However, rather than extending fully radially, an angular offset is applied to each elongate portion 60 to orientate them more tangentially to the circumference.

This structural arrangement is similar to a tangential spoke configuration. The elongate portion 60 is filled and comprises a plurality of axially-extending, separated apertures 160, which extend along the length of the elongate portion 60. Each elongate portion 60 is fluidly coupled with a downstream swept outlet cavity 70. The shape of the swept outlet cavities 70 downstream of the elongate portion 60 becomes more circular in cross-section towards downstream outlet manifold 80.

Outlet Manifold

The outlet manifold 80 comprises a mirror structure to that of the inlet manifold 30 and is shaped to combine the five separate streams from their associated swept outlet cavity 70 and provide the combined reagent stream to the outlet conduit 90 along the axial direction A-A. In particular, the outlet manifold 80 has a static impeller structure having five sets of vanes, each defining five trailing edges which face along the major direction of flow of the combined reagent stream provided to the outlet conduit 90. The trailing edges are configured to extend radially from the axial direction A-A. The vanes provide surfaces which take each separated reagent stream and combines their flow into the outlet conduit 90.

In operation, a gas, such as a reagent stream is received at the inlet aperture 25 and travels axially along the inlet conduit 20. The reagent stream is received by the downstream inlet manifold 30 and is split into five separated reagent streams by the leading edges 150. Each separated reagent stream is directed by the vane 140A, 140B into an associated swept inlet cavity 50. The curvature of the vanes 140A, 140B in combination with the curvature and shape of the swept inlet cavity 50 and the increasing cross-sectional area causes the separated reagent streams to rotate and recirculate within the swept inlet cavity 50 and slow. Separating the reagent stream and providing a plurality of parallel heat exchange chambers 40 helps to reduce flow rates in each heat exchange chamber 40 and increase dwell times. The separated reagent streams flow towards its associated downstream elongate portion 60 and flow through the apertures 160. The number, sizing and positioning of the apertures 160, together with the thermal

conductivity of the elongate portion 60 and the performance of the associated Peltier devices 110, are selected to provide a required temperature change of the separated reagent streams as they flow through the elongate portion 60. The Peltier devices 110 are operated to provide the required temperature change
5 (cooling or heating) of the separated reagent streams. The separated gas streams exit the elongate portions 60 and enter the downstream outlet manifold 80, which is essentially a mirrored version of the inlet manifold 30. The separated reagents streams are recombined by the outlet manifold 80 which acts to rotate the combined reagent stream as it flows into the outlet conduit 90, which
10 improves mixing and provides for a more uniform temperature across the reagent stream as it exits the outlet conduit 90.

Hence, some embodiments provide an arrangement that heats a range of gasses up to 180°C with a flow rate of 250 SLM. The arrangement is compact and inline
15 flow design to heat or cool gases providing an abatement assist to reduce/eliminate contamination build up within exhaust fore lines due to process gas contaminants.

In some embodiments, the reagent stream is nitrogen, the 10 Peltier devices 110
20 have a contact area with the elongate portions 60 measuring 100mm x 25 mm and the apertures 160 have a diameter of 1mm. Modelling was performed at a standard condition temperature (273.15K) and absolute pressure (100kPa) to obtain mass flow at the inlet aperture 25. The nitrogen is assumed to be at an operating pressure of 220.83 kPa (32.03 psi) with a thermal conductivity of
25 0.0242 w/m-k. The heat exchanger 10 is assumed to be made of stainless steel having a density of 9030 kgm-3, a specific heat of 502.48 J/kg-k and a thermal conductivity of 16.27 w/m-k. The nitrogen is assumed to have a mass flow inlet of 5.137E-03 kg/s (250 SLM) and an inlet temperature of 20.05°C, an outlet pressure of 0 Pa and a constant surface temperature of the 10 Peltier devices
30 110 of 210°C. The average temperature of the nitrogen is calculated by the modelling to be 181.62°C.

Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing
5 from the scope of the invention as defined by the appended claims and their equivalents.

REFERENCE SIGNS

	Heat exchanger	10
	Inlet conduit	20
5	Inlet aperture	25
	Inlet manifold	30
	Heat exchange chamber	40
	Swept inlet cavity	50
	Elongate portion	60
10	Edge	65
	Swept outlet cavity	70
	Outlet manifold	80
	Outlet conduit	90
	Outlet aperture	95
15	Major surfaces	100a, 100b; 120a
	Peltier devices	110
	Static impeller structure	130
	Vanes	140a, 140b
	Leading edges	150
20	Apertures	160

CLAIMS

1. A heat exchanger for a reagent stream, comprising:
an inlet conduit configured to receive said reagent stream;
5 an inlet manifold fluidly coupled with said inlet conduit; and
a plurality of heat exchange chambers fluidly coupled with said inlet manifold, wherein said inlet manifold has a static impeller structure configured to separate said reagent stream into a plurality of separated reagent streams and to direct each of said plurality of separated reagent streams to a corresponding one
10 of said plurality of heat exchange chambers.
2. The heat exchanger of claim 1, wherein said static impeller structure is shaped to present a plurality of leading edges facing towards a major flow direction of said reagent from said inlet conduit and positioned to separate said
15 reagent stream into said plurality of separated reagent streams.
3. The heat exchanger of claim 2, wherein said plurality of leading edges at least one of:
extend radially from a central axis aligned with said major flow direction;
20 extend radially from said central axis to define a spiral structure facing towards said major flow direction;
extend radially from said central axis to define a helical structure facing towards said major flow direction;
are positioned to redirect flow of said reagent stream from said major flow
25 direction along said central axis to a radial flow direction for each of said plurality of separated reagent streams; and
are provided by connected vanes defined by a continuous surface.
4. The heat exchanger of claim 2 or 3, wherein said static impeller structure
30 is shaped to impart a rotational flow about said radial flow direction to each of said plurality of separated reagent streams.

5. The heat exchanger of any preceding claim, wherein each heat exchange chamber comprises a swept inlet cavity configured to receive one of said plurality of separated reagent streams in said radial flow direction and to redirect that separated reagent stream to flow in a direction parallel to said central axis.
- 5 6. The heat exchanger of claim 5, wherein said swept inlet cavity is at least one of:
- shaped as a double offset structure;
 - enlarges along a direction of flow of that separated reagent stream.
- 10 transitions from a generally circular cross section to a generally rectangular cross section along a direction of flow of that separated reagent stream.
7. The heat exchanger of claim 5 or 6, wherein each heat exchange chamber
- 15 comprises an elongate portion downstream of said swept inlet cavity, said elongate portion having a generally rectangular cross section.
8. The heat exchanger of claim 7, wherein each rectangular cross-section extends generally radially and tangentially to said central axis.
- 20 9. The heat exchanger of claim 7 or 8, wherein said elongate portion comprises at least one of:
- a solid insert defining a plurality of conduits configured to divide said separated reagent stream;
 - 25 a planar external surface configured to receive a heating/cooling device;
 - and
 - a pair of opposing planar external surfaces, each configured to receive a heating/cooling device.
- 30 10. The heat exchanger of claim 9, wherein said heating/cooling device comprises a Peltier device.

11. The heat exchanger of any one of claims 7 to 10, wherein each elongate portion extends along a plane which is angularly offset from circumferentially adjacent elongate portions.
- 5 12. The heat exchanger of any preceding claim, wherein each heat exchange chamber is at least partially nested within a circumferentially adjacent heat exchange chamber.
- 10 13. The heat exchanger of any preceding claim, wherein said inlet conduit extends along said central axis and each elongate portion extends in a direction parallel to said central axis.
- 15 14. The heat exchanger of any preceding claim, comprising an outlet manifold fluidly coupled with said a plurality of heat exchange chambers, wherein said outlet manifold has a further static impeller structure configured to combine said plurality of separated reagent streams into a combined reagent stream and to direct said combined reagent stream to a fluidly coupled outlet conduit.
- 20 15. The heat exchanger of claim 14, wherein said further static impeller structure is shaped to present a corresponding one of a plurality of vane surfaces positioned to combine each of said plurality of separated reagent streams into said combined reagent stream, said plurality of vane surfaces extending to trailing edges facing away from a major flow direction of said combined reagent stream.
- 25 16. The heat exchanger of claim 15, wherein said plurality of trailing edges at least one of:
- extend radially from a central axis aligned with said major flow direction;
 - extend radially from said central axis to define a spiral structure facing
 - 30 away from said major flow direction;
 - extend radially from said central axis to define a helical structure facing away from said major flow direction; and

are positioned to redirect flow from a radial flow direction of each of said plurality of separated reagent streams to a major flow direction of said combined reagent stream along said central axis.

5 17. The heat exchanger of claim 15 or 16, wherein said static further impeller structure is shaped to impart a rotational flow about said major flow direction of said combined reagent stream.

10 18. The heat exchanger of any one of claims 15 to 17, wherein said plurality of vane surfaces comprise a plurality of connected vane surfaces defined by a continuous surface.

15 19. The heat exchanger of any preceding claim, wherein each heat exchange chamber comprises a swept outlet cavity configured to receive one of said plurality of separated reagent streams in said direction parallel to said central axis and to redirect that separated reagent stream to flow in said radial flow direction.

20 20. The heat exchanger of claim 19, wherein said swept outlet cavity is at least one of:
shaped as a double offset structure;
narrows along a direction of flow of that separated reagent stream; and
transitions from a generally rectangular cross section to a generally
circular cross section along a direction of flow of that separated reagent stream.

25 21. The heat exchanger of any preceding claim, wherein said inlet conduit extends along said central axis and each elongate portion extends in a direction parallel to said central axis.

30 22. The heat exchanger of any one of claims 14 to 21, wherein said outlet conduit extends along said central axis.

23. The heat exchanger of any one of claims 14 to 22, wherein said inlet conduit and said outlet conduit are inline, positioned on said central axis.

24. A method, comprising:
5 receiving a reagent stream at an inlet conduit;
conveying the reagent stream from the inlet conduit to an inlet manifold fluidly coupled with said inlet conduit; and
separating said reagent stream into a plurality of separated reagent streams with a static impeller structure and directing each of said plurality of separated reagent
10 streams to a corresponding one of a plurality of heat exchange chambers.