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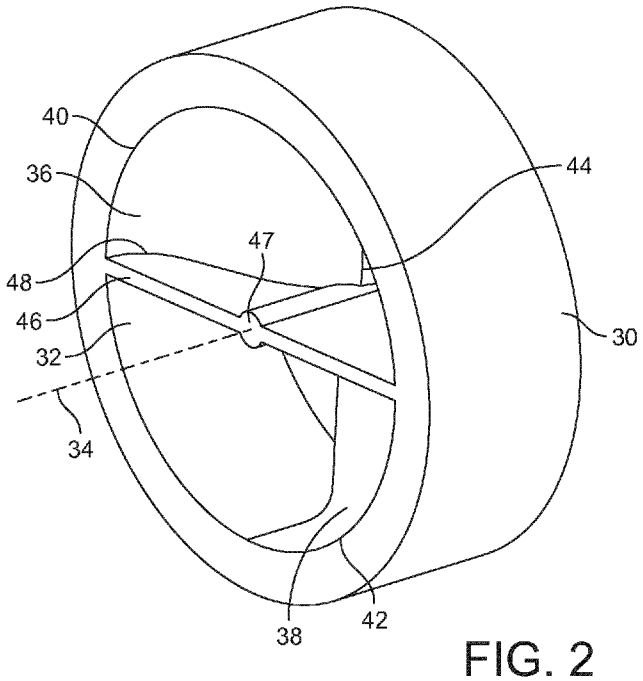

FIG. 2

(57) Abstract: A fluid mixing device comprises a tubular structure (30) including an inner wall (32) which defines a channel, the channel having a central longitudinal axis (34) and being configured to convey a fluid in a longitudinal direction along the structure, and a plurality of flow deflection elements (36, 38) which are supported by the structure and located within the channel. Each flow deflection element (36, 38) defines a surface that extends between a first leading edge (40, 42), which extends transversely around a first portion of the inner wall (32) of the hollow tubular structure, and a first trailing edge (44) which is spaced in the longitudinal direction from the first leading edge and extends radially inwardly from the inner wall.

WO 2018/178261 A1

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Title: Fluid Mixing Device

Field of the Invention

The present invention concerns a fluid mixing device and more particularly it relates to devices for increasing the homogeneity of a fluid, mixing together dissimilar fluids, or for minimising thermal gradients across a fluid stream. Such a device may be used on a large scale, for example in industrial systems, and also on a smaller scale, such as in microfluidic systems for biological and chemical analysis.

Background to the Invention

Precision and ultra-precision machine tools commonly incorporate hydrostatic guideways and spindle bearings to ensure that the structural loop supporting the machining process is optimised to be highly stiff and well damped. Specialist hydrostatic fluid delivery equipment built for use in such machines must minimise audible noise and transmitted vibrations from its pumps and fluid flow, to avoid disturbing the machine structure and causing damage to the surface integrity of the workpiece. Fluid mass flow rate is deliberately kept low in such equipment, with pipes and restrictors designed to ensure laminar flow with minimal turbulence. However, low turbulence leads to poor thermal mixing of the fluid and this can make it more difficult to maintain accurate temperature control of the machine, which can reduce the dimensional accuracy of the machining process.

Fluid delivery equipment may use temperature feedback control linked to fast acting heaters to trim the temperature of a pressurised hydraulic fluid at the point of delivery of the fluid to the machine tool. The heater elements are located in chambers where the oil is caused to flow chaotically around the elements. Whilst this chaotic motion of the fluid in the chambers improves the heat mixing, it is at the expense of turbulent flow and a consequent increase in background noise and vibration.

It is desirable to accurately measure the temperature of the fluid close to the point of use in the machine tool. However, there tends to be a temperature gradient across the

pipework in the fluid delivery system so it is not possible to accurately assess the overall temperature of the fluid using a single sample point. Multi-point temperature sampling may be used, but is complex and not guaranteed to produce consistent results.

Various devices have been developed to cause dissimilar fluids to be combined involving labyrinthine pipework, grids and pocketed structures, for example. However, many existing devices tend to cause eddy currents and turbulent flow to develop, and provide an inadequate degree of mixing.

Summary of the Invention

The present invention provides a fluid mixing device comprising a tubular structure including an inner wall which defines a channel, the channel having a central longitudinal axis and being configured to convey a fluid in a longitudinal direction along the structure; and a plurality of flow deflection elements which are supported by the structure and located within the channel, with each flow deflection element defining a surface that extends between a first leading edge, which extends transversely around a first portion of the inner wall of the hollow tubular structure, and a first trailing edge which is spaced in the longitudinal direction from the first leading edge and extends radially inwardly from the inner wall.

The first leading edge extends from the inner wall transversely around a first portion of the inner wall, that is, the first leading edge is in a plane that is transverse to the longitudinal axis, so that the first leading edge extends circumferentially around a first portion of the inner wall.

The surface of the flow detection element typically also has a radially and longitudinally extending connecting edge that extends between one end of the first leading edge and one end of the first trailing edge.

The configuration of the flow deflection elements tends to direct fluid flowing close to the inner wall of the tubular structure away from the wall and preferably generally

towards the centre of the channel. At the same time, it rotates the fluid flowing over the elements relative to the longitudinal direction. Depending on the configuration of the element, rotation may be in a clockwise or anti-clockwise sense around the central longitudinal axis. Improved mixing may be achieved without causing excessive turbulence using such arrangements. The mixing device may cause heat energy within the fluid to be substantially evenly distributed across a transverse cross-section of the flow before the fluid exits the device.

The flow deflection elements may be arranged such that the cross-sectional area through which the fluid flows as it passes over the fluid deflection elements remains substantially constant. This minimises changes in the flow velocity which might otherwise tend to increase turbulence.

The mixing device may be configured to divide and recombine the fluid flow multiple times. The shape of the fluid deflection elements may tend to cause the fluid flow to be both rotated and carried through cross-sections of different shapes to enhance the mixing process.

The leading edges may extend around a portion of the inner wall of the tubular structure in a plane perpendicular to the central longitudinal axis.

The flow deflection elements may be supported at fixed locations within the device by the tubular structure. They may be supported along their leading and/or trailing and/or connecting edges. For example, a respective radial supporting member or plate may be provided for the trailing edge and/or for the connecting edge, typically extending radially inwardly from the inner wall.

In a preferred embodiment, the first trailing edge of each of the plurality of flow deflection elements extends radially inwardly from a point on the inner wall which is substantially aligned in the longitudinal direction with one end of the first trailing edge. This may tend to lead to smoother flow of the fluid after the deflection element.

A gradient of the surface of each of the plurality of flow deflection elements, with respect to the longitudinal direction and in a plane which includes the central longitudinal axis, may increase and then decrease from the first leading edge to the first trailing edge. Such a profile may tend to increase the rate of mixing whilst maintaining smooth fluid flow.

In preferred examples, the rate of change of a gradient of the surface of each flow deflection element, with respect to the longitudinal direction and in a plane which includes the central longitudinal axis, from the first leading edge to the first trailing edge:

(a) increases to a maximum, positive value;

(b) then decreases to a minimum negative value; and

(c) then increases again.

Preferably, a gradient of the surface of each of the plurality of flow deflection elements, with respect to the longitudinal direction and in a plane which includes the central longitudinal axis, is substantially zero at the first leading edge and the first trailing edge. This serves to minimise disturbance of smooth fluid flow by the fluid deflection elements.

In preferred configurations, each of the plurality of flow deflection elements is (preferred substantially) confined transversely between radially inwardly extending lines (preferably straight) which extend from each end of the first leading edge towards the central axis. These lines may be defined by surfaces of supporting members. This facilitates combination of the elements in such a way as to ensure thorough mixing of the fluid without excessively impeding the fluid flow, by arranging a sequence of elements so that their respective radially inwardly extending lines are substantially aligned in the longitudinal direction, with the elements in combination extending substantially over the entire cross-section of the channel when viewed in the longitudinal direction.

For example, the radially extending lines may subtend an angle at the central longitudinal axis of around 90°. In that case, it can be seen that four elements are able

in combination to impinge on the fluid flow across the whole cross-section of the channel. Alternatively, the radially extending lines may subtend other angles, for example 60°, 120°, and other subdivisions of a full rotation.

A number of different combinations of flow deflection elements with different subtended angles and rotational senses may be adopted, for example alternating 90° clockwise and anti-clockwise; 120° clockwise, 60° anti-clockwise, 60° clockwise, 120° anti-clockwise (possibly repeated), and the like.

Preferably, each of the plurality of flow deflection elements is paired with another flow deflection element which defines a surface that extends between a second leading edge, which extends transversely around a second portion of the inner wall of the hollow tubular structure, and a second trailing edge which is spaced in the longitudinal direction from the second leading edge and extends radially inwardly from the inner wall, with the second leading edge and second trailing edge being substantially diametrically opposite to the first leading edge and the first trailing edge, respectively. Two or more such pairs may be provided at substantially the same longitudinal locations in the structure with each pair being rotationally displaced (from the others) relative to the central longitudinal axis. Multiple pairs may be provided which are spaced longitudinally along the tubular structure, with adjacent pairs being rotationally displaced from one another relative to the central longitudinal axis.

The device may include a supporting plate which extends diametrically across the channel and parallel to the central axis and provides support for a respective pair of diametrically opposed flow deflection elements.

In a preferred example, a pair of flow deflection elements which acts to deflect flow in a clockwise sense around the central longitudinal axis is located upstream of a further pair of flow deflection elements which acts to deflect flow in an anti-clockwise sense around the central longitudinal axis, or vice versa. Reversing the direction of rotation imposed on the fluid by the flow deflection elements tends to enhance the

mixing effect. It has been found that such combinations of elements are particularly effective for mixing.

Preferably, each pair of a set of (or all of the) flow deflection elements rotates the flow in the opposite sense around the central longitudinal axis to each adjacent pair.

In a further example, a sequence of four consecutive pairs of flow deflection elements in the longitudinal direction acts to deflect flow around the central longitudinal axis in a clockwise sense, a clockwise sense, an anti-clockwise sense, and an anti-clockwise sense, respectively, or vice versa.

A set of two longitudinally spaced apart pairs of flow deflection elements which acts to deflect flow in the same rotational sense may be provided. They may be configured such that all fluid around the circumference of the channel impinges on at least one of the flow deflection elements so as to avoid any fluid travelling adjacent to the wall of the channel and being substantially undisturbed by the deflection elements.

A fluid mixing device embodying the invention may comprise a multiplicity of groups of flow deflection elements, each group comprising four elements spaced consecutively along the structure in the longitudinal direction, with the groups provided in series to iteratively improve the uniformity of mixing of the fluid flow along the device. Each group may comprise a set of four pairs of flow deflection elements as defined above. Other arrangements can be readily envisaged.

The fluid mixing device is typically stationary in use, with fluid supplied in a longitudinal direction to one end.

A fluid mixing device as described herein may be included in a fluid delivery system for a machine tool. The present invention further provides a machine tool including such a fluid delivery system.

For some applications, the fluid mixing device may be provided within a pressure resistant tube such as a hydraulic pipe for example. This may serve to increase the

burst pressure of the device, and may therefore be desirable in high pressure systems. Fabrication of the fluid mixing device may involve 3D printing techniques.

The fluid mixing device may be used to minimise thermal gradients across fluid streams. It may also be used to mix dissimilar fluids, which may be in the form of liquids, aerosols or gases.

Brief Description of the Drawings

A known fluid mixing device and embodiments of the invention will now be described by way of example and with reference to the accompanying schematic drawings, wherein:

Figure 1 is a perspective view of sections of a fluid mixing device configuration which is outside the scope of the present invention;

Figure 2 is a perspective view of a section of a fluid mixing device according to an embodiment of the invention;

Figures 3 to 7 are perspective, top, front, side and rear views of part of a device section similar to that shown in Figure 2;

Figure 8 is a plot to illustrate a profile of a flow deflection element in the embodiment of Figures 2 to 7;

Figure 9 is a perspective exploded view of a sequence of sections of a fluid mixing device according to an embodiment of the invention;

Figure 10 depicts the results of a simulation based on the known mixing device configuration of Figure 1;

Figure 11 is a depiction of a simulation based on a fluid mixing device embodying the invention using sections of the configuration shown in Figures 2 to 7; and

Figure 12 shows plots of temperature gradients generated by the simulations of Figures 10 and 11.

Detailed Description of the Drawings

Figure 1 shows two sections of a fluid mixing device outside the scope of the present invention which has a configuration similar to that disclosed in US 3,286,992. This document relates to a device for mixing two or more fluid feed materials and dispensing the resulting composition.

The device of Figure 1 includes a hollow cylindrical tube 10 of uniform cross-section. This tube has been divided transversely into two parts in Figure 1 so that the internal structure is more clearly visible. In use, two feed liquids A and B may be fed via feed end 12 through the tube 10.

Two curved elements 14 and 16 are provided within the tube in sequence along the axial direction. Each curved element is formed from a thin flat sheet which has been twisted about the central axis 18 of the tube so that upstream and downstream edges of the tube are at a substantial angle to each other. Curved element 16 is located downstream of element 14. Curved element 14 twists in the opposite rotational direction to element 16.

The initial stream consisting of components A and B strikes the upstream edge 20 of the first curved element 14 which splits it into two partial streams. The curved elements rotate the flows helically in one direction and then the other.

A section of a fluid mixing device embodying the invention is shown in Figure 2. It includes a hollow tubular structure 30 having an inner cylindrical wall 32 which defines a channel having a central longitudinal axis 34. A pair of flow deflection elements 36 and 38 is provided within the channel at substantially the same axial location. Flow deflection element 38 is the same shape as flow deflection element 36,

but it is rotated through 180° about the central axis of the tubular structure relative to element 36.

Each flow deflection element has a leading edge 40, 42, respectively, which extends transversely (that is, in a plane that is transverse to the longitudinal axis), part way around the inner wall 32, thus extending circumferentially around the inner wall. Each flow deflection element also has a trailing edge (part of trailing edge 44 of one of the flow deflection elements is visible in Figure 2) which is spaced axially from its leading edge. Each flow deflection element 36, 38 defines a continuous curved surface that extends between its leading and trailing edges for deflecting fluid flowing towards it along the channel. Each trailing edge extends radially inwardly from the inner wall towards the central axis 34 of the tubular structure 30.

A supporting plate 46 extends diametrically across the tube between opposing parts of the inner wall and extends axially along the tubular structure, with an enlarged central longitudinal core 47.

The leading edge of each flow deflection element is supported by the inner wall of the tubular structure. The element meets the supporting plate 46 along a radially and longitudinally extending connecting edge 48 which extends between the leading edge and the trailing edge of the deflection element. The trailing edge 44 extends radially between the inner wall of the tubular structure and the supporting plate 46. In the embodiment illustrated, the radially extending edges 44 and 48 subtend an angle of around 90° at the central axis 34 (when projected onto a plane which is perpendicular to the central axis).

The deflection elements 36 and 38 are located at diametrically opposite positions, on opposite sides of central axis 34.

In the example illustrated in Figure 2, the flow deflection elements are each configured to rotate fluid flow in a clockwise direction from their leading to trailing edges, when viewed in the direction of fluid flow. As the elements extend inwardly from leading edges which are located on the inner wall of the tubular structure, the

deflection elements also tend to divert fluid flowing close to the inner wall radially inwardly. The flow deflection elements are able to do this without causing excessive internal turbulence. In comparison to the configuration shown in Figure 1, this tends to encourage greater mixing of the fluids. It was found that when using an arrangement of the form shown in Figure 1, there was a tendency for fluids to be able to travel largely undisturbed in the region proximate to the inner wall of the hollow cylindrical tube 10.

Figures 3 to 7 show perspective, top, front, side and rear views of flow deflection elements similar to that depicted in Figure 2, with the tubular structure 30 and core 47 omitted. The structure of Figures 3 to 7 differs from that shown in Figure 2 in that the flow deflection elements are configured to rotate flow in the opposite sense, that is, in an anti-clockwise direction when viewed in the direction of fluid flow. The same reference numerals are used to identify corresponding features in each configuration.

The trailing edge 50 of flow defection element 38 is visible in Figure 5. The trailing edges 44, 50 of the flow deflection elements meet radially extending supporting plates 52.

The flow deflection elements are configured such that the cross-sectional area through which the fluid flows is substantially constant and does not vary significantly as the fluid passes over the flow deflection elements and is rotated.

The inner diameter of the hollow tubular structure (that is, the width of the channel defined between opposite sides of its inner wall) may be selected to optimise the degree of fluid mixing for a given fluid (with the fluid deflection elements being scaled accordingly). For example, when mixing oil for use in a machine tool to minimise any temperature variations, it was found that a preferred diameter was around 20mm. The wall thickness of such configuration may be around 5mm to give sufficient structural strength for example. It was found that a required level of mixing was achieved using a fluid mixing device having a hollow tubular structure around 205mm long (which included 8 pairs of flow deflection elements). It will be appreciated that further pairs of flow deflection elements may be added (or pairs

removed) to attain a desired level of mixing, whilst minimising the overall length of the device. In this example, the axial length of each module comprising a pair of flow deflection elements was around 20mm.

Figure 8 shows a plot of the shape of edge 48 of a fluid deflection element in an example embodying the invention. The distance, r, of the edge measured radially outwardly from the central axis 34 is plotted against the distance, x, measured along the central axis 34. It can be seen that the gradient of the plot is substantially zero at the start and end points 60, 62 of the edge. This is to minimise disturbance of the flow as it impinges on and then leaves the surface of the flow deflection element. Moving along the edge from the start point 60, the gradient gradually increases to a maximum at a midpoint 64, before gradually decreasing back to at or near zero at point 62. Smooth flow over the flow deflection element is also encouraged by gradually changing the rate of change of the gradient from the start point 60 at the leading edge to the end point 62 at the trailing edge. In this direction, the rate of change of the gradient increases to a maximum, positive value, then decreases to zero at the midpoint 64, before it decreases to a minimum negative value and increases again before the end point 62 where it is again zero.

In embodiments of the invention, mixing device sections as depicted in Figure 2 which impart a clockwise rotation to the fluid (and the counterpart sections which impart an anti-clockwise rotation) may be combined in various ways along the mixing device. It may be preferable to alternate sections of different rotation senses to enhance mixing. As a further possibility, it may be useful to have groups of two or more sections which rotate in the same sense followed by two or more sections which rotate in the opposite sense. In the embodiment depicted in the Figures, each flow deflection element of each pair subtends an angle of around 90° at the central axis. Thus, following such a section by an identical section which is rotated through 90° results in providing four flow deflection elements which together impinge on the full cross-sectional area of the channel.

Figure 9 depicts an exploded view of such an embodiment in which a pair 70 of sections (74, 76) which rotate the flow in a clockwise sense is followed by a pair 72 of

sections (78, 80) which rotate the flow in an anti-clockwise sense. The second section 76 is identical to first section 74, but is rotated 90° clockwise about the central axis 34. The fourth section 80 is identical to the third section 78, but rotated 90° anti-clockwise when looking along the direction of flow.

In a preferred embodiment (not illustrated), a series of sections is provided comprising alternating adjacent sections 74 which rotate flow in a clockwise sense and sections 80 which rotate flow in an anti-clockwise sense.

In order to compare the performance of a mixing device embodying the present invention with a device having a configuration of the form shown in Figure 1, simulations were carried out using computational fluid dynamics (CFD) and the results are depicted in Figures 10 and 11. Figure 10 relates to a device 81 of the form depicted in Figure 1 and Figure 11 relates to a device 82 according to an embodiment of the invention. In each case, a flow consisting of a combination of two parts (having semi-circular cross-sections and labelled 83a, 83b and 84a, 84b, respectively) at different temperatures was fed into the input end of each device. It will be appreciated that this is an extreme "worst case scenario", whereas in reality, the fluid will always already be in a partially mixed state, with the transition to an acceptable level of mixing happening sooner within the mixer than in these simulated examples.

In these examples, the left hand, more lightly shaded semi-circular flows (83a and 84a) were at 293.70°C initially and the right hand, darker semi-circular flows (83b and 84b) were at 292.70°C. Cross-sections (84 and 85, respectively) of the fluid flows are shown downstream of each of eight flow mixing portions (not shown) which are provided within each device. Each cross-section is shaded according to the temperature at each point across the flow.

In the device of Figure 10, each flow mixing portion includes a curved element of the form shown in Figure 1 (in which the curved elements are numbered 14 and 16), with the direction of twist of each element alternating along the length of the tube. In the device of Figure 11, each flow mixing portion comprises of a pair of sections of the form shown in Figure 9 (in which the pairs are numbered 70 and 72), with the

direction of fluid rotation caused by each pair alternating along the length of the device.

It can be seen that thorough mixing of the fluid occurs much more quickly in the embodiment 82 of the invention shown in Figure 11 compared to the device 81 of Figure 10. In the device of Figure 11, regions of clearly different temperature are no longer discernible after just three mixing portions, whereas, in the device of Figure 10, temperature differences can still be seen after all eight mixing portions. According to the simulations, there was still a temperature spread of 0.4°C at the downstream end of the device of Figure 10, whereas any temperature spread remaining in the device of Figure 11 was less than 0.01°C.

The improved performance achieved using a device embodying the invention is further illustrated by the diagram in Figure 12, which corresponds to the simulations shown in Figures 10 and 11. It shows plots of fluid temperature against axial distance along each fluid mixing device, with data points after each of the eight flow mixing portions. Plots 90 and 92 are the maximum and minimum temperatures in the device of Figure 10, whilst plots 94 and 96 are the maximum and minimum temperatures in the device of Figure 11 embodying the present disclosure. It can be seen that the temperature range decreases much more rapidly in the device of Figure 11.

A fluid mixing device embodying the invention may be constructed using 3D printing methods for example. This facilitates accurate construction of the desired structural elements. A wide range of plastics are suitable for use in 3D printing techniques. A device for use in a hydraulic fluid system should be resistant to degradation in the presence of oils, and could be formed from nylon for example.

Claims

1. A fluid mixing device comprising:

a tubular structure including an inner wall which defines a channel, the channel having a central longitudinal axis and being configured to convey a fluid in a longitudinal direction along the structure; and

a plurality of flow deflection elements which are supported by the structure and located within the channel,

with each flow deflection element defining a surface that extends between a first leading edge, which extends transversely around a first portion of the inner wall of the hollow tubular structure, and a first trailing edge which is spaced in the longitudinal direction from the first leading edge and extends radially inwardly from the inner wall.

2. A device of claim 1, wherein the first trailing edge extends radially inwardly from a point on the inner wall which is substantially aligned in the longitudinal direction with one end of the first trailing edge.

3. A device of claim 1 or claim 2, wherein a gradient of the surface of each flow deflection element, with respect to the longitudinal direction and in a plane which includes the central longitudinal axis, increases and then decreases from the first leading edge to the first trailing edge.

4. A device of any preceding claim, wherein the rate of change of a gradient of the surface of each flow deflection element, with respect to the longitudinal direction and in a plane which includes the central longitudinal axis, from the first leading edge to the first trailing edge:

(a) increases to a maximum, positive value;

(b) then decreases to a minimum negative value; and

(c) then increases again.

5. A device of any preceding claim, wherein a gradient of the surface of each flow deflection element, with respect to the longitudinal direction and in a plane

which includes the central longitudinal axis, is substantially zero at the first leading edge and the first trailing edge.

6. A device of any preceding claim, wherein each flow deflection element is substantially confined transversely between radially inwardly extending lines which extend from each end of the first leading edge.

7. A device of claim 6, wherein the radially extending lines subtend an angle at the central longitudinal axis of around 90°.

8. A device of any preceding claim, wherein each flow deflection element is paired with another flow deflection element which defines a surface that extends between a second leading edge, which extends transversely around a second portion of the inner wall of the hollow tubular structure, and a second trailing edge which is spaced in the longitudinal direction from the second leading edge and extends radially inwardly from the inner wall, with the second leading edge and second trailing edge being substantially diametrically opposite to the first leading edge and the first trailing edge, respectively.

9. A device of claim 8, wherein a pair of flow deflection elements which acts to deflect flow in a clockwise sense around the central longitudinal axis is located upstream of a further pair of flow deflection elements which acts to deflect flow in an anti-clockwise sense around the central longitudinal axis, or vice versa.

10. A device of claim 9, wherein a sequence of four consecutive pairs of flow deflection elements in the longitudinal direction acts to deflect flow around the central longitudinal axis in a clockwise sense, a clockwise sense, an anti-clockwise sense, and an anti-clockwise sense, respectively, or vice versa.

11. A fluid delivery system for a machine tool, which system includes a fluid mixing device of any preceding claim.

12. A machine tool including a fluid delivery system of claim 11.

13. A computer-readable medium storing computer-executable instructions adapted to cause a 3D printer to print a fluid mixing device of any of claims 1 to 10.

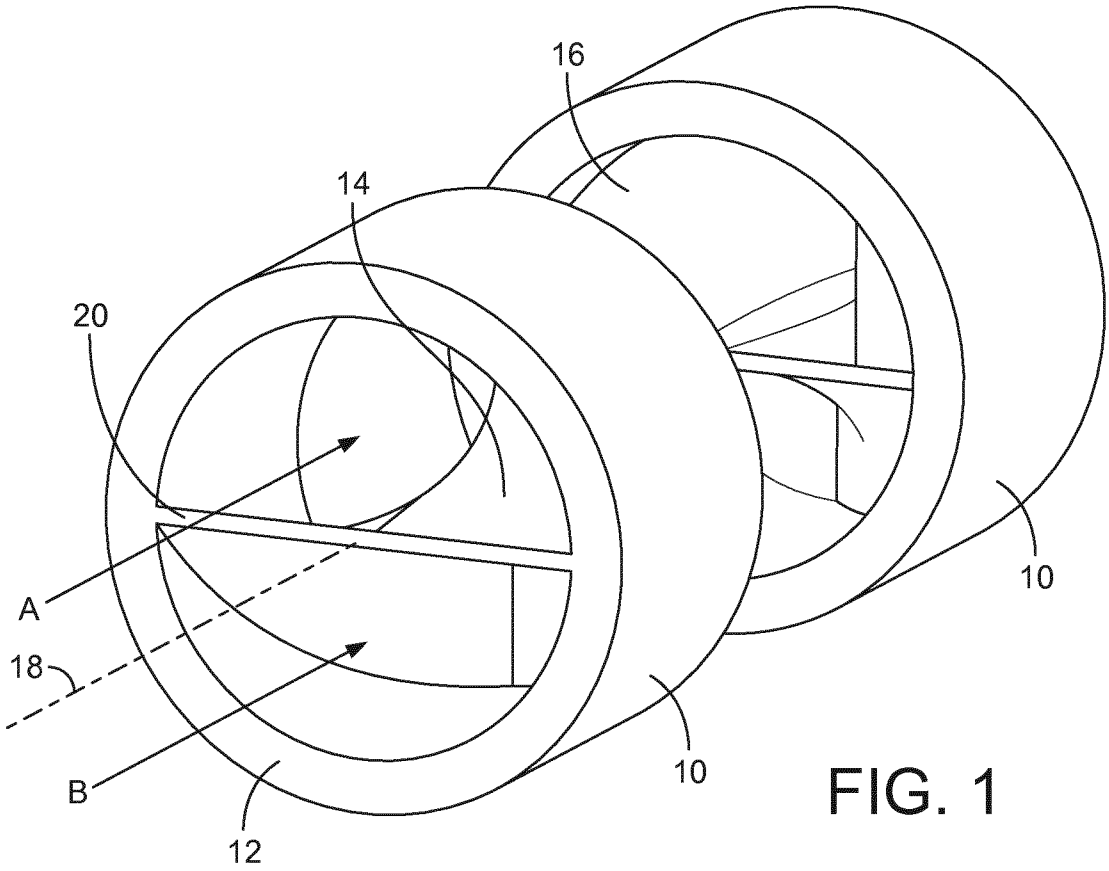

FIG. 1

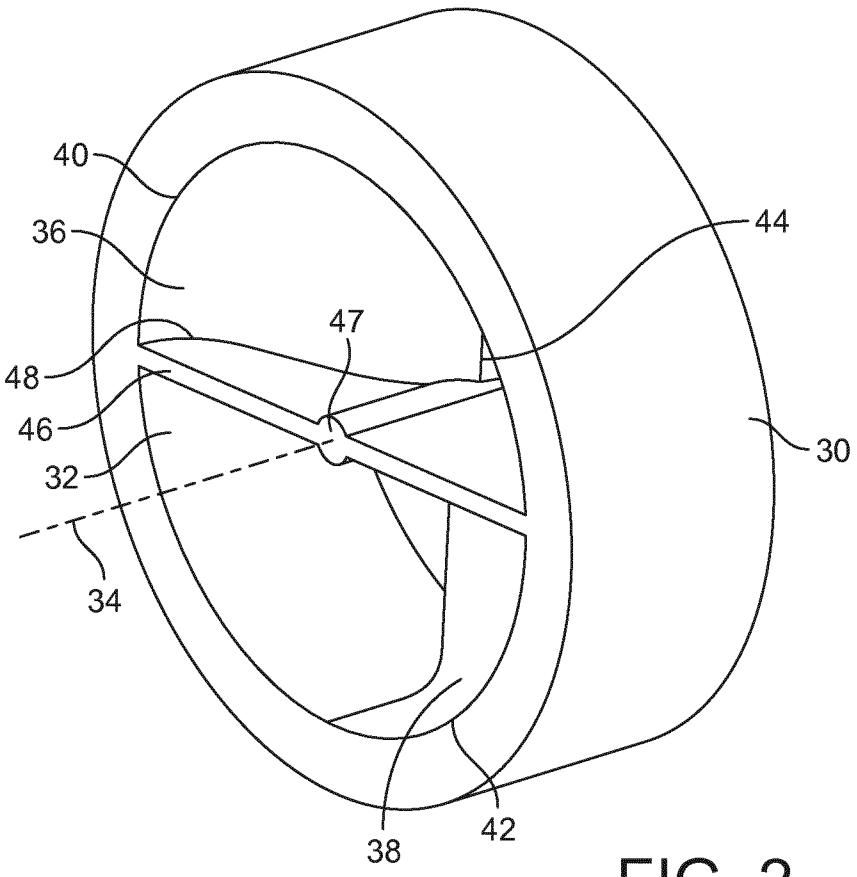

FIG. 2

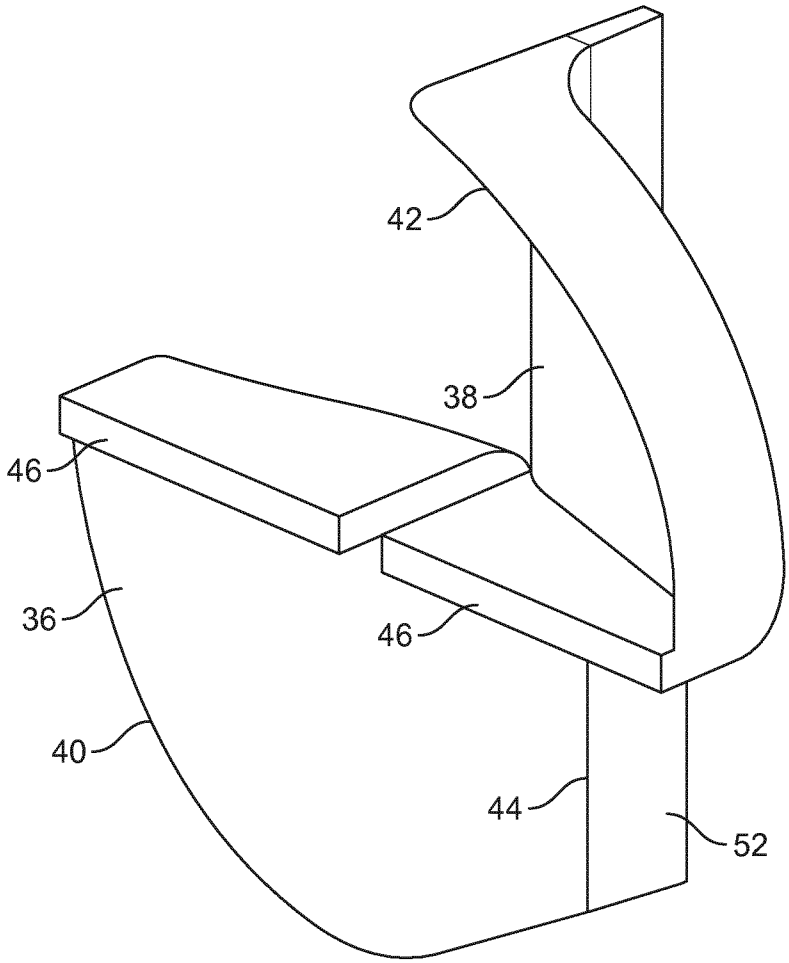

FIG. 3

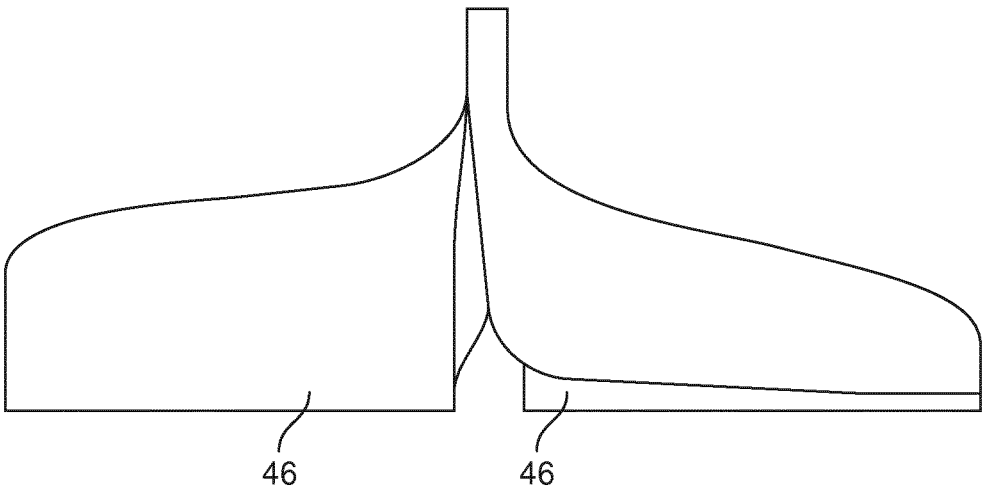

FIG. 4

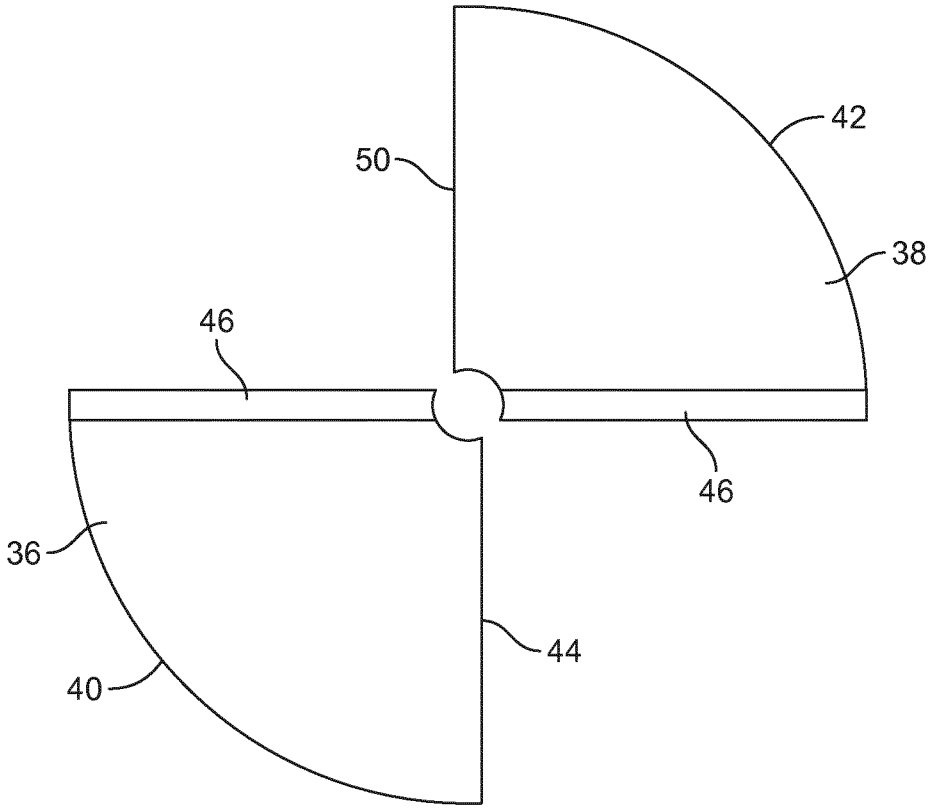

FIG. 5

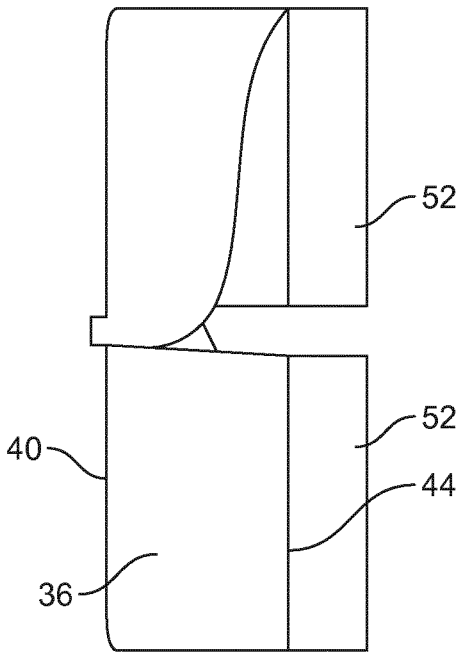

FIG. 6

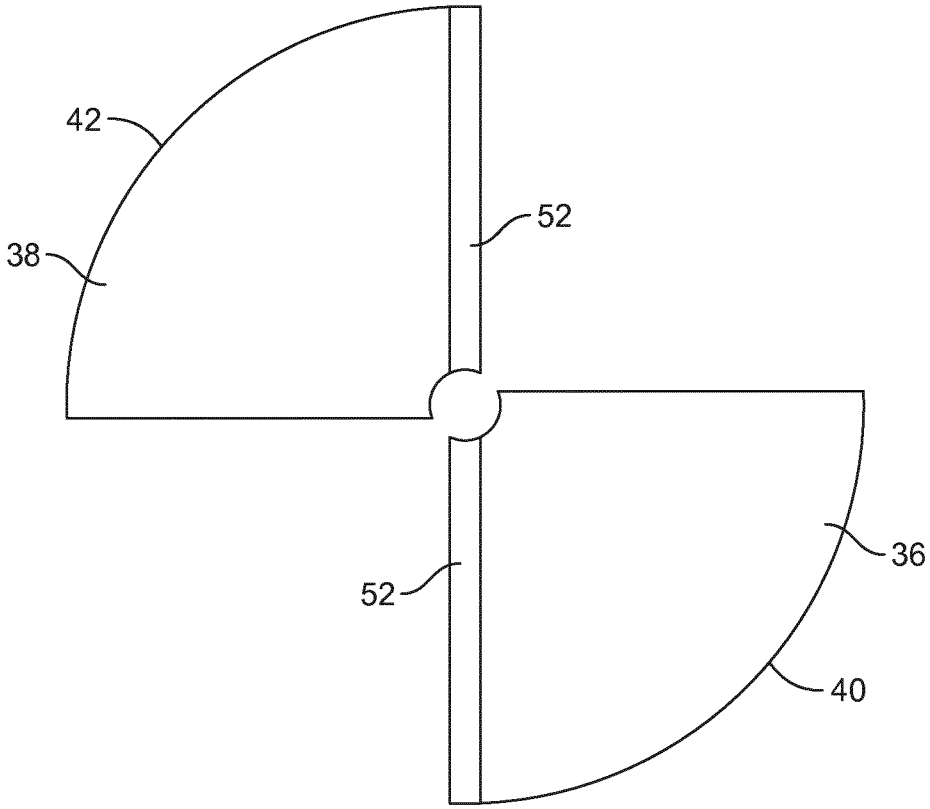

FIG. 7

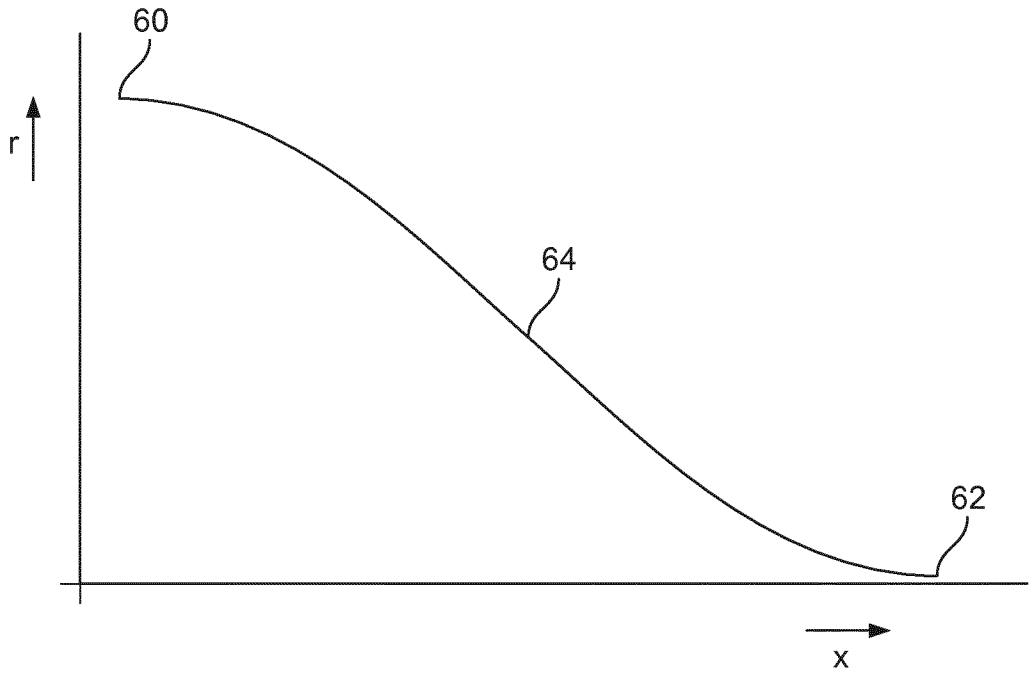

FIG. 8

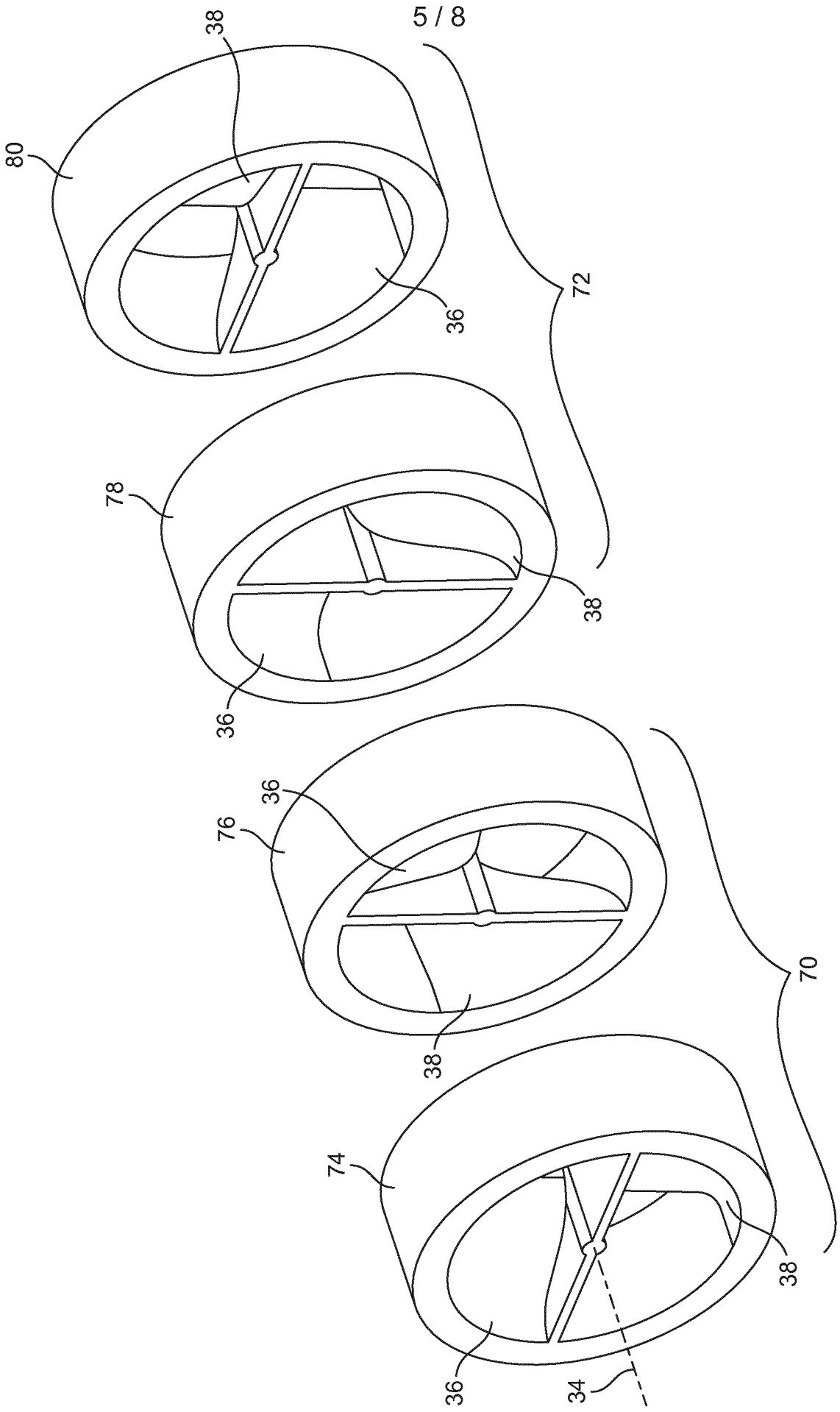

FIG. 9

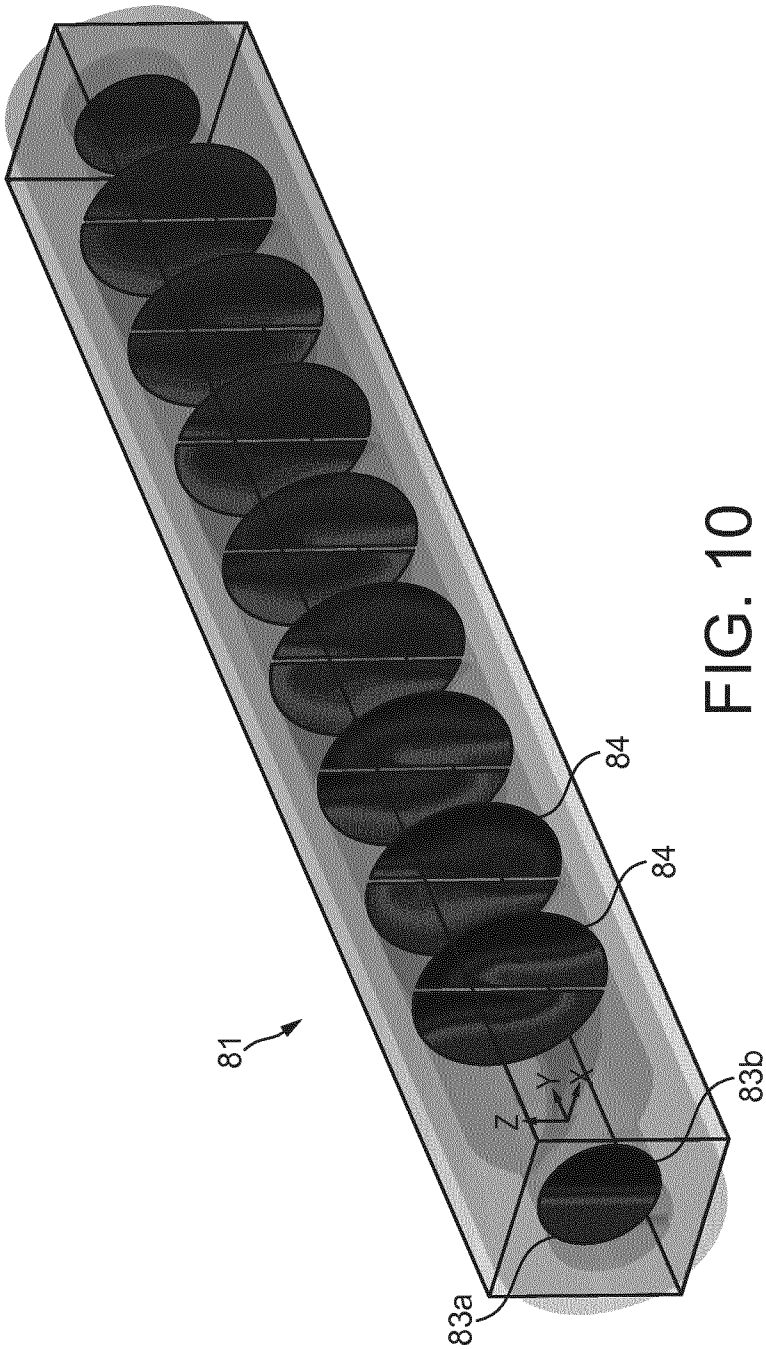

FIG. 10

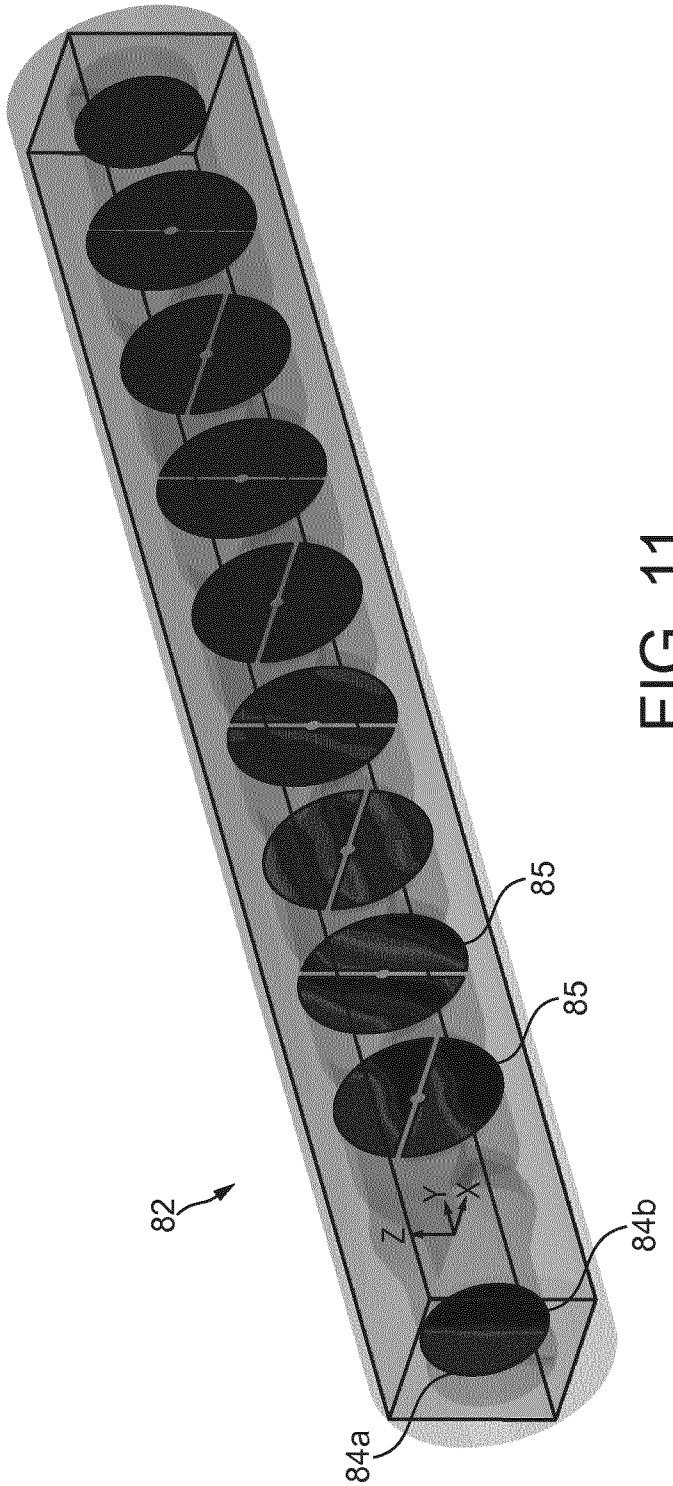

FIG. 11

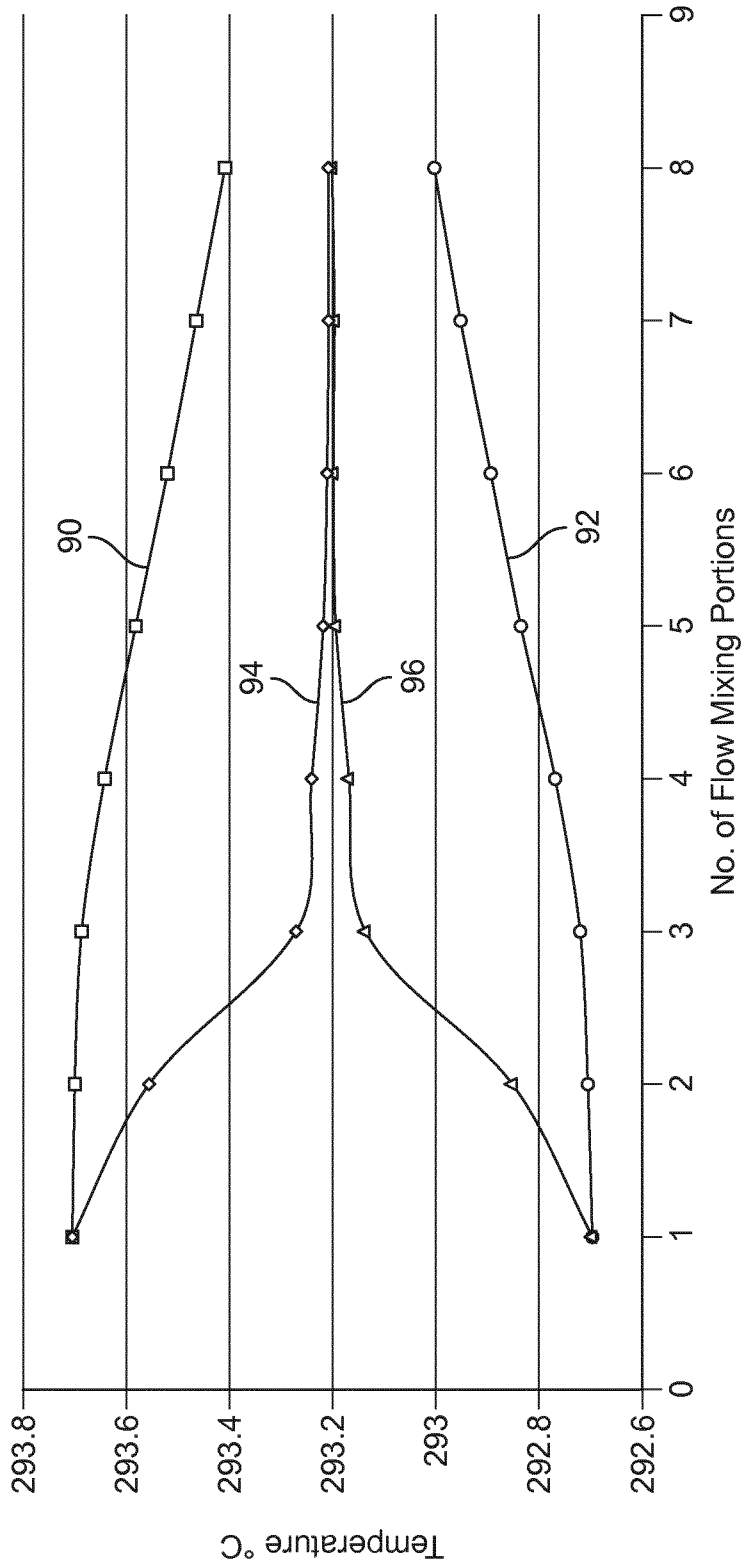
293.8
293.6
293.4
293.2
293
292.8
292.6
Temperature °C
0
1
2
3
4
5
6
7
8
9
No. of Flow Mixing Portions
90
92
94
96

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/058125

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01F5/06 B33Y80/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01F B33Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/004875 A2 (TAH IND INC [US]) 15 January 2004 (2004-01-15)	1,2,6-13
A	abstract figures 1, 9A-9C paragraphs [0024], [0033]	3-5
X	US 4 179 222 A (FINCH GEORGE W [US] ET AL) 18 December 1979 (1979-12-18)	1,3-13
A	figures 1-9 abstract column 3, line 51 - column 5, line 30	2
X	US 4 034 965 A (KING LEONARD TONY) 12 July 1977 (1977-07-12)	1,2,8-13
A	abstract figures 1-9	3-7

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

[X] See patent family annex.

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 2018	21/06/2018

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

1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/058125

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 747 697 A (KOJIMA HISAO [JP]) 31 May 1988 (1988-05-31) abstract figures 1-17 -----	1-13

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2018/058125

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