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(71) Applicant: **JASCO Corporation**
Hachioji-shi
Tokyo 192-8537 (JP)

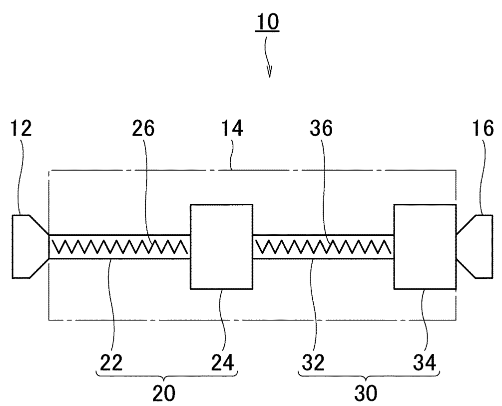
(72) Inventors:
- **BOUNOSHITA Masao**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **YANO Hiroki**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **IIJIMA Satoe**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **ISOGAI Atsushi**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **KAMEZAWA Kazutoshi**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **YOSHIDA Kengo**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **MOTEKI Tomohiro**
  Hachioji-shi, Tokyo 192-8537 (JP)
- **KUWAJIMA Miki**
  Hachioji-shi, Tokyo 192-8537 (JP)

(74) Representative: **Henkel & Partner mbB**
Patentanwaltskanzlei, Rechtsanwaltskanzlei
Maximiliansplatz 21
80333 München (DE)

(54) **STATIC MIXER**

(57) The present invention pertains to improving the mixing efficiency in a static mixer for mixing two or more types of liquids. The present invention provides a static mixer 10 comprising: a liquid inlet 12 through which two or more types of liquids flow in; a liquid mixing unit 14 for mixing the two or more types of liquids, the liquid mixing unit 14 being connected to the post stage of the liquid inlet 12; and a liquid outlet 16 through which the mixed liquid flows out, the liquid outlet 16 being connected to the post stage of the liquid mixing unit 14, The liquid mixing unit 14 has a turbulent diffusion mixer unit 20 configured so as to include: a substantially cylindrical, long and thin capillary mixer 22,

FIG.1



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Description

Related Application

[0001] This application claims the priority of Japanese Patent Application No. 2019-005793 filed on January 17, 2019, the disclosure of which is incorporated herein by reference in its entirety.

Technical Field

[0002] The present invention relates to a mixer for mixing liquids, and particularly to improvement in a mixing efficiency of a static mixer for mixing two or more types of liquids.

Background Art

[0003] Static mixers have been conventionally used for mixing liquids in various analysis fields such as liquid chromatography. There are various types of static mixers, and they are variously devised in accordance with their applications. In particular, there is a wide variety of types of liquids to be mixed these days, and the static mixers are variously devised in order to deal with those liquids and enhance a mixing efficiency as a mixer.

[0004] Patent Literature 1, for example, discloses a technique related to a fluid stirring apparatus (static mixer). The fluid stirring apparatus comprises: a twisted blade element disposed to divide the cross-section of the cylindrical inner space of the pipe into two parts to form two channels; and a hole provided to make a part of the fluid that flows either of the two channels to flow into the other channel, so that the fluid stirring apparatus can achieve an improved stirring action, a wider range of fluids to be stirred, and a low pressure-loss.

[0005] Patent Literature 2 discloses a technique related to a fluid mixing apparatus. In the fluid mixing apparatus, a plurality of half-open valves (ball valves or butterfly valves) are disposed in series inside the pipe, and the valves are set to have angular difference in the position around the axis thereof, so that turbulence of liquids that passed the pipe is promoted to achieve sufficient mixing.

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Unexamined Patent Publication No. 2005-34750 A
Patent Literature 2: Japanese Unexamined Patent Publication No. 2011-83763 A

Summary of Invention

Technical Problem

[0007] In the structure disclosed in Patent Literature 1, the stirring efficiency can be improved by simply devising the structure of the conventional static mixer such as providing a hole at a predetermined position of the twisted blade element; however, since mixing is performed with the conventional mechanism, it cannot be said that the mixing efficiency greatly improves.

[0008] Similarly, in Patent Literature 2, sufficient mixing can be achieved by disposing the plurality of valves in series to promote turbulence; however, it is extremely difficult to improve the mixing efficiency greatly since it is similar to conventional methods even if it has a unique structure. Therefore, there is still room for improvement.

Solution to Problem

[0009] The present invention has been made in view of the problems of the above-mentioned conventional art, and an object thereof is to improve a mixing efficiency compared with conventional static mixers, and provide a static mixer having a mixing efficiency that is not inferior to a dynamic mixer having a power unit when compared with the same.

[0010] In order to solve the above-mentioned problem, a statice mixer of the present invention comprises:

a liquid inlet provided to let two or more types of liquids to flow into the static mixer; a liquid mixing unit connected to the rear part of the liquid inlet to mix the two or more types of liquids; and a liquid outlet connected to the rear

part of the liquid mixing unit to let the mixed liquids flow out from the static mixer,
wherein
the liquid mixing unit has a turbulent diffusion mixer part that comprises: a substantially cylindrical, thin and long capillary mixer that mixes the liquids by turbulence with a twisted spiral rod comprised inside; and a mixing chamber that is located at the rear part of the capillary mixer and mixes the liquids that flow in inside,
the mixing chamber has a volume that is at least larger than the capillary mixer, and
the liquid mixing unit has at least two turbulent diffusion mixer parts connected in series.

[0011] In the static mixer of the present invention,

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and a liquid capacity of the first turbulent diffusion mixer part is greater than that of the second turbulent diffusion mixer part.

[0012] In the static mixer of the present invention,

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and a liquid capacity of the first turbulent diffusion mixer part is substantially equal to that of the second turbulent diffusion mixer part.

[0013] In the static mixer of the present invention,

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and a liquid capacity of the first turbulent diffusion mixer part is smaller than that of the second turbulent diffusion mixer part.

[0014] In the static mixer of the present invention,

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and the liquid mixing unit further comprises a third turbulent diffusion mixer part that is located on the liquid outlet side than the second turbulent diffusion mixer part.

[0015] In the static mixer of the present invention,
the liquid outlet comprises a twisted spiral plate inside thereof, and the twisted spiral plate further mixes the liquids mixed by the liquid mixing unit and lets the liquids flow out of the static mixer.
[0016] The static mixer of the present invention comprises
a switching valve mechanism that switches the plurality of series connections in the liquid mixing unit, and the liquid capacity of the liquid mixing unit can be varied by a switching action of the switching valve mechanism.
[0017] In the static mixer of the present invention,
the liquid capacity of the liquid mixing unit can be varied by connecting at least two turbulent diffusion mixer parts to each other by piping.

Advantageous Effects of Invention

[0018] According to the present invention, the liquid mixing unit has a characteristic turbulent diffusion mixer part that comprises a capillary mixer and a mixing chamber that is located on the rear part thereof, and at least two turbulent diffusion mixer parts are connected in series, so that a static mixer having an improved mixing efficiency than before can be provided.

Brief Description of Drawings

[0019]

FIG. 1 is a schematic configuration of the static mixer according to an embodiment of the present invention.
FIG. 2 is photographs of the capillary mixer and the twisted spiral rod according to the embodiment of the present invention.

FIG. 3 is a schematic view of the structure in which the connecting part of the capillary mixer and the mixing chamber has an angle in the static mixer according to the embodiment of the present invention.
FIG. 4 is a schematic view when the twisted spiral plate is provided to the liquid outlet in the static mixer according to the embodiment of the present invention.
FIG. 5 is a schematic view when a porous body is provided to the liquid outlet in the static mixer according to the present invention.
FIG. 6 is a schematic view of another configuration when a porous body is provided in the static mixer according to the embodiment of the present invention.
FIG. 7 is a schematic configuration when three turbulent diffusion mixer parts are connected in series in the static mixer according to the embodiment of the present invention.
FIG. 8 is a schematic configuration of a modification in the static mixer according to the embodiment of the present invention.
FIG. 9 is a schematic configuration of a modification in the static mixer according to the embodiment of the present invention.
FIG. 10 is a schematic configuration of a modification in the static mixer according to the embodiment of the present invention.
FIG. 11 is a schematic configuration of a modification in the static mixer according to the embodiment of the present invention.
FIG. 12 is a measurement result of baseline variation and noise by a gradient liquid feeding.

Reference Signs List

[0020]

10	Static mixer
12	Liquid inlet
14	Liquid mixing unit
16	Liquid outlet
18	Twisted spiral plate
18b	Porous body
20	First turbulent diffusion mixer part
22	Capillary mixer
24	Mixing chamber
26	Twisted spiral rod
30	Second turbulent diffusion mixer part
32	Capillary mixer
34	Mixing chamber
36	Twisted spiral rod
40	Third turbulent diffusion mixer part
50	Switching valve

Description of Embodiments

[0021] In the following, the static mixer of the present invention is described with reference to the drawings; however, the present invention is not limited to the examples given below as long as the spirit of the present invention is not exceeded.

[0022] FIG. 1 is a schematic configuration of a static mixer according to an embodiment of the present invention. A static mixer 10 of FIG. 1 comprises: a liquid inlet 12 that is provided to let two or more types of liquids to flow into the static mixer 10; a liquid mixing unit 14 that is connected to the rear part of the liquid inlet 12 and mixes the two or more types of liquids; and a liquid outlet 16 that is connected to the rear part of the liquid mixing unit 14 and provided to let the mixed liquids flow out from the static mixer 10.

[0023] The liquid inlet 12 is provided to let the liquid from the outside flow into the static mixer 10. The liquid inlet 12 is connected to two or more liquid tanks and liquid channels from the liquid tanks to the liquid inlet 12, for example (not shown in the drawing). The liquid tanks each contain different types of liquids. Accordingly, from the outside of the static mixer, two or more types of liquids flow into the liquid inlet 12.

[0024] The liquid mixing unit 14 has, connected in series, a first turbulent diffusion mixer part 20 that is located on the liquid inlet 12 side, and a second turbulent diffusion mixer part 30 that is located on the liquid outlet 16 side than the first turbulent diffusion mixer part 20. In the present embodiment, the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 having characteristic structures are used to mix two or more types of liquids efficiently.

[0025] The first turbulent diffusion mixer part 20 comprises a capillary mixer 22 and a mixing chamber 24. The capillary mixer 22 comprises a twisted spiral rod 26 inside, and mixes the two or more types of liquids by turbulence with the twisted spiral rod 26. The mixing chamber 24 is located at the rear part of the capillary mixer 22, and mixes the liquids that flow in by internal diffusion.

[0026] The capillary mixer 22 is a substantially cylindrical, thin, and long pipe or the like that is formed of stainless, PEEK (polyether ether ketone), PTFE (polytetrafluoroethylene), or the like. The inner diameter of the capillary mixer 22 is preferably about 0.25 to 3 mm, particularly preferably about 0.5 to 2 mm, and more preferably about 0.5 to 1 mm. The longitudinal dimension of the capillary mixer is preferably five times larger than its inner diameter (or outer diameter).

[0027] As shown in the photograph of FIG. 2, in the present embodiment, the capillary mixer 22 has the twisted spiral rod 26 inside thereof. The twisted spiral rod 26 in the present embodiment is not limited to this shape, and it may be of other shapes as long as it can mix the liquids inside the capillary mixer 22. The capillary mixer 22 of FIG. 1 has a linear, thin and long shape in the longitudinal direction; however, the effect of the present invention can be exhibited even when it has a curved shape that curves in the middle of the longitudinal direction.

[0028] The mixing chamber 24 has a substantially cylindrical shape, and has a space where the liquid can flow in and stay inside for a predetermined time. The mixing chamber 24 of the present embodiment is a substantially cylindrical shape; however, it may be of other shapes such as a conical shape, a combined shape of a conical shape and a cylindrical shape, a spherical shape or the like.

[0029] The mixing chamber 24 has a volume at least larger than the capillary mixer 22. The volume of the mixing chamber 24 is preferably 1.2 times or larger than that of the capillary mixer 22, more preferably 2 times or larger than that of the capillary mixer 22, and further preferably 5 times or larger. The mixing chamber 24 preferably has a widened shape relative to the substantially cylindrical, thin, and long capillary mixer 22.

[0030] The capillary mixer 22 and the mixing chamber 24 are linearly connected in FIG. 1; however, the connecting part between the capillary mixer 22 and the mixing chamber 24 may be bent upward, as shown in FIG. 3 for example, or in other directions. That is, the connecting part (the part where the liquid flows into the mixing chamber 24) may have a predetermined angle. Although it is not shown in the drawing, the part where the liquid flows out from the mixing chamber 24 may also have a predetermined angle.

[0031] Similarly, the second turbulent diffusion mixer part 30 comprises: a capillary mixer 32 and a mixing chamber 34. The capillary mixer 32 comprises a twisted spiral rod 36 inside, and mixes the two or more types of liquids by turbulence with the twisted spiral rod 36. The mixing chamber 34 is located at the rear part of the capillary mixer 32, and mixes the liquids that flows in by internal diffusion.

[0032] In the present embodiment, the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 may be of the same volume. Or, the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 of different volumes may be connected in series. In the static mixer 10 according to the present embodiment, the volume of the first turbulent diffusion mixer part 20 is larger than that of the second turbulent diffusion mixer part 30. The volume of the first turbulent diffusion mixer part 20 can be made smaller than that of the second turbulent diffusion mixer part 30.

[0033] The liquid outlet 16 is provided to let the liquid, that is efficiently mixed by passing through the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 of the liquid mixing unit 14, flow out of the static mixer 10. In component analysis, for example, the liquid outlet 16 can be used as a connecting port for connecting a component parts or the like to the rear part to the static mixer 10.

[0034] The two or more types of liquids flow in from the outside via the liquid inlet 12, pass through the liquid mixing unit 14 (the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30) to be mixed, and then flow out to the outside via the liquid outlet 16. The static mixer 10 according to the present embodiment is schematically configured as described above. In the following, mechanism of mixing liquids in the present embodiment will be described in detail.

<Mixing of liquids>

[0035] As described above, the static mixer 10 according to the present embodiment mixes two or more types of liquids with the liquid mixing unit 14. Here, flow of the liquids inside the liquid mixing unit 14 is described. First, the two or more types of liquids that flow in from the liquid inlet 12 reaches the capillary mixer 22 of the first turbulent diffusion mixer part 20.

[0036] The capillary mixer 22 in the present embodiment is a thin and long pipe or the like that has a substantially cylindrical shape, and has the twisted spiral rod 26 inside the thin and long pipe. The twisted spiral rod 26 is a stainless rod, for example, having a spiral stirring member (see FIG. 2). The liquids that flow in from the liquid inlet 12 pass through the inside of the capillary mixer 22, so that the two or more types of liquids are mixed by turbulence that occurs thereby (this is called a first mixing). Turbulence as used herein refers to a flow of which velocity or pressure of liquid changes irregularly.

[0037] As shown in FIG. 1, the twisted spiral rod 26 in the present embodiment is located entire the longitudinal direction inside the capillary mixer 22; however, it can be provided to a part of the longitudinal direction, or a short twisted spiral rod 26 can be provided in one or more locations. The twisted spiral rod 26 may be fixed inside the capillary mixer, or it may be provided to be movable inside to some extent.

[0038] The liquids that are mixed in the first mixing by turbulence inside the capillary mixer 22 flow into the mixing chamber 24 that is located at the rear part. As described above, the mixing chamber 24 has a substantially cylindrical shape, and has a space inside where the liquids can stay for a predetermined time.

[0039] The liquids that are mixed in the first mixing inside the capillary mixer 22 is further mixed by diffusion or turbulent diffusion inside the mixing chamber 24 (called as a second mixing). Diffusion as used herein refers to a state such that two or more different types of liquids becoming mixed uniformly. Turbulent diffusion as used in the present embodiment refers to a state such that the flow rate of the liquids becomes slower when the liquids flow in from the capillary mixer 22 to the mixing chamber 24, that is, the channel of the liquids becomes wider, so that the flow becomes turbulent therein, and thus a mixing effect occurs thereby.

[0040] In the first turbulent diffusion mixer part 20 of the present embodiment, the two or more types of liquids are mixed in the first mixing by turbulence generated by the capillary mixer 22, and, at the rear part, the liquids are further mixed in the second mixing by diffusion or turbulent diffusion generated by the mixing chamber 24. That is, the first turbulent diffusion mixer part 20 of the liquid mixing unit 14 in the present embodiment mixes the liquids in phases to improve the mixing efficiency.

[0041] The liquid mixing unit 14 of the present embodiment further comprises the second turbulent diffusion mixer part 30 at the rear part of the first turbulent diffusion mixer part 20. This second turbulent diffusion mixer part 30 may be the same as the first turbulent diffusion mixer part 20, or may be one of different shapes or volumes. The first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 are directly connected in the present embodiment; however, a liquid channel or the like (e.g., a tube or the like) for suitably connecting the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 can be provided, for example.

[0042] It can be expected that, in the mixing chamber 24 of the first turbulent diffusion mixer part 20, turbulence generated by the capillary mixer 22 in the front part may be further promoted by using the inner space of the mixing chamber 24. Specifically, after irregularly changing the flow of the liquids that are mixed to some extent by turbulence generated by the capillary mixer 22, the liquids can be sent to the second turbulent diffusion mixer part 30.

[0043] In the present embodiment, the first turbulent diffusion mixer part 20 performs the first mixing and the second mixing to mix the liquids in phases, and the second turbulent diffusion mixer part 30 further performs mixing in phases (a third mixing that corresponds to the first mixing, and a fourth mixing that corresponds to the second mixing) at the rear part, so that the mixing efficiency can be improved remarkably.

[0044] As shown in FIG. 4, a twisted spiral plate 18 is provided inside the liquid outlet 16 to mix additionally by turbulence. That is, in the static mixer 10 of FIG. 4, mixing can be performed in three phases without adding a new component, and, as a result, the mixing efficiency can be further improved.

[0045] As shown in FIG. 5, a porous body 18b having an effect of rectifying the flow of the liquids can be provided to the liquid outlet 16. As a result, a stable mixed liquid can be sent from the static mixer 10 to columns or detectors. This porous body 18b may be disposed, for example, inside the liquid outlet 16, or at an exit of the mixing chamber 34 (on the liquid outlet 16 side). Here, the porous body 18b in the present embodiment comprises a material having an extremely large number of pores. In the present embodiment, a monolithic structure (bicontinuous body), a sponge structure (open-cell structure), a sintered body of powder or the like can be used as the porous body 18b, for example. The porous body 18b can comprise metal materials such as SUS 316, or polymer materials such as PEEK.

[0046] FIG. 6 is a schematic view of another configuration that comprises a porous body in the static mixer according to the present embodiment. As shown in FIG. 6, the porous body 18b (liquid outlet 16) is provided to both of the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30, so that a stable mixed liquid produced by the first mixing (the mixed state produced by the first mixing) can be obtained, and then the liquid can be further mixed by the following second mixing.

[0047] In the present embodiment, the liquid mixing unit 14 comprises the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30; however, as shown in FIG. 7, it may further comprise a third turbulent diffusion mixer part 40 (a third capillary mixer 42 and a third mixing chamber 44), for example, so that a further improvement in the mixing efficiency can be expected depending on the types of liquids to be mixed and conditions. In the static mixer 10 comprising this third turbulent diffusion mixer part 40, for example, the characteristic structure as shown in FIG. 6, i.e., the porous body 18b (or the twisted spiral plate 18 shown in FIG. 4), can be provided to the outlet sides of the respective turbulent diffusion mixer parts (20, 30, 40).

<Modification>

[0048] FIG. 8 is a schematic configuration of a modification of the static mixer according to the embodiment of the present invention. The modification shown in FIG. 8 basically comprises the same components as the static mixer 10 shown in FIG. 7. In addition to the configuration of FIG. 7, it comprises switching valves 50 for switching the series connection of the turbulent diffusion mixer parts (20, 30, 40) inside the liquid mixing unit 14. Although the reference signs are omitted in FIG. 8, each turbulent diffusion mixer part comprises the capillary mixer and the mixing chamber like in FIG. 1 and FIG. 7.

[0049] As shown in FIG. 8, the static mixer 10 in this modification comprises four switching valves 50 inside the liquid mixing unit 14. These switching valves 50 may be automatic switching valves that performs a switching action automatically, or may be manual switching valves that performs the switching action by hand as necessary, for example. The turbulent diffusion mixer parts may be connected to each other with tubes, for example, without using the switching valves for switching the turbulent diffusion mixer parts (20, 30, 40).

[0050] In FIG. 8, the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 are connected in series by adjusting the switching valve 50 (the third turbulent diffusion mixer part 40 is not connected in FIG. 8). By employing the switching valves 50 to the static mixer 10 according to the present embodiment, the necessary turbulent diffusion mixer parts (20, 30, 40) can be suitably selected in accordance with measurement conditions of component analysis or the like. If the static mixer comprises such switching valves, a plurality of static mixers does not have to be prepared in accordance with analysis conditions, and analysis over a wide range can be performed with one static mixer.

[0051] For example, when the volume of the first turbulent diffusion mixer part 20 is 125 μl, the volume of the second turbulent diffusion mixer part 30 is 240 μl, and the volume of the third turbulent diffusion mixer part 40 is 370 μl, the static mixer 10 can be used as the static mixer having the volume of 365 μl in FIG. 8.

[0052] As shown in FIG. 9, the second turbulent diffusion mixer part 30 and the third turbulent diffusion mixer part 40 may be connected in series by adjusting the switching valves 50, so that it can be used as the static mixer 10 having the volume of 610 μl. Similarly, as shown in FIG. 10, the first turbulent diffusion mixer part 20 and the third turbulent diffusion mixer part 40 may be connected in series by adjusting the switching valves 50, so that it can be used as the static mixer having the volume of 495 μl.

[0053] As shown in FIG. 11, all of the first turbulent diffusion mixer part 20, the second turbulent diffusion mixer part 30, and the third turbulent diffusion mixer part 40 may be connected in series by adjusting the switching valves 50, so that it can be used as the static mixer having the volume of 735 μl.

Examples

[0054] In the following, the present invention is described in further details with Examples; however, the present invention is not limited to the examples given below as long as the spirit of the present invention is not exceeded. First, improvement in the mixing efficiency by series connection was confirmed.

<Confirmation of mixing efficiency by series connection of turbulent diffusion mixer parts>

[0055] The static mixer 10 according to the present invention achieves a good mixing efficiency by connecting the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer parts 30 in series. The mixing efficiency of the static mixer 10 according to the present invention was confirmed under the following conditions.

• Test method

[0056] First, as a reference, the mixed state of the liquid in a tube without a mixer (twisted spiral rod 26) is measured as a mixing noise (μV). Next, the mixing noises (μV) in each flow rate in the case of one turbulent diffusion mixer part (370 μl) and two of the same (125 μl + 240 μl = 365 μl) were measured. How much the mixing noise reduced relative to this reference is shown as a reduction rate.

• Condition

[0057]

Solvent A:	20 mM Ammonium formate aqueous solution
Solvent B:	Acetonitrile/water (80/20)
A/B	20/80
Detecting wavelength:	220 nm
Flow rate:	0.25, 0.5, 1.0 mL/min
Back pressure tube:	I.D. 0.064 × 500 mm

(continued)

Pump type:	PU-4185-B (manufactured by JASCO Corporation)
Detector type:	UV-4070 (manufactured by JASCO Corporation)

[Table 1]

Mixer volume	Value of noise for each flow rate (μV)		
	0.25	0.5	1.0 (mL/min)
Reference	6521	3580	1019
370 μl	92	52	60
Reduction rate (%)	98.6	98.5	94.1
240 μl + 125 μl	22	22	48
Reduction rate (%)	99.7	99.4	95.3

[0058] As shown in Table 1, in any flow rates of 0.25, 0.5 and 1.0 mL/min, it can be seen that the reduction rate of the mixing noise is greater in the case of two turbulent diffusion mixer parts than the case of one turbulent diffusion mixer part. That is, it can be seen that a better mixing efficiency can be achieved by connecting two turbulent diffusion mixer parts in series in the static mixers having the liquid mixing units 14 of the same volumes.

<Comparison with dynamic mixers>

[0059] Next, the mixing efficiencies of the static mixer 10 according to the present invention and a dynamic mixer having a power unit were compared.

• Test method

[0060] A gradient liquid feeding was performed with two types of liquids to measure a baseline variation and noise of the dynamic mixer (1.5 ml) and the static mixer (having three turbulent diffusion mixer parts connected in series) of the same volume as the dynamic mixer.

• Measurement condition

[0061]

Volume of the dynamic	1.5 ml
Volume of the static mixer:	1.56 ml (520 μl × 3)
Mobile phase A:	water (0.1% TFA contained)
Mobile phase B: mixer:	70% acetonitrile (0.1% TFA contained)
Flow rate:	1.0 ml/min
Detecting wavelength:	220 nm, STD response, Conventional cell
Piping between modules:	to the mixer SUS 0.25 mm I.D. beyond the mixer PEEK 0.25 mm I.D

• Gradient condition

[0062]

Time [min]	Function	L(A) side	R(B) side
0.00	Composition ratio	100%	0%
15.00	Composition ratio	0%	100%
20.00	Composition ratio	0%	100%
25.00	Composition ratio	100%	0%
35.00	Composition ratio	100%	0%

[0063] FIG. 12 is the measurement result of baseline variation and mixing noise by the gradient liquid feeding. As shown in FIG. 12, it can be seen that the amounts of the mixing noise after 5 minutes are equivalent in the dynamic mixer having a power unit and the static mixer in this measurement. This shows that, in this gradient liquid feeding, the static mixer has a mixing efficiency equivalent to that of the dynamic mixer.

[0064] It can be seen that the time for going back to the base (position zero in the vertical axis (Intensity) at the start of measurement) is shorter in the static mixer than the dynamic mixer after 30 minutes or 35 minutes. This shows that the static mixer according to the present embodiment has a better replaceability of the solvent compared with the dynamic mixer having a power unit. Accordingly, it was found that the static mixer in the present embodiment has an excellent mixing efficiency equivalent to that of the dynamic mixer.

[0065] As described above, in the static mixer 10 according to the present invention, the liquid mixing unit 14 has the characteristic turbulent diffusion mixer part comprising the capillary mixer and the mixing chamber located at the rear part thereof, and at least two turbulent diffusion mixer parts are connected in series; therefore, the mixing efficiency can be greatly improved than before.

[0066] In the modification of the static mixer 10 according to the present embodiment, four switching valves are used to switch three turbulent diffusion mixer parts (20, 30, 40). For example, the volume of the liquid mixing unit 14 may be switched by connecting respective turbulent diffusion mixer parts to one valve. In the present embodiment, the cases of connecting two and three turbulent diffusion mixer parts in series are described; however, it is not limited to these numbers, and it can be expected to achieve a similar effect when four or more turbulent diffusion mixer parts are connected in series.

[0067] The capillary mixer and the mixing chamber are described as separate configurations in the present embodiment; however, the capillary mixer and the mixing chamber can be configured integrally, for example. Such configuration enables to solve leakage of the liquid, and thus a turbulent diffusion mixer part having a strong pressure resistance can be obtained. As a result, a static mixer having a good mixing efficiency and an excellent durability can be provided.

[0068] In the modifications (FIG. 8 to FIG. 11) of the present embodiment, the turbulent diffusion mixer parts are switched by the switching valves. For example, when connecting the first turbulent diffusion mixer part 20 and the second turbulent diffusion mixer part 30 (and the third turbulent diffusion mixer part 40), the turbulent diffusion mixer parts (freely combining the turbulent diffusion mixer parts 20, 30, 40) may be freely selected and connected with connecting members such as tubes to configure the static mixer 10, so that an effect similar to that of the modification of the present invention can be achieved.

Claims

1. A static mixer comprising:

a liquid inlet provided to let two or more types of liquids to flow into the static mixer; a liquid mixing unit connected to the rear part of the liquid inlet to mix the two or more types of liquids; and a liquid outlet connected to the rear part of the liquid mixing unit to let the mixed liquids flow out from the static mixer,
wherein
the liquid mixing unit has a turbulent diffusion mixer part that comprises: a substantially cylindrical, thin and long capillary mixer that mixes the liquids by turbulence with a twisted spiral rod comprised inside; and a mixing chamber that is located at the rear part of the capillary mixer and mixes the liquids that flow in inside,
the mixing chamber has a volume that is at least larger than the capillary mixer, and
the liquid mixing unit has at least two turbulent diffusion mixer parts connected in series.

2. The static mixer of claim 1, wherein

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and the liquid capacity of the first turbulent diffusion mixer part is greater than that of the second turbulent diffusion mixer part.

3. The static mixer of claim 1, wherein

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and the liquid capacity of the first turbulent diffusion mixer part is substantially equal to that of the second turbulent diffusion mixer part.

4. The static mixer of claim 1, wherein

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and the liquid capacity of the first turbulent diffusion mixer part is smaller than that of the second turbulent diffusion mixer part.

5. The static mixer of any one of claims 1 to 4, wherein

the liquid mixing unit has a first turbulent diffusion mixer part that is located on the liquid inlet side, and a second turbulent diffusion mixer part that is located on the liquid outlet side than the first turbulent diffusion mixer part, and the liquid mixing unit further comprises a third turbulent diffusion mixer part that is located on the liquid outlet side than the second turbulent diffusion mixer part.

6. The static mixer of any one of claims 1 to 5, wherein
the liquid outlet comprises a twisted spiral plate inside thereof, and the twisted spiral plate further mixes the liquids mixed by the liquid mixing unit and lets the liquids flow out of the static mixer.

7. The static mixer of any one of claims 1 to 6, wherein
a switching valve mechanism that switches the plurality of series connections in the liquid mixing unit, and the liquid capacity of the liquid mixing unit can be varied by a switching action of the switching valve mechanism.

8. The static mixer of any one of claims 1 to 6, wherein
the liquid capacity of the liquid mixing unit can be varied by connecting at least two turbulent diffusion mixer parts to each other by tubing.

FIG.1

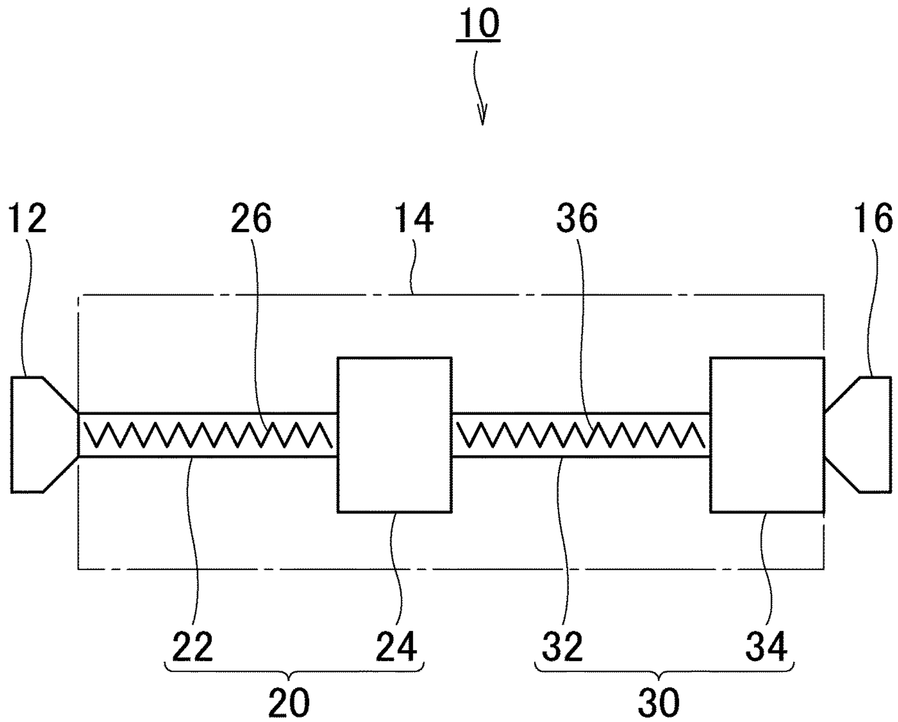
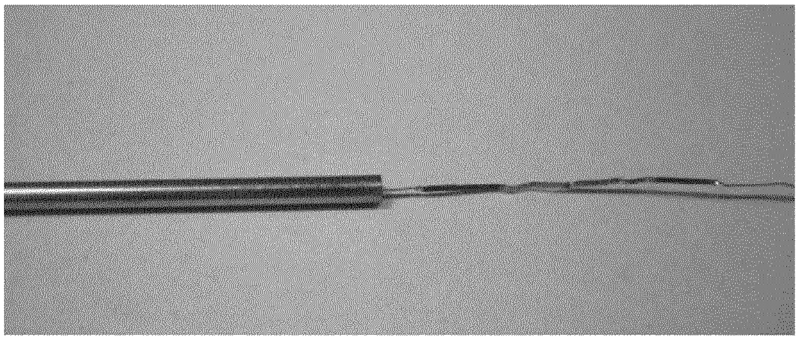


FIG.2



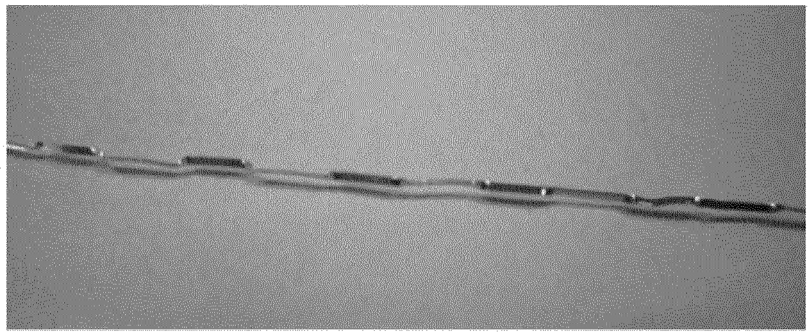


FIG.3

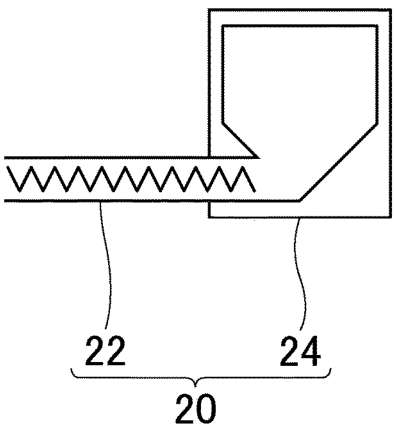
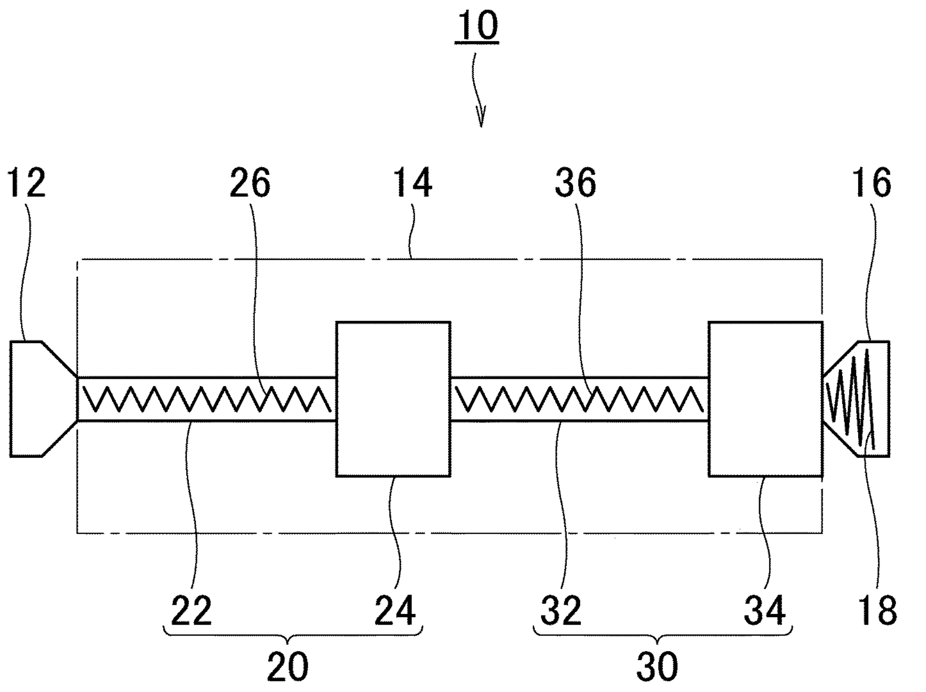


FIG.4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12
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14
36
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32
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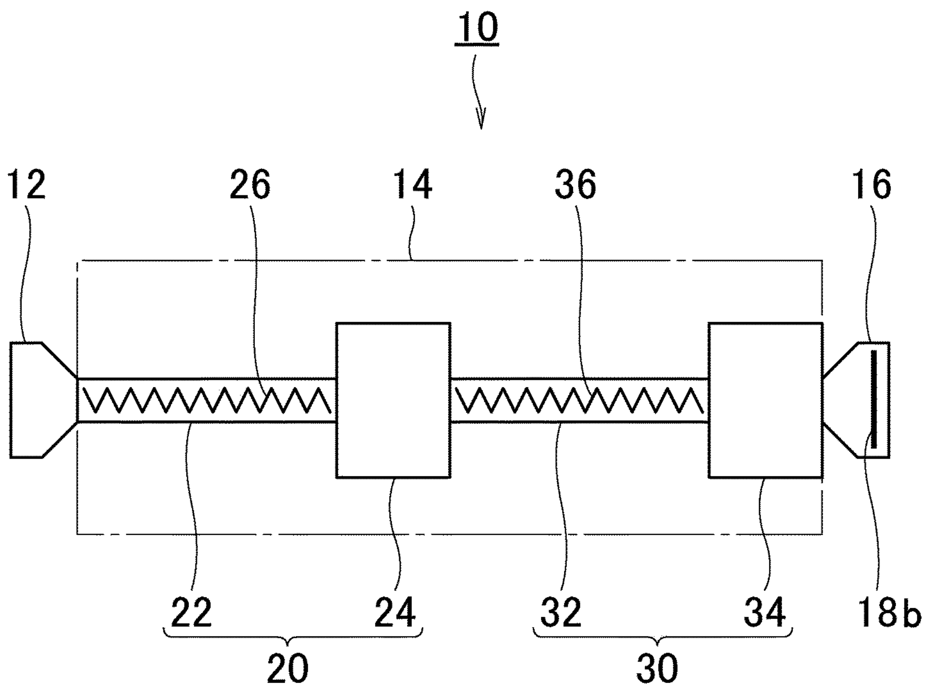
18
20
30

FIG.5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18b
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FIG.6

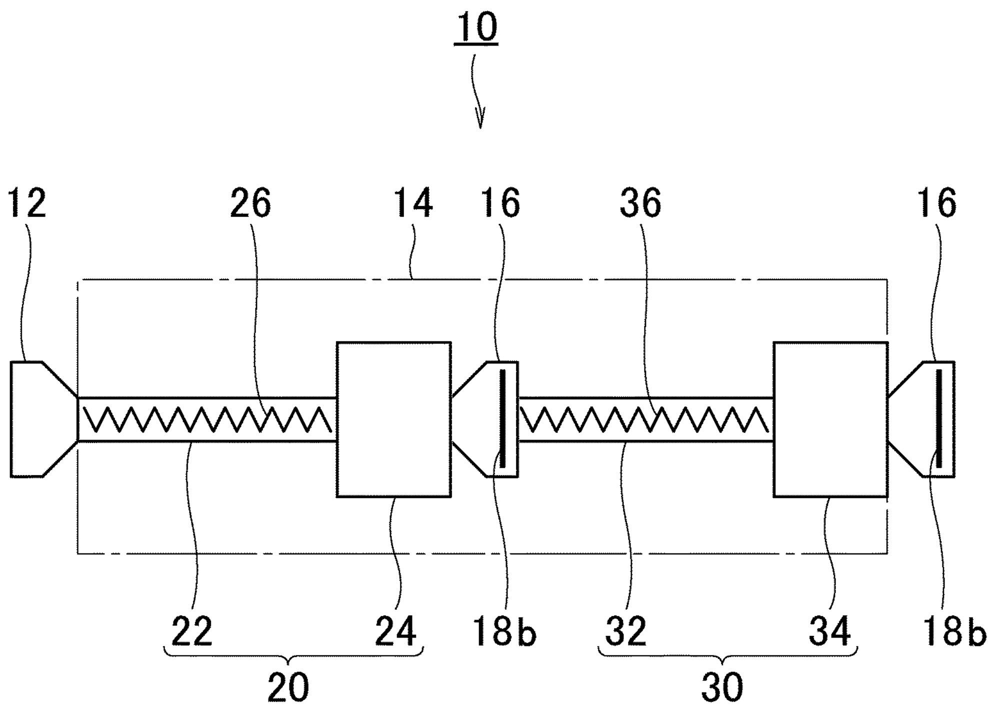


FIG.7

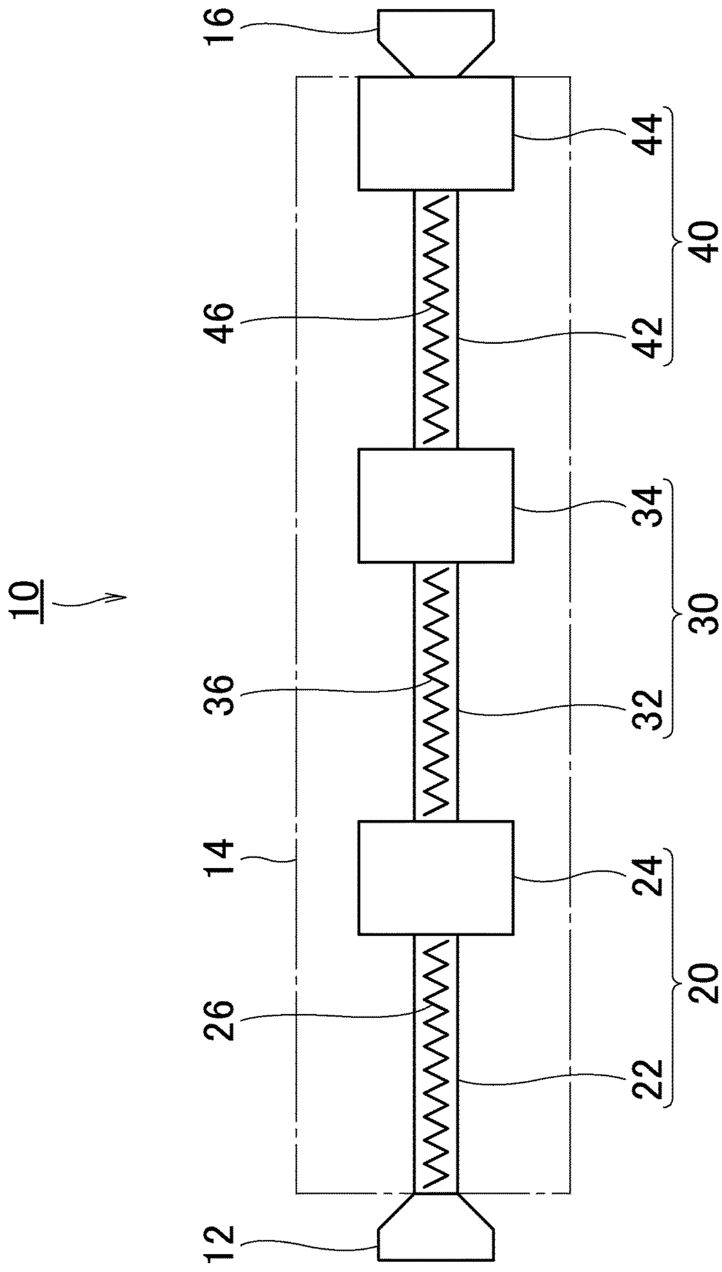


FIG.8

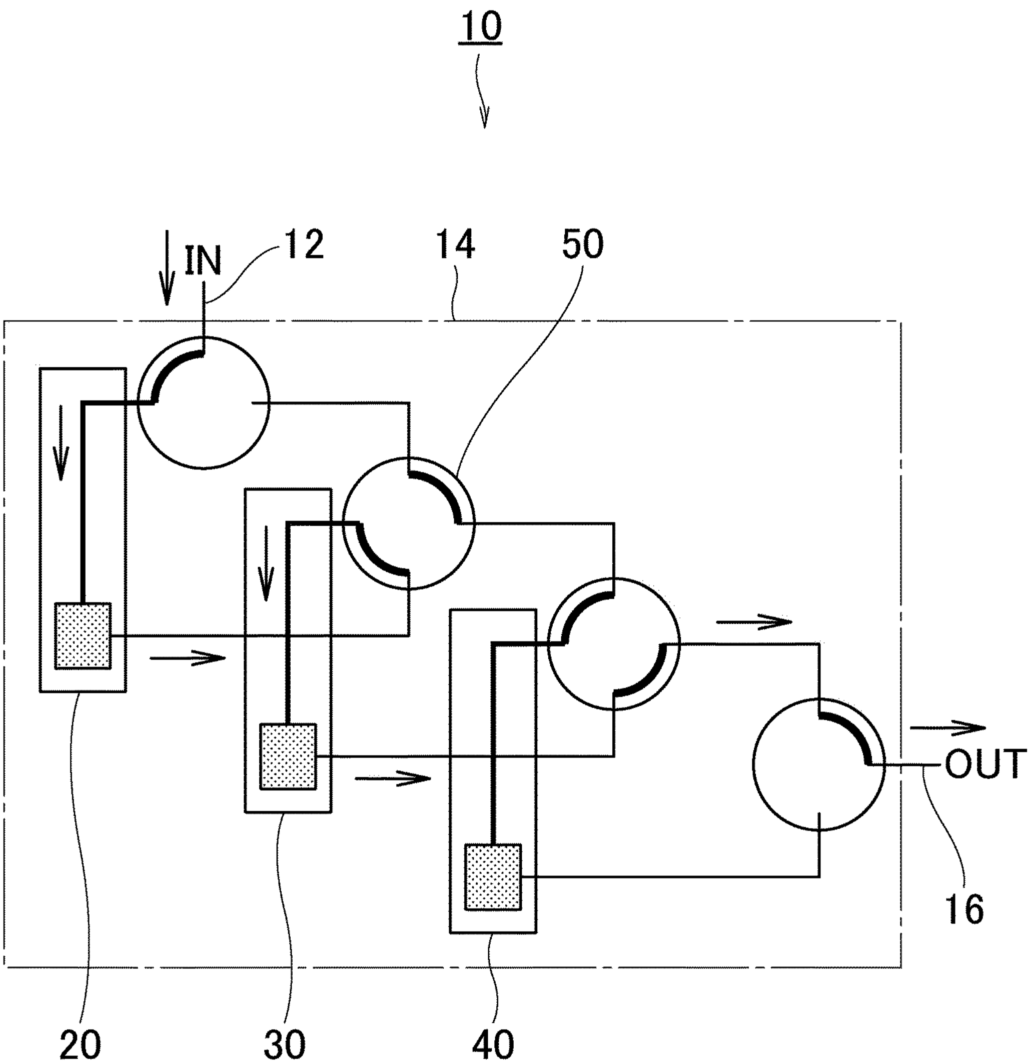


FIG.9

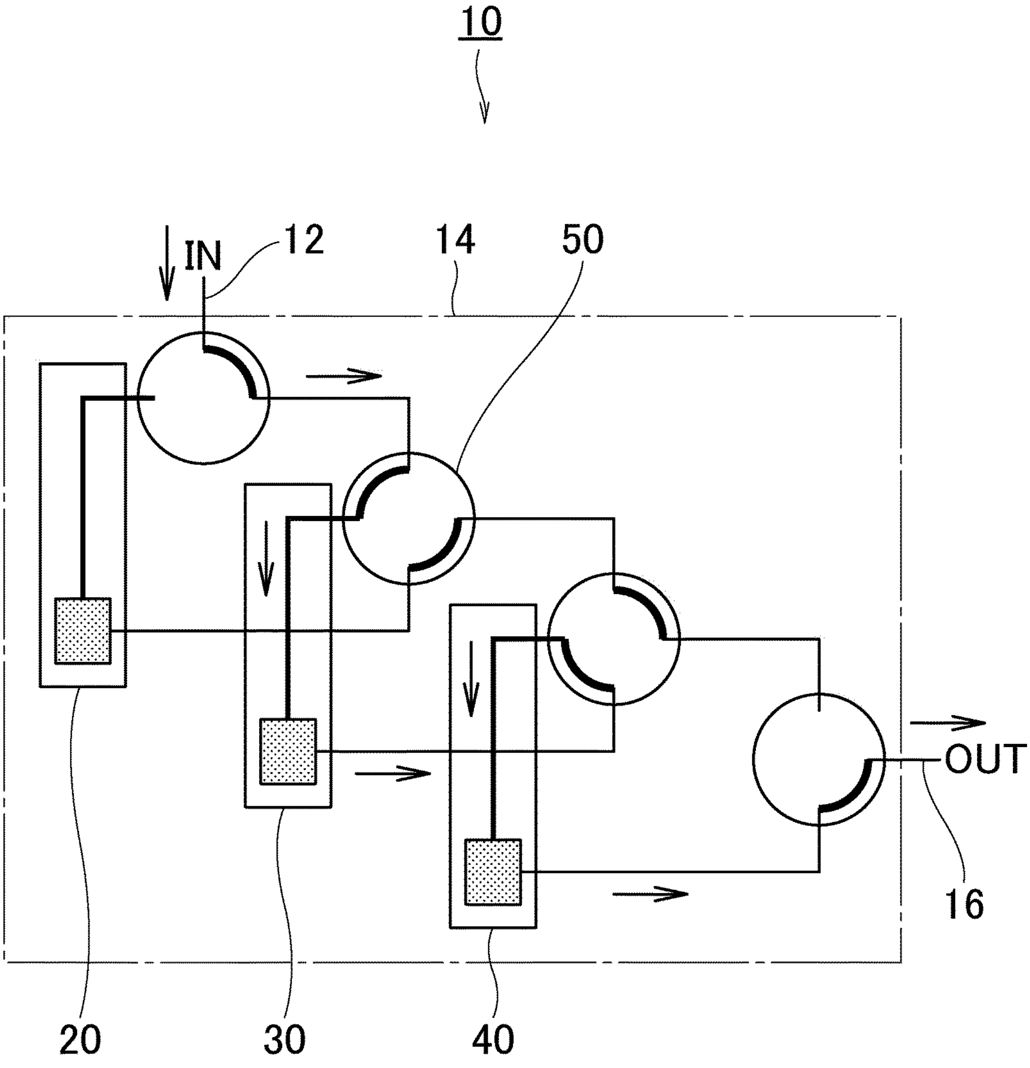


FIG.10

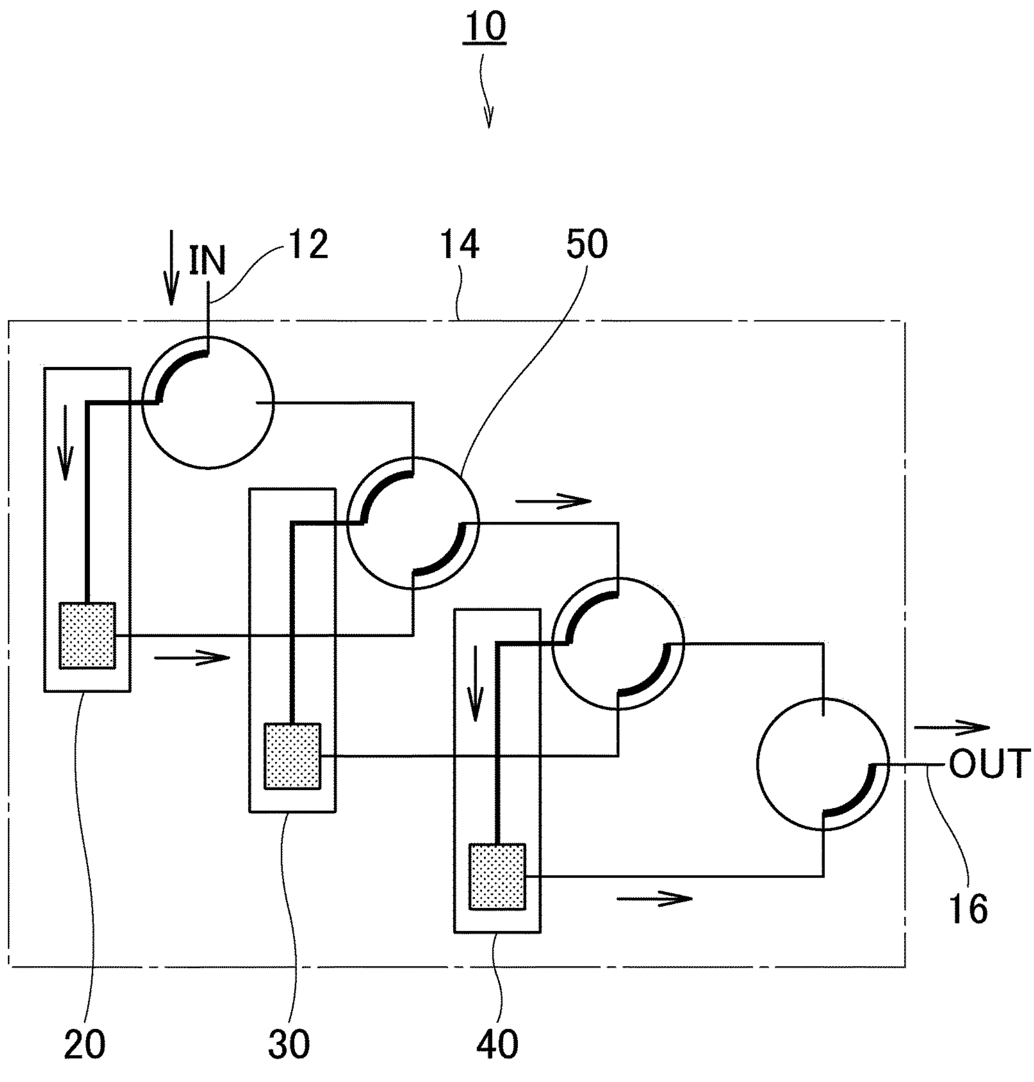


FIG.11

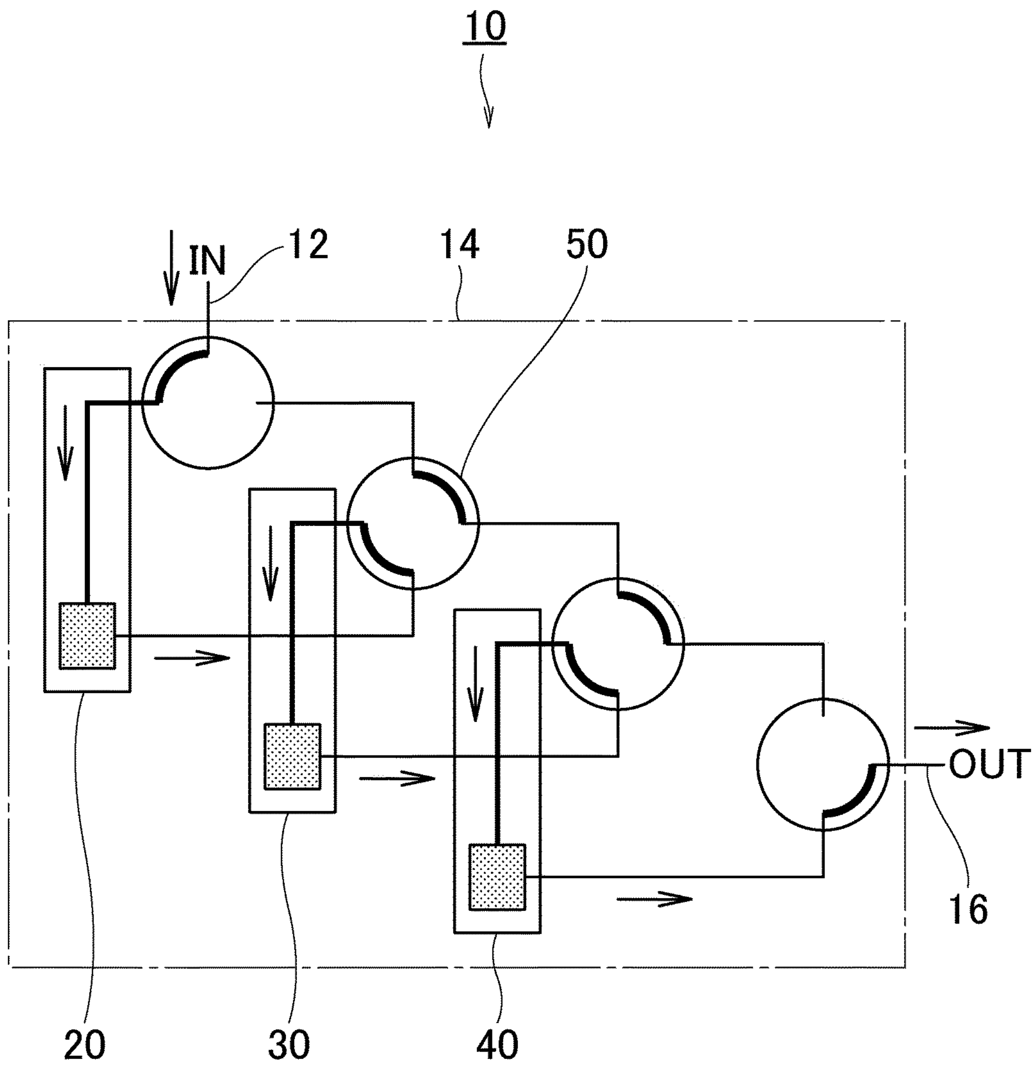
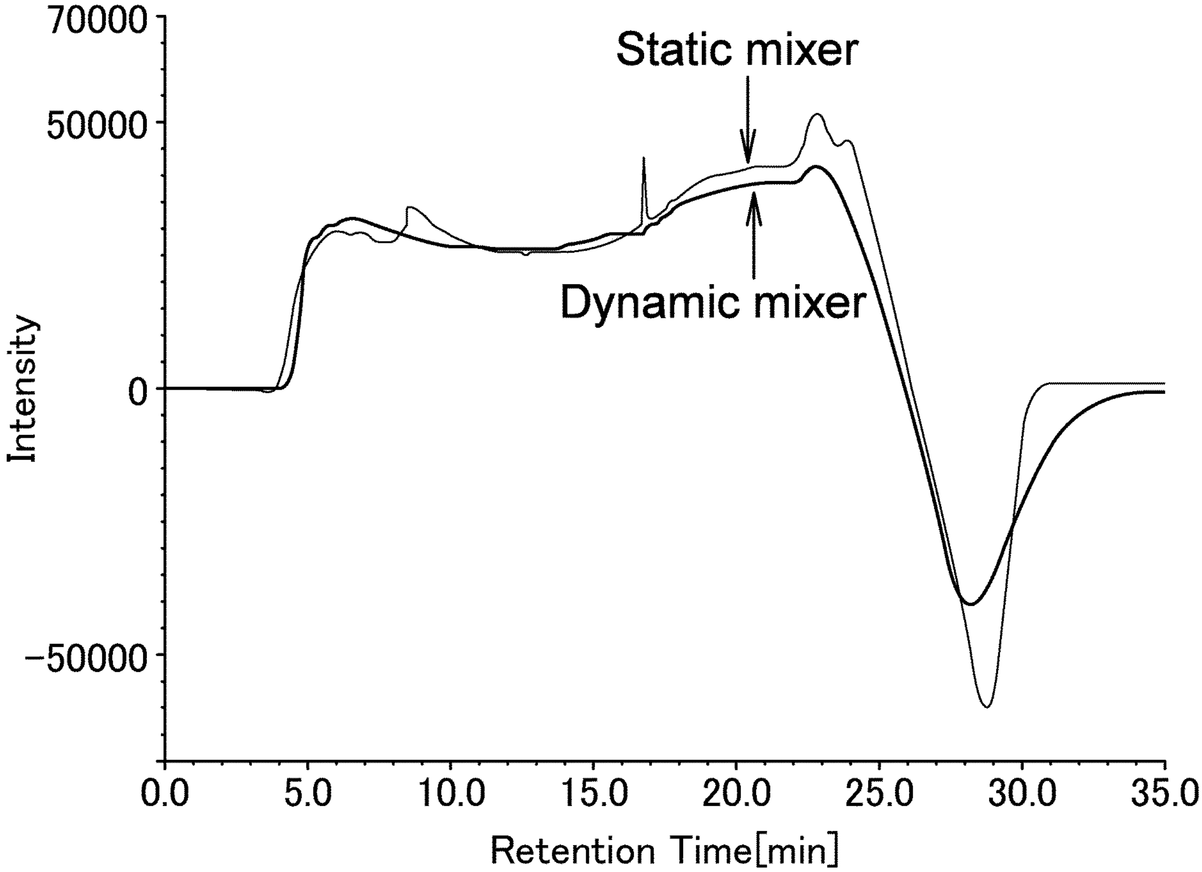


FIG.12


Static mixer
Dynamic mixer
70000
50000
0
−50000
Intensity
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Retention Time[min]

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/048793

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B01F5/00(2006.01)i
FI: B01F5/00D, B01F5/00F

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)
Int.Cl. B01F5/00, G01N30/34

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 121442/1983 (Laid-open No. 31329/1985) (YKS CO., LTD.) 02.03.1985 (1985-03-02), fig. 2-4	1-8
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 115421/1985 (Laid-open No. 24933/1987) (YKS CO., LTD.) 16.02.1987 (1987-02-16), fig. 1, 2	1-8
Y	JP 2011-104482 A (ASAHI ORGANIC CHEM IND CO., LTD.) 02.06.2011 (2011-06-02), paragraph [0040], fig. 10	6-8

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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- "O" document referring to an oral disclosure, use, exhibition or other means
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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
26.02.2020	10.03.2020

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/048793

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2018-514761 A (WATERS TECHNOLOGIES CORPORATION) 07.06.2018 (2018-06-07), claims, fig. 10	1-8
Y	US 5076705 A (TEXACO, INC.) 31.12.1991 (1991-12-31), fig. 1	7-8
X Y	JP 2007-132873 A (NIPPON SODA CO., LTD.) 31.05.2007 (2007-05-31), paragraph [0056], fig. 8	1-5 6-8
A	US 2009/0308472 A1 (HARMAN, J. D.) 17.12.2009 (2009-12-17)	1-8
A	JP 1-257268 A (BIOTRACK INC.) 13.10.1989 (1989-10-13)	1-8

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2019/048793

JP 60-31329 U1	02.03.1985	GB 2146912 A fig. 2-4
JP 62-24933 U1	16.02.1987	(Family: none)
JP 2011-104482 A	02.06.2011	WO 2011/059113 A1
JP 2018-514761 A	07.06.2018	US 2018/0088091 A1 claims, fig. 10 WO 2016/160157 A1 EP 3278099 A1 CN 107430101 A
US 5076705 A	31.12.1991	(Family: none)
JP 2007-132873 A	31.05.2007	(Family: none)
US 2009/0308472 A1	17.12.2009	(Family: none)
JP 1-257268 A	13.10.1989	US 4868129 A US 5077017 A US 4946795 A EP 305210 A2 CA 1333850 C AU 2163988 A AU 615208 B2

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2019005793 A **[0001]**
- JP 2005034750 A **[0006]**
- JP 2011083763 A **[0006]**