

Feb. 11, 1969

F. WILDING

3,427,002

PROCESS AND APPARATUS FOR MIXING VISCOUS LIQUIDS

Filed July 11, 1967

Sheet 1 of 2

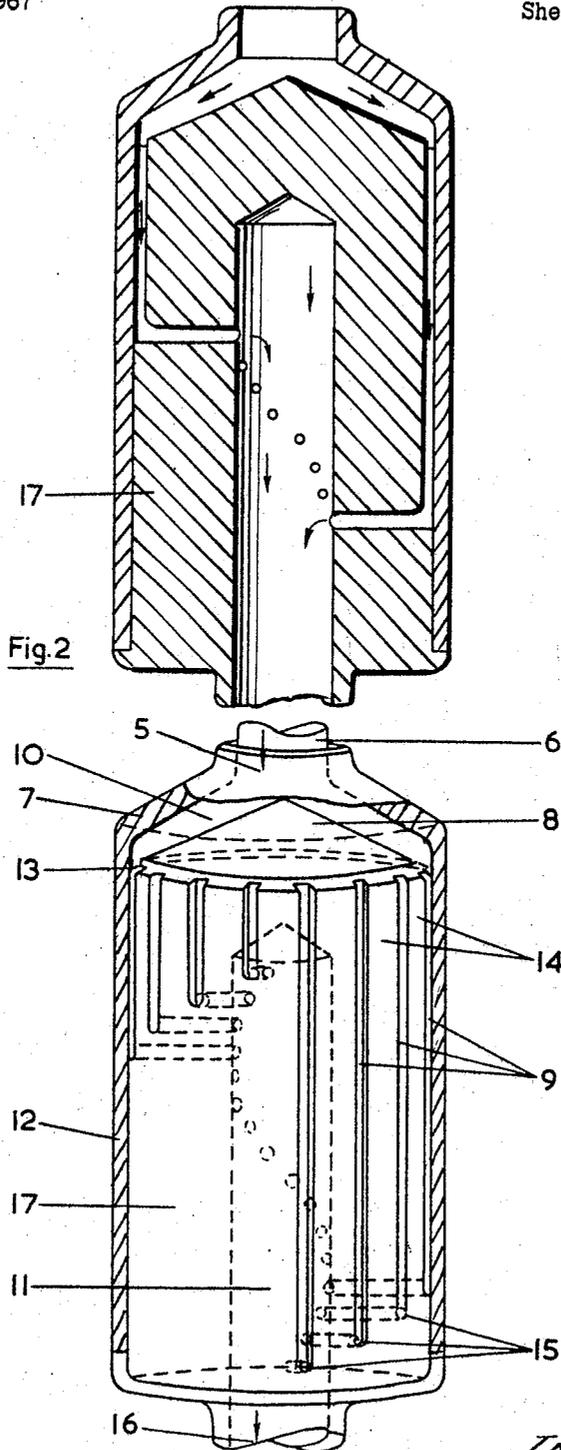


Fig. 2

Fig. 1

INVENTOR
FRANK WILDING

By
Cushman, DeWitt & Cushman
ATTORNEYS

Feb. 11, 1969

F. WILDING

3,427,002

PROCESS AND APPARATUS FOR MIXING VISCOUS LIQUIDS

Filed July 11, 1967

Sheet 2 of 2

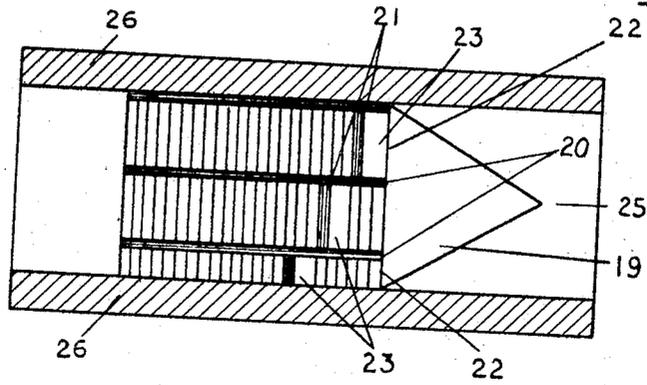


FIG. 3

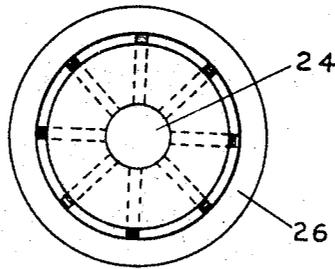


FIG. 4

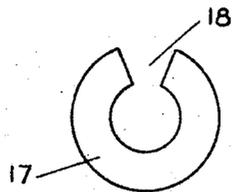


FIG. 5

INVENTOR
FRANK WILDING

By
Cashman, *Cashman & Cashman*
ATTORNEYS

1

2

3,427,002
**PROCESS AND APPARATUS FOR MIXING
 VISCOUS LIQUIDS**

Frank Wilding, Harrogate, England, assignor to Imperial
 Chemical Industries Limited, London, England, a corporation
 of Great Britain

Continuation-in-part of application Ser. No. 536,509,
 Feb. 18, 1966. This application July 11, 1967, Ser.
 No. 652,560

Claims priority, application Great Britain, Feb. 18, 1965,
 7,079/65

U.S. Cl. 259—4

14 Claims

Int. Cl. B01f 15/02; F15d 1/00

ABSTRACT OF THE DISCLOSURE

A mixing apparatus for mixing a stream of viscous liquid or liquids which splits the total flow into a number of sub-flows, each of which contains about the same amount of each of the parts to be mixed, and recombines them one at a time.

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation in part of our copending application, Ser. No. 536,509 filed Feb. 18, 1966, and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to the mixing of viscous liquids, that is of liquids of which the viscosity is sufficiently high that under practical conditions their flow is laminar and turbulence is absent.

A variety of methods is known for the improvement of uniformity in liquid systems. These can be classified into agitation methods, in which a member is moved through the liquid, and streaming methods, in which high speed jets of liquids to be mixed are directed together so as to achieve turbulence with consequent intermingling. Of interest in connection with the latter class are United States patent specifications Nos. 2,597,422, 2,788,337 and 3,072,261.

Neither of the classes of methods described is suitable for effecting the mixing of viscous liquids, since with such liquids the requisite high speed of movement of a member through the liquid is impossible, or at least demands a very high expenditure of energy, and the attainment of turbulence is impracticable. These problems are of particular importance where mixing is required of a flowing stream, in which case the time available is limited.

SUMMARY

An object of our invention is the improvement of the homogeneity of a plurality of liquids or of a liquid having a plurality of disparate parts.

By the expression "improvement of the homogeneity" we mean increasing the likelihood that a particular sample portion of the flow taken at random will have the same average composition or other characteristics as any other sample taken at random. In the case of liquids of high viscosity, wherein flow is strictly laminar and turbulence is absent, the improvement in homogeneity will consist in the thinning out of adjacent layers of the liquids, the properties of adjacent layers tending to be dissimilar. Of particular interest is the similarity between the average composition over the various sections of the cross-section of the combined flow from the apparatus.

By the expression "having a plurality of disparate parts" we mean being composed of more than one zone, the zones differing in respect of a secondary characteristic, for example temperature or content of a thermal degradation product rather than in respect of chemical nature.

The object of our invention is achieved by the splitting of a composite laminar flow comprising a plurality of liquids or a liquid having a plurality of disparate parts into more than two sub-flows or more than two series of sub-flows each sub-flow containing approximately the same proportion of each of the liquids or disparate parts of the liquid as any other sub-flow and combining the sub-flows or the series of sub-flows severally.

By the combining of the sub-flows severally is meant that a sub-flow or series of sub-flows is added individually to another sub-flow or to a combination of sub-flows. The order of combination is optional. In the case of series of sub-flows all of the sub-flows of a series will be combined simultaneously with another series or combination of series. One or more of the series may consist of one sub-flow.

The disposition in the flow of the plurality of liquids or disparate parts of a liquid is preferably arranged to be symmetrical in cross-section in order that the splitting of the sum of the flows into sub-flows or series of sub-flows each containing approximately the same proportion of each of the liquids or each of the disparate parts, shall be facilitated. In the case wherein the sum of flows is in the form of skin and core, such splitting of the sum of flows may be facilitated by attenuating the sum of the flows to form annular flows prior to separation into sub-flows. In cases wherein the sum of the flows is side-by-side, such splitting of the sum of the flows may be facilitated by attenuating to a thin sheet of flow prior to separation.

We have found that 16 is an adequate number of sub-flows into which to split the sum of the flows. A greater number of sub-flows will be no less effective, although presenting increasing practical difficulty as the number increases, and a lesser number may be satisfactory depending on the degree of disparity between the plurality of liquids or parts of a liquid and the perfection of mixing required.

It is preferred to split the sum of the flows into sub-flows or series of sub-flows of which each sub-flow carries approximately the same volume of each liquid or disparate parts of a liquid as any other sub-flow or of which each series of sub-flows carries the same volume of each liquid or disparate parts of a liquid as any other series of sub-flows. This can be achieved according to known principles of compensating longer paths by correspondingly wider bores or by arranging to have a greater number of sub-flows in a series wherein the path is longer.

Considering the sub-flows as numbered consecutively, for example round the perimeter in the case of an annular flow, the order of combination may, for example, be 2 added to 1, 3 added to 1+2, 4 added to 1+2+3 and so on, or the order can be staggered, for example, 5 added to 1, 2 added to 1+5, 6 added to 1+2+5 and so on, or the order may be random. In the case of series of sub-flows, each member of the series is, of course, combined simultaneously, but each member of the series should be combined with the flow comprising another series or combination of series at as disparate points as possible.

The point of addition of the sub-flows to another flow may be on the center-line or on the periphery or at any point intermediate between the center-line and the periphery of the space wherein combination takes place. The various sub-flows may be added at points on a line parallel to the center-line, otherwise the addition of the sub-flows may, for example, be at different points on the periphery of the cross-section. The space in which combination of the sub-flows is effective may be of such configuration, that is of progressively increasing cross-section, that the linear flow is substantially constant throughout the zone wherein the sub-flows are combined despite the gradually increasing volumetric flow.

The process of our invention is suitable for the mixing of liquids of gradually varying properties throughout their mass, for example of melts handled in the melt-spinning of fibre-forming polymers, or for the mixing of more than one liquid. Any or all of the liquids subjected to the mixing treatment may be a solution or a dispersion.

DESCRIPTION OF DRAWINGS

FIGURE 1 shows a partially cut-away perspective view of a mixing device having 16 sub-flows.

FIGURE 2 shows a cross-section through the long axis of the mixing device of FIGURE 1 showing the course of the flow of one of the sub-flows.

FIGURE 3 shows a mixing device fabricated from a series of metal washers.

FIGURE 4 shows an end view of the device of FIGURE 3 from the end distant from the cone.

FIGURE 5 shows a washer with segment removed.

PREFERRED EMBODIMENTS

Referring to FIGURE 1, a tube 6 (of internal diameter 0.5 inch) communicates with a passageway 10 delineated by a flared tube 7 and a solid conical body 8; the end of the passageway 10 distant from the tube 6 communicates with sixteen smaller passageways 9 disposed parallel to the axis of the tube 6 the shortest passageway being $\frac{5}{8}$ inch in length and the length of successive passageways 9 increasing by $\frac{1}{8}$ inch progressively around the periphery. Each of the smaller passageways 9 communicates at its end distant from the passageway 10 with a radial passageway 15 of $\frac{3}{4}$ of an inch in length and with circular cross-section of $\frac{3}{16}$ inch diameter, communicating in turn with the central passageway 11 and thence to the exit tube 16. The smaller passageways 9 are each composed of a groove $\frac{1}{16}$ inch deep and $\frac{3}{16}$ inch wide in the periphery 13 of the inner annulus 17 and in part bounded by a portion of the inner wall of the outer annulus 12. The radial communicating passageways 15 are bored through the inner annulus 17.

In operation, in homogeneous liquid or liquids at 5 are forced through the passageway 10 and a portion of each of the differing portions of the liquid or liquids passes into each of the smaller passageways 9, the liquid from each of the smaller passageways then flows into the central passageway 11 in succession. The liquid flowing from the tube 16 is found to be substantially homogeneous.

Example 1

In a particular experiment, there was fed to the tube 6 a flow composed of a core of a liquid of viscosity 3,000 poises under the conditions of operation and in which had been dissolved 0.1% by weight of a blue dyestuff surrounded by an annulus of the liquid containing no dyestuff. The volumetric flows of the dyestuff-containing and colourless liquid were in the ratio 4:21. In order to test the efficiency of improvement of homogeneity produced by the mixing device, the composite flow after passage through the mixing device, was separated into three sub-flows, two of the sub-flows (hereinafter termed *a* and *d*) each being equal to a quarter of the composite flow and taken from diametrically opposite sides of the pipe carrying the composite flow and the third sub-flow being the residue of the composite flow. The residue of the composite flow was further split into two sub-flows (hereinafter termed *b* and *c*).

Analysis was carried out of each of the sub-flows, *a*, *b*, *c* and *d* in order to determine the concentration of dyestuff by weight in the liquid. The results of the analyses were as follows:

Sub-flow:	Concentration of dyestuffs, percent by weight
<i>a</i> -----	0.012
<i>b</i> -----	0.021
<i>c</i> -----	0.022
<i>d</i> -----	0.009

Example 2

The mixing used was as described in Example 1 except that the number of passageways 9 was 20 each having a wide of only $\frac{1}{4}$ inch and the lengths of the 20 passageways were as follows. Numbering the passageways consecutively around the periphery from 1 to 20, the first passageway was of $\frac{5}{8}$ inch in length and the remainder of the passageways increased in length by $\frac{1}{16}$ inch in the following order: 1, 5, 9, 13, 17, 2, 6, 10, 14, 18, 3, 7, 11, 15, 19, 4, 8, 12, 16, 20.

The radial passageways were duplicated so that each of the 20 passageways led into 2 radial passageways each of $\frac{1}{8}$ inch diameter and of $\frac{3}{4}$ inch length.

The effectiveness of the mixing device was tested as described in Example 1 by feeding a composite flow of dyestuff-containing core and colourless annulus and splitting the composite flow after passage through the mixing device into four sub-flows *a*, *b*, *c* and *d* as described in Example 1. The results of analyses of the four sub-flows were as follows:

Sub-flow:	Concentration of dyestuff, percent by weight
<i>a</i> -----	0.01
<i>b</i> -----	0.02
<i>c</i> -----	0.014
<i>d</i> -----	0.016

Example 3

The mixing device used was described in Example 1 except that the number of passageways 9 was 20 each having a width of only $\frac{1}{4}$ inch and in respect of length the passageways were arranged in 5 series. Numbering the passageways consecutively around the periphery from 1 to 20, the lengths of passageways were as follows:

Numbers 1, 5, 9, 13 and 17 were of 2 inches length. Numbers 3, 7, 11, 15 and 19 were of $1\frac{1}{8}$ inches length. Numbers 4, 8, 12, 16 and 20 were of $1\frac{1}{4}$ inches length. Numbers 6, 10 and 18 were of $1\frac{1}{2}$ inches length. Numbers 2 and 14 were of $\frac{9}{16}$ inch length.

The radial passageways were duplicated so that each of the 20 passageways led into 2 radial passageways each of $\frac{1}{8}$ inch diameter and of $\frac{3}{4}$ inch length.

Calculation based on the flow properties of liquids through pipes shows the quantity of liquid passing per unit time through a passageway of each of the series given hereinbefore is proportional respectively to 1, 1.05, 1.49, 1.64 and 2.76. Thus the quantity of liquid passing per unit time through each of the five series of passageways is proportional to:

$$\begin{aligned} 1 \times 5 &= 5 \\ 1.05 \times 5 &= 5.25 \\ 1.49 \times 5 &= 7.45 \\ 1.64 \times 3 &= 4.92 \\ 2.76 \times 2 &= 5.52 \end{aligned}$$

That is, the flow rate through each series was of the same order.

The effectiveness of the mixing device was tested as described in Example 1 by feeding a composite flow of dyestuff-containing core and colourless annulus and splitting the composite flow after passage through the mixing device into four sub-flows *a*, *b*, *c* and *d* as described in Example 1. The results of analyses of the four sub-flows were as follows:

Sub-flow:	Concentration of dyestuff, percent by weight
<i>a</i> -----	0.024
<i>b</i> -----	0.025
<i>c</i> -----	0.033
<i>d</i> -----	0.025

Example 4

The utility of a mixing device having a lesser number of sub-flows was demonstrated by the use of a mixing device of similar design to that used in Examples 1, 2 and

5

3 but fabricated from a series of metal washers. Referring to FIGURES 3, 4 and 5, the mixing device was formed from 24 metal washers 17 each in the form of an annulus of outside diameter 35 mm., internal diameter 13 mm. and of thickness 1.6 mm. From each of 16 of the washers there was cut a segment 18 of 45°. The 24 washers were assembled face to face by means of an adhesive to form a pile, as shown in FIGURE 4, the order being:

2 washers with segment removed and with segments in coincidence, 1 entire washer, 2 washers with segment removed and with segments in coincidence but out of phase by 45° with the 1st and 2nd washers, 1 entire washer, 2 washers with segment removed and with segments in coincidence but out of phase by 45° with the 4th and 5th washers and out of phase by 90° with the 1st and 2nd washers, 1 entire washer, and so on.

To the free face of the 1st washer, there was stuck by means of a suitable adhesive the base of a cone of polymethylmethacrylate 19 of 38 mm. base and 32 mm. height. Lengths of plastic coated cable 20 and 21 were stuck onto the assemblage of washers on the periphery parallel to the axis of the assemblage and along the diameter of each entire washer in the vicinity of the removed segments respectively. The whole assemblage was forced into a tube 26 of internal diameter 38 mm. thus producing a series of passageways 22 terminating in radial passageways 23 each in turn communicating with a tube 24. In operation, a composite flow is fed to the mixing device at 25, the flow is attenuated as it passes the cone 19 into a sheet flow, split into a series of sub-flows through the passageways 22 and combined severally by passage through the radial passageways 23 into the tube 24.

The effectiveness of the mixing device was tested by feeding at 25 a flow composed of a core of a liquid of viscosity 3,000 poises under the conditions of operation and in which had been dissolved 0.1% by weight of a blue dyestuff surrounded by an annulus of the same liquid containing no dyestuff. Visual examination of the flow clearly showed it to consist of a blue core surrounded by a clear annulus. On emergence from the mixing device, the flow appeared to be uniformly blue.

What we claim is:

1. A process for mixing a composite laminar flow of a plurality of liquids, or a liquid having a plurality of disparate parts, comprising the steps of:

splitting a sum of the plurality of liquids, or a sum of the disparate parts, into more than two sub-flows, with each sub-flow containing approximately the same proportion of said liquids or disparate parts as any other sub-flow, and

combining said sub-flows severally.

2. A process according to claim 1 wherein the composite flow consists of a core and annulus or annuli.

3. A process according to claim 1 wherein each of the sub-flows carries approximately the same volume per unit time.

4. A process according to claim 1 wherein the composite flow consists of a core and annulus or annuli and each of the sub-flows carries approximately the same volume per unit time.

5. A process for mixing a composite laminar flow of a plurality of liquids, or a liquid having a plurality of disparate parts, comprising the steps of:

splitting a sum of the plurality of liquids, or a sum of the disparate parts, into more than two series of sub-flows, with each sub-flow containing approximately the same proportion of said liquids or disparate parts as any other sub-flow, and

combining said series of sub-flows severally.

6

6. A process according to claim 5 wherein the composite flow consists of a core and annulus or annuli.

7. A process according to claim 5 wherein each of the series of the sub-flows carries approximately the same volume per unit of time.

8. An apparatus for improving the homogeneity of a composite laminar flow comprising:

inlet means for introducing a composite laminar flow into a passageway where the said composite laminar flow can be split into a plurality of sub-flows,

more than two channels in communication with said

inlet means for receiving said composite laminar flow and for splitting the laminar flow into a plurality of sub-flows, with each sub-flow containing approximately the same proportion of each liquid making up the composite liquid, each of said channels communicating with a common outlet duct, with entry points of the various channels with the common outlet duct being distributed between more than two zones along the length of the common outlet duct, said common outlet duct functioning to receive and to severally combine said plurality of sub-flows from said channels.

9. An apparatus according to claim 8 wherein the relationship between the length, cross-sectional area and perimeter of the various channels is such that a flow of liquid passing through the apparatus from the inlet to the common duct is distributed equally to each channel feeding into each zone of the common duct.

10. The apparatus of claim 8 wherein said passageway is defined by a flared extension of said inlet means and a conical core means having its apex directed towards an inlet tube of said inlet means.

11. The apparatus of claim 8 wherein each of said channels is constructed to receive a distribution of the composite laminar flow which is approximately equal to that of each of the remaining channels.

12. An apparatus for improving the homogeneity of a composite laminar flow comprising:

inlet means for introducing a composite laminar flow into a passageway where the said composite laminar flow can be split into a plurality of sub-flows,

more than two series of channels in communication with said inlet means for receiving said composite laminar flow and for splitting the laminar flow into a series of sub-flows, each of said channels communicating with a common outlet duct, with entry points of the various channels with the common outlet duct being distributed between more than two zones along the length of the common outlet duct, said common outlet duct functioning to receive and to severally combine said series of sub-flows from said channels.

13. The apparatus of claim 12 wherein said passageway is defined by a flared extension of said inlet means and a conical core means having its apex directed towards an inlet tube of said inlet means.

14. The apparatus of claim 12 wherein each of said series of channels is constructed to receive a distribution of the composite laminar flow which is approximately equal to each of the remaining series of channels.

References Cited

UNITED STATES PATENTS

2,597,422	5/1952	Wood	-----	259—4	XR
2,788,337	4/1957	Preiswerk et al.	----	259—8	XR
3,072,261	1/1963	Smith	-----	138—42	XR

JOHN M. BELL, *Primary Examiner.*

U.S. Cl. X.R.

138—42