United States Patent

[11] 3,620,506

[72] Inventor Stephen W. So
Wilmington, Del.

[21] Appl. No. 52,823
[22] Filed July 7, 1970
[45] Patented Nov. 16, 1971
[73] Assignee FMC Corporation
Philadelphia, Pa.

[54] **FLUID-MIXING DEVICE**
10 Claims, 8 Drawing Figs.

[52] U.S. Cl. 259/4, 259/180
[51] Int. Cl. B01f 5/00
[50] Field of Search 259/180, 4, 18, 36

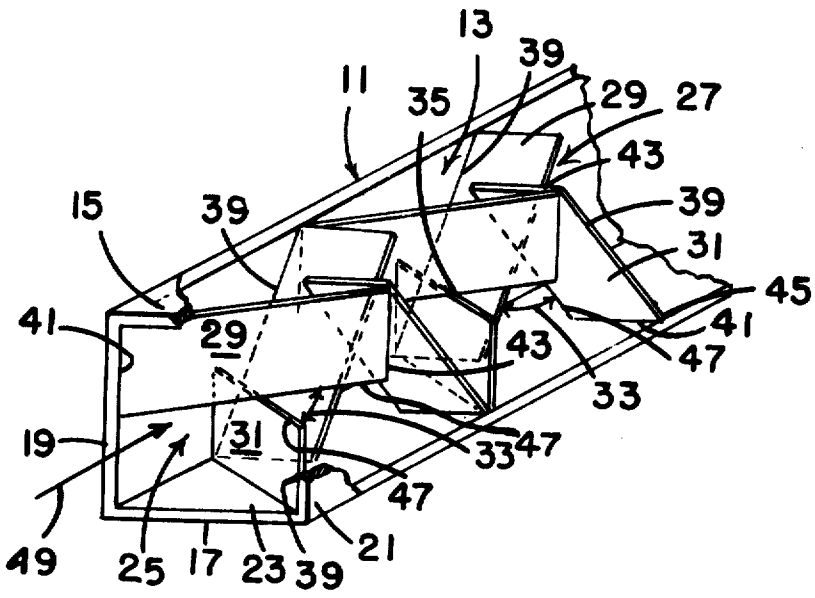
[56] References Cited

UNITED STATES PATENTS

3,051,453	8/1962	Slvijters	259/180 X
3,195,865	7/1965	Harder	259/4
3,239,197	3/1966	Tollar	259/4
3,328,003	6/1967	Chisholm	259/4
3,406,947	10/1968	Harder	259/4
3,470,912	10/1969	Bydal	259/4 X
3,506,244	4/1970	Strang	259/4

Primary Examiner—Peter Feldman
Attorneys—Thomas R. O'Malley, George F. Mueller and Eugene G. Horsky

ABSTRACT: Fluid-mixing apparatus which includes a plurality of stationary mixing units, formed of planar members, disposed in series longitudinally of a passage for sequentially and repeatedly dividing and recombining fluid flows during the travel thereof through the passage, with the fluid flows being directed along different serpentine paths after each division thereof.



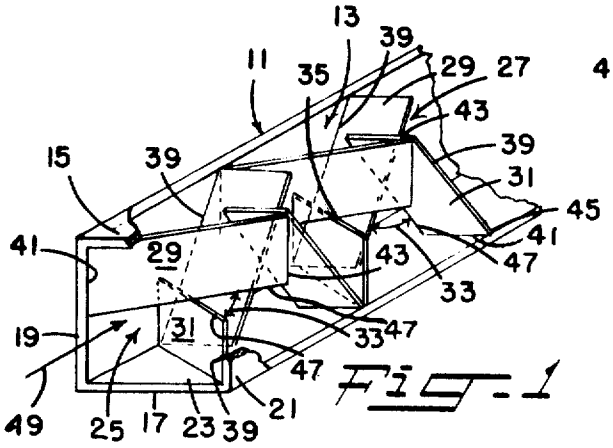


Fig. 1

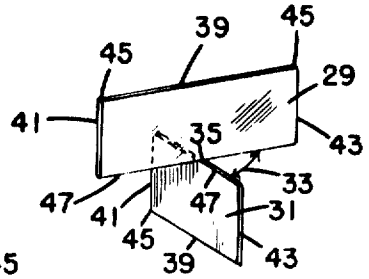


Fig. 2

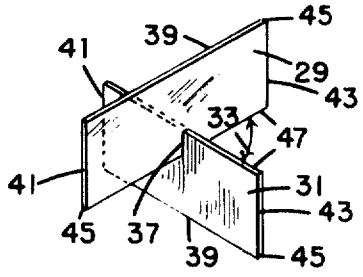


Fig. 3

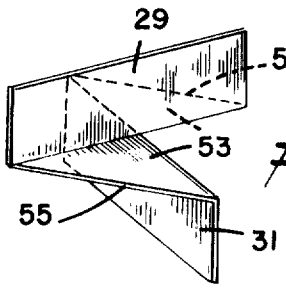


Fig. 4

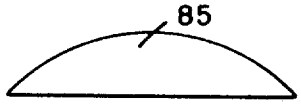


Fig. 7

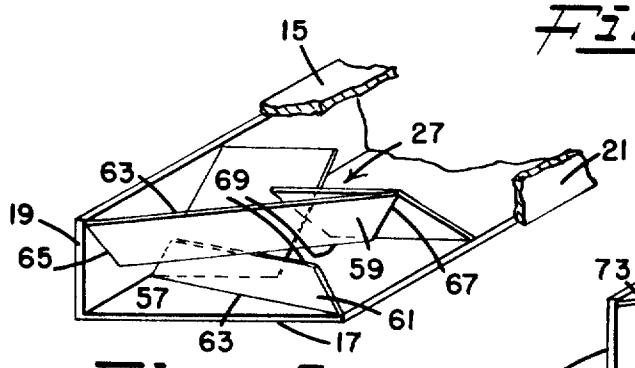


Fig. 5

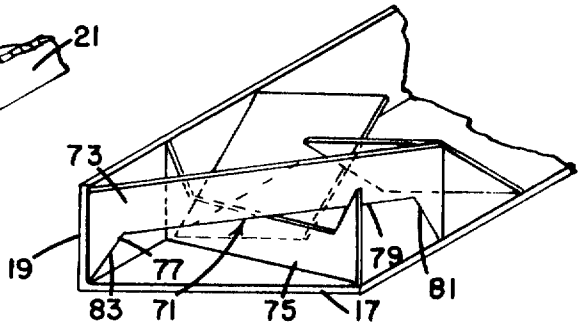


Fig. 6

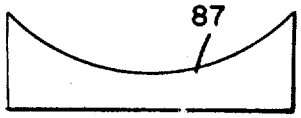


Fig. 8

FLUID-MIXING DEVICE

The present invention is directed to a mixing apparatus having stationary mixing units for sequentially and repeatedly dividing and recombining fluid flows or streams.

U.S. Pat. Nos. 3,051,452; 3,051,453; 3,195,865; 3,206,170; and 3,506,244 are typical of a large number of prior disclosures relating to mixing devices which employ stationary baffles for dividing, repositioning, and recombining a fluid stream during its flow through a conduit.

Generally, the baffles employed in known fluid-mixing devices are of complex configuration making their fabriction costly and their assembly, disassembly, and cleaning difficult. Such faffles are generally bulky, occupying much of the conduit passage and often causing a large drop in the fluid pressure and/or stagnant fluid areas or areas of low fluid flow.

Disclosed in U.S. Pat. No. 3,286,992 is a mixing device of relatively simple construction wherein a plurality of curved or twisted sheetlike elements are disposed in series within a hollow cylindrical tube. These curved elements are arranged alterantely and in point-contact with each other; that is, with the edges of each element which extend transverse of the tube being positioned at an angle to the contacting edges of adjacent of such elements. The curvature of each of these elements is such as to turn the direction of the flowing fluid.

The elements employed in the above-described device must be twisted to a rather precise curvature and are thus expensive to fabricate. Further, such elements must be fixed to each other or to the wall of the cylindrical tube to retain their relative positions. Thus, removal of elements, for example to change the mixing characteristics of the device or for cleaning of such elements or the mixing device itself, can be achieved only with difficulty, if at all possible. More important, these curved or twisted elements are each formed from a thin, flat sheet which must be at least of a certain minimum length relative to its width to facilitate twisting thereof into a desired curvature. Thus, the length of the hollow cylindrical tube employed in such device will vary directly with the tube diameter and, to accommodate a required number of twisted elements for proper fluid mixing, is often physically too large for use in many applications. Accordingly, a primary object of this invention is to provide a generally new or improved or more satisfactory fluid mixing apparatus.

Another object is the provision of an apparatus for mixing fluids which includes a plurality of stationary mixing units, comprised of intersecting planar members, which may be fabricated by simple and inexpensive techniques and from a variety of materials.

Still another object is to provide a fluid-mixing apparatus formed of separable units which may be easily assembled and disassembled for cleaning and/or to vary the mixing characteristics of the apparatus.

A further object is the provision of a fluid-mixing device which includes a plurality of individual but cooperating mixing units, the configurations of which may be varied to suit particular mixing requirements.

A still further object is to provide a fluid-mixing apparatus which is of linear construction, compact, and not limited to a particular size or range of sizes.

These and other objects are accomplished in accordance with the present invention by an apparatus which includes pairs of opposing spaced walls which together define a rectangular passage of substantially uniform cross section throughout its length, and a plurality of mixing units or baffles arranged in series longitudinally of such passage. Adjacent of the mixing units of such series of units are disposed in abutting and 90° out-of-phase relationship with each other to provide for a desired dividing and recombination of a fluid stream during its travel through the rectangular passage.

Each of the mixing units is composed of a pair of like planar members disposed along planes which intersect with each other and which extend at substantially right angles to opposing walls of the rectangular passage. The planar members of each such units have corresponding outer edges thereof snugly engaged with opposing walls of the passage and which define,

with adjacent edges of the respective planar members, corners which are seated within corners of the passage.

The respective planar members of such mixing units each have an inner edge which is spaced from opposing walls of the passage, with such inner edges of the members of each mixing unit being spaced at their midpoints away from the outer edges of the respective members a distance equal to at least one-half of the spacing between the opposing walls with which such outer edges are engaged.

Desirably, the planar members of at least alternate of such mixing units are of rectangular configuration and, in a preferred construction, all of the planar members of all of such mixing units are of rectangular configuration. In either of the arrangements, flow divider plates of triangular configuration may be provided between the individual edges of the respective rectangular planar members of the mixing units, with each of such divider plates having an edge extending between opposing walls of the rectangular passage.

In embodiments of the apparatus of the present invention in which only alternate of the mixing units are formed of planar members of rectangular configuration, each of the remaining of the mixing units may be composed of planar units each having an inner edge of arcuate shape, as defined by a line of smooth, continuous curvature or a series of lines disposed in angular relationship with each other. For example, such planar members may have a configuration of an isosceles trapezoid or the edge thereof may define, with opposing walls of the passage, like openings which have a configuration of an isosceles trapezoid. In all of the embodiments of the apparatus of the present invention, the inner edges of the respective members of each mixing unit are spaced from each other a distance substantially equal to or slightly greater than one-half of the spacing between the opposing walls with which the corresponding outer edges of such members are engaged.

The planar members of the respective mixing units are fixed to each other at their locations of crossing. The angle at which the planes of such members intersect with each other may be varied, with the smaller the angle between such planes resulting in a greater pressure drop in the fluid stream flowing through the mixing apparatus but permitting a greater number of mixing units to be assembled within a fixed length of the rectangular passage.

A variety of materials may be employed in the fabrication of the mixing apparatus of the present invention as, for example, thin metal sheets of copper, brass, steel, plastic. The materials used must neither react with the fluid being mixed nor encourage reactions between mixtures of fluids. Further, such materials must impart to the planar members sufficient rigidity as to enable them to resist the pressures which might be applied to fluids during the mixing thereof. Fabrication of the planar members may be achieved, for example, by a conventional sheet-stamping operation.

The apparatus of the present invention may be employed as a heat exchanger using a heat transfer medium comprised of one or more liquids or gases. The mixing of such heat exchange medium during its flow through the apparatus of the present invention will result in a more uniform temperature along the outer surface of such apparatus and thus provide for efficient heat transfer. Such apparatus may be used also to mix a plurality of fluids, in liquid or gaseous form. Fine particulate matter, such as pigments or short fibers may be carried by the fluids which are being mixed without materially affecting the efficiency of the mixing apparatus of the present invention.

The number of mixing units employed will vary with such factors as the particular construction of the mixing units, the fluid or fluids being mixed, and the degree of mixing desired. Desirably, the mixing units are engaged snugly with the walls of the rectangular passage merely by friction so as to provide easy assembly and disassembly of the mixing apparatus for cleaning and/or to facilitate variation in the number of such units employed.

For a greater understanding of this invention, reference is made to the following detailed description and drawing in

which FIG. 1 is a perspective view of one embodiment of the mixing apparatus of the present invention, with a portion thereof being removed to illustrate the interior construction;

FIG. 2 is a perspective view illustrating a single mixing unit employed in the apparatus shown in FIG. 1;

FIG. 3 is a view similar to FIG. 2 illustrating a modified form of mixing unit;

FIG. 4 is a view similar to FIGS. 2 and 3 illustrating a still further modified form of mixing unit;

FIGS. 5 and 6 are views similar to FIG. 1 illustrating further embodiments of the mixing apparatus of the present invention; and

FIGS. 7 and 8 are side views of planar members which may be employed in the mixing apparatus shown in FIGS. 5 and 6, respectively.

With reference to the drawing, FIG. 1 illustrates a fluid-mixing apparatus 11 which includes a conduit 13 having pairs of spacing, parallel opposing walls 15 and 17 and 19 and 21. The walls 15, 17, 19, and 21 together define a uniform rectangular passage 23 into either end of which is delivered one or more fluid streams which are to be mixed. Arranged in series longitudinally of the passage 23 are a plurality of abutting mixing units or baffles, with adjacent of such units 25 and 26 being disposed in 90° out-of-phase relationship with each other.

In the preferred embodiment shown in FIG. 1, the mixing units 25 and 27 are of like construction, each being composed of a pair of like planar members 29 and 31. The planar members 29 and 31 of the mixing units 25 are disposed along intersecting planes which are substantially perpendicular to the conduit walls 15 and 17, while the like members of the mixing units 27 are disposed along intersecting planes which are substantially perpendicular to the conduit walls 19 and 21. As indicated at 33, the planar members 29 and 31 of the respective mixing units 25 and 27 intersect with each other at like acute angles. Such angle 33 may be varied, with the pressure drop which is experienced by the fluid stream passing through the conduit passage 23 being indirectly proportional to such angle 33. To maintain the desired angular relationship, the planar members 29 and 31 of the respective mixing units 25 and 27 are fixed to each other, as by welding, soldering or brazing, as indicated at 35 in FIGS. 1 and 2, or by notching one or both of such members, as indicated at 37 in FIG. 3.

The planar members 29 and 31 of the respective mixing units 25 and 27 are of such widths and lengths that they fit snugly against the walls of the conduit passage 23. More particularly, and as illustrated in FIG. 1, corresponding outer edges 39 of the planar members 29 and 31 of the units 25 and 27 snugly engage with opposing walls 15 and 17 and 19 and 21, respectively. These outer edges 39 define, with adjacent edges 41 and 43 of such members corners 45 which are seated snugly within corners of the conduit passage 23. The inner edges 47 of the respective planar members 29 and 31 of each of the mixing units are spaced at least one-half the distance between the opposing conduit walls with which the outer edges 39 of such members are engaged. Thus, the edges 47 of these planar members may be in a common plane, as illustrated in FIG. 2, or in different planes, as shown in FIG. 3.

Assembly of the apparatus 11 shown in FIG. 1 merely involves the insertion of the mixing units into the conduit 13 through one or both ends of the passage 23, with the adjacent of such units 25 and 27 being in abutting and 90° out-of-phase relationship with each other. The number of mixing units which are assembled within the conduit 13 will depend upon such factors as the angular relationship of the planar members 29 and 31 of the mixing units, the particular fluid or fluids to be mixed, and the degree of mixing desired.

As noted above, the mixing units may be frictionally engaged with the conduit walls and, in general, are satisfactorily retained in desired positions. If necessary, end sleeves, not shown, may be inserted into the conduit passage 23 to retain the mixing units in desired abutting relationship. Mixing units may be easily added to or removed from the conduit 13 to vary the mixing characteristics of the apparatus or to effect complete disassembly for cleaning. Removal of units may be achieved by merely applying force to an endmost unit or by pulling individual endmost units by a rod having a hook at one end thereof.

In the operation of the apparatus shown in FIG. 1, a stream containing one or more fluids is delivered under pressure into one end of the conduit 13, as indicated by the arrow 49. Such stream is divided along a horizontal plane into two separate flows by the first of the illustrated mixing units 25. The upper and lower of such separator flows are channeled along diverging paths by the planar members 29 and 31 and, after passing beyond the edges 47 of the members 29 and 31, are again combined into a single stream. Upon movement of this stream relative to the first of the mixing units 27, it is divided along a vertical plane into two separate flows. One of such flows is channeled upwardly along the conduit wall 19 by the planar member 29 of such unit 27, while the other of such flows is directed downwardly along the conduit wall 21 by the planar member 31. As such flows pass beyond the edges 47 of the planar members 29 and 31 of the mixing unit 27 they are recombined into a single stream. Repeated division of the stream into separate flows and recombination of the separate flows into a single stream is repeated in sequence in a manner as described above by the remaining units 25 and 27 of the mixing apparatus.

It will be noted that upon division of the stream alternately along horizontal and vertical planes, at least portions of the separate flows which are thereby provided travel generally serpentine paths, moving alternately in horizontal and vertical directions. The angular relationship of the planar members of the respective mixing units 25 and 27 provide for a sharp division of the stream as it flows relative thereto and effects a continuous and smooth channeling of the resulting flows without creating excessive turbulence or stagnant areas or areas of low fluid flow. While the planar members 29 and 31 of the units 25 and 27 have been illustrated and described as intersecting at like acute angles, such angle of the respective units may be varied if desired.

The modified mixing unit illustrated in FIG. 4 is similar to that shown in FIG. 2 in that it includes intersecting planar members 29 and 31. This particular unit includes also a pair of divider plates 53 which are fixed to the inner edge 47 of the planar members 29 and 31. Each of these plates 53 has a free edge 55 which will extend between the walls 19 and 21 when such units are inserted into the conduit 23.

Mixing units of a construction as shown in FIG. 4 may be employed alone or in combination with either the units 25 or 27 heretofore described. Such modified units are assembled within the conduit 13 in abutting and 90° out-of-phase relationship with each other or either the units 25 and 27. The presence of the divider plates 53 effects sharper divisions of a stream passing through the mixing apparatus and serves to minimize the turbulence in the separate flows which are provided thereby.

The apparatus shown in FIG. 1 may be further modified in a manner as illustrated in FIGS. 5 and 6. More particularly, FIG. 5 illustrates an apparatus in which mixing units 27 are employed in combination with mixing units 57. These latter units 57 each include like planar members 59 and 61, which are of isosceles trapezoid configuration, disposed in crossing relationship. As with the units 25 heretofore described, the members 59 and 61 are disposed in planes which are perpendicular to the conduit walls 15 and 17 with the outer edges 63 thereof snugly engaging with such walls. The edges of these respective planar members 59 and 61 cooperate with adjacent edges 65 and 67 thereof to define corners which are received within corners of the conduit passage 23. The edges 65 and 67 of the respective members 59 and 61, however, extend along converging planes and, together with inner edges 69 thereof, provide each such member with a configuration of an isosceles trapezoid.

The apparatus shown in FIG. 6 differs from that illustrated in FIG. 5 by employing mixing units as indicated at 71. The

units include planar members 73 and 65 each having inner edges 77, 79, and 81 which together with and opposing conduit wall 15 or 17, define an opening 83 having the shape of an isosceles trapezoid.

With the apparatus shown in FIG. 5 a stream flowing relative to the mixing unit is divided into separate flows by the planar members 59 and 61, with such separate flows being further and concomitantly divided by the edges 65 and 67 and the adjacent conduit walls 19 and 21. The portions of the stream nearest the walls 19 and 21 will flow at a faster rate than the remainder thereof and a greater and different intermixing of the stream is generally achieved then with the apparatus shown in FIG. 1. With the embodiment shown in FIG. 6, the end portions of the planar members 73 and 75 retard stream flow in these areas and thus encourage different portions which extend longitudinally of the stream to intermix with each other concomitantly with their travel relative to the units 71.

Generally, a stream will experience greater turbulence in the apparatus shown in FIGS. 5 and 6 than that which is created within the apparatus illustrated in FIG. 1. It will, of course, be apparent that the mixing units 57 and 71 may be employed with the mixing units 25, rather than the units 27 as is illustrated. Further, the planar member of the unit 57 and 71 may be formed with inner edges having smooth, continuous curvature, as shown at 85 in FIG. 7 and 87 in FIG. 8.

It is to be understood that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. Apparatus for mixing fluids including pair of opposing spaced walls which together define a rectangular passage of substantially uniform cross section throughout its length and a plurality of mixing units arranged in series longitudinally of said passage with adjacent of said mixing units in abutting and 90° out-of-phase relationship with each other, each of said mixing units comprised of a pair of like planar members disposed along planes which intersect each other and extend at substantially right angles to opposing walls of said passage, the members of each of said units having corresponding outer edges thereof snugly engaged with opposing walls of said passage and which define with adjacent edges of the respective members corners which are seated within corners of said passage, the respective members of said mixing units each having an inner edge which is spaced from opposing walls of said passage, said inner edges being spaced at their midpoint away from the outer edges of such respective members a distance equal to at least one-half of the spacing between the opposing walls with which such outer edges are engaged.

2. Apparatus as defined in claim 1 wherein the planar members of at least alternate of said mixing units are of rectangular configuration.

3. Apparatus as defined in claim 1 wherein said corresponding edges and said outer edges of the respective rectangular members are spaced from each other a distance equal to substantially one-half the spacing between the opposing walls with which such outer edges are engaged.

4. Apparatus as defined in claim 2 wherein all mixing units are comprised of planar members of like configuration.

5. Apparatus as defined in claim 4 further including flow divider plates of triangular configuration extending between said inner edges of the respective members of said mixing units, with each of said divider plates having an edge extending between opposing walls of said passage.

6. Apparatus as defined in claim 1 wherein said corresponding edges and said inner edges of the respective rectangular members are spaced from each other a distance slightly greater than one-half of the spacing between the opposing walls with which such outer edges are engaged.

7. Apparatus as defined in claim 3 wherein the mixing units between alternate of such mixing units are comprised of planar members each having a configuration of an isosceles trapezoid.

8. Apparatus as defined in claim 3 wherein the mixing units between alternate of such mixing units are comprised of planar members in which said inner edge thereof together with opposing walls of said passage define like openings each having a configuration of an isosceles trapezoid.

9. Apparatus as defined in claim 1 wherein each of said mixing units disposed snugly within yet slidable relative to the walls defining said passage.

10. Apparatus as defined in claim 9 wherein the planar members of each of said mixing units are fixed to each other at their locations of crossing.

* * * * *