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Huber et al.

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[45] **Mar. 18, 1975**

[54] **MIXING APPARATUS AND METHOD**

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[52] **U.S. Cl.** **259/4**

[51] **Int. Cl.** **B01f 5/06**

[58] **Field of Search** ..... 259/4, 95, DIG. 30; 23/283, 291; 261/101; 148/42, 43, 44, 45, 46

[56] **References Cited**

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[57] **ABSTRACT**

At least one fluid medium is passed in uniflow relation through one or more filler elements comprising layers which contact one another and bound flow channels, the longitudinal axes of the flow channels in each layer extending substantially parallel to one another at least in groups, the longitudinal axes of the flow channels in adjacent layers being inclined relatively to one another, the flow channels of at least any two adjacent layers being at least partly open towards one another.

16 Claims, 6 Drawing Figures

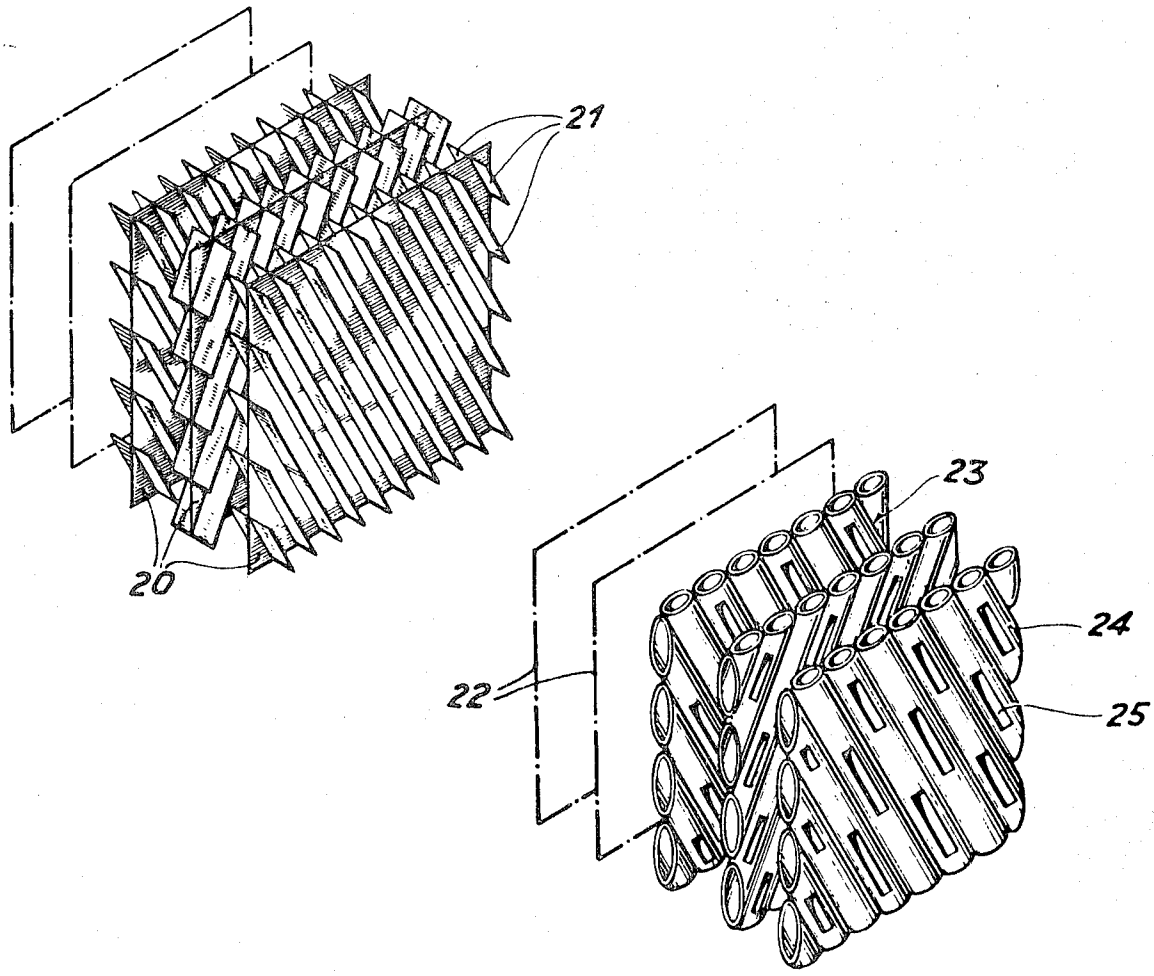


Fig. 1

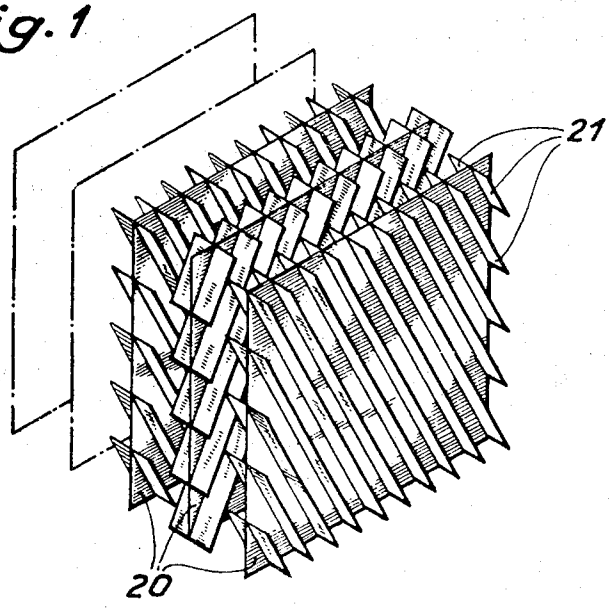


Fig. 2

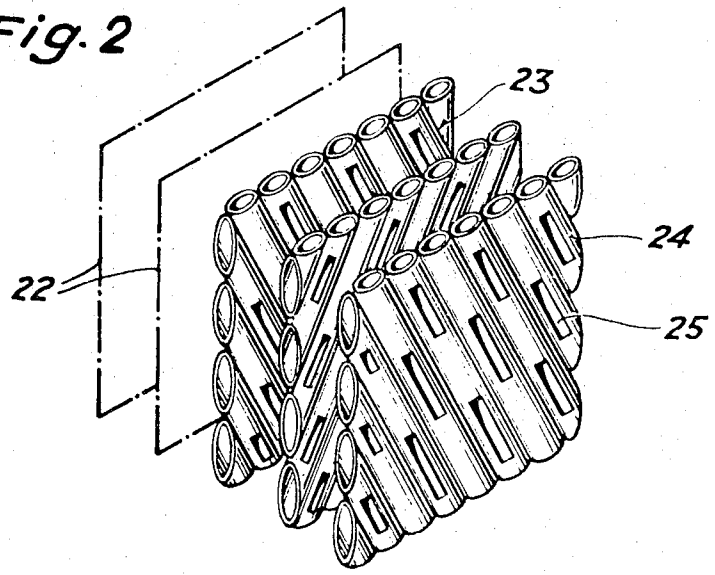


Fig. 3

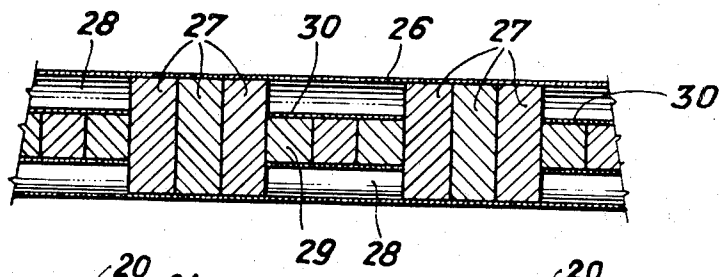


Fig. 5a

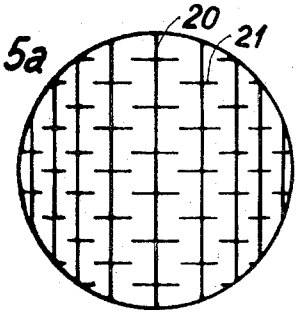
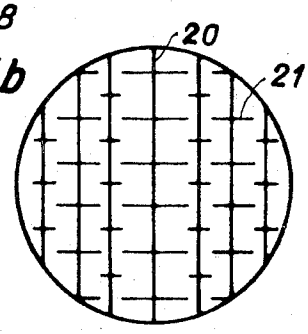


Fig. 5b



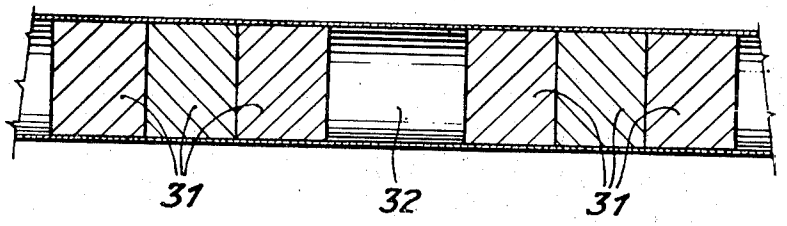


Fig. 4

MIXING APPARATUS AND METHOD

This invention relates to a mixing apparatus and method. More particularly, this invention relates to a mixing apparatus and method for the mixing of concurrent flows of at least one fluid medium.

It is an object of the invention to provide a mixer with mixing elements of simple, relatively inexpensive construction.

It is another object of the invention to obtain ready adaption of a mixing element in a mixer to any specific mixing problem without regard to the diameter or length of the mixer.

It is another object of the invention to obtain axial mixing of fluid media in a mixer utilizing filler elements having criss-cross flow passages.

It is another object of the invention to obtain uniform mixing of fluid media introduced at different rates into a mixer.

Briefly, the invention provides a mixing apparatus and method for fluid media which are directed to flow in a concurrent relation. The apparatus utilizes at least one mixing element in the path of flow which serves to mix the various media together both under longitudinal and transverse mixing. The fluid media may have uniform or different chemical composition and may also be nonhomogeneous in regard to temperature, velocity and so on. Each mixing element includes a plurality of layers which contact each other and bound flow channels. The longitudinal axes of the flow channels in each layer extend substantially parallel to one another at least in groups while the longitudinal axes of the flow channels in adjacent layers are inclined relatively to one another. In addition, the flow channels of at least any two adjacent layers are at least partly open towards one another. Advantageously, to achieve substantially uniform mixing over the whole cross-section of the mixer, at least two adjacent mixing elements with the layers of adjacent elements are staggered angularly to one another, advantageously by 90°, around the mixer longitudinal axis.

In the mixing elements according to the invention, the fluid media experience one kind of mixing as a result of being compelled to flow through the flow channels in the layers. Since the flow channels of adjacent layers are at least partly open towards one another, the media also experience mixing by shear forces on those surfaces of the flow channels which contact one another. The shear forces detach boundary layers of the fluid media, particularly in the case of highly viscous liquids and turbulence is produced on the contact surfaces, so that the distribution of the media over the mixing element cross-section is further improved and very good mixing achieved.

In one embodiment, a mixing element is formed of layers of flat thin plates to which flat thin guide elements disposed at an angle are connected, so that the flat thin plates bound the various flow channels on one side, and two parallel adjacent guide or deflector elements in each case bound the flow channels on two other sides. For instance, the guiding or deflecting elements on a layer can have a herringbone pattern.

In another embodiment, each layer of the mixing element comprises a tube bank in which the tubes form the flow channels and contact one another longitudinally, the tubes of at least any two adjacent tube banks

may communicate with one another by way of apertures.

Mixing elements according to the invention can be used with advantage in relatively large diameter, e.g., more than 50 millimeters (mm), mixers, e.g., in tubes or receptacles, since the good transverse mixing properties rapidly ensure uniform conditions in such mixers.

If required, a mixer according to the invention can be used to improve, simultaneously with and in addition to a rapid uniform mixing of the media flowing through the mixer in concurrent relation, a chemical reaction of the fluid media which have been brought into contact with one another. In this case it is possible, if necessary, either for the channel-bounding layers themselves to be made of a catalyst material or to apply such a material to the layers.

The term "fluid media" is to be understood as denoting liquids, gases and their mixtures, low-viscosity media, high-vicosity media and flowable solid particles. The device can be flowed through, e.g., by one or more concurrent liquids, by gases and mixtures thereof, by a liquid and a gas or a liquid and a finely divided solid.

Some of the problems which a mixer of this kind can help to solve are as follows:

a. Mixing of two liquids: Neutralization of an acid, e.g., the waste acid from pickling baths, by means of an alkali liquor. The plates or lamella can be made, e.g., of plastics.

b. Mixing a gas with a liquid: Hydrogenation processes, water chlorination or waste water aeration.

c. Mixing two gases: Oxygen and ammonia to produce nitric acid.

d. Catalytic reactions: e.g., ammonia synthesis.

e. Mixing highly viscous media: e.g., plastics, doughy media.

These and other objects and advantages of the invention will become more apparent from the following detaild description and appended claims taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a mixing element constructed of flat thin plates according to the invention;

FIG. 2 illustrates a mixing element constructed of tubes according to the invention;

FIG. 3 diagrammatically illustrates a view of a mixer constructed according to the invention to accommodate fluid media flows of varying supply rates;

FIG. 4 diagrammatically illustrates a view of a mixer constructed in accordance with the invention to obtain axial mixing;

FIG. 5*a* illustrates a cross-sectional view of a mixer element as shown in FIG. 1 wherein different layers have channels of different cross-section; and

FIG. 5*b* illustrates a view similar to FIG. 5*a* wherein alternate layers have channels with different cross-section.

Referring to FIG. 1 each mixing element is made of discrete layers of flat thin plates **20**, e.g., of sheet metal while rows of spaced-apart parallel guide or deflector elements **21**, e.g., in the form of metal strips are connected to the two major surfaces of the elements **20** at an angle, preferably a right-angle, to the plane of the elements **20**. The connection can be, for example, by welding or brazing. As shown, adjacent layers of the mixing element are so disposed that the guide elements **21** contact one another at intersections, thus providing the same distribution in a mixing process as is provided

by a mixing element shown in the U.S. Pat. No. 3,785,620, assigned to a common assignee.

Referring to FIG. **2**, each mixing element can also be constructed so that each layer **22** comprises a tube bank **23**. Each tube bank **23** includes tubes **24** which contact one another along their length and are angled to the longitudinal axis of the layers. Also, each tube **24** may be provided with apertures **25**. As shown in the U.S. Pat. No. 3,785,620, where the corrugated sheets or the guide element of adjacent layers contact one another at intersections, the tube axes of adjacent layers cooperate to include an angle, and the tubes **24** which define the flow channels communicate with one another via the apertures **25**.

Advantageously, a mixer having mixing elements of the kind shown in FIGS. **1** and **2**, comprises at least two mixing elements, with the layers of adjacent elements being offset from one another around the mixer longitudinal axis by an angle, preferably a right-angle.

The cross-section of the rectangular flow channels (FIG. **1**) or the tube diameter of the flow channels (FIG. **2**) can be adapted to suit individual mixing requirements. For instance, if it is required to disperse in one another two low-viscosity liquids having a viscosity of, for example 1 to 5 centipoise, the operation is, with advantage, performed in mixing elements whose flow channels are relatively narrow so that the resulting shear forces are sufficient to distribute the fluid media but are not so strong that stable emulsions are produced.

For gas mixing, for example, mixing warm air and cool air in air conditioning the losses of heat in the mixer must be small so as to keep down fan or compressor power consumption. Since gas-mixing processes usually do not present anything like the same dificulties as liquid-mixing processes, mixing elements having flow channels of fairly large cross-section can be used. In addition to the gases being distributed in the mixing elements as a result of constrained guidance in the flow channels, mixing is further improved by the turbulence produced at the intersections of the flow channels of adjacent layers.

Liquids having very different viscosities are very difficult to mix. An example is the mixing of water, with a viscosity of 1 centipoise, with a flow of methyl cellulose, whose viscosity is 10^6 centipoise. With high water concentrations of, for example 20%, there is a tendency for the water to form its own flow channel and to flow virtually unmixed through the methyl cellulose introduced into the mixing element. The result is water break-through upon leaving the mixing element.

It has been found that the main problem is the initial coarse distribution of the admixed water. If a coarse or rough distribution can be performed rapidly, i.e., if the water can be distributed to a very large number of channels at the start of the mixing path, subsequent further reduction is facilitated and the risk of water break-through greatly reduced. In this kind of mixing, coarse distribution can be in relatively narrow channel mixing elements, but to ensure very reduced loss of pressure in the mixing elements, subsequent further homogenisation may be obtained in mixing elements having relatively large cross-section channels.

The mixers hereinbefore described and shown in the drawings provide satisfactory cross-mixing but relatively little axial mixing, i.e., each volume element of the fluid media to be mixed stays in the mixing zone for about the same time. This behavior is required for a number of mixing problems.

However, in some cases it is advantageous to have some stretching of the "residence time distribution" for instance, in cases where the quantities of fluid media injected into mixers are not constant in time. For instance, a big problem in continuous mixing is accurate metering of the fluid media. If each volume element has the same residence time in the mixer, variations in metering are noticeable in the end product. It may therefore be desirable precisely in the case of metering difficulties for different volume particles to have different holdup times, for variations in dosage, which take the form of concentration variations in the mixer, are "stretched" in time and compensated.

Referring to FIG. **3**, in order to extend the reside time distribution a number of mixing elements **27**, e.g., of the kind shown in FIGS. **1** or **2**, are arranged in spaced apart groups in an outer tube **26** of a mixer to define free zones **28** therebetween. A second tube **30** of smaller cross-section than the outer tube **26** and filled with mixing elements **29** is introduced into the free zones **28** between each two groups of elements **27**. Of course, it is not necessary to enclose the mixing elements **29**, within a tube. The annular gap between the tubes **26** and **30** can be filled with mixing elements **29** while the central tube **30** is left open. Since the volume flows through the inner tube **30** and the empty annular gap are in inverse proportion to the corresponding pressure drops, the volume flows are displaced longitudinally in the mixer, and the same therefore provides the required axial mixing.

Of course, when there is an axial flow in an empty tube the maximum velocity at the center of the tube is twice as great as the mean velocity. The result is a wide residence time distribution over tube cross-section. Consequently, and as shown in FIG. **4**, a desired axial distribution can be provided by groups of mixing elements **31** alternating with empty tube portions **32**.

Referring to FIGS. **5***a* and **5***b*, axial mixing can also be obtained by forming mixing elements, for example, of the kind shown in FIG. **1** with channels of different cross-sections. The fluid media moves faster in the large cross-section flow channels than in the narrow cross-section flow channels. This also "stretches" the residence time distribution and thus leads to axial mixing in addition to thorough cross-mixing. As shown in FIG. **5***a*, the channels of the centrally located layers as viewed, have larger cross-sections than the laterally placed layers. As shown in FIG. **5***b*, the layers are alternately provided with larger or smaller cross-sections of the channels.

What is claimed is:

1. A mixing apparatus comprising

a first means for defining a passageway along a longitudinal axis thereof for the flow of at least one fluid medium therethrough;

at least two mixing elements disposed in said passageway for the flow of the medium therethrough, each said element including a plurality of layers, each layer having a spaced apart flat thin plate and a plurality of flat guide elements disposed angularly on at least one side of said plate with adjacent ones of said guide elements being in spaced apart parallel relation to define flow channels therebetween, said guide elements being angularly disposed with respect to said guide elements of an adjacent layer,

and each said mixing element being angularly offset to an adjacent mixing element about said longitudinal axis of siad means; and

means disposed on one side of said mixing element for introducing at least one fluid medium into said passageway to flow through said mixing elements for mixing therein.

2. A mixing apparatus as set forth in claim 1 wherein said guide elements of one layer are disposed in intersecting relation to said guide elements of an adjacent layer.

3. A mixing apparatus comprising

a first means for defining a passageway along a longitudinal axis thereof for the flow of at least one fluid medium therethrough;

at least two mixing elements disposed in said passage for the flow of the media therethrough, each said mixing element including a plurality of tube banks in contact with each other, each tube bank having a plurality of tubes disposed in contiguous relation and oriented in a different direction from said tubes of an adjacent tube bank, at least one of two sequentially arranged tube banks relative to the direction of media flow being disposed at an angle to said longitudinal axis of said means, and each said mixing element being angularly offset to an adjacent mixing element about said longitudinal axis of said means; and

means disposed on one side of said mixing elements for introducing at least one fluid medium into said passageway to flow through said packing element for mixing therein.

4. A mixing apparatus as set forth in claim 3 wherein said tubes are provided with apertures longitudinally thereof.

5. A mixing apparatus as set forth in claim 3 wherein said tubes of each tube bank are disposed in parallel planes and in intersecting relation to said tubes of an adjacent tube bank.

6. A mixing element comprising a plurality of layers, each layer having a spaced apart flat thin plate and a plurality of flat guide elements disposed angularly on at least one side of said plate with adjacent ones of said guide elements being in spaced apart parallel relation to define flow channels therebetween. said guide elements being angularly disposed with respect to said guide elements of an adjacent layer.

7. A mixing element as set forth in claim 6 wherein said guide elements of one layer are disposed in intersecting relation to said guide elements of an adjacent layer.

8. A mixing element comprising a plurality of tube banks in contact with each other, each tube bank having a plurality of tubes disposed in contiguous relation and oriented in a different direction from said tubes of an adjacent tube bank.

9. A mixing element as set forth in claim 8 wherein said tubes of each tube bank are disposed in parallel planes and in intersecting relation to said tubes of an adjacent tube bank.

10. A mixing element as set forth in claim 8 wherein said tubes are provided with apertures longitudinally thereof.

11. A mixing apparatus comprising

a first tube;

at least two groups of mixing elements disposed in said first tube for mixing fluid media flowing therethrough together, said groups of mixing elements being spaced from each other;

at least one second tube of smaller cross-section than said first tube disposed in said first tube between said groups of mixing elements to define an annular gap with said first tube;

a plurality of mixing elements disposed between said groups of mixing elements selectively in one of said second tube and said gap for mixing fluid media flowing therethrough together whereby fluid media passing from one of said groups of mixing elements is axially mixed with fluid media passing from said plurality of mixing elements upon entering the other of said groups of mixing elements.

12. A mixing apparatus as set forth in claim 11 wherein each mixing element includes a plurality of layers in contacting relation, each layer defining a plurality of flow channels having longitudinal axes extending in parallel at least in groups, said longitudinal axes of said flow channels in adjacent layers being inclined relative to each other, said flow channels of at least two adjacent layers being at least partly open towards each other.

13. A mixing apparatus as set forth in claim 12 wherein a plurality of said layers have flow channels of different cross-section from other of said layers.

14. A mixing element having a plurality of layers in contacting relation, each layer defining a plurality of flow channels having longitudinal axes extending in parallel, said axes of said flow channels in adjacent layers being inclined relative to each other, said flow-channels of at least two adjacent layers being at least partly open towards each other, a plurality of said layers having flow channels of different cross-section from others of said layers.

15. In a mixing apparatus,

a first means for defining a passageway along a longitudinal axis for the flow of at least one fluid medium therethrough;

at least one mixing element in said passageway for mixing the flow of fluid medium under longitudinal and transverse mixing, said mixing element including a plurality of rows of flat guide elements,

said elements in each row being disposed in spaced apart parallel relation to each other to bound flow channels between adjacent ones of said guide elements,

said elements in adjacent rows being disposed in angular relation and in contact with each other, said flow channels of at least two adjacent rows being at least partly open towards one another; and

means disposed on one side of said mixing element for introducing at least one fluid medium into said passageway to flow through said mixing elements for mixing therein.

16. A mixing element for disposition in a passageway of a mixing apparatus for mixing a flow of at least one fluid medium under longitudinal and transverse mixing, said mixing element including a plurality of rows of flat guide elements,

said elements in each row being disposed in spaced apart parallel relation to each other to bound flow channels between adjacent ones of said guide elements, and

said elements in adjacent rows being disposed in angular relation and in contact with each other, said flow channels of at least two adjacent rows being at least partly open towards one another.

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