

# United States Patent [19]

Archer

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## [54] MOTIONLESS MIXING DEVICE

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[51] Int. Cl. .... B01f 5/00

[58] Field of Search ..... 259/4, 18, 36, DIG. 30,  
259/180

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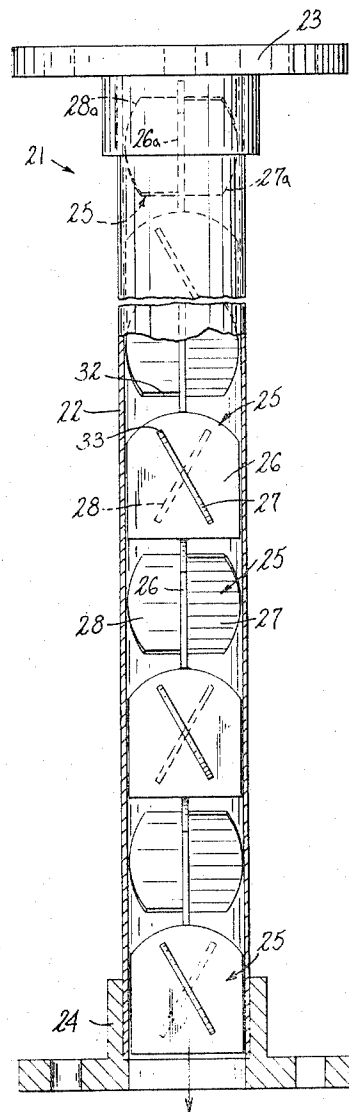
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Primary Examiner—Robert W. Jenkins  
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### [57] ABSTRACT

A motionless mixing device in which a hollow, cylindrical tube has fixedly positioned within the tube a plurality of mixing elements in end-to-end contact, wherein each mixing element comprises a flat, generally rectangular plate-like member having a pair of flat, plate-like vanes mounted substantially perpendicular on opposite faces of the plate-like member, the vanes in each pair being angled in opposite directions, the angle between any pair of adjacent plate-like members being about 90°. An apertured disk may be positioned between the mixing elements to improve transverse flow.

13 Claims, 10 Drawing Figures



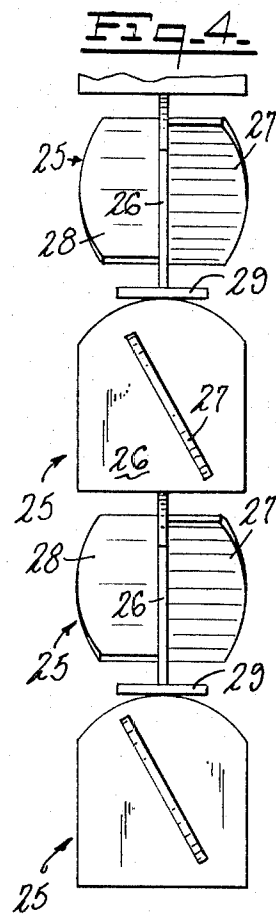
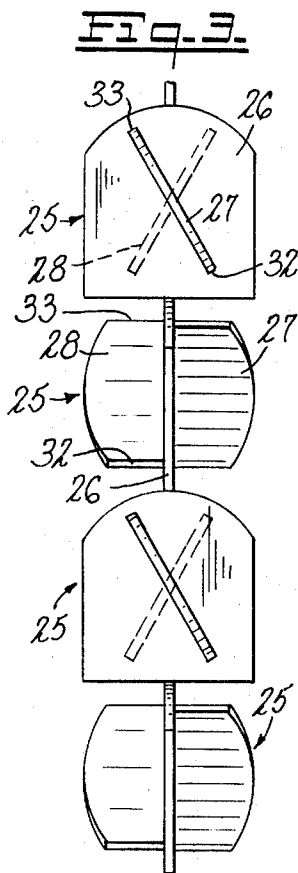
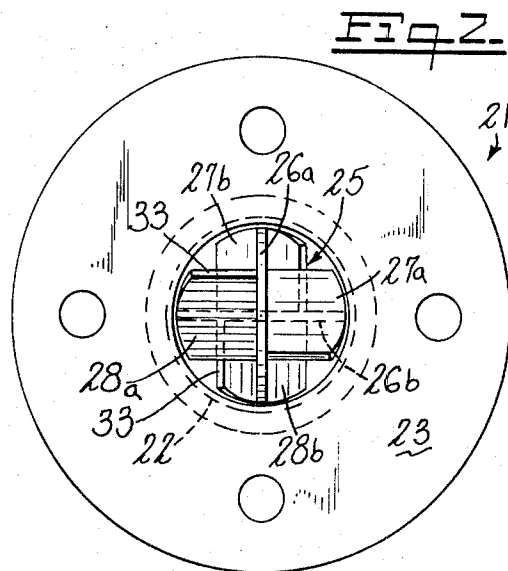
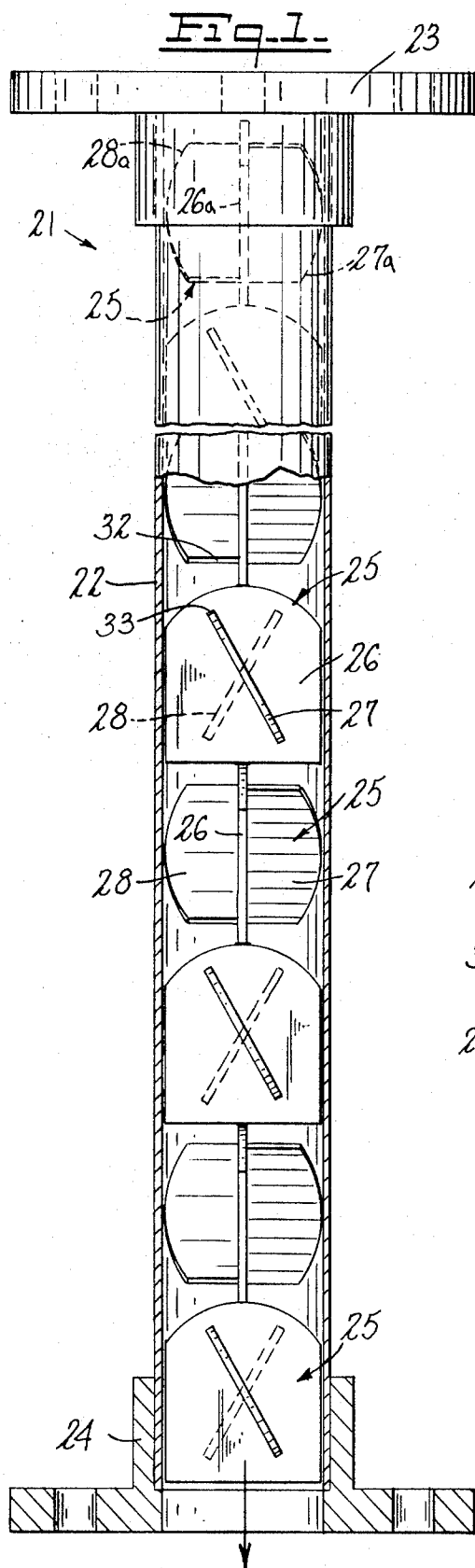


Fig. 5.

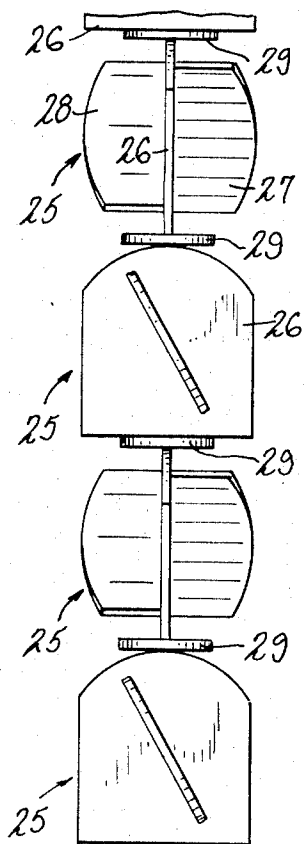


Fig. 6.



Fig. 7.

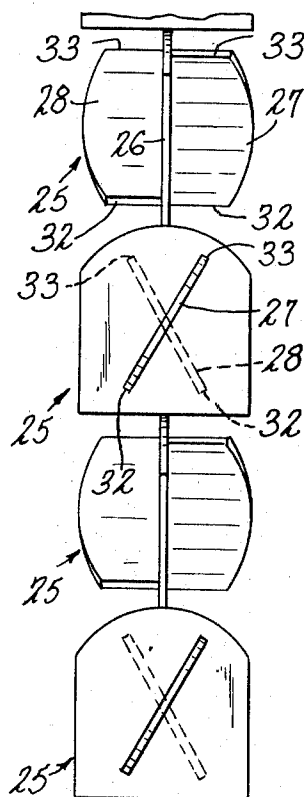


Fig. 8.

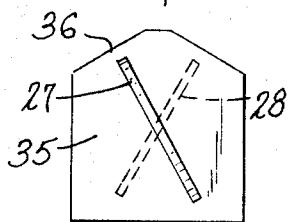


Fig. 9.

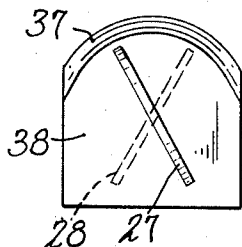
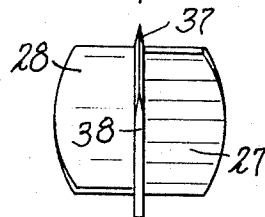


Fig. 10.



## MOTIONLESS MIXING DEVICE

## BACKGROUND OF THE INVENTION

This invention relates to a new and improved motionless mixing device, that is, to a mixing device in which the mixing elements remain stationary during the mixing operation. More particularly, the invention relates to motionless mixing devices of the mechanical type rather than motionless mixing devices primarily based upon the application of a nonmechanical external force as in sonic or magnetic mixing.

The advantages of motionless mixing over mechanical dynamic mixing are well appreciated. These advantages include more efficient use of external material-transferring devices such as pumps and the like, since motionless mixers are not wasteful of power requirements as are dynamic mixers when the viscosity of the material being mixed is initially high or increases during the mixing operation. Moreover, motionless mixers normally can be engineered to suit the particular materials being admixed, in terms of the dimensions and number of mixing elements and the like. Motionless mixers also avoid the undesirable heat, shear and vibration often generated by mixers having moving elements, and motionless mixers require only a minimum of maintenance.

One problem of motionless mixers, however, has been excessive pressure drop as material is passed through the mixer. It is evident that if the flow rate of the material through a mixing device falls off rapidly as the material moves from the inlet to the outlet, the device will be inefficient for many applications even though it provides good mixing. This problem has at least been partially solved by mixing devices in which the mixing elements are helical in configuration, as in U.S. Pat. No. 3,286,992 — Armeniades et al. However, while solving the problem of pressure drop, the known motionless mixing devices remain deficient in other respects. For example, the helical mixing elements of the foregoing patent require very careful tooling in order to provide the proper twist. This adds substantially to the expense of the completed mixing device and makes it uneconomical to use the device for many relatively commonplace mixing operations.

Another problem is the lack of usefulness of the known motionless mixing devices for certain mixing applications, such as the aeration of sludge. Even when the mixing device can be adapted to a wider range of mixing applications, the adaptation requires major redesigning of the device and the resulting costs often make the adaptation uneconomical.

## OBJECTS AND SUMMARY

Accordingly, an object of the invention is to provide a new and improved motionless mixing device wherein the mixing elements and other structural elements are simple and easily constructed, such that the cost of the completed device is low in comparison with known motionless mixing devices.

Another object is to provide a new and improved motionless mixing device which is useful without adaptation to a wide variety of mixing operations or, if adaptation is required, the adaptation is easily and inexpensively achieved.

Still another object of the invention is to provide a new and improved motionless mixing device which is substantially more efficient in providing aeration of

materials when this result is desirable, as in the digestion of sewage or sludge by the bubbling of air there-through.

These and other objects, features and advantages of the invention will be apparent from the specification which follows.

In summary outline, these and other objects are achieved by a motionless mixing device in which a plurality of mixing elements are fixedly positioned substantially end-to-end within a hollow, cylindrical tube having an inlet and an outlet for passage of material through the tube. Each mixing element comprises a flat, generally rectangular plate-like member having a pair of flat, plate-like vanes mounted substantially perpendicular on opposite faces of the plate-like member, the vanes in each pair being angled in opposite directions, the angle between any pair of adjacent plate-like members being about 90°. An apertured disk may be positioned between any of the mixing elements to improve transverse flow.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

## DETAILED DESCRIPTION

For a fuller understanding of the nature and objects of the invention, reference is had to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an elevational view of a device of the invention with some portions sectioned or shown diagrammatically;

FIG. 2 is a top, partially diagrammatic view of the device of FIG. 1;

FIG. 3 is an elevational, partly schematic view of one embodiment of mixing element combination for use in a device of the invention;

FIG. 4 is an elevational view of another embodiment of mixing element combination;

FIG. 5 is an elevational view of still another embodiment of mixing element combination of the invention;

FIG. 6 is a top view of a disk shown in the mixing element combinations of FIGS. 4 and 5;

FIG. 7 is an elevational, partly schematic view of another arrangement of the mixing element combination shown in FIG. 3;

FIGS. 8 and 9 are elevational, partly schematic views of two embodiments of a portion of the mixing element illustrated in FIGS. 3, 4, 5 and 7; and

FIG. 10 is a side view of the mixing element portion of FIG. 9.

With reference to FIGS. 1-3, a motionless mixing device 21 of the invention includes a hollow cylindrical tube 22 having an inlet and outlet, preferably at opposite ends of the tube. For some applications, as in countercurrent mixing, the inlet and outlet may be in the same end of the tube or spaced closer together at some point along the length of the tube. In the device of FIG. 1, the inlet is covered by a cap member 23 and the outlet has a similar capping member 24. Flow direction is from top to bottom, as indicated by the arrow. The capping members may be provided with suitable valving devices (not shown) and other elements for connection with separate or converging inlet and outlet flow lines (not shown). In the usual case, the capping elements

are flanged and have holes therethrough for bolting or for otherwise affixing the mixing device to a suitable support or stage in a processing operation. The details of such capping elements and other auxiliary structure are well known and therefore require no further description.

The primary mixing element 25 has three sections. The first is a generally rectangular, flat, plate-like member 26. The other sections are a pair of weirs or vanes 27 and 28 which are also flat and plate-like in configuration but are not necessarily rectangular. As shown, the vanes preferably have rounded edges and, like the plate-like members 26, preferably are elongated in the direction of the longitudinal axis of the tube 22. With respect to the plate-like members 26, a length of about 1.4 times its width has been found useful, but the relative dimensions may be varied as desired. It will be noted that the longitudinal dimensions of the vanes 27 and 28 are somewhat less than those of the plate-like members 26 but these dimensions may generally correspond if desired.

The vanes 27 and 28 are mounted perpendicularly on opposite faces of the plate-like member 26 by any suitable means such as by welding. The vanes are mounted such that their lateral axes are on the centerlines of the plate-like member, and the vanes are angled in opposite directions, as shown. Each vane preferably is angled from about 20° to about 40° from the longitudinal centerline of the plate-like member 26, best results being obtained at an angle of about 30°. A plurality of such mixing elements 25 are stacked substantially end-to-end in the tube 22 so that the angle between any adjacent plate-like members 26 is about 90°. The mixing elements 25 are fixed within the tube 22 either individually as by welding or pinning through the wall of tube 22 or, preferably, the mixing elements are welded or fastened together to form a unitary string of elements. The plurality of mixing elements when thus made unitary may be maintained clear of the sides of the tube, their fixed position in relation to the tube being determined by mounting contact with the capping members 23 and 24. Alternatively, in the preferred arrangement in which the individual mixing elements 25 are unitarily fixed to each other, each end of the completed assembly of mixing elements may be pinned, welded or otherwise affixed to the inner walls or ends of the tube 22, thus also providing a unitary combination of the tube and mixing elements.

Clearances between the plate-like members 26, vanes 27 and 28, and the inside wall of the tube 22 may be varied as desired for the particular mixing operation. It will be evident that if the mixing device is to be re-used, a degree of clearance between the mixing elements and the inside wall of the tube will be desirable, so that the mixing device can be more easily cleaned.

The top end view of FIG. 2 illustrates the arrangement of plate-like members 26 and vanes 27 and 28 relative to clearance and channels of flow through the tube. As shown, the uppermost mixing element has a plate-like member 26a and vanes 27a and 28a. Shown in partially diagrammatic form below this uppermost element is the next adjacent mixing element comprising a plate-like member 26b and vanes 27b and 28b. It will be noted that the rounded edges of the vanes provide a close fit within the tube but there is retained four longitudinal channels which serve to avoid substantial

pressure drop as material moves through the tube, and to facilitate cleaning.

In the embodiment of combination of mixing elements as shown in FIG. 3, the relationship of the trailing edges 32 of one pair of vanes 27 and 28 relative to the orientation of the leading edges 33 of the next adjacent pair of vanes 27 and 28 should be noted. In this embodiment, which is especially useful for low and medium viscosity mixtures, a major portion of the material moving downwardly over the surfaces of vanes 27 and 28 meets the nearly abutting leading edges 33 of the next pair of vanes with the result that a new division of the material is achieved in a relatively short space. As the material moves downwardly and off vanes 27 and 28, the flow of material is directed out towards the inside wall of tube 22 but in opposite directions within the same cross sectional region of the tube. As a result of the transverse currents, good cross mixing is obtained, this result being efficiently promoted by the relatively close spacing of adjacent pairs of vanes.

The transverse flow is promoted further by the placement of disk-like members 29 between some of the mixing elements 25, such as between each mixing element 25 (FIG. 5) or between every other mixing element 25 (FIG. 4). The transverse flow provided by the disk 29 is sometimes called "plug flow" and is successful with respect to the present mixing device, only if at least one aperture 31 is provided in the disk 29. The aperture 31 provides pressure relief so that plugging or undue pressure drop do not occur at this point. For certain applications, it may be desirable to provide more than one of such holes 31. The disks 29 may vary in diameter from about one-fourth to three-fourths of the inside diameter of the tube 22, and preferably their diameter is about one-half of the inside diameter of the tube 22.

For the mixing of high or moderately high viscosity materials, the orientation of vanes 27 and 28 shown in FIG. 7 may be more desirable. As compared with the arrangement of FIG. 3, the trailing edges 32 of the vanes in FIG. 7 are positioned away from the leading edges 33 of the next adjacent pair of vanes. The result is a freer flow of material from one pair of vanes to the next since a major portion of the material flowing from the trailing edges will initially contact the adjacent pair of vanes near the trailing edges of the latter pair of vanes rather than near their leading edges. Accordingly, the flow of material through the tube will be faster than in the arrangement of FIG. 3, given materials of the same viscosity.

In mixing operations where good slicing or shearing action is desirable, the leading edges of the mixing elements 25, especially the leading edges of the plate-like members 26 but the leading edges of the vanes as well if desired, may be curved, rounded or otherwise adapted to promote this result. Whereas the embodiments of the mixing elements shown in the preceding figures are rounded, FIG. 8 shows a pointed plate-like member 35 with its angled or otherwise pointed leading edge 36. A knife edge such as the knife edge 37 on the plate-like member 38 illustrated in FIGS. 9 and 10 is another embodiment. The knife edge design is particularly suitable for the efficient admixture of solid or semi-solid materials.

In operation, materials to be mixed are admitted in one or more streams to the inlet end of the tube 22 through the inlet cap 23, either under fluid pressure or

under gravity flow. Then begin numerous divisions of the materials as they contact the leading edges of the plate-like members 26 and the vanes 27 and 28. It should be noted that the materials will divide almost simultaneously into six paths, the first two divisions being to each side of the plate-like member 26 and each of these divisions then being further divided over the leading edges of the vanes 27 and 28. But division is not the only mixing means. The vanes 27 and 28, being angled in opposite directions, cause the divided material to flow outwardly towards the inner walls of the tube 22, resulting in good cross currents and cross mixing. As indicated, the division is promoted by the slicing leading edges of the plate-like members 26 and/or vanes 27 and 28.

This essentially simultaneous, multiple division is a unique aspect of the present invention and it will be noted that it is a function of essentially a single mixing element, the combination of the plate-like member 26 and the vanes 27 and 28. Accordingly, any number of such mixing elements 25 may be combined and encased in the mixing tube 22, and the diameter of the tube and its length may be varied to satisfy the requirements of any mixing operation. For example, tubes are commercially available having diameters of from about three-sixteenths inch (inside diameter) to about 36 inches (outside diameter), and lengths can range from a few inches to 30 feet and more.

Of course, diameters and lengths of tubes, as well as the dimensions of the mixing elements, will depend on flow rates and other empirically determined mixing requirements. The mixing device of the invention can be designed from the data of simple experiments and then scaled to suit any actual mixing requirement. The device is useful for virtually unlimited combinations of fluids, whether liquids or gases, as well as for combinations of solids and fluids, or even for so-called "solid" mixtures. Moreover, the mixing device may be easily manufactured from any suitable material such as steel, metal alloys or heavy duty plastics, and may be coated with various materials such as rubber for use with highly corrosive or reactive materials.

The mixing device of the invention has all the advantages of known motionless mixing devices with the additional advantages of low cost construction, adaptability to almost any mixing operation, and excellent aerating ability if such is desired. The relatively simple elements of the device may be manufactured by simple stamping techniques rather than by complex twist tooling, and the pressure drops encountered within the device are comparable to those of the best of the known motionless mixers for the same flow rates and viscosities. Moreover, the numerous edges to which the materials flowing through the tube are exposed, contributes to "self-cleaning" qualities of the device, and sediments which normally might cake in such a device, are carried through.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. In a motionless mixing device, the combination of a hollow cylindrical tube having an inlet and an outlet, and a plurality of mixing elements fixedly positioned within said tube; each of said mixing elements comprising a flat, generally rectangular plate-like member having a pair of flat, plate-like vanes mounted substantially perpendicular on opposite faces of said member, the vanes in each said pair being angled in opposite directions, said mixing elements being aligned substantially end-to-end within said tube such that the angle between any adjacent plate-like members is about 90°.

2. A mixing device as in claim 1 further including a plurality of disks separating some of said plate-like members, said disks being co-axial with the longitudinal axis of said tube and having at least one aperture therethrough for relief of pressure.

3. A mixing device as in claim 2 wherein every other of said plate-like members is separated by one of said disks.

4. A mixing device as in claim 2 wherein all adjacent plate-like members are separated by one of said disks.

5. A mixing device as in claim 2 wherein the diameter of said disks is from about one-fourth to about three-fourths of the internal diameter of said tube.

6. A mixing device as in claim 1 wherein the length of said plate-like member is greater than its width, and the leading edge of said member is adapted for the slicing of solid material entering said tube.

7. A mixing device as in claim 6 wherein said leading edge is rounded.

8. A mixing device as in claim 6 wherein said leading edge is a knife edge.

9. A mixing device as in claim 6 wherein said leading edge is generally pointed.

10. A mixing device as in claim 1 wherein the trailing edges of any pair of said vanes are oriented with respect to the leading edges of an adjacent pair of vanes such that a major portion of the material transferred from said trailing edges initially contacts said adjacent pair of vanes near said leading edges.

11. A mixing device as in claim 1 wherein the trailing edges of any pair of said vanes are oriented with respect to the leading edges of an adjacent pair of vanes such that a major portion of of material transferred from said trailing edges initially contacts said adjacent pair of vanes near the trailing edges of said adjacent pair of vanes.

12. A mixing device as in claim 1 wherein said mixing elements are unitarily connected, whereby said plurality of mixing elements may be removed as a unit from said tube.

13. A mixing device as in claim 1 further including a plurality of disks separating some of said plate-like members, said disks being co-axial with the longitudinal axis of said tube and having at least one aperture therethrough for relief of pressure, wherein said vanes are angled from about 20° to about 40° from the longitudinal centerline of said plate-like members, and wherein the leading edge of said plate-like member is adapted for slicing of solid material entering said tube.

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