

[54] FLUID BLENDING DEVICE TO IMPART SPIRAL AXIAL FLOW WITH NO MOVING PARTS

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[22] Filed: May 12, 1972

[21] Appl. No.: 252,701

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

[51] Int. Cl. B01f 15/02

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

[56] References Cited

UNITED STATES PATENTS

2,847,196	8/1958	Franklin.....	259/8
3,167,305	1/1965	Backx	259/4
3,190,618	6/1965	Katzen.....	259/4
3,239,197	3/1966	Tollar	259/4

Primary Examiner—Robert W. Jenkins
Attorney—Walter J. Monacelli et al.

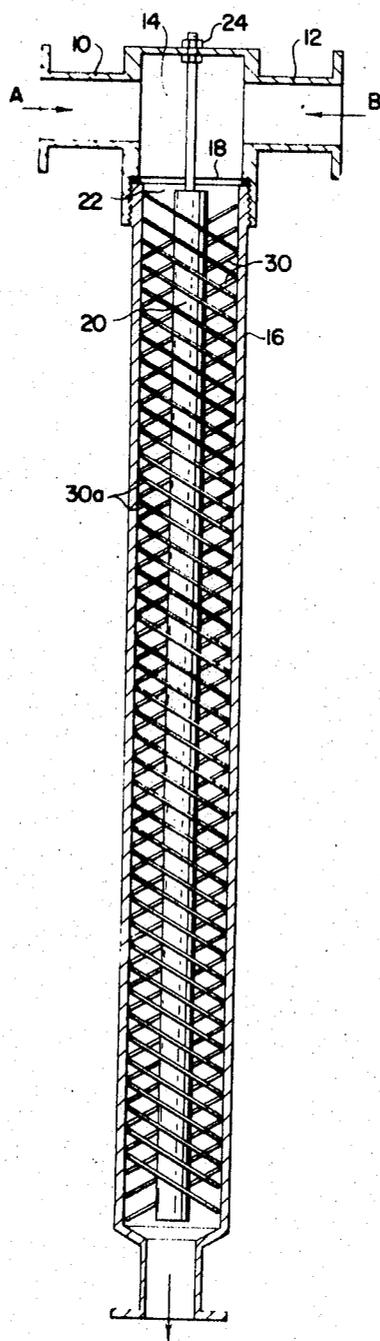
[57] ABSTRACT

A blending device with no moving parts, useful to blend at least two liquids co-currently fed to the device in predetermined proportions and spirally flowed axially along the length of the device to exit as a single homogeneously blended stream. Blending is effected by plu-

ral flow-director-dividers, diverters, flow-dividers or flow-guides which effect a multiplicity of minor diversions and divisions, without a noticeable blocking effect, to provide a spiral flow of plural parallel streams which are converged into blending zones between successive, longitudinally disposed flow-guides with the same circumferential orientation, and thereafter subdivided into plural separate streams upon leaving each blending zone. The device is also useful as a blender-reactor for relatively viscous fluids which are desirably kept flowing in the same direction, that is, in which an abrupt change of direction is undesirable.

Another embodiment of this invention is a heat exchanger in which plural, parallel, spiral, axially-flowing divisions of a relatively hot first stream are to be heat-exchanged with plural, parallel, spiral, axially-flowing divisions of a relatively cold second stream without any intermixing of first and second streams. One stream flows through an inner housing longitudinally, coaxially disposed within an outer housing through which the other stream flows. The inner housing is equipped with a multiplicity of inclinedly disposed interior flow-guides which provide spiral, axial flow as in the blending device hereinabove. A multiplicity of exterior flow-guides are inclinedly fixedly disposed on the surface of the inner housing peripherally abutting the inner wall of the outer housing in fluid-tight engagement so as to provide spiral axial flow for the second fluid.

5 Claims, 10 Drawing Figures



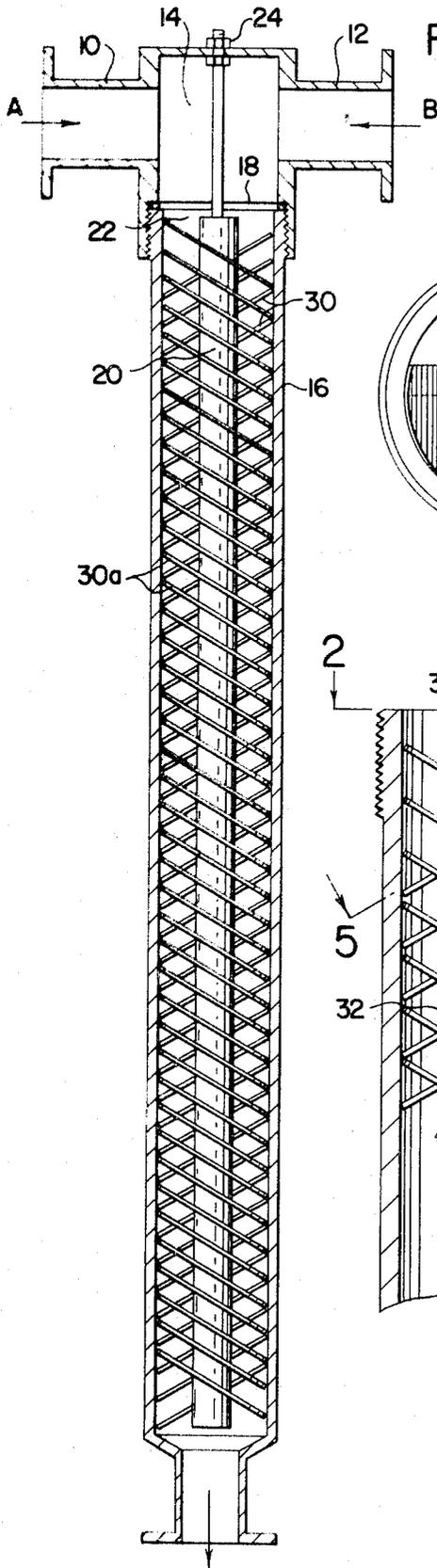


FIG. 1

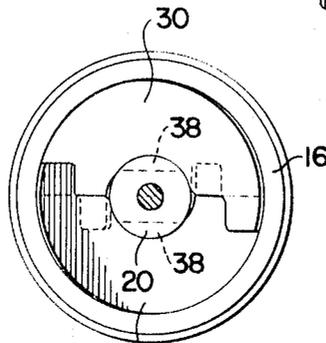


FIG. 2

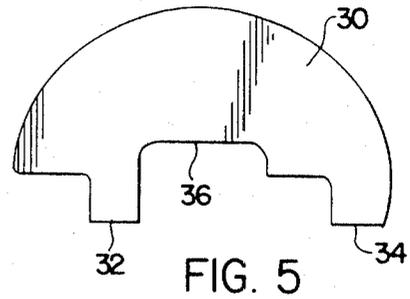


FIG. 5

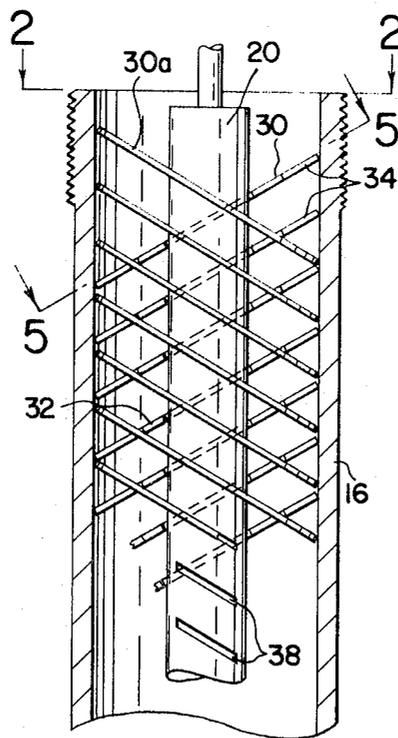


FIG. 3

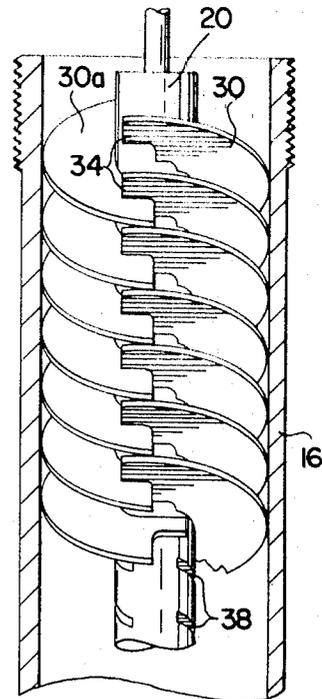
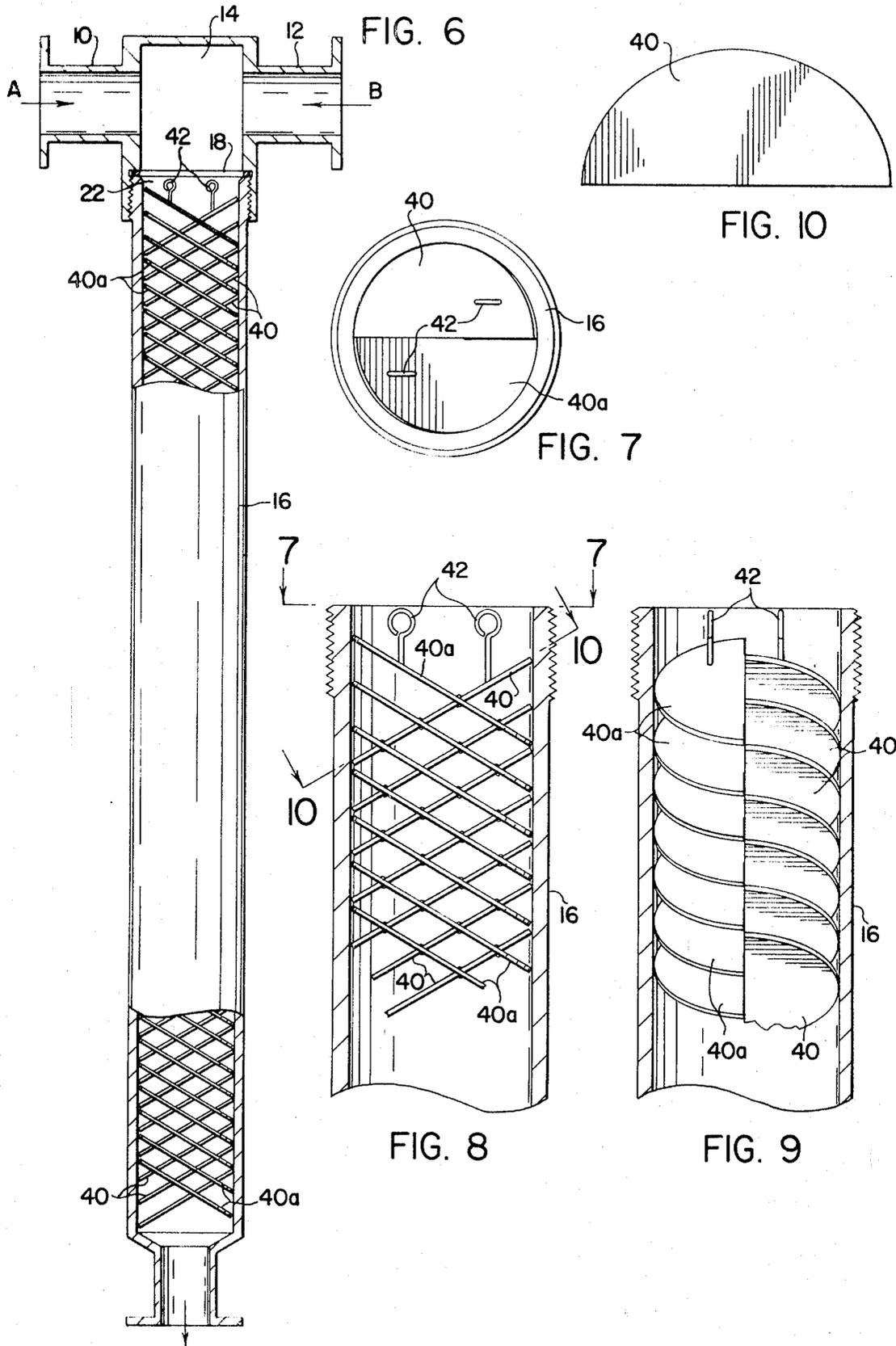


FIG. 4



FLUID BLENDING DEVICE TO IMPART SPIRAL AXIAL FLOW WITH NO MOVING PARTS

BACKGROUND OF THE INVENTION

The introduction of corn syrup as one component of a liquid stream used by food processors, and the requirement for blending various syrup streams for use in the fruit and canning industry, initiated the interest and development of fluid-blending devices, particularly those with no moving parts. Soon thereafter the technology of polymer processes used for the formation of fibers and other synthetic resinous goods further enhanced the development of special-application liquid blending and mixing devices. Most of the devices based upon the use of a mechanically driven agitator or stirrer operating in the material to be mixed are designed on the assumption that the repetitive shear thereby induced will eventually produce a relatively homogeneous blend. Methods employing shear, particularly when applied to highly viscous systems, are notably inefficient. In such cases, a large quantity of power is required to drive the agitating or mixing members, and much of the power is unavoidably converted into heat in the mixture which contributes nothing to the mixing. In cases where thermally sensitive materials are being mixed, the heat generated must be removed to avoid detrimental overheating of the mixture. In other devices, mixing is effected by building up of pressure and counter-pressure, the parabolic movement of transport produced by the pressure being superimposed by frictional transverse and backward movement of the material being mixed. The material being mixed is vigorously moved at random in each and every direction. Again, this requires high use of energy and leads to the material to be mixed being heated, causing damage to temperature sensitive materials.

Efforts to overcome the problems discussed hereinabove have resulted in devices using a single helix in a cylindrical mixing chamber, as shown in U. S. Pat. No. 2,847,649, or a double helix, as shown in U. S. Pat. No. 2,847,196. Another type of device used, referred to as an interfacial surface generator, is described in U. S. Pat. Nos. 3,239,197; 3,195,865; 3,583,678. Still another device which overcomes a number of the problems referred to hereinabove is described in U. S. Pat. No. 3,286,992.

The interfacial surface generators referred to hereinabove as well as many of the mixing devices which incorporate no moving parts are difficult to fabricate, utilize complicated elements which are difficult to fit, and after being fitted are difficult to clean. An attempt to overcome some of these problems is made in the device described in U. S. Pat. No. 3,190,618 wherein two fluids are introduced in countercurrent direction (column 3, line 16) in an annular space fitted with inclined semi-elliptical baffles which cause a major diversion and change of direction of the fluid flow (column 3, lines 33-34) by repeated impingement and diversion of the fluid mass during passage. The device requires that successive baffles in the line of flow have different circumferential orientations within the annular space so as not to permit "two or more parallel flow paths leading to ineffective mixing action" (column 3, lines 56-57). Surprisingly, highly effective blending action is obtained in our invention which utilizes successive flow-guides with identical circumferential orientations, deliberately to form two or more parallel, spiral flow

paths coaxially and co-currently in such a manner that plural parallel streams are blended in a narrow blending zone between adjacent flow-guides, in which zone there is no back mixing and no impingement, and thereafter the mass liquid flow is divided, necessarily non-equivolumetrically, into plural separate streams, each of which continues in spiral axial parallel flow. The number of separate streams leaving the blending zone preferably is numerically equal to the number of parallel streams entering it. This action is repeated as often as is necessary to effect a desired degree of blending. The heat generation is limited to that of the theoretical amount required for mixing the fluids, the pressure drop is essentially the same as that for spiral flow in a conduit, and there is essentially no energy dissipation. At the same time, our blending device permits easy fabrication, and a multiplicity of uses in blending-related applications including those in which temperature sensitive materials are involved.

SUMMARY OF THE INVENTION

A compact, inexpensive and easily fabricated apparatus is provided for the manipulation of viscous fluids or fluidizable materials of varying viscosities, including those which are temperature sensitive. There is essentially no heat dissipation problem as is conventionally encountered in high energy mixing devices since the efficiency of the instant device is predicated upon inclinedly disposed identical flow-guides with identical circumferential orientations within the mixing chamber, the orientations of the flow-guides being such as to form plural, parallel, spiral, co-current, axially directed streams which repeat a pattern of plural streams blending into a relatively narrow blending zone; upon leaving a blending zone, the fluid therein is sub-divided into plural streams, each having spiral, axial flow without being subjected to back mixing or a direct obstruction on which they may impinge.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-section side elevational view of a blender;

FIG. 2 is a plan view of the upper portion of the blender detailed in FIG. 3;

FIG. 3 is a cross-section side elevational view of the upper portion of the blender;

FIG. 4 is another side elevational view showing interlocking, semi-elliptical, inclinedly disposed flow-guides;

FIG. 5 is a plan view of a single flow-guide;

FIG. 6 is a cross-section side elevational view of another embodiment of the instant blender;

FIG. 7 is a plan view of the upper portion of the blender in FIG. 6;

FIG. 8 is a cross-section side elevational view of the upper portion of the blender in FIG. 6;

FIG. 9 is another cross-section side elevational view showing the end-on-end disposition of the inclinedly disposed flow-guides; and

FIG. 10 is a plan view of a semi-elliptical flow-guide used in the embodiment illustrated in FIG. 6.

DETAILED DESCRIPTION OF THE INVENTION

The instant apparatus is useful for continuously homogenizing and blending flowable substances such as viscous liquids and liquids containing pulverulent materials. It is especially useful for efficiently blending tem-

perature sensitive materials of differential viscosities in which the heat generated by a dissipation of shear energy is required to be held to a minimum. Other applications in which our blender is especially useful include liquid-liquid extraction processes typified by a process for recovery of copper disclosed in U. S. Pat. No. 3,428,449. It will be apparent that our blender may be used for blending any fluids or fluidizable materials which are to be blended by converging and dividing parallel, spirally, axially flowing streams. The following description refers specifically to the blending of two liquids.

A particular embodiment of our blender includes a tubular housing in which is inclinedly disposed a multiplicity of identical flow-guides, each formed by dividing an elliptical plane along the major or longer axis of the ellipse. Each flow-guide has essentially the same peripheral orientation within the tubular housing in which they are snugly accommodated in such a manner as to form plural parallel spiral channels which flow-communicate in a narrowly defined blending zone defined by successive longitudinally displaced flow-guides and which thereafter are split up into the same number of parallel spiral streams as entered the blending zone, this blending and sub-dividing of the mass liquid flow being repetitively performed to such extent as is necessary for a desired or predetermined degree of homogeneity. It will be apparent from the detailed description hereinafter, and from the illustrations of preferred embodiments herein, the number of flow-guides used, the angle of inclination and spacing, and the length of the housing will be determined by the physical properties of each fluid and the blending characteristics of the fluids. Depending upon these properties and characteristics, the mass flow during blending may be such as to be laminar or turbulent or laminar near one end of the blender and turbulent near the other end. Again, though the detailed description herein refers to the blending of two fluids in the preferred embodiment, more than two fluids may be blended. The fluids may be introduced together at one end of the blender, or separately at different locations in the housing. It will also be apparent that, though the preferred embodiment of the instant blending device includes a cylindrical tubular housing fitted with a multiplicity of identical semi-elliptical flow-guides, other geometrical shapes may be effectively utilized to reproduce the identical blending and sectioning of plural spiral axially-directed streams.

Referring now, in more detail, to the specific embodiment illustrated in FIG. 1, liquids A and B are supplied, preferably under identical pressures, through the inlet nozzles 10 and 12, oppositely disposed in a mixing head 14 which is demountably disposed on one end of a cylindrical housing 16. A gasket 18 is conveniently provided to form a fluid-tight seal between the mixing head and the cylindrical housing. The blending device of this invention includes the mixing head 14 which defines a mixing chamber 15 and the cylindrical housing 16 which defines a blending chamber 22. Within the cylindrical housing 16 is coaxially disposed a rod 20 along the longitudinal axis. One end of the rod 20 is fixedly disposed within the end wall of the mixing header 14 as with lock nuts 24 which serves to maintain the axial orientation and precise longitudinal disposition of the rod 20 within the tubular housing 16. The portion of the rod within the cylindrical housing 16 is preferably of

sufficient diameter as to permit a multiplicity of flow-guides 30 to be fixedly disposed thereupon. Each flow-guide 30, shown in more detail in FIG. 5, is in the form of a semi-elliptical section along the major axis of the ellipse, with tabs 32 and 34 and a notched section 36, specifically adapted to engage an identical semi-elliptical flow-guide and to fit into a slot 38 in a rod 20, respectively. The tabs 32 and 34 may be dispensed with, that is, each flow-guide may have straight edges on either side of the rod 20 to which it is affixed. Such flow-guides with straight edges are preferably in abutting engagement with the straight edges of oppositely disposed flow-guides, and more preferably, spot-welded, to provide both rigidity to the rod-flow-guide assembly as well as predictable and precise spiral flow.

For convenience of construction, it is also preferred that the semi-elliptical flow-guides 30 be rigidly secured in the slots 38 as by welding. Consecutive vertically spaced-apart flow-guides 30 are welded in angular disposition upon the rod 20 at uniformly spaced-apart intervals as shown in FIG. 3 to provide a three-into-three blender, i.e., three parallel spirally flowing streams are converged into a narrow blending zone between successive vertically spaced-apart flow-guides, and then trisected into three separate parallel spirally flowing streams leaving the narrow blending zone. For each flow-guide 30 fixedly disposed in the rod 20 is an oppositely disposed flow-guide 30a inclinedly disposed at the same acute angle to the longitudinal axis of the tubular housing as is each flow-guide 30. With the alternating oppositely inclined flow-guides fixedly disposed on the rod 20, it will be apparent that, where tabs are used, the tab section 32 of each flow-guide will be locked inside of the next succeeding oppositely disposed flow-guide, the inside edge of the tab 32 abutting the rod 20; and the tab 34 will be abuttingly pressed against an oppositely disposed flow-guide, two flow-guides removed from the flow-guide against which the tab 32 is pressed. For a four-into-four, five-into-five, or other blender configurations, abutting flow-guides will be determined by the angularity of their disposition and the longitudinal spacing.

The disposition of the alternately, oppositely disposed inclined flow-guides on the axially disposed rod 20 requires that the semi-elliptical elements be so constructed that each snugly fit the inside surface of the cylindrical housing at the predetermined acute angle at which it is disposed upon the central rod 20. All the flow-guides being fixedly secured to the actual rod permits disassembly of the blending device for cleaning and inspection. This is accomplished simply by removing locking nut 24 and unscrewing the mixing head 14 from the cylindrical housing 16, leaving the rod-flow-guide assembly in the blending chamber 22. The inclinedly disposed flow-guides permit easy extraction of the assembly. If desired, the rod-flow-guide assembly may be withdrawn from the exit end of the cylindrical housing 16. As is shown in FIG. 6, the exit end 40 of the blender is threadedly disposed on the cylindrical housing 16 and it may be removed if extraction of the rod-flow-guide assembly is easier from that end. It will be apparent that, since the flow-guides are snugly accommodated in the cylindrical housing 16, removal and insertion of the rod-flow-guide assembly must be done with due care.

It will be apparent that separate blenders may be designed with different angles of inclination of the flow-

guides with respect to the longitudinal axis of the cylindrical housing, as long as the flow-guides are not orthogonally disposed on the axial rod 20, and that this angle of inclination will determine the pitch of spiral, axial flow through the blender. Best results are obtained in the angular range from about 20° to about 60°, and the pressure drop through the blending device is less when the pitch of the spiral axial flow is relatively steep, as with an angle of about 20°, than when the pitch of said flow is relatively flat, as with an angle between the flow-guides and the longitudinal axis of about 60°. Similarly, the longitudinal spacing between successive flow-guides may be varied from blender to blender. Closer spacing makes for a greater number of streams entering and leaving each blending zone between two adjacent flow-guides, and wider spacing reduces the number of such streams. The effect on pressure drop through the blending device is that closer spacing of flow-guides makes for greater pressure drop than does wider spacing.

It will be deduced from the foregoing, that, at least as far as viscous liquid streams are concerned, the fluid flow through the instant device is to be laminar. Since the instant device is to be a continuous blending device, the fluid flow is expected to be steady and the fluid stream lines will coincide with particle paths and the fluid material, as it is mixed, will be transported along streamlines.

Where very viscous liquid streams are concerned, control of concentration and temperature gradient must be achieved by bulk movement of material, that is, by first sub-dividing then redistributing the flow streamlines systematically without encountering a restriction which will be at odds with the systematic zonal blending and redistribution of the fluid which is a primary goal of the instant blending device.

The length of the instant blending device is determined by the angular disposition of, and space required between, successive flow-guides 30 for obtaining laminar flow with viscous liquids, and turbulent flow in non-viscous liquids without excessive energy loss in either case; and the number of times the spirally channeled streams must be blended together and redistributed to effect the desired degree of homogeneity. Where additional turbulence is to be imparted to the streams being blended, the rod 20 may be adapted to provide such additional turbulence, for example, by having stubby projections on its surface. Alternately, the rod may be rectangular in cross section, so that the edges will provide turbulence.

In a variation of the embodiment described hereinabove, it will be apparent that where the cylindrical housing 16 is of a relatively large diameter, the rod 20 may be replaced by an inner cylindrical housing which not only fixedly supports exterior flow-guides disposed on its circumference, but may be interiorly equipped with additional flow-guides. Such an embodiment may be used as a heat exchange means between fluids wherein accelerated heat transfer is obtained both by virtue of the spirally channeled and blended fluids as well as by virtue of the conduction of heat through the flow-guides. In such an embodiment, referred to as a multiple-spiral-flow heat exchanger, the flow of fluids would be kept separate, the outer cylindrical housing being provided with an inlet and outlet for one fluid, and the inner cylindrical housing being provided with an inlet and outlet for the second fluid.

In another embodiment of the instant invention shown in FIG. 6, the cylindrical housing 16 is fitted with inclinedly disposed flow-guides, each a semi-elliptical section along the major axis of the ellipse, as disclosed in FIG. 10. There is no axial rod, or alternatively, the axial rod may be regarded as having been reduced to an infinitely small diameter. Thus, alternating inclinedly disposed flow-guides are in abutting contact at the edges at the points at which, in a side elevational view, they intersect. As in the previous embodiment, the precise angle and spacing at which the flow-guides are disposed within the cylindrical housing is not critical provided that, with predetermined energy requirements for pressure drop, a sufficient degree of spiral flow and division and recombining is provided to effect the desired degree of blending of the streams A and B.

Since it is an object of the instant invention to provide an easily disassemblable blender which may be easily cleaned, it is preferred that each flow-guide be spot-welded to every other flow-guide oppositely disposed thereto and abutting it at its edge. Thus, the assembly of flow-guides may be inserted into the cylindrical housing 16 and removed therefrom preferably by some means such as lugs 42 welded to flow-guides at one end of the cylindrical housing 16.

As before, it will be apparent that the flow of fluid in the embodiment described in FIG. 6 is similar to that described in the embodiment shown in FIG. 1. Thus, flow of fluid into each blending zone between adjacent semi-elliptical flow-guides is received from plural streams and then, after having been blended without a direct impingement upon any flow-guide or back mixing within that zone, is sub-divided, not necessarily equivolumetrically, so as to redistribute the blended streams. This action is repetitively induced along the length of the blender until the blended fluid AB exits from the outlet 26. As shown in the illustration, the cylindrical housing may be necked down near the outlet so as to provide a stop for the flow-guide assembly within the cylindrical housing.

The scope of the invention is not limited to the slavish imitation of all of the structural and operative details mentioned above. These have been given merely by way of examples of presently preferred embodiments of the invention.

What is claimed is:

1. A blender with no moving parts for blending and homogenizing fluids including viscous liquids and fluids containing pulverulent materials comprising successive blending zones within a tubular housing; means for introducing said fluids at one end of said housing and discharging said fluids at the other end of said housing, both ends being in flow communication with said blending zones; a multiplicity of flow-guides fixedly, inclinedly disposed within said housing in opposite sides thereof, each flow-guide corresponding in shape generally to approximately one half of a cross section of said housing which cross section is formed by a truncating plane similarly inclinedly disposed as said each flow-guide to provide a flow-guide-shape with a periphery adapted to abut the inner wall of said housing in essentially fluid-tight engagement; said flow-guides being arranged in identical, longitudinally spaced apart relationship with identical circumferential orientations, and with opposite inclinations in opposite sides of said housing so as to form plural paths for an integral number of fluid streams which are convergingly flowed into

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each of said blending zones between adjacent longitudinally spaced apart flow-guides, and thereafter subdivided, as said streams emerge from each of said blending zones, into an integral number of sub-divided fluid streams which are blendingly guided in parallel, spiral paths axially through a multiplicity of said successive blending zones to provide a predetermined degree of homogeneity in the blend of said fluids discharged.

2. The blender of claim 1 wherein a cylindrical rod is longitudinally, coaxially disposed within said housing, and said flow-guides are fixedly disposed on the exterior surface of said rod.

3. The blender of claim 1 wherein said tubular housing is provided with a rod having a non-circular cross section disposed coaxially, longitudinally within said

housing, said flow-guides being fixedly disposed on the exterior surface of said rod, said non-circular cross section being adapted to provide predesired turbulence of said fluid streams through said successive blending zones.

4. The blender of claim 1 wherein said tubular housing is cylindrical, said flow-guide shape is an ellipse and said flow-guide corresponds in shape to approximately one half of said ellipse along its major axis.

5. The blender of claim 1 wherein said flow-guides are fixedly attached with respect to each other at points where the major axis of one flow-guide abuts the major axis of another flow-guide to form a flow-guide assembly which is removably disposed within said tubular housing.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,743,250 Dated July 3, 1973

Inventor(s) EDWARD F. FITZHUGH, JR., ET. AL.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 10, after "rod", insert -- or tube -- ;
line 13, after "rod", insert -- or tube -- ; line 15, after
"rod", insert -- or tube -- ; Column 8, line 2, after "rod",
insert -- or tube -- .

Signed and sealed this 22nd day of January 1974.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents