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METHOD AND APPARATUS FOR COMBINING FLUIDS

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2 Sheets-Sheet 1

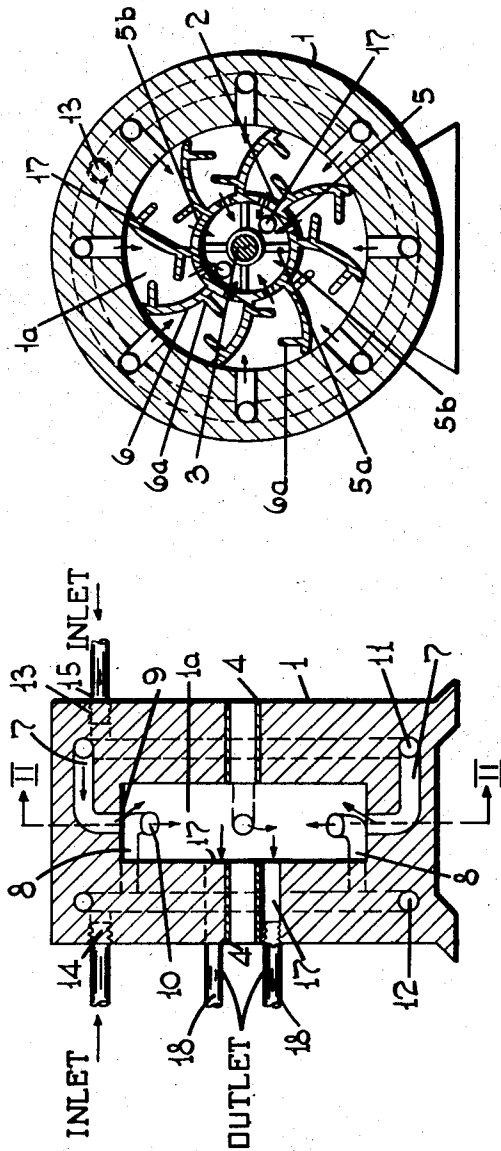


Fig. 1

Fig. 2

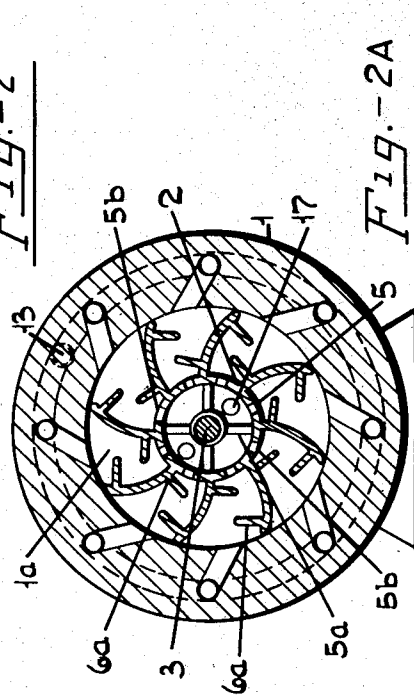


Fig. 2A

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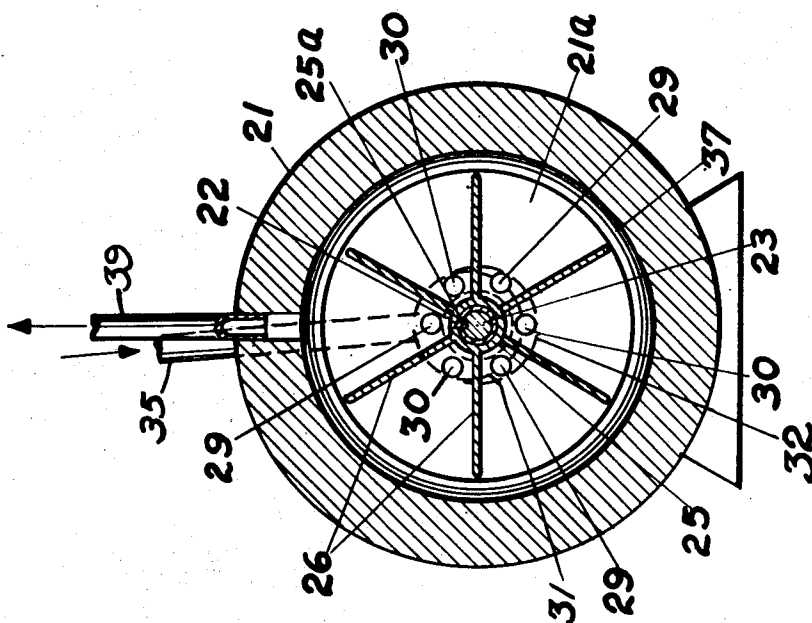
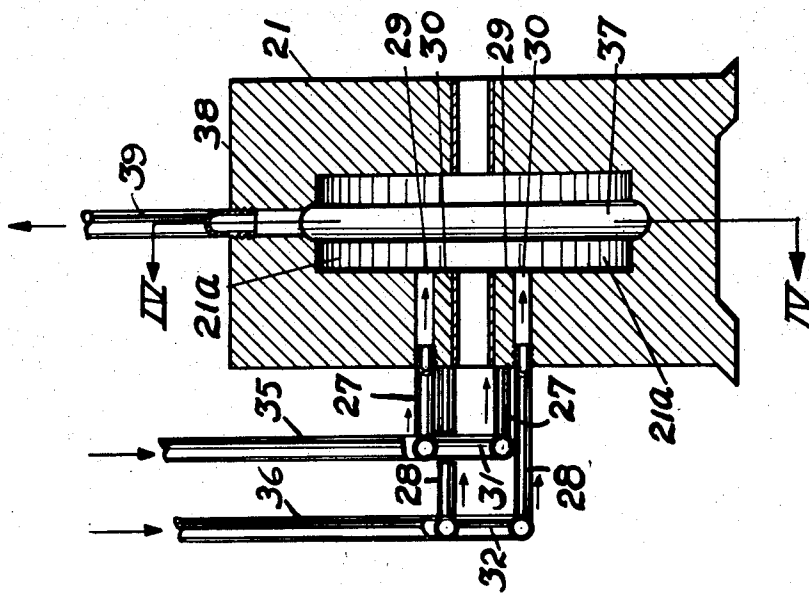
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METHOD AND APPARATUS FOR COMBINING FLUIDS

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2 Sheets-Sheet 2



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METHOD AND APPARATUS FOR COMBINING
FLUIDSFrancis R. Russell, Scotch Plains, N. J., assignor
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9 Claims. (Cl. 259-96)

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The present invention relates to improved method and apparatus for combining fluids. More particularly, the invention relates to a method and apparatus for contacting two or more liquids so as to obtain a homogeneous mixture or combination thereof. The invention also relates to a method and apparatus by means of which such combination is attained by a "micro-mixing" technique, in which the fluids are brought into intimate contact substantially as a plurality of alternate increments of each material.

In the mixing or combining of fluids, the efficiency of the system employed depends not only upon the degree of turbulence imparted to the fluid materials, but also upon the "grain size" of the fluid increments contacted. Of course, in any system, a homogeneous combination eventually may be obtained if agitation or turbulence of the materials is maintained over a sufficient period of time or with a sufficient expenditure of energy. Under certain circumstances, however, subjecting the materials to be combined to agitation for extended periods, or to a high degree may result in undesirable aeration or emulsification and may have other deleterious effects. In the conventional mixing system, the materials to be combined are brought together in more or less bulk proportions either as in a batch mixing system, or in a continuous system in which the materials are continuously introduced as proportionate streams of each material. In such systems, mixing may be accomplished either by mechanical agitation or by use of mechanical turbulence-inducing means such as orifice plates, or the like. The mixing thus obtained is frequently not uniform due to the fact that where large increments of the materials are successively brought into contact with the turbulence-inducing means, a considerable portion of the energy employed is expended in the agitation of one of the materials in the absence of the other and such mixing as occurs is almost entirely due to residual turbulence in the agitated stream of materials. In such systems, the resulting mixture or combination of the materials is frequently non-uniform, or incomplete.

It may be said that in the conventional processes for combining fluids, the result is primarily that of "macro-mixing," that is, one in which the "grain size" of the materials as brought together is large and the mixing effect is general. It is an object of the present invention to provide a mixing system in which the combination of materials is obtained by a "micro-mixing"

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procedure, namely, one in which the grain size of the materials as brought together is small and in which the combination obtained is more specific, and therefore more uniform. It is also an object of the invention to provide a system in which extended periods of agitation following initial contact of the material are substantially decreased. Another object of the invention is to provide a system in which the actual and relative grain size of the materials may be readily and effectively controlled. A further object of the invention is to provide a system in which fluid materials may be mixed or combined to obtain a product of substantially uniform characteristics, and with a maximum efficiency of operation.

The invention and its objects may be more fully understood from the following description when read in conjunction with the accompanying drawings, in which

Figure 1 is a vertical section laterally through the casing of a micro-mixing device;

Figure 2 is a vertical section through a device according to Figure 1, along a line II thereof, and including a mixing element housed by the casing of Figure 1;

Fig. 2A is a view similar to that of Fig. 2 showing a modification of the apparatus illustrated by Fig. 2;

Figure 3 is a vertical section laterally through the casing of a device similar to that of Figure 1 showing an alternate form of construction; and

Figure 4 is a vertical section along the line IV-IV of Figure 3 including a mixing element housed by the casing of Figure 3.

In the device as illustrated by Figures 1, 2 and 2A, there is provided a casing 1 adapted to house a rotatable mixing element 2 in a chamber 1a within the casing. The mixing element 2 is supported on a drive shaft 3 for rotary movement in the chamber. Bearings 4 of any conventional form including means for maintaining a substantially fluid-tight seal between the shaft and the bearings may be provided. In the form shown, the rotatable mixing element 2 is provided with a cylindrical rotor portion 5 which may be secured to the shaft 3 as by means of internal spiders 5a. Ports 5b are provided in the cylindrical portion 5 permitting communication therethrough. Routed on the exterior surface of the cylindrical rotor portion 5 are a plurality of arcuately-shaped impeller vanes 6. These vanes may be individually secured to or integrally formed with the rotor

portion 5 and are preferably formed with integral or separately attached baffle elements 6a, the baffle elements on one vane being arranged with reference to the elements on an adjoining vane so as to provide a baffled passageway between vanes. The vanes themselves are formed so as to extend from the cylindrical rotor portion 5 radially outwardly into closely-spaced relationship with the peripheral walls of the chamber 1a and laterally into a similar relationship with the end walls of the chamber 1a. The vanes with the peripheral and end wall portions of chamber 1a form a plurality of radial mixing zones or compartments.

In the casing 1, a plurality of internal passageways 7 and 8 open into the chamber 1a through ports 9 and 10. As shown, the ports 10 open radially through the periphery of the chamber 1a, but, if desired, the passageways and ports may be arranged to open tangentially into the chamber in the manner specifically illustrated by Fig. 2A. In the structure as illustrated by Figures 1 and 2, the passageways 7 and 8 and ports 9 and 10 provide inlets for the fluids to be mixed or combined. Each of the passageways 7 and 8 in turn communicate with header conduit members 11 and 12. As shown, the members 11 and 12 are formed integral with the casing, and are disposed within the casing walls, opening outwardly therefrom through the casing walls as by passageways 13 and 14 provided for threaded engagement with supply lines 15 and 16. In an alternate arrangement, however, the passageways 7 and 8 may be extended outwardly through the casing for connection to externally disposed header members, or may be individually connected to the general supply lines 15 and 16. Also provided in the casing 1 are one or more outlet conduit passageways 17 opening laterally through the end walls of chamber 1a and casing 1 and providing for threaded engagement with discharge conduits 18. The inner ends of the conduit passageways 17 are provided so as to open within the space defined by the cylindrical rotor portion 5 of the rotary element 2.

In operating the apparatus, as illustrated in Figures 1 and 2, the materials to be combined are introduced by way of lines 15 and 16 and the conduit passageways connected thereto. Where two fluids of different or similar characteristics are to be combined, they are separately introduced, one by way of line 15 and the other by way of line 16, the inlet ports 9 and 10 being disposed alternately around the periphery of the chamber. The mixing element 2 may be driven as through shaft 3 during introduction of the fluids by way of ports 9 and 10 so that the vanes or blades 6 slice comparatively thin segments from the streams of fluids entering by way of ports 9 and 10, which segments are then combined or mixed in the radial mixing zones provided between the respective vanes. The mixing or combination in these zones takes place with considerable turbulence induced by the rotational speed of the element 2, and by the baffle members 6a.

Passing through the radial mixing zones, the fluids are discharged through ports 5b into the inner zone defined by the central rotor portion 5 of element 2. The velocity of discharge through the ports 5b produces a shearing action which, combined with the agitating effect of the spider members 5a, provides for substantially complete mixing or combination of the fluids prior to discharge through the conduit passageways 17.

Although the mixing element is illustrated and here described, as an impeller type of element, it may take other forms such as a rotatable plate or cylinder, but it is intended that the operating principle remain the same, namely, the introduction of comparatively small segments of the fluids to be combined into a rotating mixing zone. The action of the apparatus with respect to the fluids to be mixed may be compared with that of a siren apparatus, in which the small segments of air are drawn into the apparatus at the proper frequency to produce sound at any desired pitch. In the system provided according to the present invention, the size of the segments of fluids cut by the vanes or blades may be varied to produce any desired grain size for the mixture or combination by varying the speed of rotation of the mixing element 2 or the rate of flow of fluids through the ports 9 and 10.

When introducing the fluids to be combined peripherally of the chamber, in the manner shown, the fluids may be utilized to drive the mixing element through pressure drop in the respective radial zones, or the mixing element may be separately driven as through the shaft 3. In the latter instance, an appreciable additional pressure must be applied to the streams of fluid entering the chamber 1a through ports 9 and 10 in order to overcome the centrifugal effect imparted by the vanes of the driven mixing element.

In the alternate form of apparatus illustrated by Figures 3 and 4, there is provided a casing 21, comparable in many respects to the casing 1 of Figures 1 and 2, providing an internal chamber 21a in which is disposed a mixing element 22. In this form of the apparatus, the element 22 is provided with a central rotor portion 25 adapted for a close sliding fit with a shaft 23 to which it is rigidly secured for rotary motion as by a key and keyways 25a. As in the form of the device illustrated by Figures 1 and 2, the central rotor portion 25 is provided with a plurality of radial vanes 26 which between them form a plurality of radial passageways and with the peripheral and end-wall portions of the casing, an annular series of mixing zones or compartments. Baffles comparable to baffle 6a in the form of the device previously described may also be provided, but, as shown, have been omitted.

The device now contemplated is arranged for introduction of the fluids to be combined radially outwardly through the passageways, or annular series of mixing zones, and, for this purpose, a plurality of inlet passageways 27 and 28 are extended through the wall of the casing so as to open through either or both end-wall portions of the chamber 21a in substantially closely-spaced annular relation to, and concentric with the drive shaft 23. As shown, the outer ends of the conduit passageways 27 and 28 are provided for threaded engagement with header ring members 31 and 32 disposed exteriorly of the casing, the header ring members 31 and 32 being in turn connected as by supply lines 35 and 36 to a source of supply for the respective fluids to be combined. The inner ends of the conduit passageways 27 and 28 open into the chamber 21a through inlet ports 29 and 30. Outlet means from the chamber and from the respective mixing zones is provided by means of an annular recess portion 37 in the peripheral wall of chamber 21a, which portion in turn is connected to at least one outlet conduit passageway 38 extending through the casing and

provided for threaded engagement with a discharge conduit 39.

In operation of the device, as shown by Figures 3 and 4, the rotor element 22 is driven through shaft 23. The fluids to be mixed are introduced through the respective inlet lines 27 and 28 issuing from the alternately arranged inlet ports 29 and 30 into the series of rotatable mixing zones defined by the vanes 26, which, when rotated, over the inlet ports 29 and 30, slice from the streams of fluids issuing from the ports 29 and 30 a successive series of small fluid increments. These fluid increments are passed through the mixing zones or passageways between the vanes 26 by centrifugal force imparted by rotation of the mixing element 22 and are thereby subjected to considerable agitation and turbulence which results in substantially complete combination of the fluids during passage through the zones into which admitted. The combined fluids are then discharged peripherally from each zone into the annular recess 37 and then through the conduit passageway 38 to be discharged through line 39.

Although substantial physical differences exist between the form of apparatus illustrated in Figures 1 and 2 as compared with the form of apparatus illustrated by Figures 3 and 4, the principle of operation is substantially identical. This principle involves the provision of a series of radially disposed mixing zones between a plurality of radial rotor vanes in which the vanes function to exert a slicing action upon the streams of fluids admitted to said zones, whereby the fluids are admitted as a successive series of alternate increments of said fluids. In such fashion, the mixing effect is that of micro-mixing rather than macro-mixing and the grain size of the fluids combined may be quite exactly controlled. The question as to whether the materials shall be passed radially outwardly or radially inwardly through the apparatus is one to which the solution is dependent upon the pressure drop tolerable and with reference to energy available for driving the rotor. The relative cost in specific instances would be the deciding factor as to which form of apparatus would be most suitable.

What is claimed is:

1. Apparatus for combining two or more fluid materials, comprising a walled casing defining a substantially cylindrical chamber internally thereof, a rotor element concentrically disposed within said chamber, a series of radial vanes rooted on said rotor between them forming with the casing a plurality of radial compartments within the chamber, conduit supply means for fluids at least partially disposed within the casing walls communicating with said chamber through an annular series of spaced inlet ports, means for rotating said rotor to bring each compartment into successive communication with said conduit means through each of said inlet ports, and discharge conduit means communicating with said chamber and disposed for substantially continuous discharge of combined fluids from each of said compartments.

2. Apparatus according to claim 1, in which said conduit supply means for fluids are annular header members, substantially concentric with

said casing, and a plurality of branch line conduits communicating at one end with one or another of said header members and at the other end opening into said chamber through the casing walls.

3. Apparatus according to claim 2, in which said branch lines are disposed in arcuately spaced relation peripherally of the chamber.

4. Apparatus according to claim 2, in which said branch lines are disposed in arcuately spaced relation peripherally of the chamber, opening tangentially into said chamber.

5. Apparatus according to claim 2, in which said branch lines are disposed so as to open into said chamber in arcuately spaced relation through at least one end wall portion of said chamber within an area radially defined by the rotor vanes, and adjacent the roots thereof.

6. Apparatus according to claim 1, in which said rotor element is a hollow cylindrical member provided for concentric relation and attachment to a rotatable shaft concentric with said casing and chamber, and a plurality of ports in said member opening therethrough and communicating between said radial compartments and the interior of said member.

7. Apparatus according to claim 2, in which said annular header members are conduit passageways formed and contained wholly within said casing and opening outwardly through the casing walls.

8. A method of combining two or more fluid materials, comprising continuously introducing said materials into a common mixing zone therefor serially, as successive, discrete incremental portions of a plurality of individual streams of said materials, agitating said incremental portions within and during passage through said zone, and continuously discharging a combined stream of said materials from said zone.

9. A method of combining two or more fluid materials, comprising continuously introducing said materials into a common mixing zone therefor serially as successive, discrete, incremental portions of a plurality of individual streams of said materials, rotating said zone to agitate said several incremental portions within and during passage therethrough, and continuously discharging a combined stream of said materials from said zone at substantially the rate of introduction of the total volume of said incremental portions.

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