

March 8, 1966

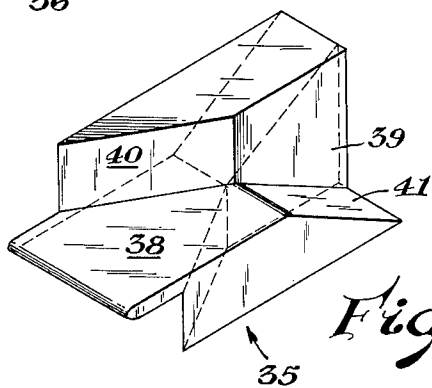
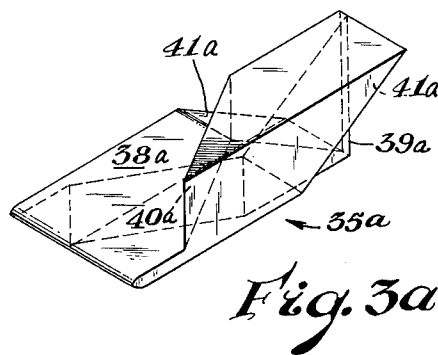
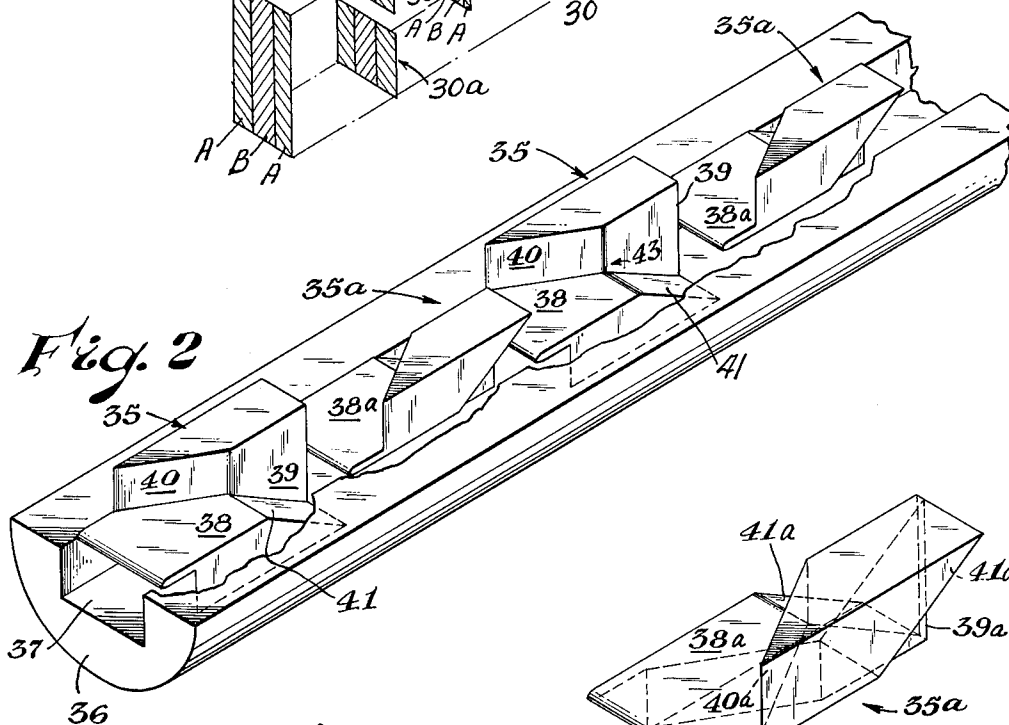
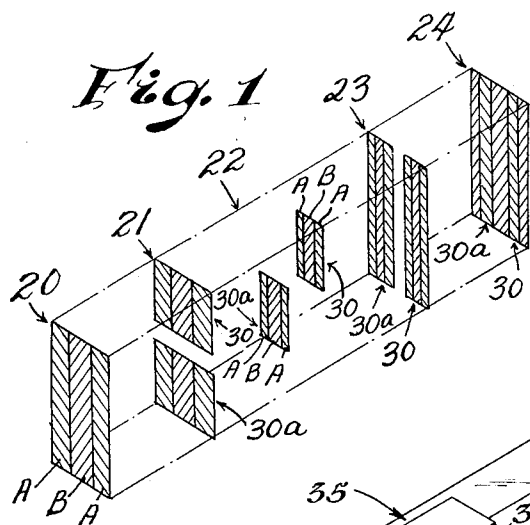
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3,239,197

INTERFACIAL SURFACE GENERATOR

Filed May 31, 1960

6 Sheets-Sheet 1



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INTERFACIAL SURFACE GENERATOR

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6 Sheets-Sheet 2

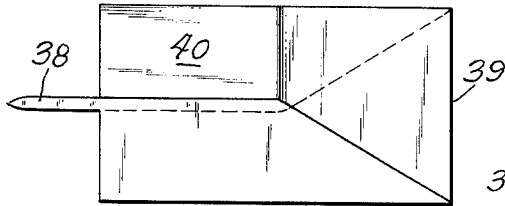


Fig. 4

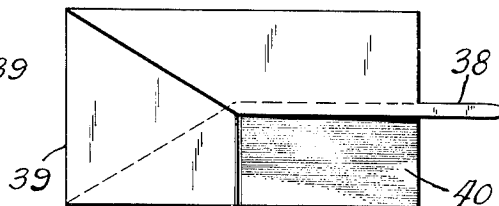


Fig. 5

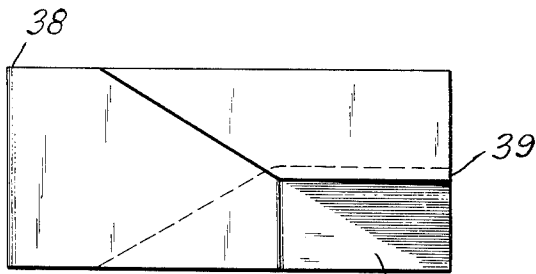


Fig. 6

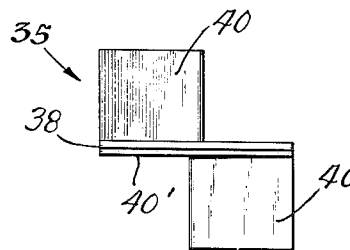


Fig. 7

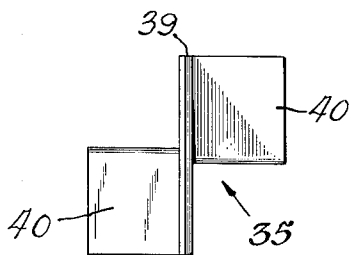


Fig. 8

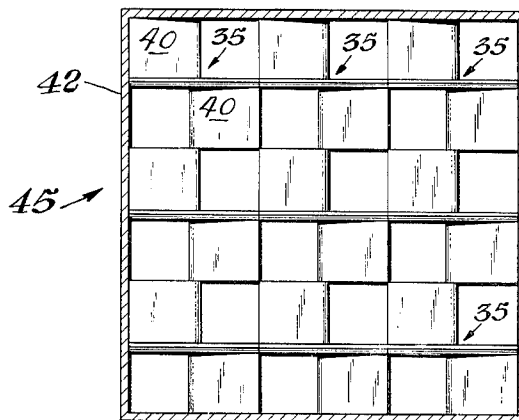


Fig. 9

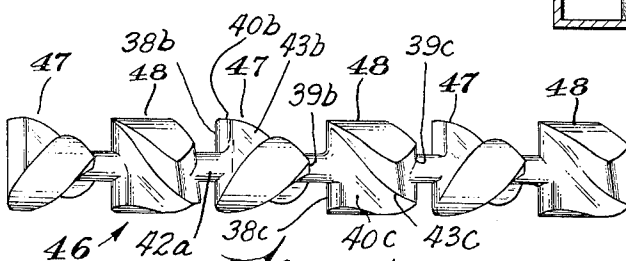


Fig. 10

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INTERFACIAL SURFACE GENERATOR

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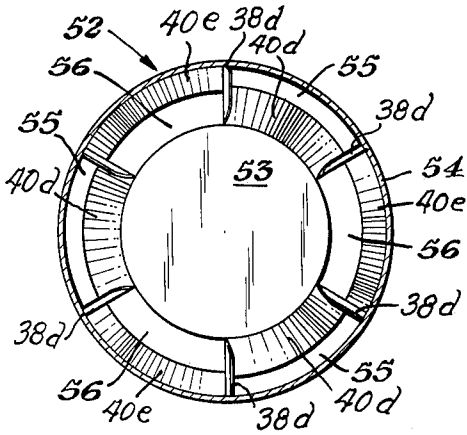


Fig. 12

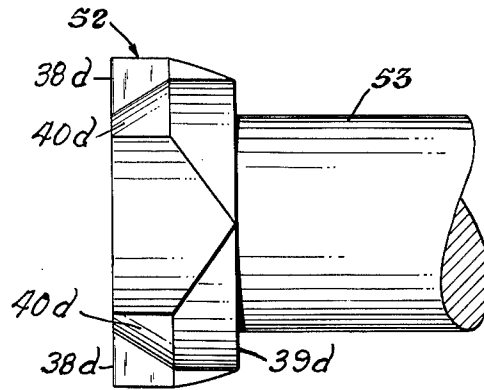


Fig. 11

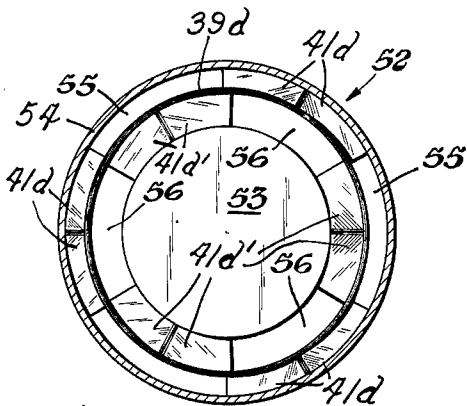


Fig. 13

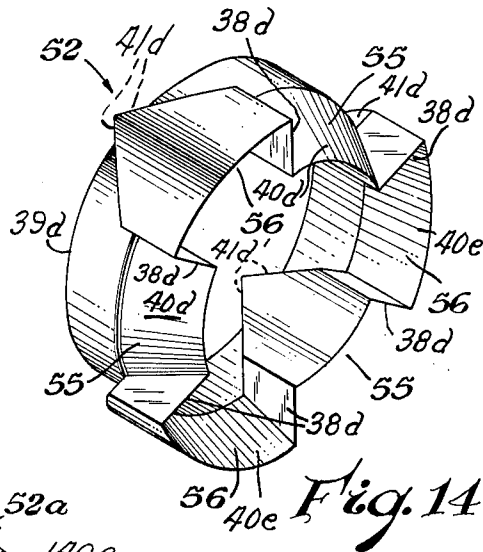


Fig. 14

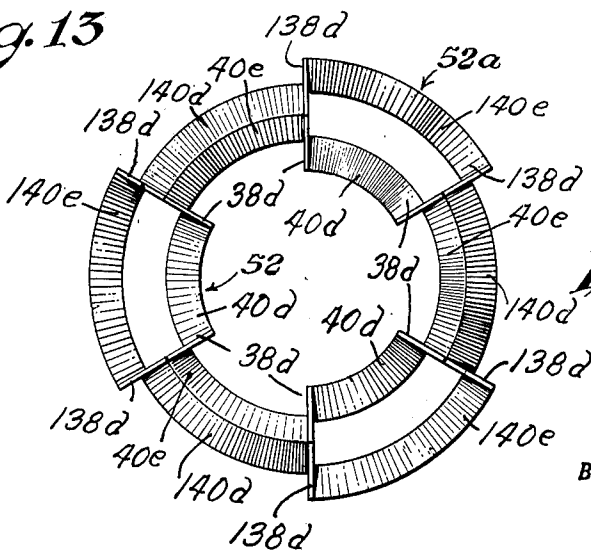


Fig. 15

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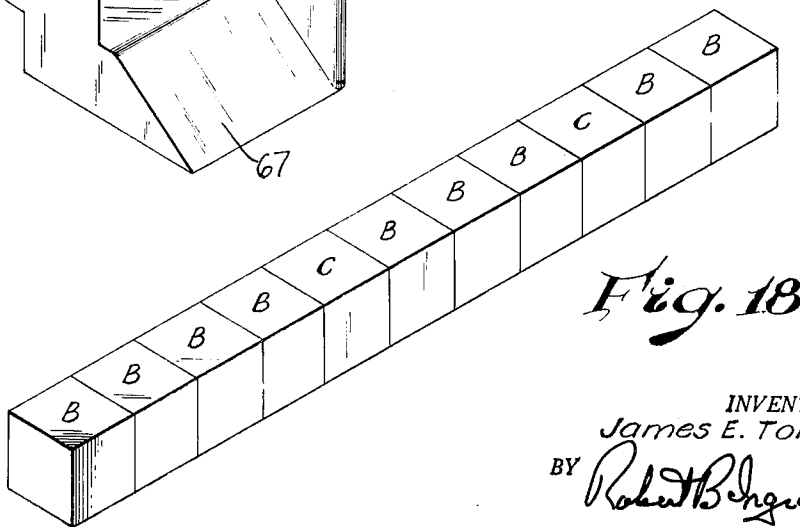
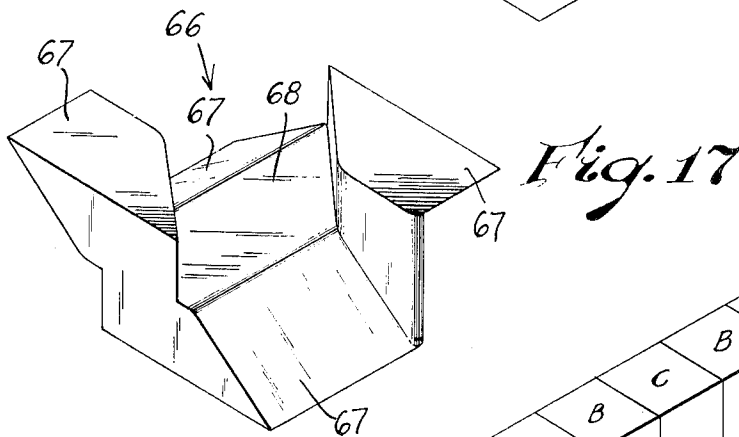
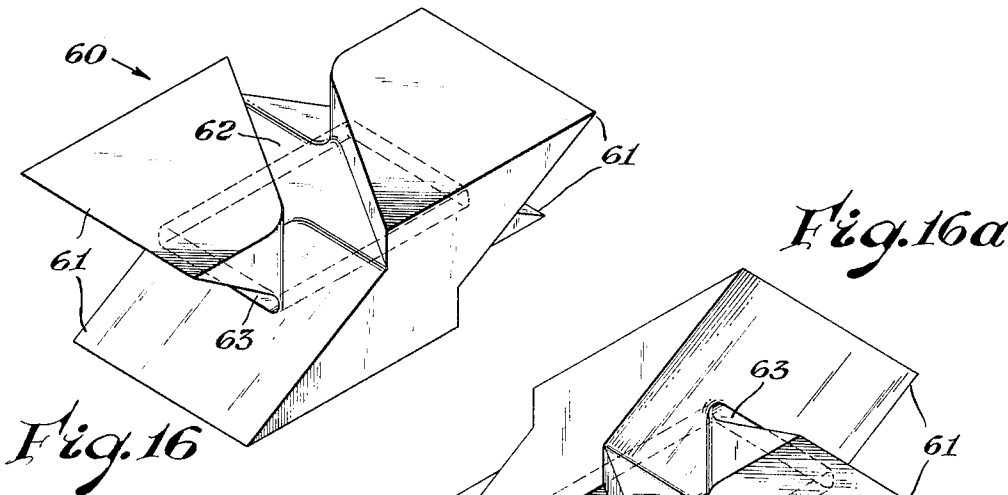
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INTERFACIAL SURFACE GENERATOR

Filed May 31, 1960

6 Sheets-Sheet 4



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3,239,197

INTERFACIAL SURFACE GENERATOR

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FIG. 17b

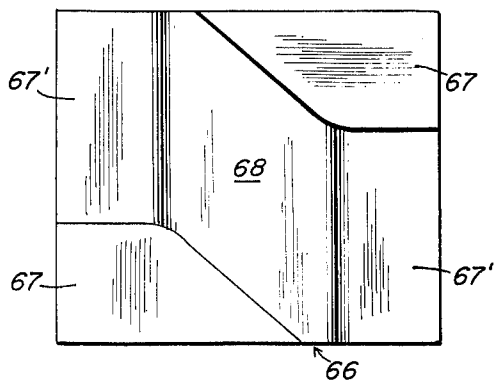


FIG.17d

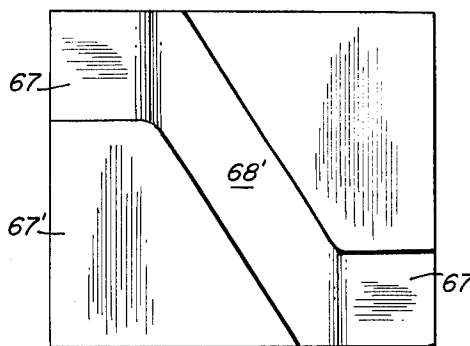


FIG. 17c

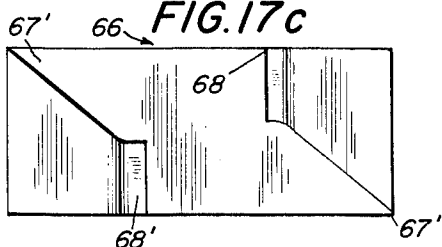


FIG.17e

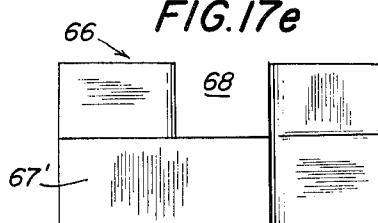


FIG. 16b

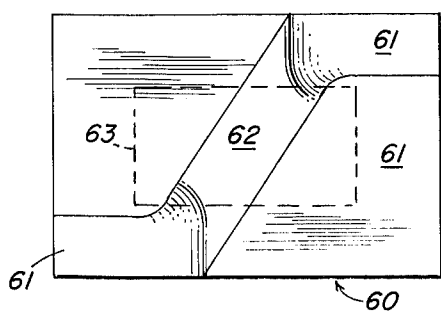


FIG. 16d 60

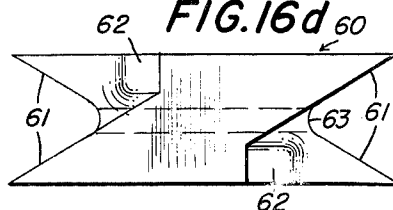


FIG. 16c

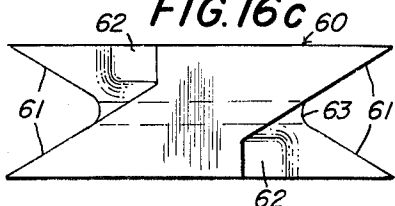
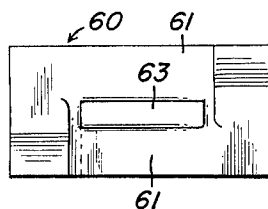


FIG. 16e



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INTERFACIAL SURFACE GENERATOR

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6 Sheets-Sheet 6

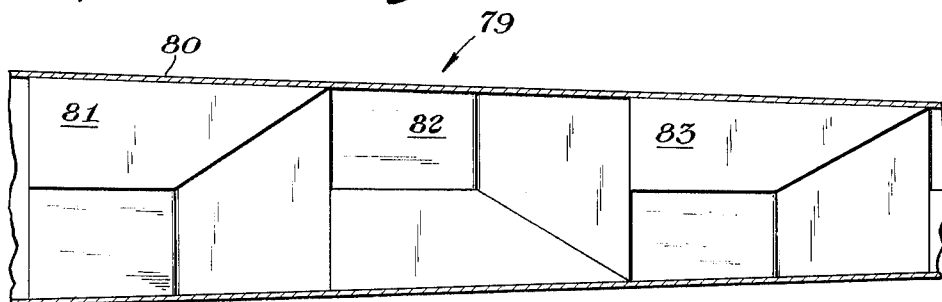
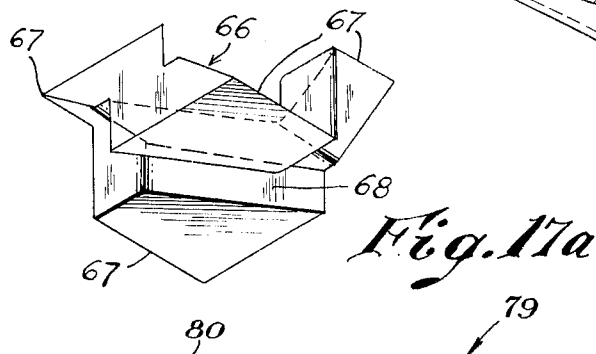
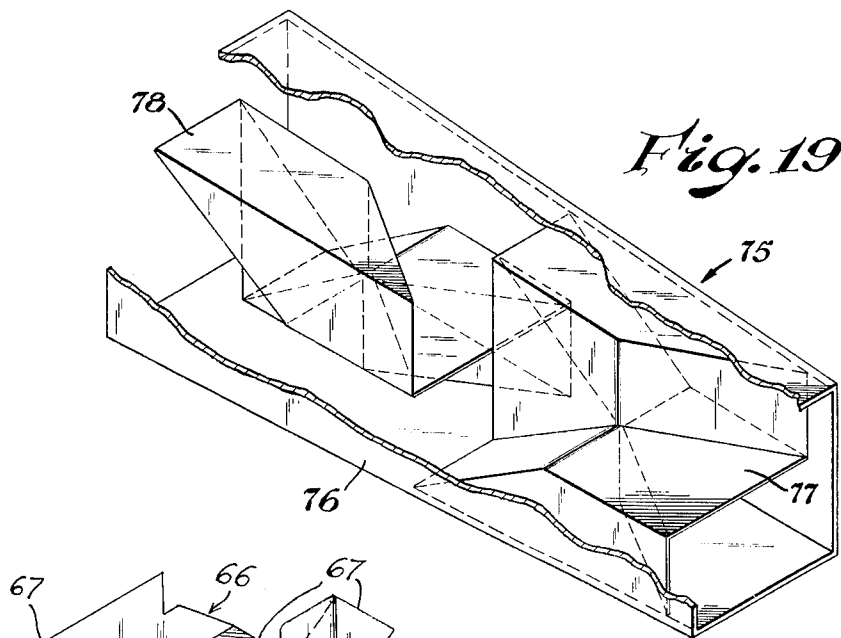


Fig. 20

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3,239,197

INTERFACIAL SURFACE GENERATOR

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Filed May 31, 1960, Ser. No. 32,727

6 Claims. (Cl. 259-4)

This invention relates to an interfacial surface generator and a method of generating interfacial surfaces and more particularly relates to a method and apparatus for generating interfacial surfaces in a fluid mass by dividing, repositioning, and recombining a stream of the fluid mass.

Various methods, machines, and devices have been employed for mixing liquids, fluids, and finely divided solid particles. Most of these are based upon the use of a mechanically driven agitator or stirrer operating in the material to be mixed. It is assumed 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, much of the power is unavoidably converted into heat in the mixture.

The energy transformed into heat usually contributes little, if anything, to the mixing. In many cases the heat must be removed to avoid undesirable overheating. Such heat is almost always wasted, especially when conventional cooling means are used to absorb it.

An apparatus employed in the manipulation of viscous liquids is generally large, massive, and costly. Frequently, the rheological characteristics of highly viscous materials are such that in order to obtain mixing, high rates of shear must be employed, therefore, necessitating employing close mechanical clearances. Oftentimes viscous materials are mixed on rolls, mills, or in rotary pumps, and the like. Frequently, it is advantageous that the liquids be reduced in viscosity by diluting with a solvent, mixing at a reduced viscosity, and subsequently removing the solvent by distillation or other evaporative means.

Viscous liquids and similar fluids have been mixed by forcing them to flow through passageways designed to cause turbulence in the flowing stream manifest by a displacement of the stream elements as they are separated and recombined during the flow. Generally, equipment of this nature presents a relatively high back pressure to the forwarding means, e.g., pump. The efficiency of mixing in any particular apparatus of this type will be proportional to the throughput. At low flow rates, a relatively small amount of mixing will occur. However, as the flow rate is increased and the amount of turbulence is thereby increased, a more homogeneous product will result.

Great difficulty has been encountered in heating and cooling viscous liquids. In many cases thermal conduction is relied upon rather than bringing the various portions of liquid into contact with a heat-exchange surface, as by agitating the liquid while in contact with a cooling surface. Adequate mixing in the heat-exchange section is required to increase over-all heat transfer.

In view of the difficulties attendant upon the use of the commercially available methods and devices in the mixing art, it is manifest that it would be advantageous if there were available an apparatus and method having no moving parts which would permit thorough mixing

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of a fluid and have an efficiency substantially independent of the rate of throughput.

It would be further advantageous if such an apparatus and method would present a relatively low back pressure to the forwarding means.

It would, also, be beneficial and advantageous if the pressure drop across such a mixing device were small relative to conventional turbulent mixing sections.

It would be advantageous if such a method and apparatus would permit the efficient transfer of heat from the viscous liquid to the walls of a heat exchanger.

These and other benefits and advantages may be obtained according to the method of the invention by generating internal surfaces within a flowing mass without significantly rotating the flow laminae of said mass; the steps of the method comprise: (a) dividing said stream into a plurality of parts by dividing means, (b) increasing the dimension of said parts in a plane non-coplanar with the plane of said dividing means, and (c) recombining said parts in overlapping relationship.

The device employed to divide and recombine a flowing mass comprises: a conduit (such as that illustrated in FIGURE 2 and formed by two halves 36 in face to face relationship) having upstream and downstream ends; said conduit having therein means defining at least one baffle (such as baffle 35, FIGURE 2); said baffle comprising a body (such as the geometric form of baffle 35) having a first end (the portion of baffle 35 adjacent the terminal portion of the conduit half 36 of FIGURE 2) and a second end (such as that portion of the baffle 35 most remote from said first end); said body defining a plurality of channels (such as the channel defined by the surfaces 38, 39, 40 and 41 of FIGURE 3) communicating with said first and second ends and having stream dividing means (such as that portion of the body adjacent the surfaces 39 and 38 of FIGURE 3) at said ends; each of said channels having a first opening (such as the entrance to the channel portion defined by the surfaces 38 and 40) and a second opening (such as defined by the surfaces 39 and 41); said first opening having a generally elongated cross-sectional configuration in a plane normal (that is, at right angles) to the longitudinal axis of said conduit; said second opening having a narrower cross-sectional configuration in a plane normal to the longitudinal axis of said conduit than the major axis (that is, the greatest dimension) of said cross-sectional configuration of said first opening in a plane containing said major axis and passing through said cross-sectional configuration of said second opening at a line of maximum contact between the plane containing the major axis of said cross sectional configuration of said first opening and passing through said cross sectional configuration of said second opening, and wider than said cross-sectional configuration of said first opening in a plane generally normal to said major axis of said cross sectional configuration of said first opening and passing through said cross-sectional configuration of said second opening at a line of maximum contact between said plane generally normal to said major axis of said cross sectional configuration of said first opening; said channels being so constructed and arranged that rotation of the flow lamina of said stream is less than the angular displacement between said stream dividing means at said first end and said stream dividing means at said second end.

Further features and advantages of the invention will be more apparent in the following description and specification when taken in connection with the accompanying drawing, wherein:

FIGURE 1 is a schematic representation of the progressive stages of division, expansion, and recombination that may occur in the apparatus and method of the invention;

FIGURE 2 illustrates a simple four-stage mixer in accordance with the invention;

FIGURE 3 is an isometric view of a baffle employed in the mixer of FIGURE 2;

FIGURES 3a, 4, 5, 6, 7, and 8 show various views of the baffles employed in the mixer of FIGURE 2;

FIGURE 9 illustrates a more complex embodiment of the invention, wherein a plurality of channels or passageways as provided in FIGURE 2 are employed in a side-by-side arrangement.

FIGURE 10 illustrates a series of interconnected baffles fabricated in accordance with the invention having a generally circular cross section and adapted to be employed within a generally cylindrical conduit;

In FIGURE 11 there is illustrated a side view of an annular interfacial surface generator fabricated in accordance with the invention;

FIGURES 12 and 13 illustrate views of opposite ends of the surface generator shown in FIGURE 11;

FIGURE 14 is an isometric view of the baffle arrangement employed in FIGURE 11;

FIGURE 15 illustrates a front view of an annular interfacial surface generator employing a baffle having passageways disposed in a plurality of coaxial cylinders;

FIGURES 16, 16a, 16b, 16c, 16d and 16e are various views of an auxiliary baffle;

FIGURES 17, 17a, 17b, 17c, 17d and 17e are various views of an alternate auxiliary baffle;

FIGURE 18 is a schematic representation of an arrangement of baffles which may be employed in accordance with the invention;

FIGURE 19 is a cut-away view of tapered baffles disposed within a tapered housing or conduit; and

FIGURE 20 represents a cut-away side view of an embodiment similar to that shown in FIGURE 19 with one wall of the conduit removed.

In FIGURE 1 there is illustrated the various operations that occur when a stream passes over a baffle in accordance with the invention. In this illustration, the main stream is composed of three smaller streams. Section 20 represents two streams designated by the letter A, and sandwiched between them stream B. Initially, in section 21 the main stream is divided into two sections designated by 30 and 30a. In section 23 the streams 30 and 30a are widened in a direction non-coplanar with the plane of division. The streams 30 and 30a are then recombined in overlapping relationship in section 24. Initially, a stream as shown in stage 20, after passing through a single baffle stage in accordance with the invention, has been transferred from three layers to six layers or five alternate layers as shown in section 24.

Alternately, in one embodiment of the invention, the cross-sectional area of the streams 30 and 30a, as shown in section 22, is reduced, as designated by the letters A and B, without significantly rotating the flow laminae. This reduction in cross section takes place where constant cross section is maintained throughout the length of the conduit or other stream containing means and baffles are inserted therein.

FIGURE 2 illustrates a simple four-stage mixer in accordance with the invention wherein four baffles indicated by the numbers 35 and 35a are employed. The baffles 35 and 35a are positioned in a housing half or stream containing means 36 in which there is formed a groove 37. By the addition of a duplicate mating housing half 36, a totally enclosed conduit results. The baffles

35 and 35a are formed as mirror images of each other, that is, one may be designated as a right-handed baffle and the other as a left-handed baffle. The baffles 35 and 35a are provided with dividing members 38 and 39 and deflecting surfaces 40 and 41. The deflecting surfaces 40 and 41 intersect the dividing members 38 and 39 to form the restriction generally indicated by the reference number 43.

In FIGURE 3 there is illustrated a detailed view of a baffle 35 arbitrarily designated as right-handed, while in FIGURE 3a there is shown a view of baffle 35a which is considered to be left-handed.

FIGURES 4, 5, and 6 present the three possible side views of the baffle 35, and FIGURES 7 and 8 illustrate the end views of baffle 35.

In FIGURE 9 there is shown an end view of an interfacial surface generator in accordance with the invention, wherein a plurality of baffles 35 have been placed in side-by-side arrangement in order to provide a mixing baffle 45 of larger cross section contained in conduit 42.

FIGURE 10 illustrates an alternative embodiment of the invention wherein the plurality baffles 47 and 48 have been formed an assembled to give a multistage mixing baffle 46 of circular cross section. Each of the baffles 47 is provided with a dividing means 38b, and dividing means 39b, and a surface 40b forms a narrowing channel toward the restricted area 43b. The surface 40b then bends away from itself to terminate at the dividing means 39b disposed substantially at right angles from the dividing means 38b. The baffles 48 are similarly provided with a dividing means 38c', a converging surface 40c', a restrictive area of restriction 43c' terminating at a dividing means disposed substantially at right angles to dividing edge 39c' disposed substantially at right angles to the dividing means 38c'.

The baffles are supported by a common mandrel 42a. The flowing stream passing a baffle 47 is divided by the dividing means 38b (while disposed within a conduit) reduced in cross sectional dimension in a plane parallel to the dividing means 38b by the surface 40c and the conduit (not shown). As the stream passes toward dividing means 39c it is expanded in a direction substantially at right angles to the plane of division and recombined in overlapping relationship. Similar division and recombination takes place when a baffle 48 is interposed in the flowing stream.

FIGURE 11 shows a side view of an annular baffle 52 having stream dividing means 38d and 39d and stream deflecting surfaces 40d. The annular baffle is supported on a mandrel 53. In FIGURE 12, there is illustrated an end view of the baffle 52 supported on the mandrel 53 and positioned within a conduit 54. The stream dividing means 38d which radially divide or section the flowing stream are disposed intermediate between alternately arranged outwardly deflecting surfaces 40d and inwardly deflecting surfaces 40e. The surfaces 40e, 40d, the stream dividing means 38d, the baffle 53 and the conduit 54 define a series of passageways 55 and 56. The passageways 55 are constricted remote from the mandrel 53, and the passageways 56 are constricted adjacent the mandrel 53. Thus, the passageways 55 discharge toward the inner surface of the conduit 54 and the passageways 56 discharge adjacent the mandrel 53. FIGURE 13 is a view of the opposite end of the assembly shown in FIGURE 12, wherein the relationship of the stream dividing means 39 is shown to the deflecting surfaces 41d and 41d'. The surfaces 41d' are disposed intermediate between the stream dividing means 39d and the mandrel 53 whereas the surfaces 41d are disposed intermediate between the surfaces 41d' and between the stream dividing means 39d and the conduit 54. FIGURE 14 is an isometric representation of the baffle 52 wherein the mandrel 53 and the conduit 54 are removed. This illustration is believed to more clearly set forth the relationship of the stream dividing means 38d and 39d of the deflecting surfaces 40, 40e, 41d and 41' to each other and to indicate

the positions of the channels 55 and 56 defined by the baffle 52.

In FIGURE 15 there is shown a front view of a mixing baffle similar to that illustrated in FIGURES 11, 12, 13, and 14 but employing a plurality of coaxially arranged layers of deflecting baffles designated by numbers 52 and 52a. The baffle 52 is positioned to show the stream dividing means 38d and the deflecting surfaces 40d and 40e. Disposed circumferentially about the baffle 52 is the baffle 52a having the corresponding stream dividing means 138d and corresponding deflecting surfaces 140d and 140e. The baffle 52a is displaced about its central axis about 60° from the position of the baffle 52a.

FIGURES 16, 16a, 16b, 16c, 16d and 16e are views of an auxiliary baffle generally indicated by the reference numeral 60. Broadly the auxiliary baffle 60 comprises four deflection wedges 61, cross-over channels 62 separating the coplanar surfaces of wedges 61. A passageway 63 is in full communication with the apexes of the spaces between the convergent surfaces of the oppositely adjacent wedges 61.

FIGURES 17, 17a, 17b, 17c, 17d and 17e are various views of an auxiliary baffle 66 which comprises four interconnected deflection wedges 67 and 67' and having cross-over channel 68 and a similar cross-over channel 68' disposed in a manner similar to the baffle of FIGURES 16, 16a, 16b, 16c, 16d and 16e.

FIGURE 18 is a schematic representation of the manner in which auxiliary baffles may be employed in conjunction with baffles 35 or 52. Blocks designated by the letter B represent baffles of the general type of baffles 35 or 52, and block carrying the letter C represent auxiliary baffles of the nature set forth in FIGURES 16, 16a, and 17.

In FIGURE 19 is depicted a cut-away view of a tapered mixing assembly indicated generally by the reference number 75. Supported within a tapered conduit 76 are a left-handed tapered baffle 77 and a right-handed tapered baffle 78.

FIGURE 20 is a cut-away plan view with one side of the tapered conduit ring an embodiment of the invention similar to that shown in FIGURE 19. The interfacial surface generator assembly is indicated generally by the reference numeral 79 comprising a tapered conduit 80, two tapered left-hand baffles 81 and 83 and a right-hand tapered baffle 82.

The operation of all or any of the previously illustrated embodiments of the invention and the method thereof is substantially in accordance with the flow patterns illustrated in FIGURE 1. The fundamental principle of the operation is the initial division of the stream into two or more parts elongating the cross section of these parts and recombining in an overlapping relationship without rotating the flow laminae from their original plane. If a spiral baffle is employed (such as is developed by rotating the ends of the sheet in parallel planes normal to the center line of the sheet) no mixing would occur. The flow laminae are rotated substantially in accordance with the surface of the sheet and recombined without the generation of additional surface.

The number of baffles or stages employed in the interfacial surface generator of the invention may be varied to give the required performance for any specific viscous liquid mixing problem. In a mixer of n baffles, the number of layers and the interface area is increased by a factor of about 2^n if a feed stream of three or more layers is utilized. This distance between the interfaces is decreased by a factor of about 2^{-n} with three or more layers in the feed stream.

In some instances wherein the fluid being passed through the apparatus of the invention exhibits a tendency to be held to the peripheral walls of the conduit containing the baffles, a tendency for incomplete blending of the portion adjacent to these walls may be observed. Such a phenomenon appears to depend on viscous drag

exerted on the fluid by the wall and on the apparent viscosity and the rheological properties of the fluid itself (i.e., dilatant, thixotropic and Newtonian). Advantageously, an auxiliary baffle as depicted in FIGURES 16, 16a and 17 may be employed to provide uniform mixing or surface generation throughout the entire stream. When the baffle 60 is positioned in a channel, the wedges 61 serve to deflect an oncoming fluid into central conduit 63 and into the cross-over channels 62. The fluid discharge from channel 63 is positioned more centrally in the stream and the flow from channels 62 has been transferred to opposite sides of the conduit containing baffle 60. In this manner a leading wedge 61 in cooperation with an adjacent channel 62 and a coplanar trailing wedge 61 places one half of the outer surface of the stream on the inside of the stream. As opposed pairs of wedges are employed in baffle 60 the result is to substantially invert the stream, that is, place the outer surface on the inside.

Conduit 63 within the baffle is provided to reduce the pressure drop across the auxiliary baffle 60 in the stream. This conduit 63 may be omitted without altering the prime function of the baffle 60 and in such a case the cross-over channels 62 may be fabricated with a proportionately greater cross-sectional area.

Although the apparatus has been described as having front and rear views, this merely is for descriptive convenience. The operation will be the same regardless of which direction of flow is employed in an interfacial surface generator constructed according to the invention. The oncoming stream may be sectioned in any plane, such as in the embodiment illustrated in FIGURE 1. Radial or annular division of the stream is employed with no significant and no appreciable difference in the result.

Advantageously, the apparatus may be constructed from any of a wide variety of materials including metal, wood, plastic, concrete, and the like or equivalent substances. The choice is predicated only upon the particular conditions which will be encountered in the situation for which the apparatus is designed.

A mixer similar to that illustrated in FIGURE 4 was fabricated from aluminum. The channel formed by a longitudinally split housing was $1\frac{1}{2}$ inches in depth, 3 inches in width, and 4 feet $11\frac{3}{4}$ inches long. Six right-hand and six left-hand baffles in alternating sequence were positioned in the channel. A stream of molten (pigmented so as to be colored white) polystyrene and a stream of molten (pigmented so as to be colored black) polystyrene were pumped into the mixer at a total rate of about 150 pounds per hour. A substantially uniform medium gray molten polystyrene was collected at the exit end of the mixer. The color was equivalent to that obtained by conventional mixing methods.

The flow of polystyrene was stopped and the mixer cooled. The two halves of the mixer housing were separated, within the housing cavity, and alternating layers of black and white solid polystyrene were observed to correspond to the pattern predicted by FIGURE 1 up to about the tenth stage. After the tenth stage the layers were sufficiently thin that they were no longer readily discernible with the naked eye.

For the sake of simplicity and clarity, the present invention is described in terms of its mixing or surface generating function. As is readily apparent the apparatus and method of the invention may be readily applied to any flowing stream, is suitable for heat transfer applications such as the heating and cooling of flowable substances, and is applied with particular advantage to viscous liquids.

In cases where a plurality of streams are being blended to a greater or lesser degree, one or more side streams may be introduced along the side of a mixer such as is illustrated in FIGURE 2. Thus, a plurality of streams may be intimately blended by passing through the entire length of the mixer while one or more other streams are

blended to a lesser degree by introducing them downstream from the entrance of the main stream or streams into the mixer in such a manner that the side stream or streams pass through a fewer number of stages of division and recombination. In such a manner, multicolor confectionaries may be prepared, and similar layering operations accomplished with ease.

The apparatus and method of the invention is also adaptable to carrying out chemical reactions wherein controlled rates of mixing may be obtained in conjunction with high heat transfer. By the addition of reactants at suitable points along a mixer (e.g., as depicted in FIGURE 2) sequential additions may be made at appropriate stages of the reaction or reactions occurring within the mixer.

The apparatus and method of the invention may be applied to streams of gases and of particulate solids in addition to liquid streams. Diverse gases may be mixed readily at low linear velocities and in the absence of substantial turbulence, thus permitting quiet operation and a minimum of back pressure across the mixer. In gaseous reactions controlled low velocity mixing may be employed to control reaction rate.

Particulate solids are readily blended with the apparatus and method of the invention. Frequently, it is beneficial to employ tapering mixing sections, such as those illustrated in FIGURES 19 and 20, for streams of particulate solids. Tapered baffles may be positioned in the lower section of a hopper or bin to assure blending of the discharge therefrom. Alternately, feeding may be done from the smaller end of a tapered mixing section and the outflow blended and discharged over a relatively larger area. Generally, it is advantageous to employ a mixer mounted in such a manner that flow of the particulate stream or streams is maintained by gravity. However, surface generators or mixers in accordance with the invention when mounted in any position readily may be employed to mix diverse gaseous suspensions of solids or liquids, or solids and liquids entrained in a gaseous stream. In a similar manner streams comprised of solids or gases entrained in liquid may be blended with equal facility.

As is apparent, the apparatus and method are susceptible of being embodied with various alterations and modifications from that which has been described in the preceding description and specification. Therefore, it is to be fully understood that all of the foregoing is merely intended to be illustrative and is not to be construed or interpreted as being restrictive or otherwise limiting of the present invention, excepting as it is set forth and defined in the hereto appended claims.

What is claimed is:

1. In an article adapted to divide and recombine a flowing mass comprising in cooperative combination a conduit having upstream and downstream ends, said conduit having therein

means defining at least one baffle, said baffle comprising

a body having a first end and a second end, said body defining a plurality of channels in communication with the first and second ends having

stream dividing means at said ends, the stream dividing means at each end of the body being disposed in angular relationship to each other in planes generally normal to the longitudinal axis of the conduit,

each of the channels having a first opening and a second opening,

said first opening having a generally elongated cross sectional configuration in a plane normal to the longitudinal axis of the conduit,

the second opening having a cross sectional configuration in a plane normal to the longitudinal axis of the conduit which is narrower than the major axis of the cross sectional configuration of the first open-

ing in a plane containing the major axis of the first cross sectional configuration and passing through the cross sectional configuration of the second opening at a line of maximum intersection between the plane containing the major axis of the cross sectional configuration of the first opening and the cross sectional configuration of the second opening,

the second opening being wider than the cross sectional configuration of the first opening in a plane generally normal to the major axis of the cross sectional configuration of the first opening and passing through the cross sectional configuration of the second opening at a line of maximum intersection between the plane generally normal to the major axis of the cross sectional configuration of the first opening and the cross sectional configuration of the second opening,

the internal configuration of the channels being so constructed and arranged that the rotation of the flow lamina of the stream is less than the angular displacement between the stream dividing means in planes generally normal to the axis of the conduit, the improvement which comprises including in the conduit downstream from a baffle at least one auxiliary baffle so constructed and arranged so that a portion of the stream adjacent the conduit periphery is repositioned closer toward the center of the stream on passing through the auxiliary baffle.

2. The article of claim 1, wherein there is included at least one auxiliary baffle for each eight baffles.

3. In an article adapted to divide and recombine a flowing mass

comprising in cooperative combination a conduit having upstream and downstream ends,

the conduit having means therein defining at least one baffle,

the baffle having a dividing means so constructed and arranged as to divide the stream into a plurality of parts, said baffle being so constructed and arranged as to increase a dimension of the cross sectional configuration of the parts in a plane noncoplanar with the plane of the dividing means

and to recombine the parts in overlapping relationship whereby the number of layers in the stream is increased,

the improvement which comprises including in the conduit at least one auxiliary baffle downstream from the baffle,

the auxiliary baffle so constructed and arranged that a portion of the stream adjacent the conduit periphery is repositioned closer toward the center of the stream on passing through the auxiliary baffle.

4. The article of claim 3, wherein there is included at least one auxiliary baffle for each eight baffles.

5. A method for generating internal surface within a stream without significantly rotating the flow laminae of said stream comprising a plurality of dividing, forming, and recombining steps, said steps comprising: (a) dividing said stream into a plurality of parts by dividing means, (b) increasing the width of said parts in a plane non-coplanar with the plane of said dividing means, (c) recombining said parts in overlapping relationship, and (d) intermediate between at least two of said recombining steps dividing said stream into at least two parts and recombining with a substantial portion of the outer portion of the original stream displaced toward the geometrical center of said stream.

6. A method for generating internal surface within a stream without significantly rotating the flow laminae of said stream comprising a plurality of dividing, forming, and recombining steps, said steps comprising: (a) dividing said stream into a plurality of parts by dividing means, (b) reducing the cross-sectional area of said parts, (c) increasing the cross-sectional area of said parts in a plane non-coplanar with the plane of said dividing means,

(d) recombining said parts in overlapping relationship, and (e) intermediate between at least two of said recombining steps dividing said stream into at least two parts and recombining with a substantial portion of the outer portion of the original stream displaced toward the geometrical center of said stream.

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