United States Patent

Chisholm

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[54] INTERFACIAL SURFACE GENERATOR AND METHOD OF PREPARATION THEREOF

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[22] Filed: **Mar. 4, 1971**

[21] Appl. No.: **120,873**

Related U.S. Application Data

[63] Continuation of Ser. No. 583, Jan. 5, 1970, abandoned.

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

[51] **Int. Cl.** **B01f 15/02**

[58] **Field of Search** 259/4, 18, 36, 60, 2

[56] **References Cited**

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3,051,452	8/1962	Nobel	259/4
3,051,453	8/1962	Sluijters	259/4
3,195,865	7/1965	Harder	259/4
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3,297,305	1/1967	Walden	259/4
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Primary Examiner—Robert W. Jenkins

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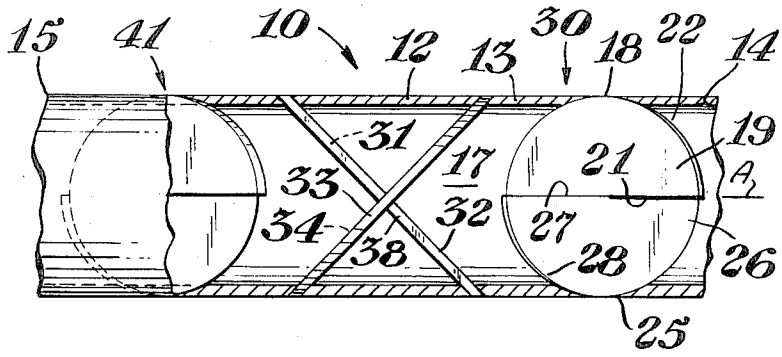
[57] **ABSTRACT**

A static element mixing tube is provided by employing opposed angularly disposed baffles of alternating hand which provides mixing action by re-positioning of the stream. Mixing action at flow rates below the turbulent level are generally independent of throughput.

9 Claims, 7 Drawing Figures



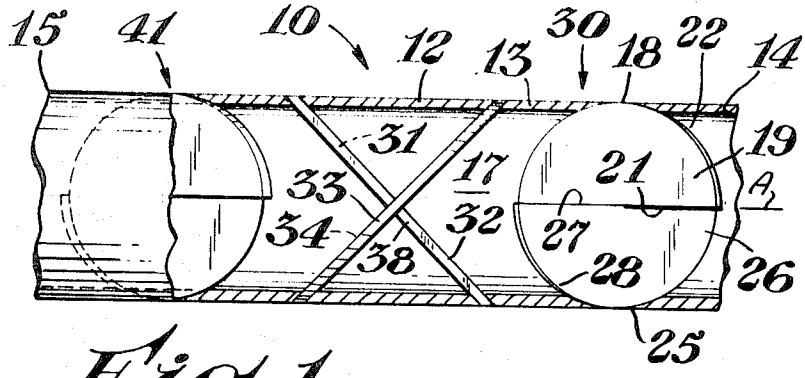


Fig. 1

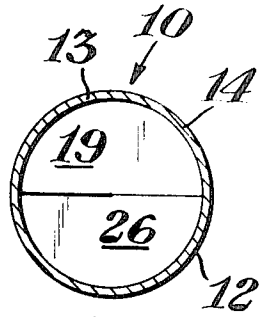


Fig. 3

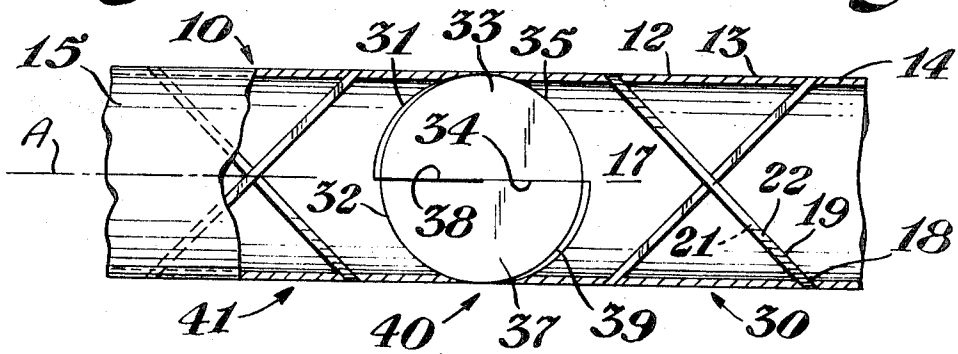


Fig. 2

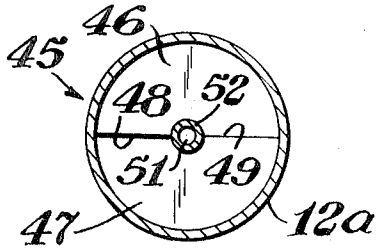


Fig. 4

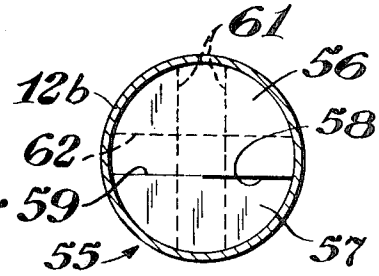


Fig. 5

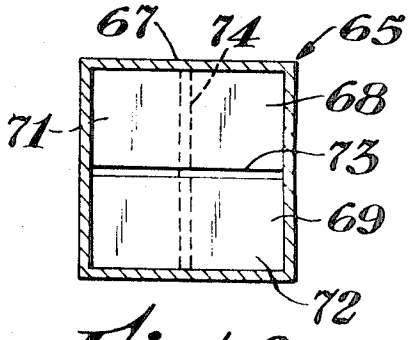


Fig. 6

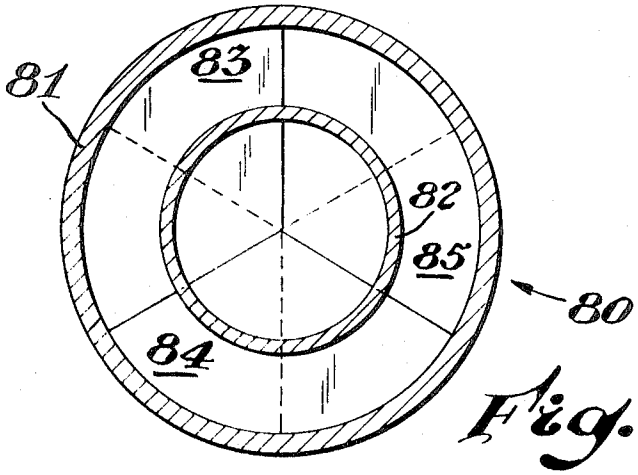


Fig. 7

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INTERFACIAL SURFACE GENERATOR AND METHOD OF PREPARATION THEREOF

This application is a continuation of my earlier filed application Ser. No. 583 filed Jan. 5, 1970, now abandoned.

This invention relates to an interfacial surface generator and a method for the preparation of interfacial surface generators.

The term "interfacial surface generator" is employed herein to describe a static mixing element through which a stream of liquid gas or particulate solids may be passed and the configuration of the generator is such that the stream is divided and recombined to provide mixing. Several varieties of such mixers are known and disclosed in the following U.S. Pat. Nos. 3,051,452; 3,051,453; 3,182,965; 3,195,865; 3,206,170; 3,239,197; 3,286,992; 3,328,003; 3,358,749; 3,394,924; 3,404,869; 3,406,947; also of interest is French Pat. No. 735,033 (1932). All of the above patents are herewith incorporated by reference. Such interfacial surface generators are generally obtained by providing a baffle or stream-deflecting element of a specific configuration within a conduit or passageway. Frequently such interfacial surface generators require machine or block molding, casting or sheet fabrication to obtain baffles of the desired configuration. U.S. Pat. No. 3,358,749 and No. 3,394,924 disclose the preparation of interfacial surface generators by the deformation of tubes. Deformation of tubes most often is suitable for mixers employing low pressure and relatively small diameters. The preparation of mixers of large diameter has generally been limited to the insertion of preformed baffle sections such as are disclosed in U.S. Pat. No. 3,051,452 and the like. Often times when baffles are inserted within a conduit, substantial difficulty is encountered in securing the baffles in the desired position where access to the inside of the tube for fabrication purposes is not readily available.

It would be desirable if there were available an interfacial surface generator prepared from a conduit and plate-like elements.

It would also be desirable if there were available an interfacial surface generator prepared from a tubular conduit wherein the plate-like elements are firmly secured to the wall of the conduit.

It would also be desirable if there were a simple method available for the preparation of an interfacial surface generator by simple fabricating techniques.

These benefits and other advantages in accordance with the present invention are achieved in a method for preparing an interfacial surface generator, the steps of the method comprising providing a hollow tubular conduit having a wall, forming a first plurality of slots in the wall of the conduit, the first plurality of slots being generally radially disposed, the first plurality of slots being disposed at an angle of substantially less than 90° to the longitudinal axis of the conduit, the first plurality of slots in an orthographic projection of an end view of the planes thereof being disposed in angular relationship to each other, providing a first plurality of plate-like elements, disposing said first plurality of plate-like elements each in a slot of the first plurality of slots, affixing the plate-like elements in generally sealing engagement to the wall of the conduit to provide a first baffle arbitrarily designated as a right-handed baffle, forming within the wall of the conduit adjacent the first baffle a second, third and plurality of slots, the second plurality of slots being disposed generally similar to the first plurality of slots but rotated about the axis of the conduit and of opposite hand to the first and second slots, disposing a second plurality of plate-like elements within the second plurality of slots in the conduit wall, affixing the second plurality of elements to the conduit wall, forming a third plurality of slots generally adjacent to the second plurality of slots and remote from the first plurality of slots, the third plurality of slots being oriented generally as the first plurality of slots, disposing a third plurality of plate-like elements within the third plurality of slots and affixing them to the conduit wall to form a third baffle of generally right-handed configuration, the second baffle having a generally mirror image configuration to the first and third baffles.

Also contemplated within the scope of the present invention is an interfacial surface generator comprising a hollow tubular conduit defining an internal longitudinal passageway, the conduit having a wall, at least a first plurality of generally opposed plate-like elements disposed in angular relationship to the longitudinal axis of the conduit to form a first baffle, the plate-like elements having at least one inwardly disposed edge, the edges of the first plurality of plate-like elements being in closely adjacent relationship, the first baffle being arbitrarily designated as being of right-handed configuration, a second baffle adjacent to the first baffle, the second baffle being of like construction to the first baffle with the exception that the plate-like elements are disposed in left-handed configuration and the edges thereof being angularly disposed about the axis of the conduit relative to the edges of the platelike element of the first baffle, a third baffle of plate-like elements of similar construction to the first baffle disposed adjacent the second baffle and remote from the first baffle and the plate-like elements having about the same angular relationship relative to the axis of the conduit as the first baffle.

Further features and advantages of the present invention will become more apparent from the following specification taken in connection with the drawing wherein:

FIGS. **1**, **2** and **3** schematically depict three views of one embodiment of the invention.

FIGS. **4**, **5**, **6** and **7** depict end views of alternate embodiments of the invention.

In FIGS. **1** and **2** are depicted schematically cutaway views of a mixer generally in accordance with the invention designated by the reference numeral **10**. FIGS. **1** and **2** are side views of a mixer wherein the mixer is rotated 90° about the longitudinal axis relative to the other view. The mixer **10** comprises in cooperative combination a generally cylindrical hollow body **12**, the body **12** having a wall portion **13**, a first end **14**, a second end **15**. The body **12** defines an internal longitudinally extending passageway **17**. Generally adjacent the first end **14** of a conduit **20** a first slot **18** is defined in the wall **13**. The slot **18** is generally angularly disposed relative to a longitudinal axis A of the conduit **12** and angularly disposed to a plane normal to the axis A. The first baffle **19** is disposed within the slot **18** and affixed therein in generally sealing engagement. The baffle **19** defines a first or inwardly projecting edge portion **21** and an external edge portion **22** having a generally hemielliptical configuration. A second slot **25** is oppositely disposed from the slot **18** having a generally like angular configuration with respect to the axis A and a plane normal to the axis A when viewed in a generally radial direction and has disposed therein a second plate-like element **26** having an internal edge **27** of generally linear configuration and an external edge **28** of generally hemielliptic configuration. The plate-like elements **19** and **26** in cooperative combination form a first baffle generally designated by the reference numeral **30**. Adjacent the first baffle **30** a housing **12** defines a first slot **31** and a second slot **32**. The slots **31** and **32** are angularly disposed with relationship to each other to the axis A and to a plane normal to the axis A of the conduit **12**. Relative to the first and second slots **18** and **25**, the slots **31** and **32** are rotated at an angle about 90° about the axis A and are of opposite hand to the slots **18** and **25** and form a configuration of opposite hand to that formed by the slots **18** and **25**. A third plate-like element **33** of generally like configuration to the baffle **19** is disposed within the slot **31**. The baffle **33** has a generally linear edge **34** disposed within the passageway **17** and a generally hemielliptical edge **35** in generally sealing engagement with the wall **13** of the conduit **12**. A fourth plate-like element **37** is disposed within the slot **32** generally opposite the third plate-like element **33**. The third plate-like element **33** has an inwardly disposed linear edge **38** and a second generally hemielliptical edge **39** in generally sealing engagement with the wall **13** of the conduit **12** thereby providing a second or left-handed baffle assembly generally designated by the reference numeral **40**. Adjacent to the baffle assembly **40** and remote from the baffle assembly **30** is a baffle assembly **41** of similar structure and orientation to the baffle assembly **30**.

Thus, mixers in accordance with the present invention generally comprise alternating baffle assemblies of like configuration wherein one set of baffle assemblies are right-handed interdigitated with left-handed baffle assemblies whose generally linear edges are rotated about the axis of the conduit. Such angular deviation for many applications is 90° but may vary between 30° to 160°. It is essential and critical to the operation of the present invention that the plate-like elements making up the baffle assembly be disposed at an angular relationship to both the longitudinal axis and to a plane normal to the longitudinal axis. The angular deviation of the linear edge such as the linear edges **21**, **27**, **34** and **38** usually is between about 30° and 70°, and beneficially between about 35° and 55°, the deviation being measured by the angular displacement of the linear edge to the longitudinal axis of the conduit. For a tube of given diameter, the greater the angular deviation, the more baffle units per unit length may be formed and thus an increased number of mixing stages may be obtained. However, employing a lesser angle, higher flow velocities are utilized before turbulent flow occurs.

FIG. **3** depicts an end view of the baffle assembly **30** of FIG. **1** depicting the relationship between the plate-like elements **19** and **26**.

In FIG. **4** there is depicted an end view of an alternate embodiment of the invention generally designated by the reference numeral **45**. The embodiment **45** comprises a generally cylindrical conduit **12***a*, a plurality of baffle assemblies each consisting of a pair of opposed plate-like elements **46** and **47** oppositely disposed in alternating pairs such as the apparatus of FIG. **1** wherein each of the plate-like members terminate in an edge **48** and **49**, respectively, which define, when axially viewed, a generally circular opening **51** between the adjacent edges **48** and **49** of the plate-like elements **46** and **47**. Such an embodiment is particularly advantageous when rapid assembly is desired. For example, a solid rod or conduit may be disposed between adjacent plate-like elements to provide indexing therefor during fabrication. The rod or conduit may be subsequently removed, or when a conduit is employed it may be left in position as depicted by the conduit **52** of FIG. **4** and utilized for heat exchange purposes. Alternately, baffles may be assembled to a rod or conduit and subsequently inserted into a surrounding conduit such as the conduit **12a** where pressure drops are relatively low. Support of plate-like elements may be entirely from the central rod or conduit **52**. In instances where higher pressure drops are encountered, the baffles should be affixed to the external conduit such as the conduit **12***a*.

In FIG. **5** there is depicted an alternate embodiment of the invention generally designated by the reference numeral **55** comprising a generally cylindrical conduit **12***b* having a plurality of plate-like elements having a similar arrangement to that of FIG. **1** wherein the plate-like elements comprises a first or large element **56** and a second or smaller element **55**, the element **56** being a portion of an ellipse somewhat greater than a hemiellipse and terminating in a straight edge **58**, whereas an element **57** comprises the remaining portion of the ellipse from which the element **56** may have been cut and terminates in a straight edge **59**. The lines designated by the reference numeral **61** represent the positioning of the linear edges of the second and fourth baffles of a mixer having the repeating pattern shown in FIG. **1** and the plate-like element configuration of FIG. **5**, and the dotted line designated by the reference numeral **62** represents the edges of the plate-like elements forming third, fifth, seventh . . . and like baffles.

The embodiment of FIG. **5** is applied with particular benefit when such a mixer is employed with viscous materials which have a tendency to be unmixed in the central portion thereof.

An alternate embodiment of the invention is depicted in FIG. **6** generally designated by the reference numeral **65**. The mixer **65** comprises a hollow rectangular tube **67** having disposed therein a first generally plate-like element **68** angularly disposed therein generally in the manner of the element **19** of FIG. **1** and a second plate-like element **69** which generally corresponds to the element **26** of FIG. **1**. A third plate-like element **71** is disposed behind the element **68** in a configuration generally similar to that of the slot **31** of FIGS. **1** and **2**. A fourth element **72** corresponding to the element **32** of FIGS. **1** and **2** is disposed adjacent the element **71**. A gap **73** is defined by the first element pair **68** and **69**. A similar pair **74** is defined between the elements **71** and **72**. The gaps **73** and **74** are disposed generally at right angles to each other and generally bisect the opposing sides of the elements **68** and **69**. The embodiment **65** is particularly advantageous wherein maximum mixing of the stream is required adjacent the outer portions thereof and minimal mixing toward the center. A typical application of such a mixer is the application of a graded coating in a generally axial direction on a wire or conduit. Typically, feeding such a mixer is done by providing a coaxial stream of diverse materials wherein a component desired to be in contact on a body such as a conduit or wire is centrally disposed, the material which is desired to form the external surface is peripherally disposed, the wire conduit and stream passed through the mixer wherein the wire or conduit passes through the common portion of the gaps **73** and **74** and the coaxial streams intermixed in the region of their interface to a desired degree dependent on the number of baffle stages through which the stream passes.

In FIG. **7** there is schematically depicted an end view of an alternate embodiment of the mixer of the invention generally designated by the reference numeral **80**. The mixer **80** comprises a first or outer conduit **81** and a second or inner conduit **82**. The conduits **81** and **82** are generally coaxially arranged. The first baffle of the mixer **80** employs three plate-like elements **83**, **84** and **85**, each having a semi circular configuration. Each of the elements **83**, **84** and **85** lies in a plane of generally like angular disposition to the axis of conduits **81** and **82** generally in the manner of the elements of FIG. **1**. Elements **83**, **84** and **85** are circumferentially disposed within slots (not shown) in the conduit **82** to provide an angular circumferential spacing of about 120°. Additional trifoliate baffles of alternating hand (not shown) are provided generally arranged as the baffles of FIGS. **1** and **2** wherein the leading edge of each element is positioned generally midway (angularly when viewed along the conduit axis) between two trailing edges of elements of an immediately adjacent baffle. In preparing a mixer in accordance with FIG. **7**, the elements may be affixed in the wall of conduit **82** and the resultant structure inserted into conduit **83** and optionally affixed to conduit **83** by welding adhesives or the like. Alternately, the elements are inserted in slots in both conduit walls and affixed by suitable means such as brazing adhesives and and the like.

The embodiment of FIG. **7** is particularly well suited for heat exchange application wherein it is desired to obtain a uniform temperature in a viscous liquid. Beneficially, the viscous liquid is passed through conduit **82** and the heat exchange liquid passed between conduits **81** and **82** either concurrently or in a countercurrent direction.

In a similar manner mixers are readily prepared employing **4**, **5**, **6** and more elements per baffle.

The interfacial surface generators in accordance with the present invention are particularly advantageous in that they may be readily fabricated from almost any material which includes glass, metal, thermoplastics, thermosetting resins, glass fiber reinforced thermosetting resins and the like. Preparation of such mixers is readily accomplished with tube and sheet stock wherein the tube is slotted, the sheet-like elements secured in the slots by a suitable means such as adhesives, fusion welding, brazing, soldering or other joining means appropriate to the material employed. In forming a mixer from a round conduit, each of the plate-like elements of a pair may have a fractional elliptical configuration or they may be rectangular if desired and the portion of the elements extending beyond the conduits employed as a support for the finished mixer.

Mixers in accordance with the present invention are useful for the mixing of solids, liquids, gases and the like. When em-

ployed to blend streams of particulate solids, it is not necessary that a liquid-tight connection be made between the plate-like elements and the conduit, but only that any gaps appearing between the tube and the plate-like elements should be of a dimension sufficiently small to prevent escape of the materials being handled. The present invention is particularly desirable in that for mixing liquids under pressure, metallic pipe such as steel or stainless steel is readily slotted, the plate-like elements inserted and welded in to provide a structure at least of equal bursting strength to the original pipe.

As is apparent from the foregoing specification, the present invention is susceptible of being embodied with various alterations and modifications which may differ particularly from those that have been described in the preceding specification and description. For this reason, it is to be fully understood that all of the foregoing is intended to be merely illustrative and is not to be construed or interpreted as being restrictive or otherwise limiting of the present invention.

What is claimed is:

1. An interfacial surface generator comprising a hollow tubular conduit defining an internal longitudinal passageway, the conduit having a wall, a first pair of opposed plate-like elements disposed in angular relationship to the longitudinal axis of the conduit to form a first baffle, the plate-like elements having at least one inwardly disposed edge, the edges of the first and second plate-like elements being in closely adjacent relationship, the first baffle being of right-handed configuration, a second baffle adjacent to the first baffle, the second baffle being of like construction to the first baffle with the exception that the plate-like elements are disposed in left-handed configuration and the edges thereof being angularly disposed about the axis of the conduit relative to the edges of the plate-like element of the first baffle, a third baffle of plate-like elements of similar construction to the first baffle disposed adjacent the second baffle and remote from the first baffle and the plate-like elements having about the same angular relationship relative to the axis of the conduit as the first baffle.

2. The generator of claim 1 wherein the plate-like elements are affixed to the conduit.

3. The generator of claim 2 wherein the plate-like elements are secured within slots in the conduit wall.

4. The generator of claim 1 wherein the conduit has a generally circular cross-sectional configuration.

5. The generator of claim 4 wherein the plate-like elements have a generally hemielliptical configuration.

6. The generator of claim 1 including a generally axially extending rod-like element disposed between adjacent pairs of plate-like elements.

7. A method for preparing an interfacial surface generator, the steps of the method comprising

providing a hollow tubular conduit having a wall,

forming first and second slots in the wall of the conduit, the first and second slots being generally diametrically opposed, the first and second slots being disposed at an angle of substantially less than 90° at the longitudinal axis of the conduit, the first and second slots in an orthographic projection of an end view of the planes thereof being disposed in angular relationship to each other,

providing first and second plate-like elements,

disposing said first and second plate-like elements in the first and second slots, respectively,

affixing the plate-like elements in generally sealing engagement to the wall of the conduit to provide a first baffle arbitrarily designated as a right-handed baffle,

forming within the wall of the conduit adjacent the first baffle third and fourth slots, the third and fourth slots being disposed generally similarly to the first and second slots but rotated about the axis of the conduit and of opposite hand to the first and second slots,

disposing third and fourth plate-like elements within the third and fourth slots in the conduit wall,

forming fifth and sixth slots generally adjacent to the second and third slots and remote from the first and second slots, the fifth and sixth slots being oriented generally as the first and second slots, disposing fifth and sixth plate-like elements within the fifth and sixth slots and affixing them to the conduit wall to form a third baffle of generally right-handed configuration, the second baffle having a generally mirror image configuration to the first and third baffles.

8. An interfacial surface generator comprising a hollow tubular conduit defining an internal longitudinal passageway, the conduit having a wall, a first plurality of opposed plate-like elements disposed in angular relationship to the longitudinal axis of the conduit to form a first baffle, the plate-like elements having at least one inwardly disposed edge, the edges of the first plurality of elements being in closely adjacent relationship, the first baffle being of right-handed configuration, a second baffle adjacent to the first baffle, the second baffle being of like construction to the first baffle with the exception that the plate-like elements are disposed in left-handed configuration and the edges thereof being angularly disposed about the axis of the conduit relative to the edges of the plate-like element of the first baffle, a third baffle of plate-like elements of similar construction to the first baffle disposed adjacent the second baffle and remote from the first baffle and the plate-like elements having about the same angular relationship relative to the axis of the conduit as the first baffle.

9. A method for preparing an interfacial surface generator, the steps of the method comprising

providing a hollow tubular conduit having a wall,

forming a first plurality of slots in the wall of the conduit, the first plurality of slots being generally radially disposed, the first plurality of slots being disposed at an angle of substantially less than 90° at the longitudinal axis of the conduit, the first plurality of slots in an orthographic projection of an end view of the planes thereof being disposed in angular relationship to each other,

providing a first plurality of plate-like elements,

disposing said first plurality of plate-like elements each in a slot of the first plurality of slots,

affixing the plate-like elements in generally sealing engagement to the wall of the conduit to provide a first baffle arbitrarily designated as a right-handed baffle,

forming within the wall of the conduit adjacent the first baffle a second plurality of slots, the second plurality of slots being disposed generally similarly to the first plurality of slots but rotated about the axis of the conduit and of opposite hand to the first plurality of slots,

disposing a second plurality of plate-like elements within the second plurality of slots in the conduit wall,

affixing the second plurality of elements to the conduit wall forming a third plurality of slots generally adjacent to the second plurality of slots and remote from the first plurality of slots, the third plurality of slots being oriented generally as the first plurality of slots,

disposing a third plurality of plate-like elements within the third plurality of slots and affixing the third plurality of elements to the conduit wall to form a third baffle of generally right-handed configuration, the second baffle having a generally mirror image configuration to the first and third baffles.

* * * * *