Oct. 8, 1968 R. E. HARDER 3,404,869

INTERFACIAL SURFACE GENERATOR

Filed July 18, 1966

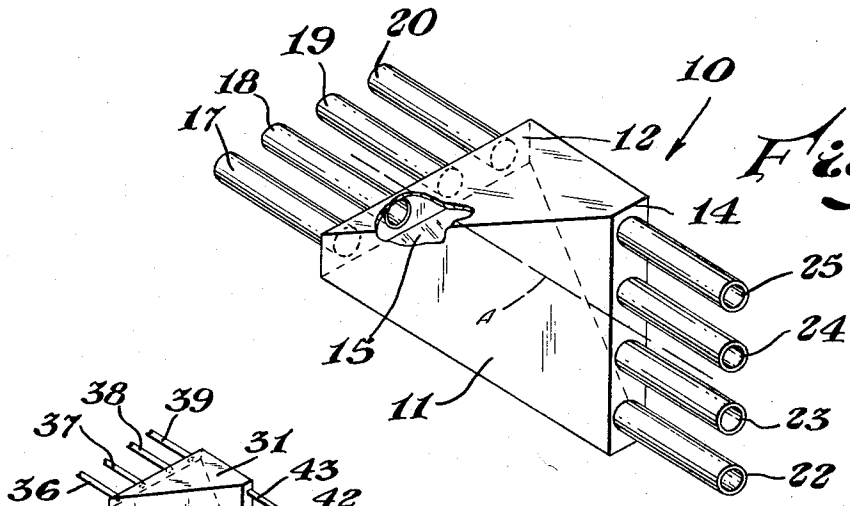

Fig. 1

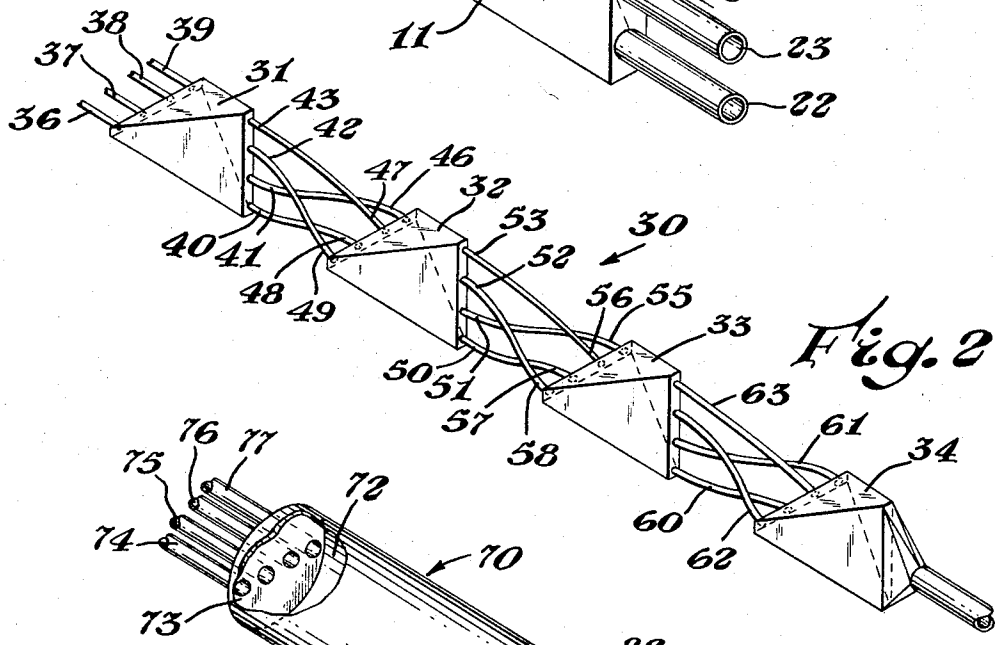

Fig. 2

Fig. 3

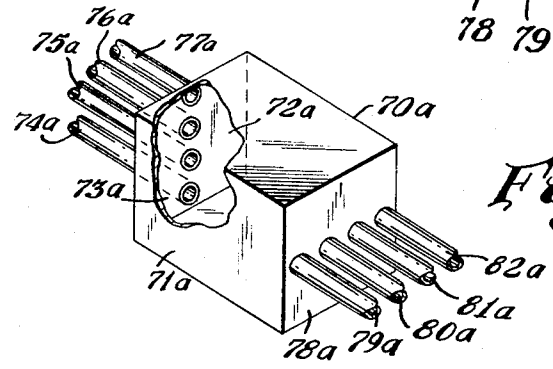

Fig. 4

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INTERFACIAL SURFACE GENERATOR

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5 Claims. (Cl. 259—4)

ABSTRACT OF THE DISCLOSURE

A static mixer is disclosed which consists of a number of chambers having two or more inlets and two or more outlets, the inlets and outlets being non-coplanar and the planes intersecting an axis of flow. A number of such elements are series-connected to provide a mixer which creates layers within a stream and the mixing or layering action is independent of throughput below the region of turbulent flow.

This invention relates to an interfacial surface generator, and more particularly relates to an interfacial surface generator which is easily constructed.

An interfacial surface generator is a static device which mixes fluids by passage of the fluid through the interfacial surface generator. Such mixing is obtained by division of the stream into a plurality of substream or branches, recombination of the substreams into a main stream and subsequent division, repositioning and recombination until the desired degree of mixing has been obtained. Several interfacial surface generators are known and set forth in U.S. Letters Patent 3,015,453, 3,182,965 and 3,195,865. Such devices employ baffles positioned within a conduit to provide the desired division, repositioning and recombination.

It would be desirable if there were available an interfacial surface generator which could be prepared from readily available materials and the degree of mixing of streams controlled by ready variation of the number of stages.

These benefits and other advantages in accordance with the present invention are achieved in an interfacial surface generator which comprises in cooperative combination a plurality of housings; each of the housings defining an internal cavity; each housing having an inlet end and an outlet end; the inlet end having at least first and second inlets; the outlet end having at least first and second outlets; the first and second outlets of a first housing being connected to the second and first inlets of a second housing; the first and second outlets of the second housing being connected to the second and first inlets of a third housing.

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

In FIGURE 1 there is schematically represented a housing for an interfacial surface generator in accordance with the present invention.

FIGURE 2 depicts one manner of connecting housings in accordance with the present invention.

FIGURES 3 and 4 are alternate embodiments of housings for the practice of the present invention.

In FIGURE 1 there is depicted a housing generally designated by the reference numeral **10**. The housing **10** comprises a hollow body **11**. The body **11** has a first or inlet end **12** and a second or outlet end **14**. The housing **10** has a generally tetrahedral configuration. The body **11** defines an internal space or chamber **15** having a direction of flow or longitudinal axis A. In operative communication with the inlet end **12** of the housing **10** are

first, second, third and fourth inlets or conduits **17**, **18**, **19** and **20**, respectively. The outlet end **14** of the housing **10** has a plurality of outlets or discharge conduits **22**, **23**, **24** and **25**, respectively. The inlet conduits **17**, **18**, **19** and **20** and the outlet conduits **22**, **23**, **24** and **25** are all in communication with the chamber **15**. Fluid entering the conduits **17**, **18**, **19** and **20** is discharged from the conduits **22**, **23**, **24** and **25**, the inlet conduits lying in a plane generally normal to a plane containing the outlet conduits. Fluid flowing into the inlet conduits is discharged from the outlet conduits in such a manner that each of the outlet conduits contains a portion of the material from each of the inlet conduits. This phenomenon occurs even at extremely low flow rates assuming generally similar viscosities and flow characteristics.

FIGURE 2 schematically depicts an interfacial surface generator in accordance with the present invention. The interfacial surface generator is generally designated by the reference numeral **30**. The generator **30** comprises a plurality of housings **31**, **32** and **33**. A discharge header is designated by the reference numeral **34**. The housing **31** has a plurality of inlet conduits **36**, **37**, **38** and **39** and discharge conduits **40**, **41**, **42** and **43**. The conduits **40**, **41**, **42** and **43** may be considered as first, third, fourth and second discharge conduits, respectively. A like housing **32** having fourth, first, second and third inlet conduits **46**, **47**, **48** and **49**, respectively is disposed generally adjacent the outlet conduits **40**, **41**, **42** and **43** of the housing **31**. By means of suitable conduits beneficially in many instances flexible conduits, the first discharge conduit of the housing **31** is in operative communication with the second inlet conduit of the housing **32**. The second discharge conduit of the housing **31** is in operative communication with the first inlet conduit **47** of the housing **32**. The third discharge conduit **41** of the housing **31** is in operative communication with the fourth inlet conduit of the housing **32** and the fourth outlet conduit of the housing **31** is in operative communication with the third inlet of the second housing **32**. The housing **32** has first, third, fourth, and second discharge conduits **50**, **51**, **52** and **53**, respectively. The third housing **33** is positioned generally adjacent the housing **32**. The housing **33** has fourth, first, second and third inlet conduits **55**, **56**, **57** and **58**, respectively. The outlet conduits **50**, **51**, **52** and **53** of the housing **32** communicate with the second inlet conduit **57**, fourth inlet conduit **55**, the third inlet conduit **58** and the first inlet conduit **56**, respectively, of the housing **33**. The housing **33** has first, second, third and fourth outlet conduits **60**, **61**, **62** and **63**, respectively, which enter a common header or discharge **34**.

The method of operation of the apparatus of the present invention is substantially that set forth in U.S. Letters Patent 3,051,453, 3,182,965 and 3,195,864. Fluid, on entering any one or more of the conduits **36**, **37**, **38** or **39**, is discharged from the conduits **40**, **41**, **42** and **43** of the housing **31**. If fluid is passed through all of the conduits, each of the discharge conduits will contain a portion of the fluid from each of the inlet conduits. The streams flowing from the discharge conduits are then repositioned relative to one another and flow into the housing **32**. The discharge conduits **50**, **51**, **52** and **53** each contain a portion of the stream from each of the inlet conduits. Similar division and recombination occurs in the transfer of the fluid from the housing **32** to the housing **33** through the outlets **50**, **51**, **52** and **53** and to the inlet conduits **55**, **56**, **57** and **58**. A similar repositioning occurs by terminating the outlet conduits **60**, **61**, **62** and **63** in a manner where initially adjacent portions of the stream are repositioned between other portions. Below the region of turbulent flow, mixing in the apparatus of

FIGURE 2 is substantially independent of flow rate. If the velocity of material flowing therethrough becomes turbulent an increase will be noticed in the degree of mixing and a marked rise in the power required to pump fluid through the apparatus.

FIGURE 3 depicts an alternate housing which may be employed in the apparatus of the present invention. The housing is generally designated by the reference numeral **70**. The housing **70** depicts a generally cylindrical hollow body **71** defining a cavity **72** therein. A first or terminal portion **73** closes one end of the body **72**. A plurality of inlet conduits **74**, **75**, **76** and **77** are disposed within the end **73**. A second end **78** is disposed opposite the end **73** and serves to close the remaining end of the hollow cylindrical body **71**. Discharge conduits **79**, **80**, **81** and **82** are disposed in the second end **78**.

FIGURE 4 depicts an alternate housing which may be employed in the apparatus of the present invention. The housing is generally designated by the reference numeral **70***a*. The housing **70***a* depicts a generally rectangular hollow body **71***a* defining a cavity **72***a* therein. A first or terminal portion **73***a* closes one end of the body **72***a*. A plurality of inlet conduits **74***a*, **75***a*, **76***a* and **77***a* are disposed within the end **73***a*. A second end **78***a* is disposed opposite the end **73***a* and serves to close the remaining end of the hollow rectangular body **71***a*. Discharge conduits **79***a*, **80***a*, **81***a* and **82***a* are disposed in the second end **78***a*.

Generally, the embodiment of FIGURES 1 and 2 employing a tetrahedral housing is preferred as the tetrahedral housing provides a minimal region in which material may "hang up," that is, the tetrahedral embodiment provides generally streamlined flow whereas the embodiments of FIGURES 3 and 4 result in relatively slow movement of the materials in corners adjacent the inlets or outlets. In systems which are non-reactive and inventory can be tolerated, the embodiments of FIGURES 3 and 4 are satisfactory and possess the distinct advantage of ease of fabrication. However, if uniform flow through the system is desired, a generally tetrahedral housing or at least a housing having a generally tetrahedral cavity such as the housing of FIGURE 1 is employed with benefit.

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, excepting as it is set forth and defined in the hereto-appended claims.

I claim:

1. An interfacial surface generator which comprises in cooperative combination a plurality of housings, each of the housings defining an internal cavity having a longitudinal axis, each housing having an inlet end and an outlet end, the inlet end having at least first and second inlets, the outlet end having at least first and second outlets, the axis of the inlets defining an inlet plane which contains the axis and the axes of the outlets defining an outlet plane which contains the axis, the inlet and outlet planes being disposed in angular relationship to each other, the first and second outlets of a first housing being connected to the second and first inlets of a second housing, the first and second outlets of the second housing being connected to the second and first inlets of a third housing.

2. The apparatus of claim **1** where the internal cavity within each housing has a generally tetrahedral configuration, the inlets being disposed along one edge of the tetrahedral configuration and the outlets disposed along an opposed edge of the configuration wherein the opposed edges are generally at right angles.

3. The apparatus of claim **1** wherein the inlet plane and outlet plane are generally normal to each other.

4. The apparatus of claim **3** wherein each housing has at least four inlets and four outlets, the inlets being arranged in a generally linear fashion, the outlets being arranged in a linear manner, and outlets disposed generally remote from the axis are connected to inlets of an adjacent housing disposed generally adjacent the axis thereof which discharge between two other inlets of the adjacent housing.

5. The apparatus of claim **1** wherein inlets and outlets of adjacent housings are interconnected by means of flexible tubes.

References Cited

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,404,869 Dated October 8, 1968

Inventor(s) Richard E. Harder

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

Column 1, line 32, the patent number "3,015,453" should read --3,051,453--.

Column 2, line 53, the patent number "3,195,864" should read --3,195,865--.

Signed and sealed this 17th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents