April 14, 1970 A. STRANG 3,506,244

MIXING APPARATUS

Filed June 26, 1968

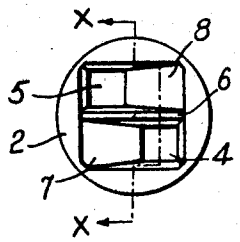

FIG.1

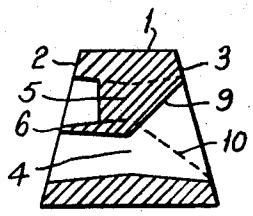

FIG.2

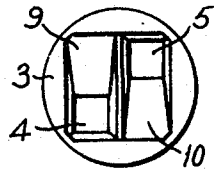

FIG.3

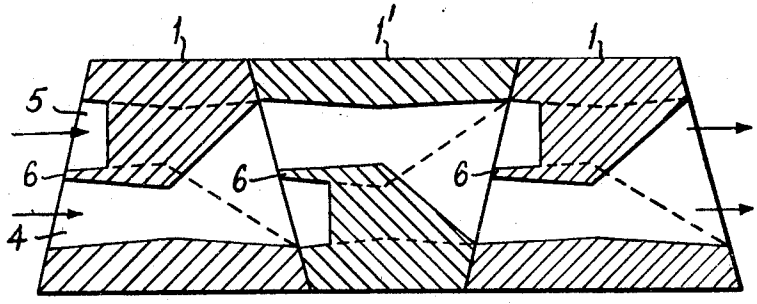

FIG.4

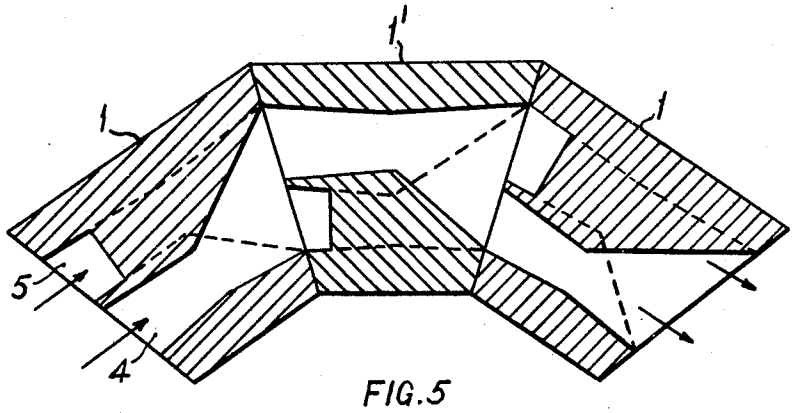

FIG.5

Inventor
ALASTAIR STRANG

By DAVIS, HOXIE,
FAITHFULL & HAPGOOD
Attorneys

United States Patent Office

3,506,244

Patented Apr. 14, 1970

3,506,244

MIXING APPARATUS

Alastair Strang, Kenilworth, England, assignor to Courtaulds Limited, London, England, a British company

Filed June 26, 1968, Ser. No. 740,216
Claims priority, application Great Britain, June 29, 1967, 30,075/67
Int. Cl. B01f 5/00
U.S. Cl. 259—4 7 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for mixing liquids which comprises a plurality of elements arranged end to end, each of which elements has an equal even number of channels passing therethrough, the flow path of the liquid through each of which channels in one element being such that the liquid flow is divided between each of the channels in the next following element, whereby the liquid in the separate channels is mixed, and in each of which elements the faces which cooperate with those of the next preceding and next following elements are oblique to the general direction of liquid flow. Preferably the elements have 2^n channels where n is an integer greater than or equal to unity.

This invention relates to mixing apparatus and in particular to the type of apparatus in which streams of fluid are divided into sub-streams and remixed, the operation being repeated until the desired degree of mixing is achieved.

It has been previously been proposed to provide apparatus in which a plurality of mixing elements are arranged end to end and cooperate with one another to provide channels through the elements which are arranged to cause mixing of liquids passing through the channels. Such apparatus may for example have two channels in each element, each of which receives a portion of the flow from each channel of the next preceding element and each of which channels discharges into the next following element, dividing the flow of liquid therethrough between the two channels of that next following element. Such apparatus provides good flow mixing if a sufficiently large number of elements are employed but, since the flow in one channel is, in effect, parallel to that in a second channel, no substantial shear forces are brought to bear. It is an object of this invention to provide an improved form of mixing apparatus which supplies shear mixing as well as flow mixing.

According to the invention apparatus for mixing liquids comprises a plurality of elements arranged end to end, each of which elements has an equal even number of channels passing therealong, the flow path of the liquid through each of which channels in one element being such that the liquid flow is divided between each of the channels in the next following element, whereby the liquid in the separate channels is mixed, and each of which elements the faces which cooperate with those of the next preceding element and the next following element are oblique to the general direction of liquid flow.

Preferably each element has 2^n channels where n is an integer greater than or equal to unity.

In each mixing element each channel receives a proportion of the flow from each channel of the next preceding element and preferably the combined flow passes through a restricted throat, following which the channels open up again to divide the liquid flow between each of the channels in the the next following element. Continued repetition of these operations repeatedly splits the liquid flow and recombines it in other distributions, thus providing efficient flow mixing.

The upstream and downstream faces of each element, which cooperate with the downstream face of the next preceding element and the upstream face of the next following element, respectively, are oblique to the general direction of liquid flow. The inclination of the faces to the flow direction is not very critical although a sharp angle will provide better results than will a more obtuse angle. Conveniently the section through the elements in the plane through the longest and shortest lengths of the side wall may be in the form of a trapezium with equal angles at the ends of its parallel sides. In this form a number of elements may if desired be assembled together in a straight line. In other cases where a straight line formation is not required, equal and opposite inclinations of the two faces of the elements are not necessary, though they will in most cases be convenient.

The construction of the present invention provides shear mixing in addition to flow mixing since the paths through which the separate liquid flows travel through the individual elements are unequal, due to the shape of the elements. Accordingly two notional points in two channels which have reached the same position in the direction of flow in one element do not reach the next element at the same time and travel through the elements in different times. Accordingly when they are reaching the point of recombination of the streams they do so with one lagging behind the other and this contributes to more efficient mixing. In some cases such notional points may catch up with one another at a later stage but the effect of the shear mixing combined with that of the flow mixing is sufficient to mix the two streams more thoroughly per element than has been achieved in the previously known mixers. In some assemblies a particularly advantageous arrangement may be one in which the elements are not arranged in a straight line but follow a curved path dictated by their shape. With such an arrangement the effect of shear mixing can be greater than with the straight arrangement.

The elements may be made of any suitable material which is not attacked by the liquids being mixed. Thus in certain applications the elements may be constructed from metals such as iron, steel, brass or other suitable metal for the particular application. Alternatively they may be made from plastics materials such as rubber compositions, polyamides, polyacetals, polyphenylene oxides, polyvinyl chloride and polyolefins.

The invention will be further described, by way of example, with reference to the accompanying drawing, in which

FIGURE 1 is a projection in the vertical plane of one end view of an element of mixing apparatus according to the invention, which element has two flow channels.

FIGURE 2 is a section along the line X—X in FIGURE 1,

FIGURE 3 is a projection in the vertical plane of the other end of the element,

FIGURE 4 is a section of similar character to the section in FIGURE 2 showing three elements arranged in a straight line, and

FIGURE 5 is a section of similar character to that of FIGURE 2 showing three elements arranged to follow a curved path.

Referring to the drawing, a mixer element **1** has oblique faces **2** and **3** of equal and opposite inclinations to the flow of liquid through the channels **4** and **5** through the elements. The channels are divided at one end by a septum **6** (FIGURES 1 and 2) and at the other end by a septum **11** (FIGURE 3) which is at right angles to the septum **6**. The channels **4** and **5** open out at one end by means of funnel-shaped sections **7** and **8** so that their openings at this end each occupy the whole of the area on one side

of the septum **6**. Similarly the channels **4** and **5** open out at the other end by means of funnel-shaped sections **9** and **10** so that they each occupy the whole of the area on one side of the septum **11**. If the direction of flow is assumed to be from left to right in FIGURE 2, in which the channel **5** is shown dotted for most of its length, the next following element will be so arranged that the projection drawing, corresponding to FIGURE 1, of the next following element will be related to the projection drawing of FIGURE 1 as object and mirror image and this will therefore equally be true of the relationship between the projection drawing of the upstream end of the next following element and the drawing of FIGURE 3. The next element in the series will be similar to that shown in the present figures and so alternately for as many elements as it is desired to use.

Referring to FIGURE 4, three elements are shown, the first and third of which are identical with that shown in FIGURES 1, 2 and 3 and the second of which, designated **1'**, is an alternative type in which the projectional representations of the respective ends are related to those of the elements designated **1** as object and mirror image. Similar relationships exist between the elements shown in FIGURE 5 although the actual shape of the elements designated **1** requires to be different from that used in the arrangement of FIGURE 4. The flow paths and the projectional representations of the ends of the elements **1** are similar to those shown in FIGURES 1 to 3.

In operation liquid flows into channels **4** and **5** in the first element and on emergence from that element each flow is split into two passing over the septum **6** in the second element. In the second element part of the flow from the first channel and part of the flow from the second channel are combined together and flows down one channel of the second element while the remainder of each flow passes down the other channel of the second element. This operation is repeated for each element with the result that, for a given number of elements x, the number of different streams formed is 2^x. According to the position in the channels, the flow in one channel continually lags or leads the flow in the other channel by virtue of the shaping of the element, thus contributing shear mixing to the flow mixing previously referred to.

While the invention has been described and illustrated in the drawing with reference to two channel elements it will be apparent that any even number of channels may be similarly arranged. In such a case each channel

in one element will divide its output between each of the channels in the next following element. Such multiple channel mixing elements have the advantage that they produce the same degree of mixing with a smaller number of elements. Thus a mixer consisting of x elements, with eight channels will divide the flow into 8^x streams, or 2^{3x} streams, so that a similar mixing effect is obtained as is provided by three times the number of two channel elements.

I claim:

1. Apparatus for mixing liquids which comprises a plurality of elements arranged end to end, each of which elements has an equal even number of channels passing therethrough, the flow path of the liquid through each of which channels in one element being such that the liquid flow is divided between each of the channels in the next following element, whereby the liquid in the separate channels is mixed, and in each of which elements the faces which cooperate with those of the next preceding element and the next following element are oblique to the general direction of liquid flow.

2. Apparatus as claimed in claim **1** in which each of the elements has 2^n channels where n is an integer greater than or equal to unity.

3. Apparatus as claimed in claim **1** in which the inclination of opposite faces of each element to the general direction of liquid flow are equal.

4. Apparatus as claimed in claim **3** in which the elements are assembled in a straight line.

5. Apparatus as claimed in claim **1** in which the elements are arranged to follow a curved path.

6. Apparatus as claimed in claim **1** in which the elements are made of a metal.

7. Apparatus as claimed in claim **1** in which the elements are made from plastics materials including natural and synthetic rubber, polyamides, polyacetals, polyphenylene oxides, polyvinyl chloride and polyolefins.

References Cited

UNITED STATES PATENTS

3,206,170	9/1965	Schippers et al.	259—4
3,239,197	3/1966	Tollar	259—4

ROBERT G. NILSON, Primary Examiner

U.S. Cl. X.R.

137—604