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2,933,293

METHOD OF INTERMIXING A PLURALITY OF LIQUIDS OF DIFFERENT SPECIFIC GRAVITIES

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The present invention relates to liquid mixing apparatus, and while useful for other purposes is especially valuable for thoroughly mixing blood or other body fluids with a processing liquid in apparatus utilized for analyzing body fluids in respect to critical constituents thereof for diagnostic purposes.

The present invention has been developed for use in the body fluid analyzer apparatus disclosed in the patent of Leonard T. Skeggs, No. 2,797,149, filed January 8, 1953, issued June 25, 1957, and assigned to the owner of present invention and application. Accordingly, the mixing device disclosed herein is illustrated in connection with such apparatus as an element thereof.

Briefly described, in the above mentioned body fluid analyzing apparatus, blood or other body fluid together with one or more primary processing fluids is caused to pass to one side of a dialyzer, and one or more secondary processing fluids are caused to pass to the other side of the dialyzer, resulting in the separation from the body fluid of the crystalloid constituents thereof, the protein or other non-crystalloid constituents being exhausted from the first mentioned side of the dialyzer. The process is a continuous flow process for each sample of fluid, and a series of samples are automatically transmitted seriatim through the apparatus, as more fully described in the above identified Skeggs application and in the application of Leonard T. Skeggs, Serial No. 547,087, filed November 16, 1955, also assigned to the owner of the present application.

The primary object of the present invention is to provide a mixing device which is well adapted to effect a thorough mixing of the body fluid and the primary processing fluid or fluids during the flow of said fluids to the dialyzer.

Another object is to provide a mixing device which requires no moving parts and which is effective automatically, merely as a result of the fluid flow therethrough and without stirrers or other agitation means, to accomplish the thorough mixing of the fluids passing there-through.

The above and other objects, features and advantages of this invention will be fully understood from the following description considered in connection with the accompanying illustrative drawings, the presently preferred embodiment of the invention being thereby described and illustrated.

In the drawings:

Fig. 1 is a more or less schematic view of body fluid analyzing apparatus provided with the liquid mixing device of the present invention;

Fig. 2 is a sectional view, on an enlarged scale, of part of the mixing device;

Fig. 3 is a sectional view of part of one of the convolutions of the mixing device, illustrating a partial mixing or blending of the liquids; and

Fig. 4 is a sectional view on the line 4—4 of Fig. 1 illustrating the complete intermixture or blending of the fluids by the mixing device before leaving the latter.

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Referring now to the drawings in detail and first to Fig. 1, the mixing device 10 embodying the present invention comprises a helical coil of tubing formed of glass or other suitable material inert to the liquids and fluids passing therethrough and preferably transparent or translucent, at least in part, so that the fluid flow therethrough can be observed. A proportioning pump 12 of any suitable type is provided for pumping the blood or other body fluid samples and the processing liquid or liquids and also preferably air, in accordance with the Skeggs processes as described in his above mentioned applications, to the inlet end portion 14 of coil 10 or to a tube connected thereto. The inlet for the body fluid sample and for said other fluids are indicated by the legends in Fig. 1. The outlet 16 of the coil 10 is disposed in a fluid flow circuit leading to the dialyzer 18 either through a heater 20 when the use of the latter is necessary in accordance with the particular process employed or directly by means of the tube 22. Valves 24 and 26 are provided in the fluid line for controlling the flow to the dialyzer either directly thereto from the outlet of the mixing coil or indirectly through the heater 20 in a manner which is obvious and which is also described in the above mentioned Skeggs applications.

The other fluids employed in the process are pumped simultaneously with the above mentioned fluids and in quantities proportionate to the latter to the dialyzer by means of the tube 28, in the case of certain of the fluids, as indicated by the legends, and to a color development chamber 30 by means of the tube 32 in the case of the liquid designated "reagent" which is effective to produce a color change in the liquid which flows to chamber 30 through tube 34 connected to the side of the dialyzer which contains the separated crystalloid constituent of the body fluid. In certain processes heat is utilized instead of a reagent for developing the color characteristic in the crystalloid containing liquid. Accordingly, the apparatus illustrated in Fig. 1 is provided with a heater 36 the inlet of which is controlled by a valve 38 which is operated to place the outlet tube 42 of the dialyzer in communication alternatively either with tube 34 which leads to mixing chamber 30 or to heater 36. A cooling coil 40 is shown interposed in the conduit 42 leading from the heater 36 to the supply tube 44 which conducts the fluids through the colorimeter 46 which controls the operation of a recorder 48, as described in the Skeggs applications.

The manner in which coil 10 acts to thoroughly mix the liquids automatically as they flow therethrough is believed to be obvious from the description and the illustrations afforded of Figs. 2, 3 and 4 of the drawings. Thus, referring to Fig. 2, it will be observed that the blood indicated at B in Fig. 2 of the sample to be analyzed joins with the processing liquid indicated at P, and since the blood has a higher specific gravity than the processing liquid the two liquids tend to stratify in the conducting tube 14. The air which enters said tube divides the stream of blood and processing liquid into a plurality of air-spaced segments indicated at S1, S2, S3, and so on, as the stream continues to flow to and through the several convolutions mixing coil. As the stream of liquid segments flows through the several convolutions of the coil, the blood and the processing liquid intermingle, a partial intermingling or mixing being indicated in Fig. 3 and a complete intermingling and thorough mixing of the blood and processing liquid being illustrated by Fig. 4. It will be observed that as the fluids pass through the coil they move in a path which is such that they tend to mix with each other and, moreover, when as in the case of blood which is heavier than the processing fluid and is supplied so that it flows initially along the outer marginal circular portion of the convolutions, the heavier fluid moves by

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gravity toward and into the lighter fluid which flows along with said heavier fluid in coil 10.

It may be noted that this intermingling and thorough mixing of the blood and processing liquid does not depend upon the admission of the air into the stream, the latter being illustrated because of the preference for its use in the process as described in the Skeggs applications.

Thus it is seen that the mixing device 10 described above is well adapted to accomplish the purpose of the present invention. It will be understood, however, that the invention may be specifically embodied otherwise herein as illustrated and described and may be used with apparatus of various constructions and for various purposes, wherein the mixing of liquids is required or desirable. Accordingly, I do not wish to be limited to invention as herein specifically illustrated or described except as may be required by the scope of the appended claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent, is:

1. The method of intermixing a plurality of liquids of different specific gravities, respectively, comprising forming a flowing stream containing said plurality of liquids, causing said stream to flow alternately and successively upwardly and downwardly in a continuous path from a lower part of said path to an upper part thereof and from said upper part thereof to a lower part thereof and in such direction that portions of the liquids flow first below other portions of the liquids, while flowing in the lower parts of said path, and above said other portions of the liquids, while flowing in the upper parts of said path, whereby said portions of the liquids are repeatedly mixed during the flow thereof, and introducing an inert gas into said stream and thereby subdividing said stream into successive segments of liquids separated by intervening segments of gas so that the mixing of the liquids during the flow thereof takes place in each liquid segment.

2. The method of intermixing a plurality of liquids of different specific gravities, respectively, comprising forming a flowing stream containing said plurality of liquids wherein said liquids of different specific gravities are in different vertical positions in said flowing stream, causing said stream to flow alternately and successively upwardly and downwardly in a continuous curved path from a position in the lower part of said path to a position in the upper part thereof and from said upper part thereof to a position in a lower part thereof and in such direction to cause portions of the liquids to change their vertical position and move into other portions of the liquids, while flowing in the lower part of said path and to again change

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their vertical positions and move into said other portions of the liquids while flowing in the upper parts of said path, whereby said liquids are repeatedly mixed during the flow thereof, and introducing air into said stream and thereby subdividing said stream into successive segments of liquids separated by intervening segments of air so that the mixing of the liquids during the flow thereof takes place in each liquid segment.

3. The method of intermixing a plurality of liquids of different specific gravities, respectively, comprising forming a flowing stream containing said plurality of liquids in a stratified condition wherein said liquids of higher specific gravities are in the lower layers of said flowing stream and said liquids of lower specific gravities are in the upper layers of said flowing stream, causing said stream to flow alternately and successively upwardly and downwardly in a continuous vertical helical path from a position in the lower part of said path to a position in the upper part thereof and from said upper part thereof to a position in the lower part thereof and in such direction to cause portions of said liquids of higher specific gravities in the lower layers of said stream, when in said lower part of said path, to move into portions of said liquids of lower specific gravities in the lower layers of said stream when said stream is in the upper part of said path and to move into portions of said liquids of lower specific gravities in the lower layers of said stream when said stream flows from said upper part of said path to said lower part thereof, whereby said liquids are repeatedly mixed during the flow thereof, and introducing air into said stream and thereby subdividing said stream into successive segments of liquids separated by intervening segments of air so that the mixing of the liquids during the flow thereof takes place in each liquid segment.

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