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Saunders

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[54] **METHOD AND APPARATUS FOR MIXING LIQUIDS**

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[52] **U.S. Cl.** **137/1,** 137/604, 259/4, 259/DIG. 41, 259/DIG. 46

[51] **Int. Cl.** **F16k 19/00**

[58] **Field of Search** ..... 137/1, 604; 259/4, 259/DIG. 46, DIG. 41, 18

[56] **References Cited**

UNITED STATES PATENTS

2,508,950	5/1950	Kaplan	259/DIG. 46
1,992,938	3/1935	Chambers et al.	259/DIG. 41
2,999,673	9/1961	Kessler	259/DIG. 46
3,128,994	4/1964	Hungate	259/4

Primary Examiner—Robert G. Nilson
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[57] **ABSTRACT**

A method and apparatus for intermixing a first liquid and a second liquid for use in automated apparatus of the continuous-flow type for the quantitative wet-chemical analysis of a treated substance. The apparatus includes a body defining a walled, elongated passageway portion, one end of which provides an inlet for a first liquid and the other end of which provides an outlet for the effluent liquid. A vibratory reed in the form of a tube is provided which carries the second liquid and has a distal discharge end portion directed into the passageway portion and spaced from the wall structure thereof. A device, external to the aforementioned wall structure, is provided which acts through this wall structure to effect a vibratory movement of the discharge end portion of the tube reed to effect mixing of the first and second liquids at their confluence within the passageway portion.

10 Claims, 2 Drawing Figures

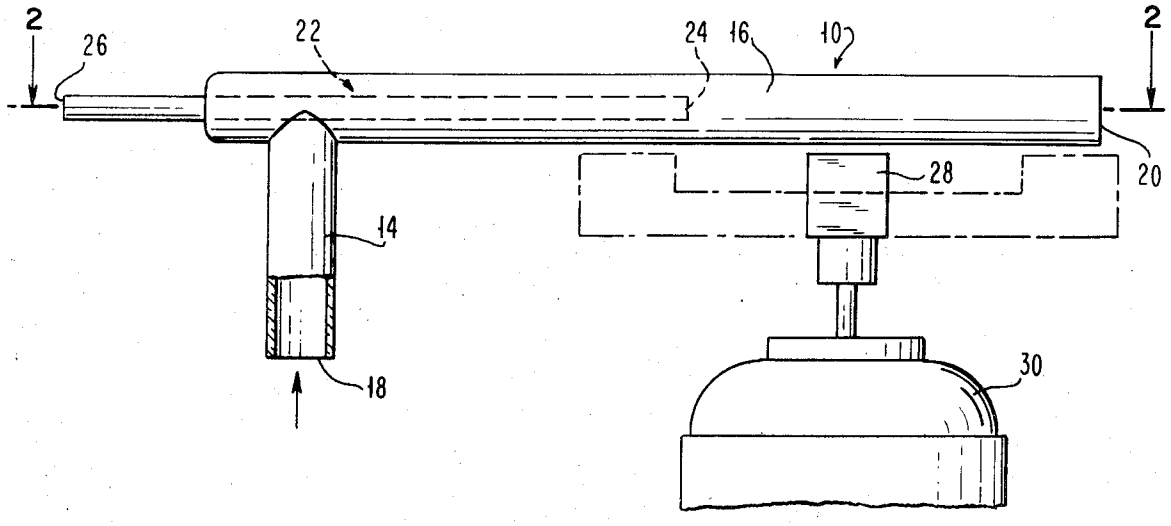
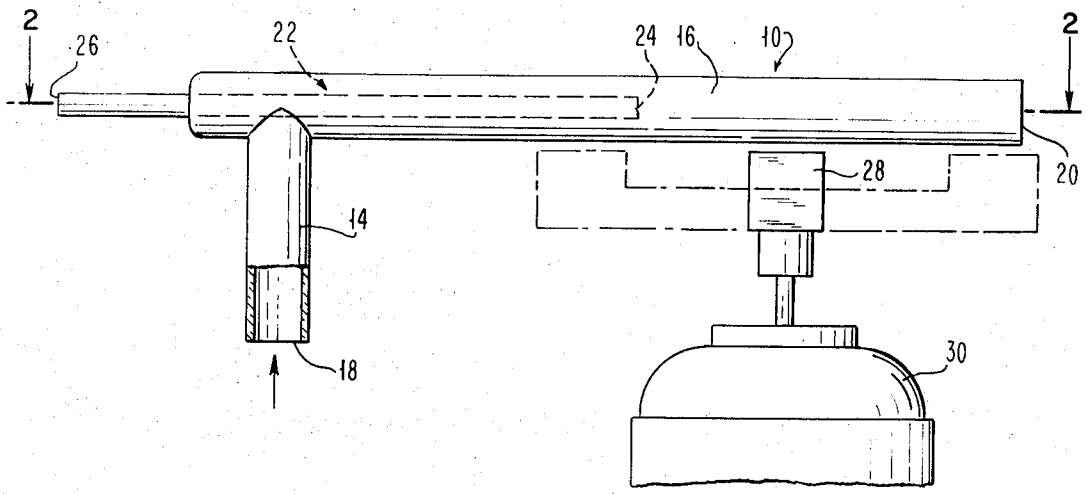


FIG. 1



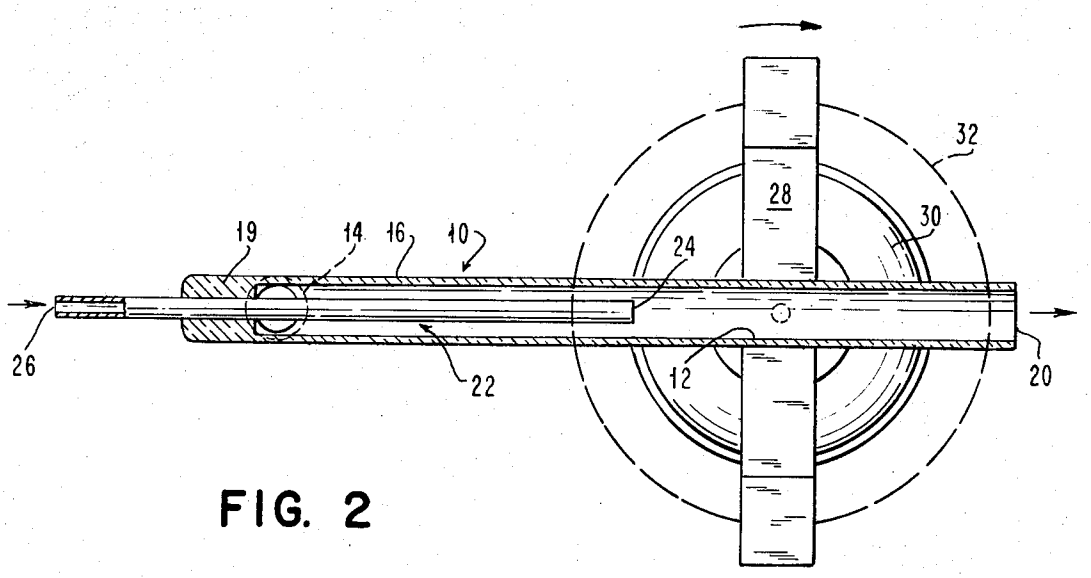


FIG. 2

METHOD AND APPARATUS FOR MIXING LIQUIDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for intermixing a first liquid with a second liquid, for use in automated apparatus for the quantitative wet-chemical analysis of a treated substance.

2. Prior Art

In analysis systems of this kind, a flowing stream of sampe liquid, which stream may be a continuous monitoring stream or a stream of sequential liquid samples, may be continuously mixed in predetermined proportions with one or more reagents, and otherwise processed to provide a color reaction, for example, the optical density of which at a particular wavelength is responsive to the concentration of a constituent of interest in the original sample. Such a system is disclosed in Skeggs U.S. Pat. No. 2,797,149 issued June 25, 1957. Skeggs et al. U.S. Pat. No. 3241,432 issued Mar. 22, 1966 shows and describes apparatus for performing multiple different tests on each of a series of samples.

Customarily, the flowing stream may comprise sample plus reagent and, perhaps, diluent. In today's systems, it is often necessary to intermix other liquids such as two or more reagents or a diluent and a reagent, for example.

Prior to being intermixed, the streams of sample and reagent, for example, are supplied in predetermined portions to a junction, as by a peristaltic proportioning pump such as shown and described in Bilichniansky et al U.S. Pat. No. 3,425,357 issued Feb. 4, 1969. The stream of sample may be supplied from a sampler including a turntable supporting a series of liquid samples in cups as shown and described in Skeggs U.S. Pat. No. 2,879,141 issued Mar. 24, 1959.

Today, in many hospitals, for example, there is a need for automated quantitative analysis apparatus which will accurately and speedily perform a large number of different tests on each one of a large number of different samples, as in the analysis of human blood samples. It is desired that up to 12 different tests or more be made on such apparatus on each of 60 or more different samples within a period of an hour. Such desirable systems must inherently employ miniscule amounts of each sample for each test and a corresponding volume of reagent. The speed of mixing liquids together is critical to the fast performance of any such apparatus which carries out the test and then records the results.

It is often desired to intermix two liquids in a stream prior to the introduction of a third liquid downstream and upstream from a mixer such as a mixing coil. It may also be desirable to maintain the points of influence of the last-mentioned liquids at a short distance apart in a stream for fast execution of a test by such apparatus. It is desirable that the first two liquids, which may react with one another, mix and commence any reaction therebetween as soon as possible after the confluence of the streams of the first and second liquids, and for this to occur it is necessary that the two streams be intermixed substantially thoroughly at the point of confluence.

As pointed out in Kessler U.S. Pat. No. 2,999,673 issued Sept. 12, 1961, in the treatment of various liquids for analysis or other purposes it is necessary when adding one liquid to another to stir or mix them immediately in order to prevent precipitation of a substance therein, or for some other reason. For example, in cholestrol determinations according to which blood serum is diluted with glacial acetic acid, and a color reagent, such as ferric chloride in concentrated sulphuric acid, is added to the diluted serum for treating the serum for colorimetric analysis, precipitation of protein from the serum occurs unless the liquids are intermixed thoroughly at the time of adding the color reagent to the serum. In performing cholestrol determinations, it is important to keep the protein in solution because cholestrol is complexed with the protein and if protein is lost, for example by adhering to the tube walls, some of the cholestrol is lost along with the lost protein. Moreover, if some of the protein of one sample is precipitated and adheres to the tube wall or other parts of the apparatus, contamination of a following sample would occur.

In the last-mentioned patent, there is illustrated and described for the instantaneous mixing at the confluence of plural liquids, an enlargement in a liquid-flow conduit which enlargement is in the form of an envelope structured of nonmagnetic material, which forms a mixing chamber having plural liquid inlets and an outlet for the effluent liquid. A bar magnet is freely supported for random movement within the envelope, which bar is agitated to provide a mixing action in the chamber. Agitation of the bar is effected through variable magnetic forces acting between it and a device external to the chamber and acting through the wall structure of the envelope.

One drawback to the last-mentioned mixer construction for use in fast-performance automated analysis apparatus is that it requires the aforementioned enlargement or envelope in a fluid conduit. This envelope, by reason of its substantial volume, creates a problem with regard to effective wash of the envelope between successive ones of liquid samples flowing in a stream through the device and separated from one another by segments of wash fluid. The wash is required to prevent contamination between samples. Such an envelope requires a large volume of wash fluid which slows the rate of analysis of multiple samples. Still further, it is obvious that the bar magnet with the envelope is permitted by the latter considerable freedom of movement, and hence is not precisely positioned with reference to either the fluid flow through the device or the agitating magnetic field of the rotary magnet.

SUMMARY OF THE INVENTION

One object of the invention is to provide an improved method and apparatus for intermixing plural liquids, for use in automated apparatus for the quantitative wet-chemical analysis of a treated substance. In accordance with the invention, there is provided a body defining a walled, elongated passageway portion, one end of which provides an inlet for a first liquid and the other end of which provides an outlet for the effluent liquid. A vibratory reed in the form of a tube is provided which carries the second liquid and has a distal discharge end portion directed into the passageway portion and spaced from the wall structure thereof. A device, external to the aforementioned wall structure, is provided which acts through this wall structure to effect a vibratory movement of the discharge end portion of the tube to effect mixing of the first and second liquids at their confluence within the passageway portion. Further ob-

jects of the invention will be apparent from the following detailed description of preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is a fragmentary, somewhat diagrammatic, view in elevation illustrating apparatus for mixing plural liquids and embodying the invention, and;

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the drawing, there is illustrated a body, indicated generally at **10**, defining a walled, elongated passageway portion **12** which extends through arms **14** and **16** which may be integrally formed with one another. The passageway portion **12** has a liquid inlet **18** at one end thereof and an outlet **20** at the other end of the passageway portion for effluent liquid. The body **10** is structured of nonmagnetic material and may be conveniently formed of a corrosion-resistant glass. The body **10** may also be conveniently structured of tubing as shown. While not limited thereto, the tubing may have a cylindrical cross section and the internal diameter of the part of the passageway portion **12** within arm **16** may be approximately 0.079 inch. While the internal diameter of the part of the passageway portion **12** lying within the arm **14** is shown as being approximately the same as the internal diameter of the first-mentioned part of the passageway portion **12**, in practice it may be somewhat smaller.

In the illustrated form, the tubing material of which the arm **16** is structured extends to the left as viewed in FIG. **2** beyond the junction of the arm **14**. This extension to the tubing material beyond the arm **14** is closed around a tube, generally indicated at **22**, intermediate of the ends of the latter as by being fused or otherwise secured in a closing manner, as at **19**, around the tube **22** for a liquid-tight connection and tube support. It is to be noted that this closed portion of the arm **16** is substantially flush with the liquid inlet provided by the arm **14** as shown in the last-mentioned view. This effectively tends to ensure that a liquid pocket or trap is not formed at the junction of the arms **14** and **16** which provide the passageway portion **12**.

The tube **22**, which constitutes a vibratory reed for excitation by a device externally of the body **10**, may be structured of any suitable material. It is located centrally and with clearance with the part of the passageway portion **12** formed in the arm **16**. The tube reed is illustrated as agitated by a time-variable magnetic field and, to this end, the tube reed **22** may be structured, at least in part, of any suitable ferromagnetic material.

The tube **22** conveys a second liquid into the passageway portion **12** to be mixed therein with the first fluid by the vibratory movement of the tube reed. While not limited thereto, the tube, which is shown as straight from end to end, may have an outer diameter of 0.020 inch and an inner diameter of approximately 0.010 inch. The portion of the tube reed **22** which extends freely in cantilever fashion into the passageway portion **12** may be approximately 2.0 inches in length by way of example. As shown, the tube **22** has a discharge end **24** extending to the right as viewed in FIG. **2** beyond the part of the passageway portion **12** provided in the arm **14**. The inlet end **26** of the tube **22** extends to the left as viewed in FIG. **2** beyond the left extremity of the body **10** to facilitate connection of the tube **22** with a liquid supply tube not shown. If desired, the exterior portion of the tube **22** within the passageway **12** may be coated with a suitable material to resist corrosion.

Any suitable device may be provided externally of the body **10** to provide a magnetic field with which to vibrate the tube reed **22**. Such a device is illustrated as a magnet which may take the form of a bar magnet **28** which is rotated by a motor **30** on an axis midway between the magnet ends or poles. The rotation of the magnet **28** is indicated by the phantom angular position thereof in FIG. **1** and by the dashed line **32** in FIG. **2**. The magnet **28** produces a magnetic field gradient. The tube reed **22** extends into the magnetic field and vibrates in resonance with the revolutions of the magnet **28**.

In operation, a first liquid may be conveyed to the passageway inlet **18** by a proportioning pump utilizing a liquid supply tube, not shown, connected to the last-mentioned inlet. Such a pump is illustrated and described in Bilichniansky et al U.S. Pat. No. 3,425,357 issued Feb. 4, 1969. A second liquid may be delivered to the inlet **26** of the tube reed **22** in similar fashion. Either of the last-mentioned two liquids may have its origin in a stream to be monitored or, alternatively, in a series of liquid samples arranged in individual cups on the turntable of a sampler such as shown and described in Skeggs U.S. Pat. No. 2,879,141 issued Mar. 24, 1959. Further, also alternatively, either of the two liquids or both may comprise reagents to be mixed together. It is to be made clear that either of the last-mentioned two liquids may be, in fact, combinations of liquids. It will also be appreciated from the foregoing that, if desired, a third liquid may be conveyed for mixing into the passageway portion **12** by an additional inlet, not shown, formed in the body **10** short of the position of the discharge end **24** of the tube reed **22**. While the inlet arm **14** is shown rising vertically with reference to the arm **16**, this is not necessary as the arm **14** may be disposed above or to one side of the arm **16**, for example, if desired.

As shown, the discharge end **24** of the tube reed **22** terminates a distance short of the effluent liquid outlet **20** of the passageway portion **12**. As the tube reed **22** is vibrated, mixing takes place in the passageway portion **12** between the tube end **24** and the outlet **20**, and the greater part of the mixing action of the tube reed **22** is adjacent the outlet end **24** of the tube reed. The reed **22** creates a turbulence in the liquid which enters the passageway portion **12** through the inlet **18**. Concomitantly, the reed discharges into this liquid, in an area of turbulence while oscillating across a cross-sectional area of the passageway **12** during its vibratory movements, the liquid received through the inlet **26** and discharged through the outlet **24** of the reed. This provides an effective mixing action. If desired, the effluent liquid stream, mixed as aforesaid, may be segmented downstream by an inlet, now shown, for an immiscible fluid such as air, for example, so that the effluent liquid stream is divided into segments separated by gas bubbles. The apparatus has good wash characteristics.

The last-mentioned liquid stream may be further treated. If it does not contain a sample to be analyzed in a continuously flowing condition in a flow cell by

photometry, as in the apparatus of Skeggs U.S. Pat. No. 2,797,149 issued June 25, 1957, for example, it may be joined to a sample stream for such analysis, if desired.

While the presently preferred embodiments of the method and apparatus for intermixing liquids have been illustrated and described, it will be apparent, especially to those versed in the art, that such method and apparatus may take other forms, and are susceptible of various changes in details, without departing from the principles of the invention.

What is claimed is:

1. Apparatus for intermixing plural liquids, for use in an automated instrument for the analysis of a treated wet substance, comprising: a body defining a walled elongated fluid passageway portion having an inlet end for a first liquid and having an outlet end for effluent liquid, a vibratory reed, having a support, extending lengthwise into said passageway portion with clearance with said wall of said portion intermediate said inlet and said outlet ends, so that said first liquid flows externally along a portion of the length of said reed, said reed having means to transport a second liquid into said passageway portion for mixing with said first liquid, and means external to said passageway portion for effecting vibratory movement of said reed for intermixing said liquids in said passageway portion prior to flow of said liquids from said outlet end.

2. Apparatus as defined in claim **1**, wherein: said reed support is stationary and said reed extends into said passageway portion in cantilever fashion.

3. Apparatus as defined in claim **2**, wherein: said reed is formed as a tube discharging into said passageway portion.

4. A method for use in automated quantitative analysis of a wet sample, utilizing a conduit having an inlet for a first liquid and having an outlet for effluent liquid, and utilizing a tube inletted for a second liquid and having a free end portion extending a distance along the interior of the conduit, comprising: the step of flowing at a substantially constant rate said first liquid to said conduit to flow externally along a part of the length of said tube including said free end portion thereof, flowing at a substantially constant rate said second liquid to said tube inlet for discharge into said first liquid from said free end portion of said tube, while vibrating said end portion to create turbulence in said liquid and mixing of said liquids.

5. A method as defined in claim **4**, wherein: said second liquid is a sample.

6. A method as defined in claim **4**, wherein: said first and second liquids are different reagents.

7. Apparatus for intermixing plural liquids, for use in an automated instrument for the analysis of a treated wet substance, comprising: a body defining a walled elongated fluid passageway portion having an inlet end for a first liquid and having an outlet end for effluent liquid, a vibratory reed, having a support, extending into said passageway portion with clearance with said wall of said portion intermediate said inlet and said outlet ends, said reed having means to transport a second liquid into said passageway portion for mixing with said first liquid, and means external to said passageway portion for effecting vibratory movement of said reed for intermixing said liquids in said passageway portion prior to flow of said liquids from said outlet end, said means of said reed discharging said second liquid in the direction of flow of said first liquid.

8. Apparatus as defined in claim **7**, wherein: said body is structured of nonmagnetic material and said reed is structured at least in part of magnetic material, and said means for effecting vibratory movement of said reed comprises a means generating a time-variable magnetic field acting on said reed through said wall of said body, said reed being formed as a tube discharging into said passageway portion.

9. Apparatus as defined in claim **8**, wherein: said means generating a magnetic field is a magnet.

10. A method for use in automated quantitative analysis of a wet sample, utilizing a conduit having an inlet for a first liquid and having an outlet for effluent liquid, and utilizing a tube inletted for a second liquid and having a free end portion extending a distance along the interior of the conduit, comprising: the step of flowing at a substantially constant rate said first liquid to said conduit, flowing at a substantially constant rate said second liquid to said tube inlet for discharge into said first liquid from said free end portion of said tube, while vibrating said end portion to create turbulence in said first liquid and mixing of said liquids, the direction of discharge of said second liquid being in the same direction of flow as the direction of flow of said first liquid.

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