Sept. 23, 1969 G. L. HAMMOND 3,468,637

FLUID MIXING DEVICE

Filed June 9, 1965

FIG. 1

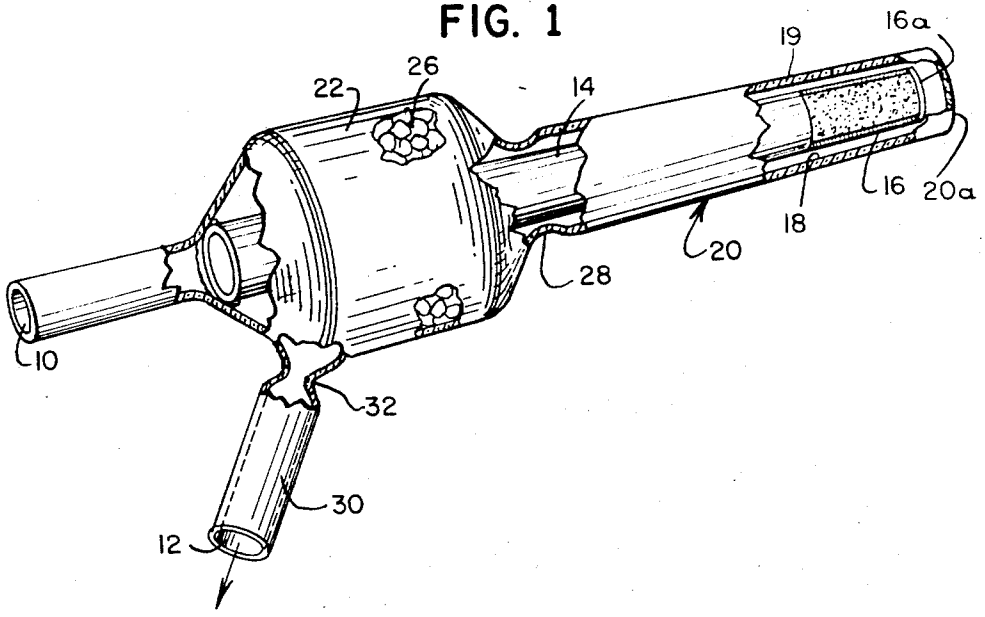


FIG. 3

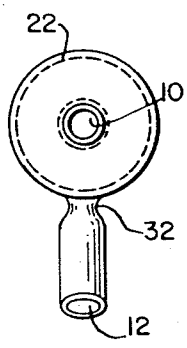
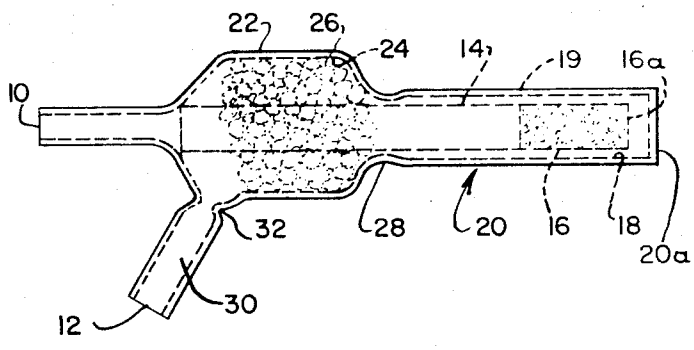


FIG. 2



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FLUID MIXING DEVICE

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U.S. Cl. 23—292 1 Claim

The present invention relates generally to devices for mixing fluids and, more particularly, to an improved fluid mixing device suitable for use in high speed colorimetric gas analyzers.

It is a primary object of this invention to provide an improved mixing device for rapidly achieving an intimate admixture of two or more fluids while maintaining a high flow rate of the fluids being mixed. A related object is to provide such a device which is suitable for use in contacting a liquid colorimetric reagent with a gas sample in a high speed colorimetric gas analyzer. Thus, it is an object of the invention to provide such a mixing device which provides a minimum response time for the colorimetric reagent in such an analyzer.

It is another object of this invention to provide an improved fluid mixing device of the foregoing type which provides a minimum volume holdup of the fluids being mixed. In this connection, it is an object to provide such a device which maintains a continuous and rapid fluid flow during the mixing operation.

It is a further object of the invention to provide an improved fluid mixing device of the type described above which is extremely compact so as to be compatible with small portable gas analyzing instruments.

Still another object of this invention is to provide an improved fluid mixing device of the above type which is simple and economical to manufacture and maintain. A related object is to provide such a device which is completely enclosed except for the fluid inlet and outlet ports.

Other objects and advantages of the present invention will be apparent from the following detailed description and accompanying drawings, in which:

FIGURE 1 is a perspective view of an improved fluid mixing device embodying the present invention with portions of the outside envelope broken away to show the internal structure more clearly;

FIG. 2 is a side elevation view of the mixing device of FIGURE 1; and

FIG. 3 is an end elevation view of the mixing device of FIGURE 1 taken from the inlet end.

While the invention will be described in connection with a preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment but, on the contrary, it is intended to cover the various modifications and equivalent arrangements included within the spirit and scope of the appended claim.

Turning now to the drawings, the illustrative embodiment of this invention is made entirely of glass, although it will be apparent that other construction materials could be utilized without departing from the spirit and scope of the invention. The illustrative mixing device is adapted to receive the two fluids to be mixed through an inlet port **10**, with the resultant mixture being subsequently discharged from the device through a downstream outlet port **12**. In order to achieve some preliminary mixing action, the two fluids are preferably fed into a single feed line upstream of the mixing device, so that the fluids

to be mixed enter the inlet port **10** simultaneously. The illustrative device has been used with outstanding success in a high speed atmosphere monitoring instrument in which samples of atmospheric air are contacted with a liquid colorimetric reagent for the selective analysis of various pollutants, but it will be apparent that the device is equally useful in numerous other mixing applications. In the atmosphere monitoring application, a short response time, i.e., fast development of color in the reagent, is especially important for accurate pollutant detection, and thus it is essential that the mixing device achieve an intimate admixture of the air and reagent rapidly and efficiently while maintaining a high fluid flow rate.

In accordance with one important aspect of this invention, the mixing device is adapted to pass the incoming fluids through an elongated tube at the end of which the fluids are simultaneously passed through a primary mixing stage comprising a cylindrical frit and a surrounding annular chamber which maintains a relatively high fluid flow rate while directing the fluid mixture back along the outer surface of the tube. At a point spaced away from the frit toward the inlet port of the tube, the fluids are passed through a secondary mixing chamber containing a particulate packing which further advances the mixing action, with the resulting mixture being quickly discharged through the outlet port. Thus, in the illustrative embodiment, the incoming air and liquid reagent are passed through an elongated glass tube **14** which terminates at its discharge end in a cylindrical glass frit **16**. The air and reagent are passed simultaneously through the frit **16** so as to form a multiplicity of minute air bubbles within the liquid reagent thereby exposing a maximum surface area of reagent to the air sample. The degree of mixing achieved in the primary mixing stage is determined mainly by the pore size of the glas frit and the pressure drop across the frit. In operation, the pore size of the frit is fixed, but the pressure drop may be controlled by adjusting the pressure differential between the inlet port **10** and the outlet port **12**. In a typical case where air and liquid reagent are fed into the mixing device at flow rates of one liter per minute and one milliliter per minute, respectively, a suitable pressure drop across the frit is about six inches of water. The desired pressure drop may be provided by conventional means, such as by feeding the fluids into the tube **14** at atmospheric pressure while maintaining the outlet **12** of the device at a desired subatmospheric pressure.

To insure that the glass frit passes both the gas and liquid phases of the fluid mixture, it is preferred to use a relatively coarse frit. Extremely fine frits tend to reject the liquid phase while preferentially passing only the gas phase. Also, the frit must have sufficient surface area to pass the fluid mixture at the desired flow rate. The required frit pore size and surface area can be readily determined for any particular system in an empirical manner by conducting a few simple tests under the desired conditions. It is preferred to use a frit which is cylindrical in shape so as to obtain 360° dispersion. Moreover, if insoluble particles are accidentally drawn into the cylindrical frit, they normally affect only the dispersion through the end of the cylinder; dispersion through the 360° side walls of the frit is unimpaired so that the operating efficiency of the device is maintained relatively high. The cylindrical frit also provides relatively even

or uniform turbulence, which is important to maintain a high flow rate between the two mixing stages.

In keeping with the present invention, the air-reagent mixture emerging from the glass frit **16** is received in an annular chamber **18** which directs the biphase mixture back along the outer surface of the tube **14** in a direction counter to that of the incoming fluid inside the tube **14**. The annular chamber **18** is formed by a glass envelope **20** which concentrically surrounds the tube **14** and is enlarged as at **22** to form a secondary mixing chamber **24** longitudinally spaced away from the frit **16** toward the inlet end of the tube **14**. Since the fluid flow is substantially unimpeded within the annular chamber **18** interconnecting the two mixing stages, the fluid flow rate within the mixing device is maintained at a relatively high level, and the holdup volume is minimized. Consequently, the overall mixing time, and thus the reagent response time, is considerably reduced in comparison with the time periods required in mixing devices available heretofore. Moreover, the countercurrent flow pattern on opposite sides of the feed tube **14** within the device permits an extremely compact and efficient construction.

For the purpose of moving the fluid mixture quickly away from the outside of the glass frit **16** and along the outside surface of the feed tube **14**, the radial width of the annular chamber **18** should be as small as possible so that there is no substantial empty volume for fluid accumulation. Consequently, the fluid emerging from the frit continuously urges the preceding fluid back through the annular passageway toward the secondary mixing chamber **24**. Similarly, the end **16***a* of the frit should be located as close as possible to the end **20***a* of the glass envelope so as to avoid the possibility of forming a stale fluid pocket in the end region of the chamber **18**.

It is important that the inlet to the secondary mixing chamber **24** be spaced away from the frit **16** so that there is a substantial interconnecting passageway **19** between the two mixing stages. This provides a relatively low resistance volume for facilitating rapid removal of fluid from the discharge side of the frit **16**, and for accelerating the fluid stream prior to its entry to the secondary mixing chamber **24**.

In order to effect a secondary mixing action within the chamber **24**, a bed of glass beads **26** is contained within the chamber adjacent the entrance end thereof. As the biphase fluid mixture enters the chamber **24**, the beads **26** break and reform the air bubbles while maintaining the two phases in continuous intimate contact. To achieve optimum mixing, the bed of glass beads **26** preferably extends along about two thirds of the axial length of the chamber **24**, with an open space remaining at the discharge end of the chamber for fast fluid discharge. The diameter of the beads **26** should be such that the resistance offered by the bead bed to fluid flow is not substantially greater than that offered by the glass frit. A bead diameter of about three millimeters is suitable for most applications.

In addition to furthering the mixing action to provide a large interface between the two fluids, the glass beads **26** serve to prevent excessive frothing of the liquid-gas mixture. Although glass beads have been described and illustrated as the preferred packing material in the illustrative embodiment of the invention, it will be understood that other particulate packing materials that are chemically inert and heavier than the fluids involved, can be used.

In accordance with one feature of this invention, the velocity of the liquid-gas mixture is preferably increased just prior to entering the secondary mixing stage so that the fluid mixture strikes the glass beads with increased force and is quickly broken up. Thus, a constriction **28** is formed in the glass envelope adjacent the entrance end of the chamber **24** so as to reduce the cross section of the interconnecting chamber **19** at that point, thereby producing a corresponding increase in the fluid velocity. Since the velocity increase is in the axial direction, it serves to reduce the fluid flow-through time as well as enhancing the mixing action. The constriction **28** also serves to prevent the glass beads from becoming accidentally lodged in the annular passageway **19**.

For the purpose of discharging the fluid mixture from the secondary mixing chamber, a transfer tube **30** is provided near the downstream end of the chamber **24**. The intake port for the transfer tube **30** is located in the open space beyond the downstream side of the bed of glass beads **26** so that the fluid mixture is continuously discharged at a high flow rate. With the mixing device provided by this invention, conditions of high velocity and turbulence are achieved in the transfer tube to further assure good mixture of the two phases.

In order to prevent the glass beads **26** from being swept out of the secondary mixing chamber **24** into the transfer tube **30**, a constriction **32** is provided at the inlet end of the tube **30** so as to reduce the intake port to a size smaller than that of the glass beads. Consequently, there is no chance of the beads clogging the transfer tube or any other downstream portion of the instrument in which the mixing device is utilized. Moreover, in addition to trapping the beads within the chamber **24**, the constriction **32** serves to increase the velocity of the fluid stream as it enters the transfer tube **30**, thereby enhancing the turbulent mixing conditions within the transfer tube.

Although the mixing device of this invention has been described with particular reference to the mixing of only two fluids, it will be understood that the invention is equally applicable to the mixing of practically any number of fluids. In the exemplary air-reagent application described above, a number of different liquid reagents may be employed, but a particularly preferred reagent for detecting nitrogen dioxide in air samples is the reagent described in copending application Ser. No. 462,226, now issued as Patent No. 3,375,079 entitled Colorimetric Reagent for Analysis of Nitrogen Dioxide in Air. The reagent described in that application has an extremely fast response time and, therefore, is especially compatible with the fast flow rates provided by the device of the present invention.

As can be seen from the foregoing detailed description, the improved mixing device provided by this invention is capable of rapidly achieving an intimate admixture of two or more fluids while maintaining a high flow rate of the fluids being mixed. Actual fluid tests have demonstrated that the mixing device of this invention is especially suitable for use in contacting a liquid colorimetric reagent with a gas sample in a high speed colorimetric gas analyzer, and that the mixing device provides a substantially shorter response time for the colorimetric reagent than any other mixing device heretofore. Moreover, the device of this invention provides a minimum volume holdup of the fluids being mixed while maintaining a continuous and rapid fluid flow during the mixing operation. Furthermore, the improved mixing device provided by this invention is extremely compact so that it is compatible for use in small portable gas analyzers. The inventive mixing device is also simple and economical to manufacture and maintain, and is completely enclosed except for the fluid inlet and outlet ports.

I claim as my invention:

1. Apparatus for rapidly mixing two or more fluids, said apparatus comprising the combination of a primary mixing stage including a frit for breaking up the two fluids so as to provide a large interface between the two fluids, an elongated tubular member for feeding the two fluids simultaneously to said frit, an annular chamber surrounding said frit and a substantial portion of said tubular member for receiving the fluid mixture emerging from the frit and directing the fluid mixture emerging outer surface of the tubular member in a direction counter to that of the incoming fluids inside the tubular

member, and a secondary mixing stage surrounding said tubular member for receiving the fluid mixture from said annular chamber, said secondary mixing stage being spaced away from said frit toward the inlet end of said tubular member and including a bed of particulate material for again breaking up the two fluids to provide a large interface between the two fluids, and an outlet port for discharging the resultant fluid mixture, said annular chamber including a restriction adjacent said secondary mixing stage to increase the velocity of the fluid mixture entering said secondary mixing stage.

References Cited

UNITED STATES PATENTS

1,887,126	11/1932	Grossman	23—292
2,382,381	8/1945	Calvert et al.	23—232
2,394,023	2/1946	Strickland	23—292

JAMES H. TAYMAN, JR., Primary Examiner

U.S. Cl. X.R.

23—254; 259—4; 261—94, 96