

[54] **MODULATOR APPARATUS UTILIZING
PIEZOELECTRIC PLATES**

[75] Inventors: **Victor G. Mossotti; Judith A. Eakin,**
both of Urbana, Ill.

[73] Assignee: **University of Illinois Foundation,**
Urbana, Ill.

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Primary Examiner—David Schonberg

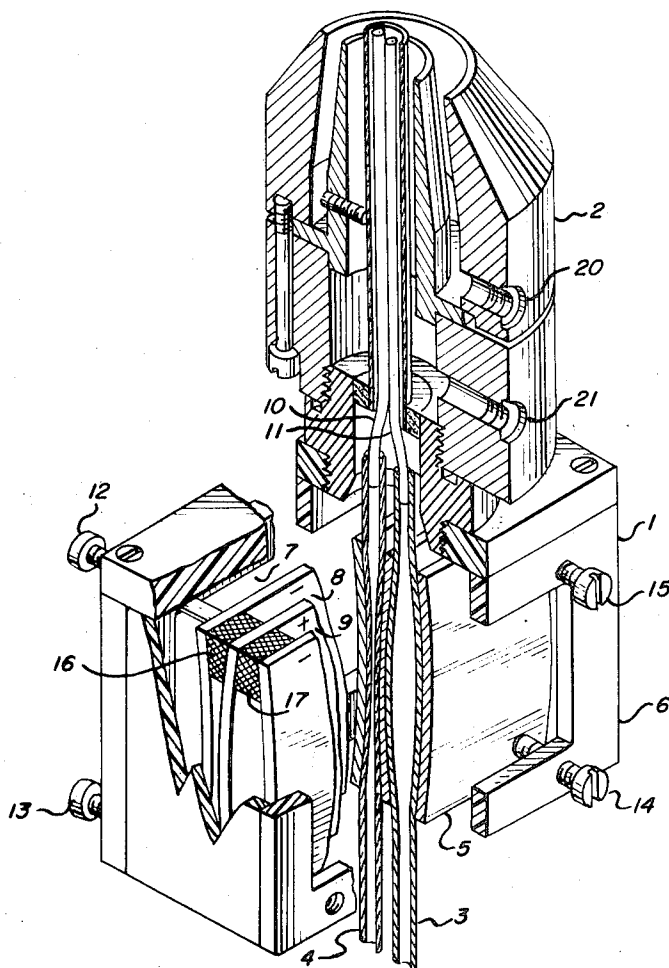
Assistant Examiner—F. L. Evans

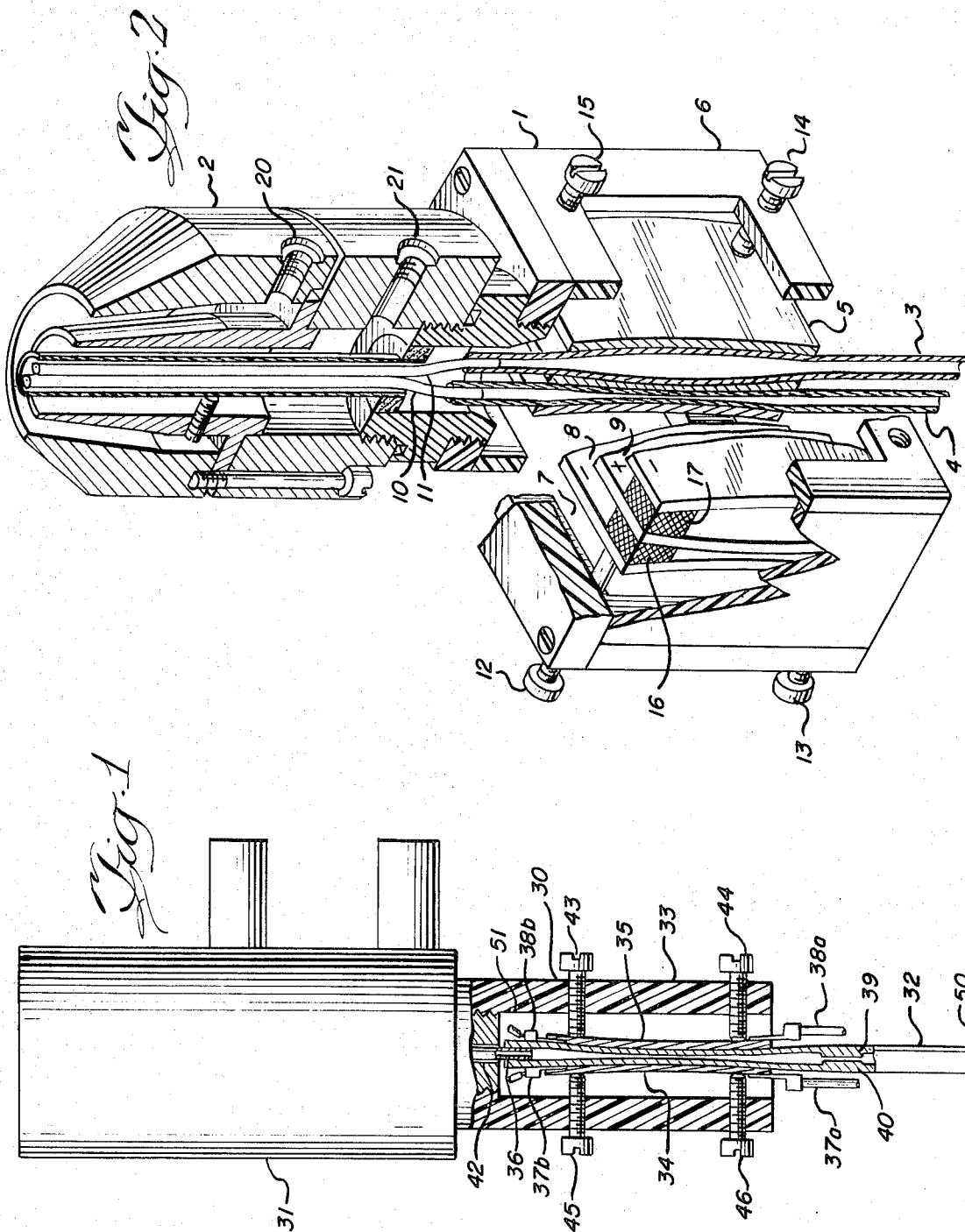
Attorney—Merriam, Marshall, Shapiro & Klose

[57] **ABSTRACT**

A modulator and method for providing uniform increments of fluid in a continuously pulsing manner, is disclosed. The modulator employs the piezoelectric effect to impart peristaltic-like action to a flexible, resilient channel causing fluid contained within that channel to be pulsed from the channel, in the form of substantially uniform increments or slugs. The modulator is employed, for example, in combination with, and to feed fluid sample to, an analytical instrument such as a flame spectrophotometer.

6 Claims, 3 Drawing Figures



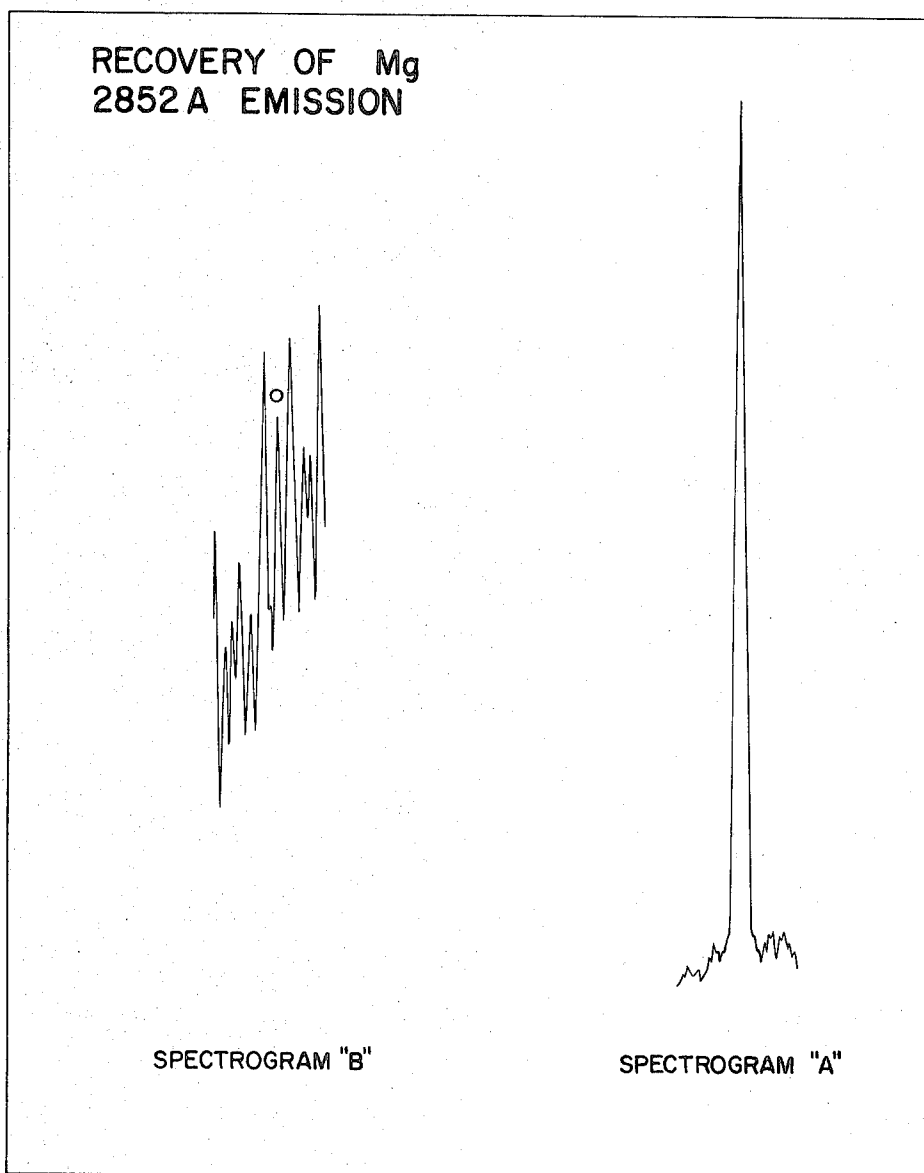


INVENTORS

Victor G. Messotti
Judith Ann Eakin

BY *Merriam, Marshall, Skyles & Kline*
 ATTORNEYS

Fig. 3



INVENTORS
Victor G. Mossotti
Judith Ann Eakin
Merriam, Michael, Shapiro & Hare
BY
ATTORNEYS

MODULATOR APPARATUS UTILIZING PIEZOELECTRIC PLATES

The present invention relates to a modulator for imparting certain flow characteristics to fluid materials. In general, it concerns an apparatus and a method for providing uniform increments of fluid materials, to be used for example in feeding fluid samples to an analytical instrument such as a flame spectrophotometer. More particularly, it involves an apparatus and a method which employ the piezoelectric effect to produce peristaltic action in a channel containing a fluid material which peristaltic action propels or injects, in a highly reproducible manner, the fluid material from the channel in the form of uniform increments or slugs.

Analytical instruments suitable for use in detecting or determining the amount of a component, i.e., analyte, present in a fluid sample are well known. Such instruments include flame spectrophotometers, plasma jets, gas chromatographs, and the like. These analytical instruments all require some means or device for feeding the fluid sample to be analyzed into the analyzing element of the analytical instrument. For example, commercial flame spectrophotometers generally employ atomizers to introduce a liquid sample to be analyzed into a flame. Such atomizers are designed based upon the important objective that the liquid sample be introduced into the flame at a stable and reproducible rate. In practice, however, changes or fluctuations in sample aspiration rate occur. Such fluctuations in the rate at which sample is aspirated into the flame, especially in view of the numerous other changes or fluctuations which occur at other points in the analytical process, adversely effect the reproducibility of the analytical measurement which, of course, limits the quantitative accuracy of the analytical instrument.

The present invention provides an apparatus as well as a method for supplying or feeding a fluid sample to an analytical instrument such as a flame spectrophotometer, in such a manner that the sensitivity and detection limits of the analytical instrument are markedly improved.

In general, the apparatus of the present invention is a modulator which employs a piezoelectric sandwich comprising at least two piezoelectric crystals or plates and a flexible, resilient channel partially sandwiched between the plates.

Piezoelectric materials are well known and per se do not form the basis of the present invention. Piezoelectric materials are materials which when subjected to an applied voltage generate a stress in the crystals of the material causing the material to deform. For example, when such a material is subjected to an alternating current (AC) voltage, it will oscillate with a frequency and amplitude proportional to the applied AC voltage. The present invention relies upon this piezoelectric effect to impart a peristaltic-like action to a flexible resilient channel.

When a flexible, resilient channel, for example a latex tube, is placed between two piezoelectric plates and an AC voltage applied to the plates, the plates deform in a manner which imparts wave-like contractions to the latex tube, thereby propelling and continuously pulsing fluid material contained in the tube through the tube and out of the tube. The fluid material leaving the tube is in the form of uniform increments.

The present invention will be better understood by reference to the accompanying drawings in which:

FIG. 1 is an end view in partial cross section of a single channel modulator of the present invention attached to a "black box" which may be, for example, an analytical instrument; and

FIG. 2 is a perspective view in partial cross section of a dual channel modulator of the present invention attached to a dual capillary total consumption burner suitable for use in flame spectrophotometry; and

FIG. 3 is a graphic illustration comparing two spectrograms, spectrogram A resulting from use of the present invention and spectrogram B resulting from conventional practice.

Referring to FIG. 1, there is shown a single channel modulator 30 of the present invention threadably attached to a black box 31. The modulator 30 is used to supply uniform increments of fluid material to box 31.

Single channel modulator 30 comprises a conduit or channel 32, the intermediate portion of which is positioned, i.e., sandwiched, between a pair of piezoelectric plates, i.e., first piezoelectric plate 34 and second piezoelectric plate 35. A frame or support 33 provides means for supporting, holding and positioning the sandwiched channel. Channel 32 has an inlet 50, an outlet 51 and consists of a flexible, resilient material, for example, a latex tube having an inside diameter of one thirty-second of an inch and a wall thickness of one sixty-fourth of an inch. The outlet 51 of channel 32 is provided with a capillary 36 or other means suitable for providing a passageway for fluid material leaving channel 32 to enter box 31 through inlet port 42. Piezoelectric plates 34 and 35 are each provided, respectively, with a pair of electric contacts 37a-37b and 38a-38b. Electric contacts 37a-37b and 38a-38b are attached to an AC power source (not shown). Any suitable AC power source may be employed. One suitable AC power source which has been found useful produces a 100 volt, 35 cycles per second signal.

A portion of channel 32 located between the inlet 50 and the intermediate (sandwiched) portion is partially restricted by means of flow restrictors 39 and 40. These flow restrictors offer resistance to the flow of fluid material and thus when an increment, or slug, or fluid is subjected to peristaltic-like action in the intermediate (sandwiched) portion of channel 32, the increment tends to exit from channel 32 into capillary 36, and then into box 31 via inlet port 42. Support 33 is provided with means such as positioning support screws 43, 44, 45 and 46 for holding and positioning the sandwiched channel.

The operation of the single channel modulator shown in FIG. 1 will now be described with reference to an application where black box 31 is an analytical instrument. In such an application the modulator is used to supply a liquid or gas sample from a reservoir (not shown) into an analytical instrument where the fluid sample is analyzed to determine the quantity of a component, i.e., analyte, contained in the sample. The single channel modulator feeds or injects fluid sample into the analytical instrument in a continuously pulsing manner. It also introduces the fluid sample into the analytical instrument in reproducibly uniform increments. Thus, the flow of fluid sample from the single channel modulator into the analytical instrument may be characterized as a continuous pulsing of uniform increments or slugs of sample. The advantages of feeding

fluid samples to certain analytical instruments in such a manner will be exemplified and further described hereafter.

FIG. 2 shows another embodiment of the present invention wherein a dual channel modulator 1 of the present invention is attached to a dual capillary total consumption burner 2 which may be employed as the burner in a flame spectrophotometer.

The dual channel modulator 1 comprises a three layer piezoelectric sandwich 5 mounted in a frame or support 6. Piezoelectric sandwich 5 comprises first channel 3 and second channel 4 and piezoelectric plates 7, 8 and 9. An intermediate portion of channel 4 is disposed (sandwiched) between first piezoelectric plate 7 and second piezoelectric plate 8 and channel 3 is similarly disposed between second piezoelectric plate 8 and third piezoelectric plate 9. Piezoelectric plates 7, 8 and 9 are provided with suitable electric contacts (not shown) for applying an AC voltage to the plates. The outlet ends of channels 3 and 4 are provided, respectively, with first capillary 11 and second capillary 10. Piezoelectric sandwich 5 is positioned and secured within support 6 by means of positioning support screws 12, 13, 14 and 15. Spacer members 16 and 17 prevent piezoelectric plates 7, 8 and 9 from making physical contact with each other.

Dual capillary total consumption burner 2 is provided with inlet ports 20 and 21 to permit support gases such as fuel and air or oxygen to enter the burner.

As mentioned above, in the embodiment illustrated in FIG. 2, the dual channel modulator of the present invention is used to feed a fluid sample to the burner of a flame spectrophotometer. Flame spectrophotometers are analytical instruments which are often employed to determine the quantity of a metallic element present, for example, as an impurity, in a liquid sample. One of the main components of a flame spectrophotometer is a burner, such as the dual capillary total consumption burner illustrated in FIG. 2. The burner, when supplied with support gases should, under optimum conditions, produce a steady flame. The sample to be analyzed is prepared in a fluid state and introduced under conditions controlled as nearly as possible into the flame causing a characteristic radiation from the flame. The characteristic radiation from the flame is collected, rendered monochromatic and focused by an optical system (not shown) onto a photosensitive detector (not shown). The intensity of the isolated radiation striking the photosensitive detector is indicated, and generally recorded, by a meter (not shown).

Operation of the dual channel modulator illustrated in FIG. 2 as it is used to supply a fluid sample to the dual capillary total consumption burner will now be described.

Before voltage is applied to the piezoelectric sandwich 5, both channels 3 and 4 of the modulator 1 are slightly compressed by means of positioning support screws 12, 13, 14 and 15.

Support gases are fed to the burner 2 through inlets 20 and 21 and ignited at the outlet of the burner nozzle. Either channel 3 or channel 4 is fed with a liquid containing solvent and the component, i.e., analyte, of analytical interest and the other channel is fed with pure solvent. The natural aspiration of the burner causes these liquids to be drawn up into channels 3 and 4. At this point, an alternating current voltage, for example a 100 volt, 35 cycles per second signal is applied to the

piezoelectric sandwich 5. During the first half cycle after the voltage is applied, the three layer piezoelectric sandwich 5 mechanically warps filling one channel, e.g., channel 3, with an additional quantity of fluid while simultaneously forcing or injecting an incremental volume of fluid out of the other channel, i.e., channel 4, into and through capillary tube 10 and into the flame. During the second half cycle after voltage is applied, the peristaltic-like action of channels 3 and 4 reverse. After a stabilization cycle, the described action results in a modulation of the analyte introduced into the flame while the net solvent injection rate remains constant and unmodulated.

Some of the practical advantages of employing a modulator of the present invention in flame spectrophotometry will now be described.

The dual channel modulator and the dual capillary total consumption burner illustrated in FIG. 2 were used, as described, in a flame spectrophotometer. The fluid analyzed was a 95 percent ethanol solution containing 2ppm of magnesium (Mg). The support gases for the burner comprised premixed acetylene and nitrous oxide. The results of the analysis were recorded as spectrograms and these spectrograms were compared with spectrograms obtained from other analyses wherein the same burner, support gases and conditions were employed to analyze samples of the same fluid fed to the burner in a conventional manner, viz, by aspiration through capillaries. FIG. 3 illustrates spectrograms representative of those obtained. As is apparent from FIG. 3, the interpretation of spectrogram A (resulting from use of the present invention) is vastly simplified as compared to spectrogram B (resulting from conventional practice). In addition, the analytical sensitivities and detection limits of the instrument were markedly improved by use of the present invention, as evidenced by the substantially improved signal to noise ratio.

While the present invention has been described, in part, with reference to analytical instruments, and more particularly in reference to flame spectrophotometers, it is apparent that the modulator of the present invention will have utility in other applications where uniform increments of fluid materials need be supplied in a continuously pulsing manner. For example, the modulator may find utility in various fuel supply applications and the like. Modifications of the invention apparent to those skilled in the art are intended to be within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A modulator for providing uniform increments of fluid material, said modulator comprising at least two piezoelectric plates, at least one flexible, resilient tube means positioned so that an intermediate portion of said tube means is interposed between said plates, support means for positioning and holding said plates, said plates being positioned and supported so that peristaltic-like action can be imparted to said tube means when AC voltage is applied to said plates.

2. The modulator of claim 1 wherein said flexible, resilient tube means is a latex tube.

3. The modulator of claim 1 wherein the inlet portion of said tube means is provided with a partial flow restriction.

4. The modulator of claim 1 wherein the outlet portion of said tube means is provided with conduit means, said outlet portion being not otherwise restricted.

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5. The modulator of claim 1 comprising three piezo-electric plates and two flexible, resilient, tubes.

6. A single channel modulator for providing, in a continuously pulsing manner, increments of fluid material, said modulator comprising a pair of piezoelectric plates, a flexible, resilient tube positioned so that an intermediate portion of said tube is interposed between said plates, means for applying an AC voltage to said

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plates, said modulator being adapted to impart a peristaltic-like action to said flexible, resilient tube when an AC voltage is applied to said plates, whereby when fluid material enters the inlet end of said tube, uniform increments of said fluid material are provided at the outlet end of said tube.

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