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[54] ULTRASONIC ATOMIZER FOR ATOMIZING LIQUIDS AND FORMING AN AEROSOL

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[58] **Field of Search** ..... 239/101, 102, 4; 310/8.1, 8.2; 259/DIG. 44, 1 R

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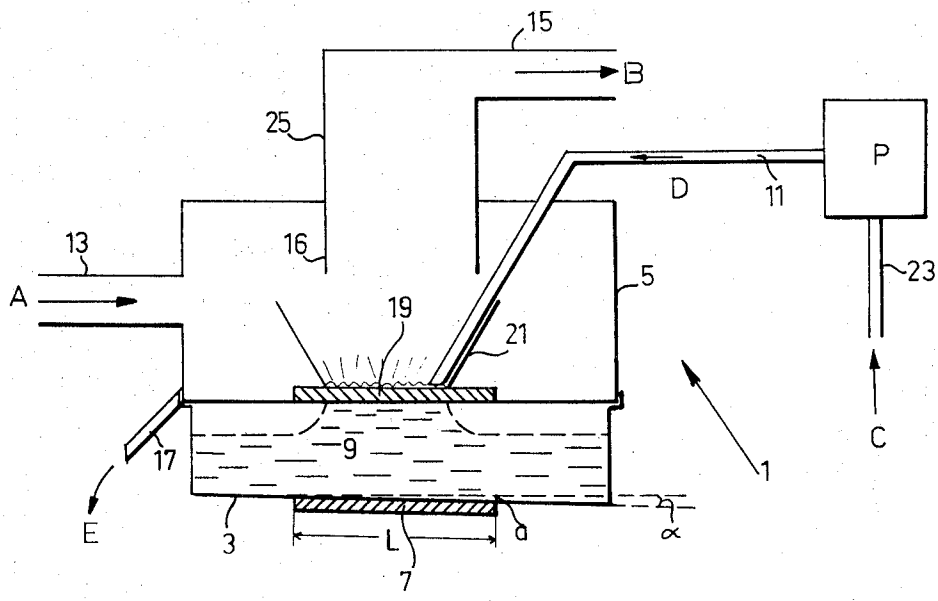
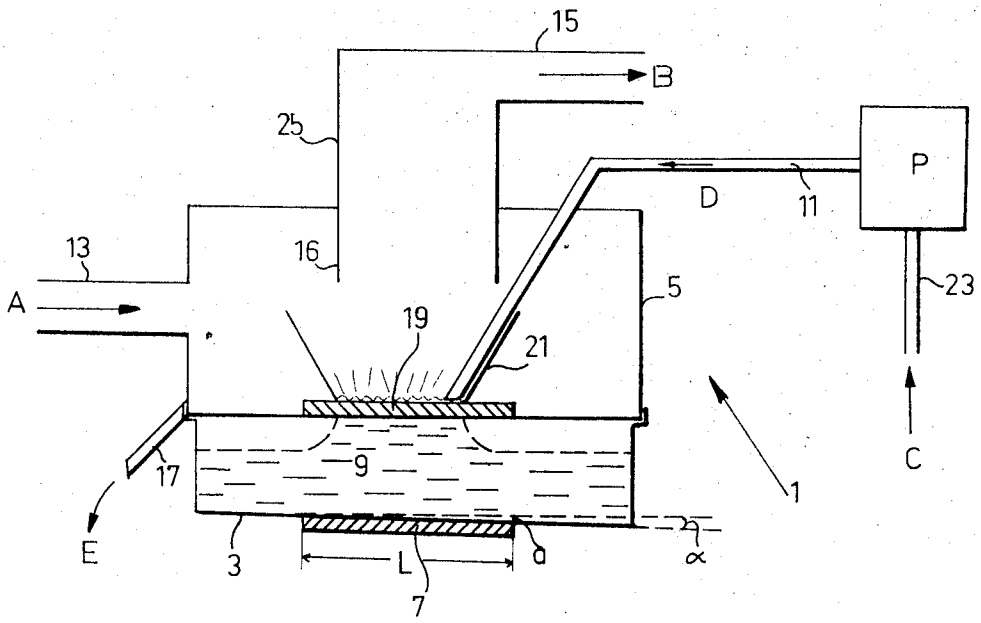
[57] **ABSTRACT**

An ultrasonic atomizer for atomizing liquids and forming an aerosol, comprising a container defining an atomizing chamber having a liquid inlet for the liquid to be atomized and a gas inlet for carrier gas and a gas outlet for discharging the aerosol formed, an ultrasonic vibrator being arranged in connection with said chamber for providing liquid atomization, a transmission chamber being positioned in connection with the ultrasonic vibrator and intended to contain a transmission medium for transferring ultrasonic energy from the ultrasonic vibrator to the vibrating element which is positioned on the opposite side of the transmission chamber.

5 Claims, 1 Drawing Figure





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ULTRASONIC ATOMIZER FOR ATOMIZING LIQUIDS AND FORMING AN AEROSOL

The present invention refers to an ultrasonic atomizer for atomizing liquids, the atomized liquid in combination with a carrier gas forming an aerosol that can be used for different purposes.

The atomization of liquids by means of ultrasonic atomizers is associated with problems of different kinds. Among these problems there may be mentioned difficulties to control the amount of liquid atomized per unit of time and to control said amount in a simple and reliable manner while maintaining the desired drop size or particle size of the atomized liquid, difficulties to obtain sufficient cooling of the vibrator or vibrating element, so that the energy supplied thereto can be increased to a sufficient extent, etc. Moreover, in ultrasonic vibrators of the prior art having a vibrating crystal with a hard metal plate glued thereto by means of an adhesive, corrosion problems arise, particularly when salt solutions are atomized. In known ultrasonic atomizers the problems indicated above have not been satisfactorily solved, in view of which as atomizers have not found such a broad use as desired.

The present invention has for its main purpose to solve the problems at hand and to provide an ultrasonic atomizer which, in view of its reliability in operation and its flexibility, can be used in a multitude of applications.

In connection with the present invention the surprising discovery has been made that a very useful ultrasonic atomizer will be obtained, if the vibrating body or vibrator proper and a vibrating element to which there is supplied the liquid to be atomized are separated by means of a transmission medium, consisting of a liquid, for instance water. For this purpose the ultrasonic atomizer of the instant invention comprises an atomizing chamber having a liquid inlet for supplying the liquid to be atomized to the vibrating element, and a gas inlet for supplying carrier gas to said chamber and a gas outlet for discharging the aerosol formed from said chamber, an ultrasonic vibrator being arranged in connection with said chamber for providing the liquid atomization necessary for the aerosol formation. For obtaining the purpose of the invention the ultrasonic atomizer is provided with a transmission chamber positioned in connection with the ultrasonic vibrator and intended to contain a transmission medium for transferring ultrasonic energy from the ultrasonic vibrator to a vibrating element positioned on the opposite side of the transmission chamber and adjacent to which the liquid inlet opens.

In those cases where it is desirable to atomize a certain predetermined amount of liquid per unit of time it is preferred to supply the liquid to the vibrating element by means of some form of feeder, for instance a displacement pump, giving a controllable constant flow of liquid supplied in a desired amount per unit of time.

The invention will now be described by a non-limiting example while referring to the appended drawing, where the FIGURE shows diagrammatically and partly in cross section a preferred embodiment of the ultrasonic atomizer of the invention.

The ultrasonic atomizer shown in the drawing comprises a container generally designated 1 having a lower part 3 and an upper part 5, said parts having circular cross sections and being separably adjoined in a manner not shown. The assembly of parts 3 and 5 can be done in several ways, for instance by simple press fit, so that the upper part 5 may be easily removed if access to the interior of the ultrasonic atomizer is desirable. The container 1 has a gas inlet tube 13 arranged in the side wall of the upper part 5, and a gas outlet tube 25 concentric with the upper part 5 and extending through said part so that the lower end 16 extends a distance into the container 1. The upper end of the gas outlet tube 25 is bent under essentially a right angle and extended into a narrower pipe or tube 15. Finally, the container 1 is provided with a drain tube 17 for a purpose to be explained below.

In connection to the bottom of the lower part 3 of container 1 there is arranged an ultrasonic vibrator diagrammatically shown by means of the vibrating body 7 proper. This body consists in the embodiment shown in a manner known per se of a piezoelectric crystal supplied with electric energy. The vibrating body 7 may be considered as forming part of the bottom of the lower part 3. The lower part 3 of the container 1 forms a liquid-tight container which is intended to contain a liquid transmission medium, preferably consisting of water, suitably distilled or deionized water.

In a similar way as e lower part 3 the upper part 5 is provided with a bottom, wherein there is attached a vibrating plate 19 that may be considered as forming part of the bottom of the upper part 5. Said vibrating plate is preferably made of a hard material, for instance glass. The thickness thereof should be tuned to the resonance of the vibrating body, i.e., the vibrating plate 19 shall have a thickness which is an integer multiple of $\lambda/2$, where λ is the wavelength of the ultrasonic energy issuing from the vibrator 7. Moreover, the vibrating plate 19 is arranged essentially parallel with the vibrating body 7. In connection with the vibrating plate 19, which is circular in the embodiment shown there is arranged a circular conical baffle 21 which is concentric with the vibrating plate. Said conical baffle 21 extends upwardly and outwardly somewhat outside the lower part 16 of the gas outlet tube 25.

As regards the relative position of vibrator 7 and plate 19 with regard to the parallelism thereof, it has been found that arranging said members under a small angle to each other, as indicated by the angle α in the drawing, leads to certain advantages, particularly as regards the starting up of the device. With the designations of the FIGURE, where L is the width of the vibrator 7 and a is the distance of edge inclination of body 7, the angle α may be obtained from the equation:

$$tg\,\alpha = a/L = (k \cdot \lambda/2)/L;$$

where $k = 0.2$–1 and

λ = wavelength of the ultrasonic energy.

The distance a is preferably of the order of some tenths of λ and not more than $\lambda/2$. A preferred range when using a frequence of the energy supplied of 3 MhZ (megahertz) is 0.2°–0.5°.

The small deviation from parallelism between body 7 and plate 19 indicated above has for an effect that the adaptation of the thickness of plate 19 to obtain a resonating system is much less critical than if exact parallelism is at hand.

The liquid to be atomized is supplied through an inlet tube **23** and transported by means of a pump P through a liquid supply tube **11** up to the vibrating plate **19**, as indicated in the drawing by arrows C and D. The end of tube **11** opening adjacent to plate **19** is bevelled to conform closely to the top surface of said plate.

The operation of the above described device is briefly the following.

With the upper part **5** with associated gas inlet and gas outlet tubes **13**, **25** removed the lower part **3** is filled with a transmission medium, in the embodiment shown with water. In this connection the water level at rest need not reach the vibrating plate **19** in the position thereof after the attaching of the upper part **5** on top of the lower part **3**. When the vibrating body **7** is in operation the central part of the liquid surface is elevated in view of the radiation pressure generated by the ultrasonic energy until the liquid arrives into contact with the lower surface of the vibrating plate **19** as indicated by broken lines in the drawing.

A controlled flow of carrier gas is supplied to container **1** through gas inlet **13**, as indicated by arrow A, gas outlet **25**, **15** being connected to a site to be supplied with an aerosol, for instance a respirator, an oil burner or the like. With the carrier gas flow set at a suitable rate the ultrasonic vibrator **7** and the pump P are started. The pump capacity is adjusted to a suitable level and a predetermined amount of liquid per unit of time is now transported to the vibrating plate **19**, where it is atomized and carried by the carrier gas out through outlet **15**, as shown by arrow B.

Atomized liquid possibly being condensed on the interior of the walls of the gas outlet **25** is returned by the conical baffle **21** to the vibrating plate **19** for renewed atomization. In this way atomization of all of the supplied liquid is ensured and thus a safer measurement or dosage will be obtained. In case of splashing of the supplied liquid, for instance when starting the atomization, it is possible that liquid is transferred into the area outside the conical baffle **21** and the lower part **16** of the gas outlet tube **25**. Such liquid will be discharged through drain tube **17**, as indicated by arrow E.

The arrangement described above offers several advantages. Due to the presence of the transmission medium **9** an efficient cooling of the vibrating body **7** is obtained. This means that the energy supplied can be increased in a manner not possible in the prior art devices without causing super-heating problems. In view of the fact that the vibrating plate **19** is separated from the vibrating body **7** proper, problems encountered in the prior art devices such as corrosion, providing for a resistant joint between vibrating body and vibrating plate, etc., are avoided by the invention. In view of the fact that the vibrating plate of the present device is not attached to the expensive piezoelectric crystal of vibrating body **7**, for instance by an adhesive, it may easily be replaced and can be manufactured from a non-expensive material having a short life time, for instance glass.

Finally, due to the small non-parallelism of body **7** and plate **19**, the atomizer is very reliable with regard to its starting up from rest and the exactness in tuning the vibrating plate **19** to the resonance of vibrator **7** is not critical.

The present invention thus provides for an ultrasonic atomizer having a versatile usefulness in view of its ability of generating an aerosol having a well defined composition. It may for instance be used in respirators for the supply of moisture, anaesthetics, etc., in flame spectrophotometry, in fuel supply to diesel engines or oil burners, in fuel supply for jet engines etc.

Of course, the invention is not delimited to the embodiment shown in the drawing. Thus, the vibrating body **7** and the vibrating plate **19** may be positioned otherwise than horizontally, for instance in a vertical position. Moreover, pump P can be replaced by another device for liquid supply, for instance a drop bottle. However, it is preferred to use a positive displacement pump as a liquid supply device, since this makes possible a careful control of the amount of liquid supplied to the plate **19** per unit of time. Moreover, the liquid may be supplied evenly distributed around the periphery of the vibrating plate **19**, either through a circumferentially extending peripheral slit or through recesses or the like evenly distributed around the periphery of the vibrating plate **19**.

What is claimed is:

1. An ultrasonic atomizer for atomizing liquids and forming an aerosol comprising a container defining an atomizing chamber, a vibrating element positioned within said atomizing chamber, said atomizing chamber having a liquid inlet for supplying liquid to be atomized to said vibrating element, a gas inlet for supplying carrier gas to said atomizing chamber and a gas outlet for discharging the aerosol formed from said atomizing chamber, means including an ultrasonic vibrator associated with said vibrating element for providing the liquid atomization necessary for the aerosol formation, wherein the improvement comprises that said vibrating element forms a portion of a side of said container, said means includes a transmission chamber in communication with the side of said container which includes said vibrating element, said transmission chamber arranged to contain a liquid transmission medium for transferring ultrasonic energy therethrough from said ultrasonic vibrator to said vibrating element, said vibrating element being located adjacent the end of said liquid inlet, said vibrating element being formed as a plate having a thickness which is an integer multiple of the wavelength λ divided by 2 where λ is the wavelength of the ultrasonic energy issuing from said vibrator, so that the thickness of the plate-form said vibrating element is tuned to the resonance of said vibrator, and the active surface of said vibrator being located within said transmission chamber and contacted by said transmission medium, the active surface of said vibrator and the surface of said vibrating element within said transmission chamber are in approximately parallel relationship but with the active surface of said vibrator forming a small angle relative to a plane parallel to the surface of said vibrating element within the transmission chamber.

2. An ultrasonic atomizer, as set forth in claim **7**, characterized in that said container is formed of a first part and a second part located below said first part, said first part forms said atomizing chamber and said second part forms said transmission chamber with said ultrasonic vibrator forming at least a part of the lower side of said second part spaced below the lower side of

said first part, and said vibrating element forming at least a part of the lower side of said first part.

3. An ultrasonic atomizer, as set forth in claim 2, characterized therein by a conical baffle located within said first part concentric with said vibrating element, said baffle extending upwardly and outwardly from said vibrating element toward said gas outlet for collecting and returning condensed or unatomized liquid to said vibrating element.

4. An ultrasonic atomizer, as set forth in claim 3, characterized in that the plate-form said vibrating element has its upper and lower surfaces disposed in parallel relationship and said vibrating element is formed of glass.

5. An ultrasonic atomizer, as set forth in claim 1, characterized in that the small angle formed by the active surface of said vibrator relative to a plane parallel to the surface of said vibrating element is from 0.2° to 0.5°.

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