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[54] **GENERATOR OF MONODISPERSE AEROSOLS**

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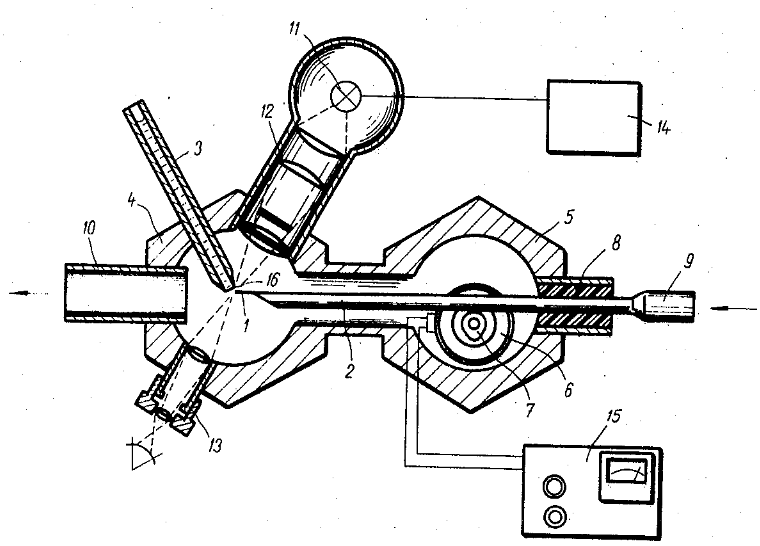
[57] **ABSTRACT**

Generator of monodisperse aerosols, which forms fine droplets of liquid of equal size by breaking a liquid bridge formed from a constant liquid volume between curved contact surfaces comprising a capillary filled with a liquid and having a blade-like projection at the outlet end strand means such as a wire or fiber of which one extremity is attached to an oscillatory or vibrating means or device having a cylindrical portion at the one extremity thereof and which is arranged so as to be located in the dead center of the extreme limits of oscillations, the strand means being a contact with the blade-like projection of the capillary and with the surface level of the liquid in the capillary, and means for directing a supply of a gaseous phase for breaking the liquid bridge located substantially perpendicular to that of the strand motion.

7 Claims, 1 Drawing Figure



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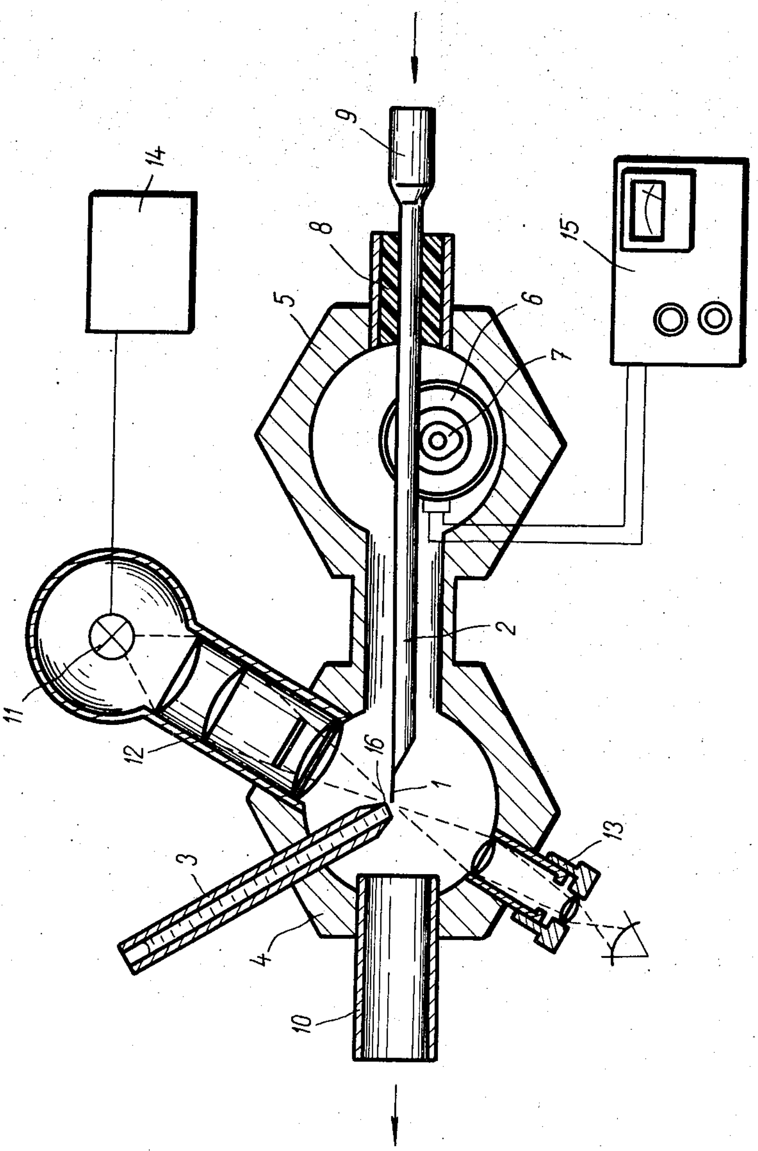

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GENERATOR OF MONODISPERSE AEROSOLS

BACKGROUND OF THE INVENTION

The present invention relates to a generator of monodisperse aerosols, designed to form repeatedly in a mechanical way fine droplets of equal size from a liquid bridge formed from a constant liquid volume between curved contact surfaces, the generator comprising a capillary filled with a liquid and having a blade-like projection at the outer end and strand means such as a wire or fiber of which one end is attached to an oscillatory means or device. The generator takes advantage of a repeated disintegration of the liquid bridge between the cylindrical surface of the filament and a blade-like projection at the outlet end of the capillary to produce fine droplets of equal size, which droplets, after having been mixed with a gaseous phase, form the monodisperse aerosol.

The hitherto used methods of and apparatuses for generating monodisperse aerosols can be divided, on the basis of physical principles, into three main categories, i.e. condensation, dispersion and separation processes.

All the well-known methods and apparatusses have been referred to in professional literature.

Among the aforementioned methods and apparatus it is only those taking advantage of the condensation of vapors of suitable substances for the formation of monodisperse aerosol particles, that have heretofore found a relatively broad utilization. However, such methods and apparatus have many disadvantages, such as, particularly, a limited choice of starting substances to be used for generating monodisperse aerosols, a high concentration of the particles formed which leads to coagulation, only limited control of the particle size and extremely complex technical construction of apparatus which must be able to achieve and maintain with a high preciseness the predetermined values of temperature and gas velocity.

On the other hand, the separation processes based upon successive fractionation of a polydisperse aerosol, are not suitable in those cases where a high degree of monodispersity is required, since they yield a final aerosol having a relatively broad particles size range. Consequently, in view of modern standards, they do not possess, in many cases the desired monodispersive character at all.

The known dispersion methods, due to the complicity of the required apparatus and to a considerable time instability inherent therein, have not yet found a practical utilization, except for apparatus designed to atomize suspensions of previously prepared monodisperse particles, such as, for instance of latex suspension prepared in a controlled styrene polymerizing process.

Laboratory apparatus for preparing a monodisperse aerosol by atomizing a liquid substance which have heretofore been developed and are also referred to in the professional literature, can be divided, on the basis of the principle utilized, into several groups. In those types of apparatus provided with the so-called vibrating capillary, the monodisperse particles are formed by a longitudinal or transverse vibration of the capillary in an alternating electromagnetic field, the frequency of which corresponds to the resonance frequency of the capillary. In the so-called disc generator type utilized for the formation of monodisperse particles, centrifugal forces acting on the edge of a horizontal disc rotating around a vertical axis to the center of which a liquid substance is uniformly supplied are typical.

High complexity is typical of apparatus based upon the utilization of electrostatic charge, since a considerable charge is placed on the generated particles.

In accordance with another method for the preparation of the monodisperse aersols a periodically vibrating needle immersed into a hanging drop of liquid or under the liquid level filling a slot in a sintered glass material has been used.

As mentioned before, the main disadvantages of the above enumerated apparatus consists in structural complexity a considerable time instability, a limited size range with respect to the generated particles, particularly within the submicron region, which according to various authers varies within the range of from 10^{-3} to 10^{-2} cm, and in the impossibility of controlling the size of generated particles.

Some authors do not even refer to the degree of monodispersity, i.e. the relative standard deviation characterizing the width of the size range of the generated aerosol.

The object of the present invention is to overcome the disadvantages of prior art as hereinbefore set forth, utilizing a repeated extracting of droplets by means of a pointed rod from a liquid filling a slot in a porous material, or from a hanging drop, the disadvantages consisting in the impossiblility of extracting droplets smaller than 10 μm even by means of thoroughly ground points on the rails; the low degree of monodispersity and time instability of the size of generated droplets when formed which is caused by a shape indefiniteness of the surface of the porous materials being used, by the vibration of the hanging drops, by the successive evaporation of the solutions being used and by an indefiniteness of the relative position of the pointed rail and the liquid; and in the random size of the generated droplets which depends upon the indefiniteness mentioned hereinabove. It, therefore, is substantially impossible to predetermine the droplet size by a mechanical adjustment of the rod position relative to the porous material or the drop, respectively.

In view of the disadvantages referred to, the above described apparatus types have been used but in the form of experimental laboratory models for the preparation of rough-dispersed aerosols, since they cannot be be either manufactured or utilized on a large scale.

The purpose of the present invention and the basic object of the same is to overcome the aforementioned disadvantages and to provide a significantly improved generator of monodisperse aerosols.

SUMMARY OF THE INVENTION

In accordance with one feature of our invention we provide a generator of monodisperse aerosols for forming repeatedly, in a mechanical way, fine droplets of liquid of equal size by breaking a liquid bridge formed from a constant volume between curved contact surfaces. The generator comprises a capillary filled with a liquid and having a blade-like projection at the outlet end, and a wire or fiber of which one end is attached to an oscillatory or vibrating means or device while having a cylindrical portion at the one end thereof and which is arranged so as to be located in the dead center of the extreme limits of the oscillations, the strand or filament means being a contact with blade-like projection of the capillary and with the level surface of the liquid in the capillary. The generator is fed with a gaseous medium, the supply direction thereof being substantially perpendicular to the direction of the strand movement.

The capillary is conically ground towards its mouth to form circular blade-like projection defining an apex angle varying within the range of from 10° to 120° and preferably from 30° to 45°; while the axes of the fiber and the capillary define an adjustable angle of from 90° to 150°.

According to another feature the generator is provided with a micro-shift device enabling the relative position of strand means and the capillary to be three-dimensionally adjusted along three co-ordinates.

The invention takes advantage of the fact that the generator comprising the capillary filled with a liquid substance, and the strand means, builds, on contact of the strand with the blade-like projection of the capillary and with the level of liquid in the capillary, fine droplets of uniform size from the liquid bridge which is being broken down.

The merit of the invention resides in the fact that it enables the preparation of a monodisperse aerosol with controllable particle size within the range of from 10^{-6} to 10^{-3} cm, the concentration of the particles varying between one and 10^4 per cubic centimeter. The degree of monodispersity (i.e. relative standard deviation) attains values of up to 10^{-3}.

The generator according to the invention enables continuous control of monodisperse aerosol formation, possesses sufficient time stability and permits an easy servicing, operation and adjustment. The generator has small dimensions and is easily portable.

The generator according to the invention can be used especially for calibrating and controlling aerosol analyzers, filtering devices, further for precisely dosing specimen to be subject to spectral analysis, in radiochemistry, medicine, and in research of aerodisperse systems.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages, will be best understood from the following description of the specific embodiment when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing shows a schematic axial sectional view of the monodisperse aerosol generator according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Discussing now the drawing in detail, it will be seen that reference numeral **1** identifies a fiber or strand means, such as, for example a quartz fiber, having a thickness of from 2 to 20 μm and attached to an oscillatory or vibrating device **2** in form of a thin-walled tube of which one extremity is resiliently supported in a silent block **8** and oscillates therein. The free extremity of the fiber **1** attached to the opposite extremity of the tube **2** is adapted to touch, in the dead center of the extreme points of oscillation, a blade-like projection **16** provided at the mouth of a capillary **3**. A transverse oscillatory motion through a cam **7** fixedly attached to the output shaft of an electric in such a manner as motor **6** to rotate therewith is imparted to the tube **2** together with the fiber **1**. The motor **6** is energized with a variable voltage current from a power source **15**. The oscillatory device as a whole as well as the capillary **3** are housed in sealed bores provided in hexagonal support blocks **4** and **5** into which a gaseous medium is forced via flared extremity **9** of the tube **2** extending from the silent block **8**. The arising monodisperse aerosol is withdrawn through an outlet tube **10**. The operation of the aerosol generator, i.e. the formation of aerosol particles, can be inspected through a sight opening provided with an eyepiece **13**, against a dark field by means of an illuminant **12** consisting of an electric lamp **11** energized from a power source **14**.

In operation, the elastic non-metallic fiber **1**, such as a quartz fiber, having a thickness of from 2 to 20 μm, is in a tangential contact with the blade-like projection **16** of the capillary mouth, defining therewith an adjustable angle of from 90° to 150° so that a short cylindrical portion of the filament **1** is immersed partially into the level meniscus of the liquid substance in the capillary **3**. The fiber **1** supported on the oscillatory tube **2** is alternately displaced from its rest position in which it is in contact with the capillary **3**, by means of an electromagnet or cam **7** driven by the electric motor **6**. As the cylindrical portion of the fiber **1** leaves the capillary **3** the liquid substance is at first drawn off, due to the action of surface tension, to the region where the fiber **1** is in contact with the capillary blade-like projection **16**.

The total amount of the drawn liquid is determined by the radius of the fiber **1**, by the radius of the capillary blade-like projection curvature and by the physical characteristics of the liquid substance. Due to the further fiber motion there is formed between the blade **16** and the fiber a liquid bridge which will be broken down into three sections, the lateral sections remaining on the blade-like projection **16** and on the fiber **1**, respectively, while the intermediate section will freely float in the gaseous medium being continuously forced into the space where the oscillatory fiber **1** operates. When, using the cylindrical surface of the fiber **1** of constant radius, and also the capillary **3** having a constant radius with respect to its blade-like projection curvature, it is possible to obtain a constant liquid volume from which the liquid bridge is formed, as well as constant conditions of the disintegration of the latter. Since the angle defined by the fiber **1** and the capillary **3** can be varied, it is possible to adjust also the depth of fiber immersion into the liquid, which depth determines the liquid volume conveyed to the contact region of fiber **1** and the capillary blade-like projection **16**. The position of the fiber **1** relative to the capillary mouth is three-dimensionally adjustable along three coordinates by means of a microshift device, and can be simultaneously inspected in dark field by an illuminating and inspecting system.

Due to the repeated motion of fiber **1**, there arises on every stroke of the fiber away from the capillary mouth a single droplet, a plurality of such droplets of uniform size giving rise, in the supplied gaseous medium, to a disperse system called monodisperse aerosol.

The concentration of the aerosol arising in such a way, i.e., the number of particles per volume unit of the carrying gas, is determined by the frequency of fiber vibrations and by the through-flow volume of the gas per time unit. By varying the aforesaid values it is possible to obtain various concentrations of the monodisperse aerosol. The size of generated droplets is primarily dependent upon the physico-chemical properties of the liquid substance used as well as on the mechanical parameters of both fibers and capillary. However, the size is adjustable, within broad limits, by changing the angle defined by the fiber and the capillary, and by the spatial location of the region of contact of the fiber with the liquid substance in the capillary mouth.

If the capillary is filled qith a solution of any optional substance, there arises, during the generator operation, corresponding droplets from which, by an appropriate choice of the gas vapor tension, the solvent can be evaporated so that it is possible to obtain either crystalline or amorphous solid particles of the equal size and structure. By gradating the concentrations of the dissolved substance used, it is possible to obtain in an easy way respectively graded particle sizes.

It will be understood that each of the elements described above, or two or more together may also find a useful application in other types of constructions differing from the type described above.

While the invention has been illustrated and described as embodied in a generator of monodisperse aerosols, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit and scope of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that from the standpoint of prior art clearly constitute essential characteristic of the generic or specific aspects of this invention and therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be projected by Letters Patent is set forth in the appended claims.

We claim:

1. Generator of monodisperse aerosols which forms in a repetitive mechanical manner fine droplets of liquid of equal size by breaking a liquid bridge formed by a constant volume of liquid dispersed between curved contact surfaces comprising a capillary filled with a liquid and having a blade-like projection at the outlet end thereof, oscillating means having a cylindrical end portion located in the dead center of the extreme limits of oscillatory distance and the opposite end provided with strand means in oscillatory contact with said projection and with the level surface of liquid in said capillary to form a bridge of said liquid and means for carrying gaseous material into contact with and to break said liquid bridge located substantially perpendicular to the direction of movement of said strand means.

2. Generator as defined in claim **1**, wherein the capillary is conically ground at the outlet end to form a circular blade-like projection defining an apex angle varying within the range of from 10° to 120°.

3. Generator as defined in claim **1**, wherein the axes of the strand means and the capillary define an adjustable angle of from **90** to **150**°.

4. Generator as defined in claim **1**, including a microshift device enabling the relative position of the strand means and the capillary to be three-dimensionally adjusted along three co-ordinates.

5. Generator as defined in claim **1** wherein the capillary is conically ground at the outlet end to form a circular blade-like projection defining an apex angle varying within the range of from 30° to 45°.

6. Generator as defined in claim **1** wherein the strand means is a wire.

7. Generator as defined in claim **1** wherein the strand means is a fiber.

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