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Sinclair

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[54] CONTINUOUS FLOW CONDENSATION NUCLEI COUNTER

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[73] Assignee: The United States of America as represented by the United States Atomic Energy Commission, Washington, D.C.

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[51] Int. Cl. G01n 1/00
[58] Field of Search 356/37, 102, 103; 340/236

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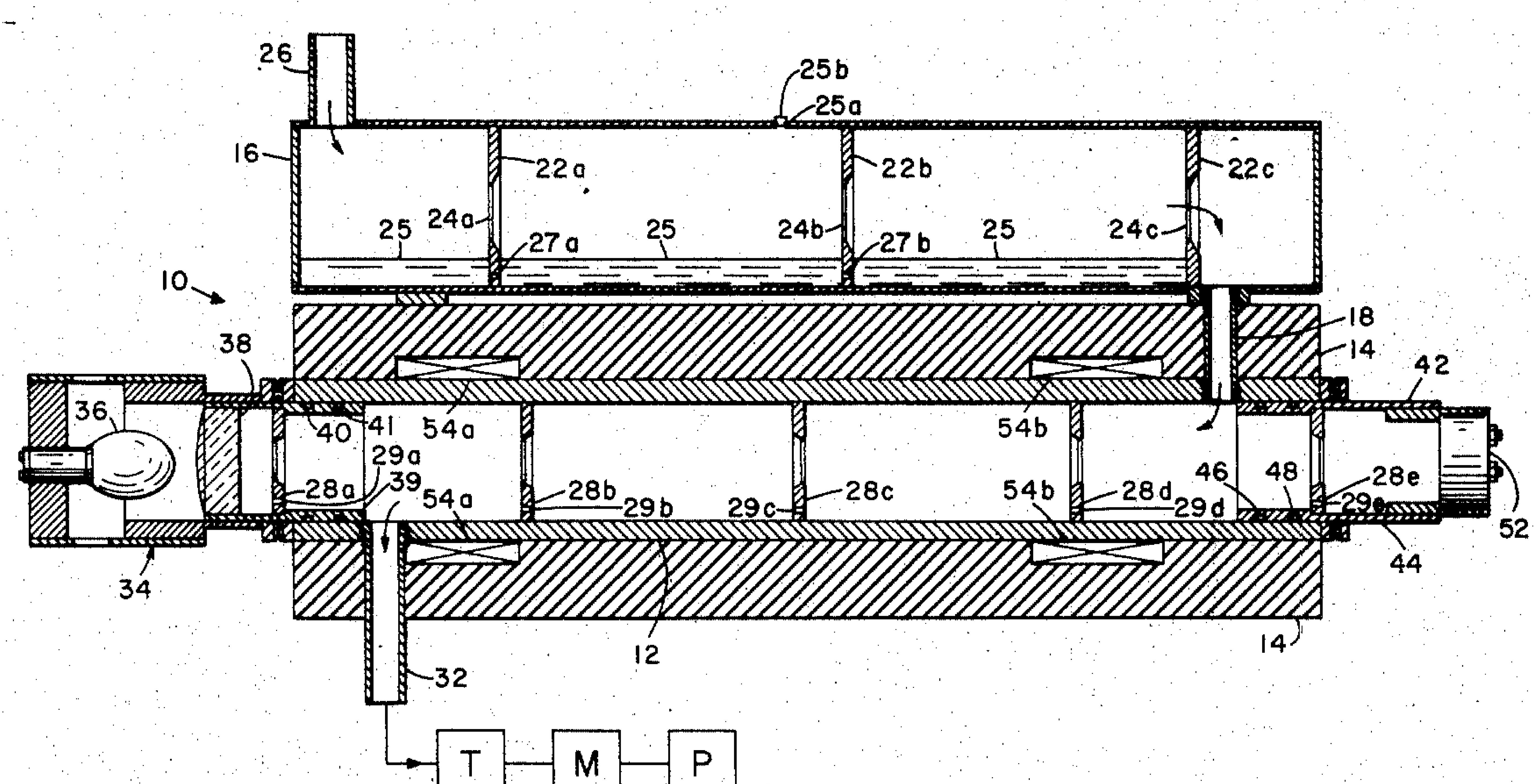
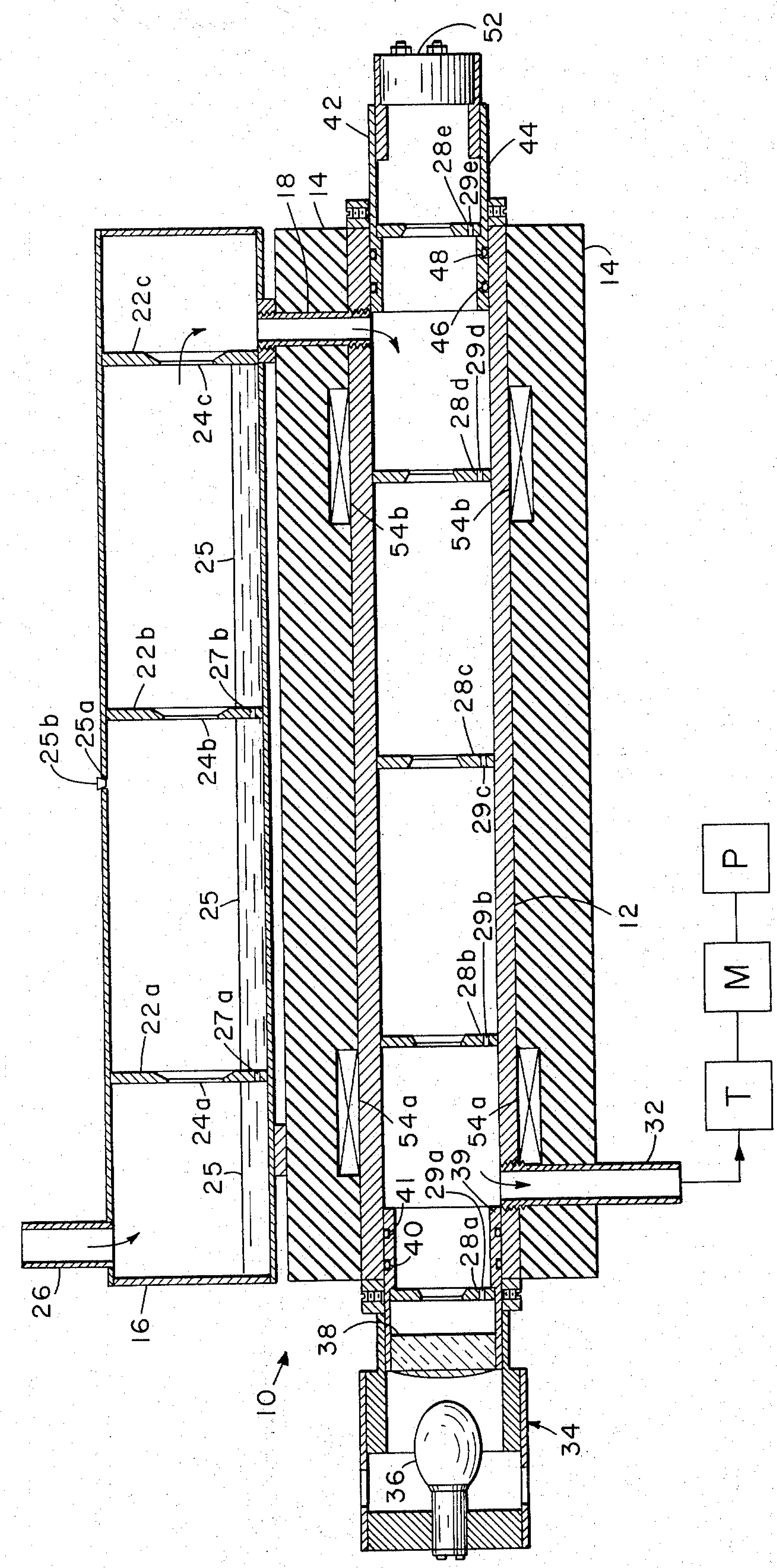
[57] ABSTRACT

A condensation nuclei particle counter for continuous operation capable of condensing out nuclei within the range of 0.002–0.1 micrometers. The aerosol is humidified by a pool of an alcohol or other volatile liquid of low freezing point and then condensed in a chamber whose walls are maintained at a temperature of −10° to −20° C. A light beam is passed through the resultant fog and the attenuation is measured as an indication of the particle density.

5 Claims, 1 Drawing Figure

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CONTINUOUS FLOW CONDENSATION NUCLEI COUNTER

BACKGROUND OF THE INVENTION

The invention described herein was made in the course of employment with the U.S. Atomic Energy Commission.

During recent years there has been increased interest in the analysis and measurement of sub-micron aerosols. Those aerosols, generally referred to as condensation nuclei, are of particular concern because they are believed to be the progenitors of a variety of larger aerosols such as cloud, fog, smog, dust, and haze in which there is a great deal of concern. The size range of particular interest for the condensation nuclei is 0.002 to 0.1 micrometers.

Conventional apparatus such as light-scattering photometers and light microscopes are not capable of measuring particulates of such small size. Furthermore, techniques which can be employed in the measurement of such small particles do not conveniently lend themselves to continuous on-line operation and are generally too inconvenient and too complicated to employ on a regular basis for monitoring atmospheric conditions. Continuously operating devices which have been developed lack sufficient portability which would permit on short notice the measurement of aerosol conditions at different locations. Furthermore, a continuous operating device which has been developed requires the use of a secondary flow of cold air to bring the temperature of the aerosol down to proper supersaturating conditions and it has been found that such an arrangement will not measure particles present down to 0.002 micrometers diameter.

SUMMARY OF THE PRESENT INVENTION

Many of the aforementioned problems are overcome by the present invention in which it is possible to measure aerosols in the sub-micron range of 0.002 to 0.1 micrometers on a continuous basis, with little difficulty and inconvenience, and with great accuracy. An additional feature of this invention is that the apparatus is such that it can be moved to different locations quickly and with a minimum of inconvenience.

Briefly described, a preferred embodiment of this invention consists of a chamber wherein the aerosol of interest is mixed with a suitable condensable vapor such as an alcohol, and another chamber maintained at a substantially lower temperature into which the mixture passes for cooling to supersaturation and formation of a fog. By substantially lower temperature is meant a temperature low enough to cause the fog to form about the nuclei. The chambers are provided with turbulence producing baffles and a detection system for measuring the visible concentration of the fog. The detection system may consist of a light source at an end of the cold chamber and a light detection and measuring device such as a photo cell at the other end to sense the light attenuation caused by the fog. The apparatus is continuously operating, that is, fresh aerosol is continuously drawn in and exhausted. Typically, the nuclei counter would be used in conjunction with an aerosol measuring system such as a diffusion battery to measure particle size and size distribution.

It is thus a principal object of this invention to provide a continuous flow particle counter for determining nuclei concentration and size in the sub-microscopic particle size range.

Other objects and advantages of this invention will hereinafter become evident from the following description of a preferred embodiment of this invention.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE illustrates an elevation view in section of a preferred embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the FIGURE, counter **10** consists of an elongated housing **12** which may be rectangular or circular in cross section surrounded by a layer of thermal insulation **14.** A cylindrical container **16** is mounted above housing **12** with an access tube **18** providing communication as illustrated between end chambers within these two members.

Container **16** is divided into several chambers by baffles *22a*, *22b* and *22c* each of which is provided with an axial opening *24a*, *24b* and *24c*, respectively. For reasons which will be apparent later, a liquid pool **25** is provided in all of the chambers, except, of course, the end chamber having access tube **18.** The liquid making up pool **25** is any liquid which will evaporate under the conditions described and condense when cooled to form a fog. The bottoms of baffles *22a* and *22b* are provided with small openings *27a* and *27b*, respectively, to provide a uniform level of said pool. Liquid is inserted through a small opening 25a which may be closed with a stopper *25b*. There is provided an aerosol inlet tube **26** to a chamber of container **16** at the upstream or opposite end of the latter from access tube **18.**

Container **12** is divided into chambers by baffles *28a–28e* having openings as illustrated. The bottoms of baffles *28a–28e* are provided with small openings *29a–29e*, respectively, to permit drainage of condensed vapor. An exhaust tube **32,** to carry away the mixture, is connected to a liquid trap T, a flow meter M, and the suction side of an air pump P to draw the aerosol through inlet tube **26** and chambers **16** and **12** as already described. Flow of the aerosol is indicated by arrows.

Extending from the downstream end of housing **12** is an assembly **34** containing an electric lamp **36** and a lens **38** mounted on a sleeve **39** with O-rings **40** and **41.** When lamp **36** is energized, light is directed by lens **38** down through the length of housing **12,** passing through the central openings in baffles *28a–28e*.

At the upstream end of container **12** is a photocell and window assembly **42** which comprises a sleeve **44** with O-rings **46** and **48,** baffle *28e*, and photocell unit **52.** The latter measures the light received from lamp **36,** and as is understood in the art, suitable apparatus (not shown) is provided to record and/or indicate the intensity of the light received by photocell unit **52.**

In order to maintain housing **12** at the proper operating temperature, wrapped around the walls of housing **12** may be refrigeration coils or thermo-electric cooling modules *54a*, *54b*, etc., disposed at suitable locations on the outside of the walls of housing **12,** as shown.

In the operation of the apparatus described, the aerosol, the extent of whose condensation nuclei is to be measured, enters counter **10** by way of inlet tube **26** and passes down through the length of container **16.** The aerosol mixes with the vapors of the liquid making up pool 25, baffles 24*a*–24*c* acting to promote turbulence thereby increasing the extent to which the mixing takes place and forming a near saturated mixture. At the downstream end of container 16 the gaseous mixture passes into housing 12 by way of access tube 18 and flows the length of housing 12 at the downstream end of which the mixture leaves by way of exhaust tube 32. Baffles 28*a*–28*e* similarly promote turbulence and thorough mixing within the chambers. The walls of housing 12 are maintained at a suitable lower temperature such that the gaseous mixture is cooled sufficiently to become super-saturated, a fog being formed due to the presence of the nuclei in the aerosol. The turbulence caused by baffles 28*a*–28*e* enhances heat transfer between the walls of housing 12 and the gaseous mixture, insuring an adequate low temperature throughout the gaseous fluid.

The resulting fog attenuates the light passing from lamp 36 to photocell unit 52 and the observed or recorded intensity of the light is a direct indication of the number of particles within the aerosol.

Counter 10 is calibrated by running aerosols of known particulate content through the apparatus.

An important aspect of this invention involves the maintenance of sufficiently high saturation under dynamic conditions in contrast to the static conditions found in other such devices during humidification and temperature equalization of the sample. This effect is enhanced in the present invention by utilizing as the liquid in pool 25 an alcohol, preferably ethanol, and maintaining the temperature of the walls of housing 12 in the range of about −10°C. to −20°C.

EXAMPLE

A counter was constructed with container 16 made from a copper tube 30.5 cm long and 5.1 cm diameter containing a 1 cm deep pool of ethyl alcohol. Housing 12 was made from copper, with a length of 30.5 cm and an inside diameter of 3.8 cm with 1.3 cm walls. Aerosol flow rate was 4 liters/min. with the time of exposure about nine seconds in container 16 and five seconds in housing 12. The wall of the latter was maintained in the −10°C. to −20°C. temperature range. This counter was able to produce a fog out of nuclei down to about 0.002 micrometers diameter.

An important feature of this invention is that it provides continuous flow counting, in contrast to conventional nuclei counters which operate by intermittent sampling and adiabatic expansion. Diffusion batteries, which are essential for rapid measurement of these sizes, require constant flow of aerosol.

What is claimed is:

1. A continuous flow particle counter for determining the nuclei concentration of an aerosol comprising:

a. means forming a first chamber for mixing therein said aerosol with a condensable vapor, said chamber containing a pool of the aforesaid condensed vapor, said mixing taking place above said pool;
b. means forming a second chamber whose walls are maintained at a temperature substantially lower than the temperature within said first chamber;
c. means for continuously delivering a mixture of said aerosol and vapor from said first chamber into said second chamber where a visible fog is formed from said mixture due to the cooling effect on the walls of said second chamber;
d. means for continuously withdrawing mixture from said second chamber; and
e. means for continuously detecting the visible nuclei concentration of said fog.

2. The counter of claim 1 having means for maintaining turbulent flow conditions within said chambers.

3. The counter of claim 2 in which said condensable vapor is an alcohol.

4. The counter of claim 3 in which the walls of said second chamber are maintained at a temperature of −10° to −20°C.

5. The counter of claim 2 in which said detecting means comprises a light source and means for measuring light from said light source after passing through said second chamber, whereby the fog within said second chamber attenuates the light passing through.

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