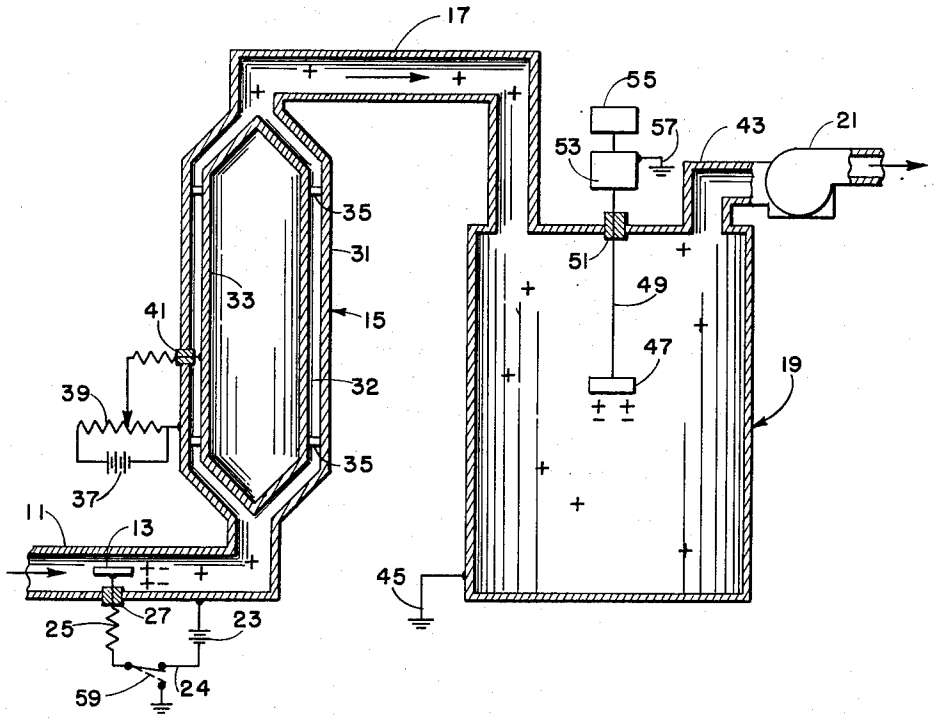
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MONITOR AND SPECTROMETER FOR ATMOSPHERIC PARTICULATE MATTER

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MONITOR AND SPECTROMETER FOR ATMOSPHERIC PARTICULATE MATTER

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This invention relates to a monitor and spectrometer device for indicating the total concentration in the atmosphere of particles below any desired maximum mobility level. This monitor is for example particularly useful in the determination of concentrations and the distribution of sizes of suspended particles in the atmosphere.

U.S. Patent 2,986,923 of Bernard Vonnegut, one of the present applicants, describes an apparatus for detecting and measuring aerosols. In that apparatus, no special provision is made for the removal of the fast charging ions. In the apparatus of the present invention, however, an electric field is imposed in an ion filter that causes the charging ions to move in a controlled fashion. Movement of the fast ions is thus controlled independently. This apparatus therefore makes it possible to obtain the approximate spectra of particle size, in the sample of gaseous fluid being examined, from the mobility of the charged particles.

This device is furthermore very well suited for continuous measurement of the concentrations of atmospheric particles of any desired size range.

Ability to predict the incidence of fog is of particular importance in air navigation and operation. High humidity alone does not necessarily bring about fog conditions. However, if high humidity—say 90%,—is accompanied by a large concentration in the atmosphere of particles detectable by the apparatus of this invention, a high obscuring fog is very likely to follow. With such forecasting, suitable precautions can be taken, and preparations made, before the fog occurs.

The device of this invention operates by electrically charging incoming airborne particulate matter to the maximum that can be accepted (under the set conditions), removing all excess charging ions and then measuring the resulting charge concentrations. The apparatus consists of (1) a suction fan or other suitable means for introducing air into the intake, (2) a charging section in which large quantities of fast, gaseous ions are produced in a potential gradient so that passing particles acquire a net charge of one polarity, (3) an ion filter section where all fast ions and charged particles with mobilities greater than some preset value are removed by electrostatic precipitation and (4) a Faraday cage in which the potential produced by the net mean charge concentration on the remaining particles is measured continuously with an electrometer.

This invention will now be described in detail in connection with the accompanying drawing, which is a partially schematic side elevation of a typical form of the apparatus, and is to be considered as illustrative rather than limiting.

The apparatus shown in the drawing comprises a duct **11** for incoming air, or other gas, to be examined, a radioactive particle charging device **13** in duct **11**, an ion filter **15** into which the duct discharges, an outlet duct **17** leading from filter **15**, a Faraday cage **19** into which duct **17** discharges, and an exhaust fan **21** connected to cage **19** and arranged to move the air or gas through the system.

A suitable potential is applied to charging device **13** by battery or other power source **23** connected across charging device **13** and the walls of duct **11** through a

protective resistance **25**. The lead-in wire to charging device **13** is suitably insulated from the duct walls, as by insulator **27**. Ion filter **15** comprises an outer electrode **31**, an inner electrode **33** mounted concentrically therewith and providing space **32** therebetween, and supported in position by insulating spacers **35**, and a battery or other power source **37** connected across the two electrodes through a variable resistance **39**. An insulator **41** is provided in the wall of the outer electrode **31** where the electrical circuit passes through the latter.

Duct **17** leads to Faraday cage **19** which is provided with an outlet duct **43** leading to fan **21**. The cage is grounded, as at **45**. It contains an element **47** adapted to measure the electric charge concentration, e.g. a polonium particles source located in the center and supported on a conductive metal probe **49** mounted through insulator **51** and connected to an electrometer **53** which in turn operates a recording galvanometer **55** and is grounded as at **57**.

Elbows making 90° turns are placed in each of the ducts **11**, **17** and **43**, as shown, so as to eliminate electrostatic interactions between sections (i.e. between each of elements **13**, **15**, **19** and **21**).

Large quantities of gaseous ions can be produced by applying high potentials to points, to flames and to radioactive sources. The latter method is chosen for the purposes of this invention, for reasons for stability and freedom from contamination after experiences with the first two. With a point at potentials greater than about 4 kv. large quantities of ions of one polarity can be produced; a supply of unipolar ions is very desirable for this instrument. The potentials necessary, however, are sufficient to precipitate some of the incoming particulate matter. The instrument response varies with any variation in potential on the point to some high power so that a closely regulated high voltage power supply is necessary. For these reasons, charging from point discharge is not suitable for use with the present apparatus.

Flames have been used for particle charging; however, the production of particulate matter by combustion is a drawback, unless hydrogen flames are used and the water produced is not allowed to condense. The difficulty and possible hazards with unattended flames can be appreciable. Hence, flames are unsuitable here also.

The technique of particle charging by the use of radioactive elements is as follows: three 500 microcurie polonium strips were mounted at **13** to form a triangular prism with the active sides facing outward. The prism was located in the center of a 10 cm. diameter metal duct **11** on Teflon insulator **27**. Potentials from an external supply **23** could be placed on the prism relative to the duct wall by use of a Teflon insulated wire **24**. The potential can be varied as desired by resistance **25** which may be of a predetermined value or may be a variable resistance.

The polonium strips (with a half life of 125 days) emit (when new) about 5×10^7 alpha particles per second and each of these produces about 3×10^4 ion pairs in a 5 cm. path of air (the range of the alpha particles). Under the influence of an applied potential difference between the source and the walls, the ions migrate perpendicularly to the axis of the duct. Particles in the air being drawn through the apparatus become charged as a result of the ion current and the potential differance in a manner somewhat similar to Wilson's mechanism explaining the charging of raindrops. The can be demonstrated to be the case even though the ions of both polarities are initially produced in identical quantities (if we neglect the positively charged alpha particles).

Charging potentials may be as low as 80–90 volts, but we find that most satisfactory results are attained at

150–200 volts. Much higher potentials can in fact be used, e.g. 500 to 1000 volts, but they give poorer results and obviously require more complex equipment.

The upper limit of mobility for a particle passing through the ion filter **15** can be determined by equating the time required for a particle to flow through the filter to the time required for an ion to drift across the annular space **32** to the collecting electrode under the influence of the potential applied across the two electrodes **31** and **33**.

From this we find that the product of the upper limit of particle mobility and the potential difference equals the ion filter figure of merit which is the product of the air flow rate times the natural logarithm of the ratio of the larger radius of the filter annulus to the smaller radius and this product divided by 2π times the length of the filter.

If for example ion filter **15** has an inner (collecting) electrode (**33**) length of one meter and outside radius of 15.3 cm., and the inside radius of the outer electrode **35** is 16.5 cm., with an air flow of 14 liters per second, the filter figure of merit equals 1.7 $cm.^2$ $sec.^{-1}$. This means that if 100 volts potential difference were placed across the ion filter, all ions with mobilities of greater than 1.7/100 or 0.017 cm. $sec.^{-1}$ per volt $cm.^{-1}$ would be removed from the gas. The maximum potential applicable across the filter is that value above which the electrodes produce spark discharges which create spurious ions. For the filter given in the example above, the maximum potential across space **32** is about 5 kv. Above this value, spark discharges occur and spurious ions are produced.

When the ion filter **15** is arranged to remove all ions with mobilities greater than 3×10^{-4} cm. $sec.^{-1}$ per volt $cm.^{-1}$, then few charged particles produced in the charging section at **11** should pass into the Faraday cage **19** unless the particles are larger than 0.05 micron. We find that condensation nuclei and other particles in the normal clean atmosphere produce relatively small signals in the apparatus under these conditions, but when the air becomes hazy the electrometer response appears to vary directly with the observed haze obstructions to visibility. The monitor of this invention gave indications that closely paralleled those of the condensation nuclei apparatus described in U.S. Patent 2,684,008 (issued to one of the present inventors) when the filter-pass mobility upper limit was set at 5×10^{-2} cm. $sec.^{-1}$ per volt $cm.^{-1}$.

Faraday cage **19** is an enclosure having electrically conductive walls and conveniently of cylindrical shape. Element **47** is for example a 500 microcurie polonium element, and is mounted and connected as already described. Other types of field-measuring such as a field mill, can be used alternatively, for measuring the field in the Faraday cage.

The space charge imposed upon atmospheric particulate matter by charging device **13** causes a potential to exist in the center of Faraday cage **19** relative to the walls. This potential is measured by electrometer **53** and a record thereof is made by recording galvanometer **55**. For most sensitive measurement, element **47** should be substantially centrally located in the cage **19**, i.e. so that it is not appreciably nearer to any one conducting wall than to another.

The difference in the work functions of the conducting walls of the Faraday cage and the probe at the center of the cage can give an appreciable but spurious signal indicating the presence of charged particles even in their absence. This effect is eliminated by a periodic grounding of the charging section by means of switch **59**, a

single-pole, double-throw type inserted in electric circuit wire **24** so that incoming particles no longer acquire a net charge and thus the effect of "no particulate matter" is simulated and shown on the recording as a zero indication.

Fan **21** or equivalent gas-impelling means should be located at the exhaust end of the system to avoid contamination of the gas under study. The gas may however be impelled in other ways, such as by moving the apparatus with respect to the surrounding gaseous atmosphere. This may be accomplished, for example, by means of a rising balloon, or by use of a moving vehicle or ship, by which the apparatus is carried.

We claim:

1. A device for indicating the total concentration of particles in a gaseous fluid comprising:
   - (*a*) an ion filter comprising a pair of concentrically arranged electrically conductive walls between which said fluid flows,
   - (*b*) means for imposing an electric potential between said conductive walls,
   - (*c*) an inlet duct leading to said ion filter and arranged to receive said gaseous fluid for testing,
   - (*d*) a radioactive particle charging element in said inlet duct,
   - (*e*) means comprising an electric circuit for imposing an electric potential between said element and the walls of said inlet duct,
   - (*f*) a Faraday cage containing means for measuring the electric charge concentration in the gaseous fluid flowing through said cage,
   - (*g*) a second duct leading from said ion filter to said Faraday cage, and
   - (*h*) an exhaust duct leading out of said Faraday cage;
   - (*i*) the electric potential between the walls of said ion filter being sufficient to remove substantially all the fast charging ions in said gaseous fluid passing through said ion filter,
   - (*j*) each of said ducts being provided with turns whereby electrostatic interactions between any of said particle changing element, said ion filter, and said Faraday cage are prevented.

2. A device in accordance with claim 1 further characterized in that said radioactive particle-charging element is polonium.

3. A device in accordance with claim 1 further characterized that said measuring means in said Faraday cage is a radioactive particle source and an electrometer connected thereto.

4. A device in accordance with claim 1 further characterized in that a fan is provided in said exhaust duct which impels the gaseous fluid through said device.

5. A device in accordance with claim 1 further characterized in that each of said ducts contains a 90 degree turn.

6. A device in accordance with claim 1 further characterized in that a switch is provided, adapted to ground said electric circuit periodically as desired.

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