Dec. 14, 1965 R. D. KRACKE ETAL 3,222,925

APPARATUS FOR THE CLASSIFICATION AND EVALUATION OF FALLOUT FROM AEROSOLS

Filed June 25, 1959

Fig. 1

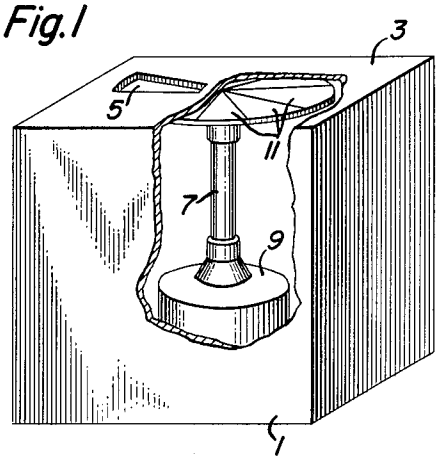


Fig. 2

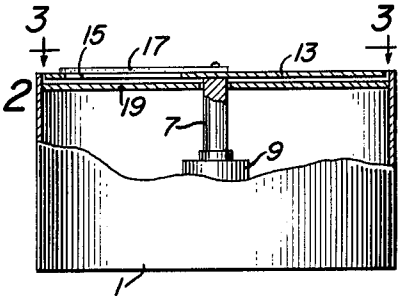


Fig. 3

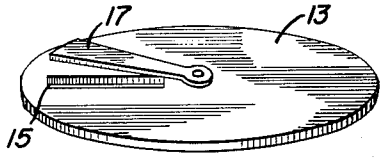


Fig. 5

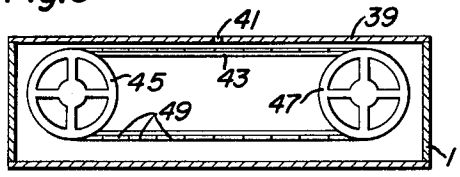
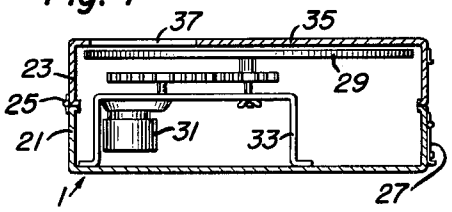


Fig. 4



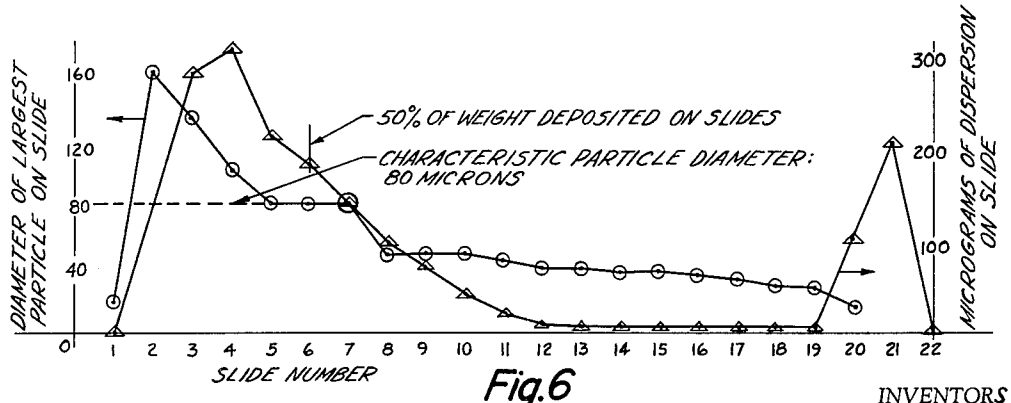


Fig. 6

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APPARATUS FOR THE CLASSIFICATION AND EVALUATION OF FALLOUT FROM AEROSOLS

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6 Claims. (Cl. 73—170)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalty thereon.

This invention relates to an apparatus for classifying fine particles that have been produced at a given time, e.g. by an explosion, according to size (or, more strictly speaking, according to their rate of fall in air) in order to determine their particle size distribution and to make other types of studies. The method is based on the fact that if a cloud of fine particles is generated at a given instant, the particles of highest terminal settling velocity in air will settle out first. For particles of the same density, these will be the largest particles. When the particles vary in density as well as size the situation is more complicated. We deal primarily with particles having substantially the same density. In this situation, and assuming Stokes' Law to apply, the settling velocity is proportional to the square of the particle diameter.

We sample and classify the particles according to particle size by allowing them to settle freely through a slot formed in a relatively thin horizontal plate onto a moving collecting surface positioned directly beneath the slot. Assuming the dispersion of particles to have been generated at a given time, e.g., by the explosion of a bomb or the release of a batch of particulate material, the largest particles are deposited first and the smaller particles in decreasing order of size along the surface as it moves beneath the slot. By combined microscopic and gravimetric, or analytical, methods we can make various analyses of the particle size distribution of the dispersion.

We have devised several forms of apparatus, which may be termed "fallout meters," for carrying out our method. In particular we have devised apparatus having different types of slots which give different types of distribution of the particles on the collecting surface.

In the drawing FIG. 1 is a perspective view of one embodiment of a fallout meter embodying our invention;

FIG. 2 is a side elevation, partially in section, of another embodiment of our invention.

FIG. 3 is a perspective view of the cover plate of the modification of FIG. 2.

FIG. 4 is a vertical section of an apparatus of the general type shown in FIG. 1, but illustrating certain mechanical features.

FIG. 5 is a vertical section of still another type of apparatus.

FIG. 6 is a graph showing the application of data obtained by our method.

In the modification shown in FIG. 1, the casing **1** is provided with a stationary top plate **3** having an unobstructed upper surface and an opening **5**. Within the casing is a rotor **7**, driven at a uniform speed by a motor **9** and having a top plate which preferably is formed of or carries separate slides **11**.

In the modification of FIG. 2 the casing **1** is open at its top. The rotor **7** carries a rotary top plate **13** which is provided with an opening **15** and a pivoted shutter **17**. A stationary collecting plate **19** is supported directly beneath rotary top plate **13**. It preferably carries slides (not shown) of the same type as slides **11** of FIG. 1.

Attention is now called to openings **5** and **15**. Opening

5 (FIG. 1) is shown with radial sides and arcuate ends. This gives a uniform concentration of particles over the entire radial extent of a given slide. FIGURE 3 shows opening **15** of FIG. 2 formed with parallel sides. This form of opening gives a concentration gradient radially of the slide with the greatest concentration at the inner end of the opening and the least concentration at the outer end. In each form the center line of the elongated opening or slot is substantially radial. Either form of opening may be used with either the stationary top plate and rotary collecting surface of FIG. 1 or the rotary top plate and stationary collecting surface shown in FIGS. 2 and 3. The shutter **17** may also be used on either of these modifications, as well as on those described hereinafter.

FIG. 4 shows a variation of the embodiment of FIG. 1, which is particularly adapted for use in the field. The casing **1** is formed of a base **21** and a cover **23**, which are hinged together at **25** and are provided with a latch **27** (shown in the open position) which may fasten the two parts together, suitcase fashion. The rotary collecting plate **29** is driven by a spring driven clockwork, **31**. The collecting plate **29** and clockwork **31** are mounted on a bracket **33** within the base **21**. The cover member **23** has a top plate **35** provided with an opening **37** which may be of either of the two forms described above.

FIGURE 5 shows still another type of apparatus included in our invention. This instrument, like that of FIGS. 1 and 4 includes a casing **1** having an unobstructed stationary top plate **39** in which there is an elongated opening **41**. Within the casing **1** is an endless belt **43** carried by pulleys **45**, **47** and driven at a uniform speed by a suitable motor (not shown). The belt **43** carries a plurality of removable slides, **49**. The upper run of the belt and the slides carried thereby are parallel to plate **39**.

Opening **41** is a slot extending transversly of belt **43**. It may be rectangular, like slot **15**, FIG. 3, or tapered, similar to slot **5**, FIG. 1. The effects of the two shapes are, however, exactly opposite to those in the former modifications. Since the velocity of belt **43** is uniform from side to side, the use of a wedge shaped opening will give a concentration gradient across the slide while a rectangular opening will give even distribution.

The underlying principle governing the shape of the slot is as follows. If the ratio of the width of the slot to the amount of movement, in a given time, of the collecting surface relative to the slot, is the same throughout the length of the slot, the concentration of particles will be constant along the length of the slot. This condition is satisfied, in the rotary species, by a slot having radial sides. In the species having rectilinear movements it is satisfied by a rectangular slot. If the ratio of slot width to the amount of movement in a given period of time varies in a regular manner from one end to the other of the slot, the concentration will vary in the same manner.

The use of the type of slot giving a concentration gradient gives advantages in making microscopic studies of the collected particles, particularly when counts are to be made on the slides. The concentration may vary along the slot from that at which the particles are too crowded to be individually distinguishable to that at which they are too scattered to obtain a satisfactory count or a representative sampling as to size. At some intermediate point, the optimum concentration will be found. This simplifies experiment by making it feasible to employ a given size of slot and a given speed of movement over a wide range of conditions.

The manner in which our method is carried out is as follows. At the proper time after the aerosol has been formed, e.g., by explosion of a bomb or by some other means forming a cloud at a given time, the apparatus is set in operation by, e.g., moving shutter **17** aside while the motor **9** is running, and the particles are allowed to

settle freely through the slot onto the collecting surface. Since the surface of the top plate (3, 13, 35 or 39) is unobstructed and since no suction or other disturbing influence is present a true settling sample is obtained. Successive slides (11 or 49) will receive particles of successively smaller particle size. The average (or some other characteristic) particle diameter is determined for each slide by, e.g. microscopic measurement and the amount settled on the slide (or some properly selected portion thereof) is determined by weight, by chemical analysis, or by counting the number of particles. When a slot giving a concentration gradient across the slide is employed, an initial inspection may be given to determine the optimum position for the measurements. For example, using the apparatus of FIGS. 2 and 3, it might be found that at the radius of about the midpoint of slot 15 the majority of the slides gave the optimum concentration. The particles in, say, a square centimeter on each slide at this radius might then be counted and plotted as to size. A complete tabulation or plot of the data would then show the particle size distribution.

A typical procedure will now be described, illustrated by FIG. 6. The apparatus employed was that of the type shown in FIG. 1 with the opening having radial sides. An aerosol of dibutyl phthalate was generated in the upper part of a chamber by a sudden burst from a two-fluid atomizer and the collector set in to operation at the same time, running at such a speed that the fallout was collected on slides 1 thru 19 over a period of about 2½ minutes. The fallout meter was then stopped and settling allowed to continue for several hours on slides 20 and 21. The slides were then removed and each was scanned with a microscope to locate and measure the largest particle. (Since the particles are to a large degree separated according to size, we have found that this observation, which might appear to be very tedious can actually be made quite quickly.)

The diameter of the largest particle on each slide is plotted as the ordinate on FIG. 6, with the slide number as the abscissa. The points of this curve are marked with circles on FIG. 6 and the ordinates are those marked on the scale at the left of the graph, as indicated by the arrow attached to the curve.

Each slide was then individually washed and the amount of material deposited on each slide was determined by chemical analysis of the washings. These values are plotted on FIG. 6, the points on the curve being marked by triangles. The ordinates are given on the scale at the right. These curves given a quick visual comparison of the amount of material found in particles of various sizes.

The results may be expressed quantitatively in various ways. One value that is very useful and readily determined is the "characteristic particle diameter" of the aerosol. The weights of materials on the various slides are accumulated, i.e., the amount on slides 1 and 2, slides 1, 2 and 3, up to, finally, slides 1–22. The slide at which half of the material had been collected is then noted (in this case, slide No. 6. The diameter of the largest particle on that slide is taken as the "characteristic particle diameter" of the aerosol.

The above discussion has been based on the situation in which the aerosol cloud is positioned considerably above the fallout meter. In the field, it would represent, for example, conditions following a nuclear bomb explosion or the dissemination of an aerosol by an airplane.

In some situations it is necessary to assay the particle size distribution in well mixed aerosols in which the cloud extends down to the fallout meter. In the field, this would represent the conditions following the dissemination of an aerosol by a generator located at or near ground level. In such a case the separation by particle size is not complete, since a small particle near the bottom of the cloud will reach the meter at the same time as a larger particle at a higher elevation. The differential settling still reveals itself, however, by the *absence* of successively

smaller particles. Thus at a certain time *all* of the particles above 100 microns diameter will have settled out, at a later time *all* of the particles above 50 microns diameter, etc. The time in each case will be that for a specified particle to settle from the *top* of the cloud.

In this case, the experiment is carried out in exactly the same manner as described above, but a different mathematical treatment is applied. First, convenient size categories are chosen which might, for example, be

(A) Over 160 microns diameter
(B) 120–160 microns diameter
(C) 80–120 microns diameter
(D) 40–80 microns diameter
(E) Under 40 microns diameter.

After determining the largest particle on each slide we may tabulate the slides in the following manner (using assumed values).

Slide numbers:	Largest particle falls in class
1 and 2	A
3, 4 and 5	B
6 and 7	C
8, 9, 10, 11 and 12	D
13, 14, 15, 16, 17, 18, 19 and 20	E

We determine, by weighing or by chemical analysis, the weight of material found on each *group* of slides. We then determine the weight of particles of each class as follows. It will be noted that slides 1 and 2 carry particles of all classes, i.e., A, B, C, D and E, while slides 3, 4 and 5 carry particles of classes B, C, D and E. Since each slide represents a certain period of time, and since the settling velocity of particles B, C, D and E is the same during the exposure of slides 1–2 as during slides 3, 4 and 5, we may assume that the average weight of material of classes, B, C, D and E on each of slides 1 and 2 is the same as the average of each of slides 3, 4, and 5 or: Weight of class B, C, D and E on slides 1 and 2=⅔ wt. of total material on slides 3, 4 and 5.

Then:

$$\text{Wt. } A = \textit{Wt.}\ 1, 2 - \tfrac{2}{3}\ \text{Wt. } 3, 4, 5$$

Where,

Wt. A=weight of particles of class A
Wt. 1, 2=weight of material on slides 1 and 2
Wt. 3, 4, 5=weight of material on slides 3, 4 and 5.

Particles of class B are found in slides 1–5.

Then:

$$\text{Wt. } B = \text{Wt. } BCDE_{(1,2)} + \text{Wt. } 3, 4, 5 - \text{Wt. } CDE_{(1-5)}$$

wherein the subscripts indicate the numbers of the slides on which weights are taken.

We have already assumed: Wt. $DCDE_{(1,2)}$=⅔ Wt. 3, 4, 5 and may now assume Wt. $CDE_{(1-5)}$=½ Wt. 6, 7 so that

$$\text{Wt. } B = \tfrac{5}{3}\ \text{Wt. } 3, 4, 5 - \tfrac{1}{2}\ \text{Wt. } 6, 7$$
$$= \tfrac{5}{3}\ (\text{Wt. } 3, 4, 5 - \tfrac{3}{2}\ \text{Wt. } 6, 7)$$

By similar derivation

$$\text{Wt. } C = \tfrac{7}{2}\ \text{Wt. } 6, 7 - \tfrac{7}{5}\ \text{Wt. } 8\text{–}12$$
$$= \tfrac{7}{2}\ (\text{Wt. } 6, 7 - \tfrac{2}{5}\ \text{Wt. } 8\text{–}12)$$

$$\text{Wt. } D = 1\tfrac{1}{5}\ \text{Wt. } 8\text{–}12 - 1\tfrac{1}{8}\ \text{Wt. } 13\text{–}20$$
$$= 1\tfrac{1}{5}\ (\text{Wt. } 8\text{–}12 - \tfrac{5}{8}\ \text{Wt. } 13\text{–}20)$$

$$\text{Wt. } E = 2\tfrac{0}{8}\ \text{Wt. } 13\text{–}20$$

The values will, of course, be correct only to the extent that the assumptions are correct, the principal ones being that the clouds are homogenous. To detect and compensate for lack of homogenity it will be necessary to use a plurality of instruments arranged in a two dimensional or three dimensional grid. The simplicity of our instruments make them readily adaptable to such arrangements.

We claim:

1. A fallout meter comprising a plate having an unobstructed upper surface and having an elongated slot

therethrough, a supporting surface positioned closely adjacent and beneath said plate, flat collecting members carried by said supporting surface and means producing relative movement between said plate and said supporting surface at a constant rate in a direction transverse to the major dimension of said slot, said slot being so proportioned that the ratio of the width of said slot to the amount of movement in a given time is constant throughout the length of said slot.

2. A fallout meter comprising a plate having an unobstructed upper surface and having an elongated slot therethrough, a supporting surface positioned closely adjacent and beneath said plate, flat collecting members carried by said supporting surface and means producing relative movement between said plate and said supporting surface at a constant rate in a direction transverse to the major dimension of said slot, said slot being so proportioned that the ratio of the width of said slot to the amount of movement in a given time continuously varies in a regular move from one end of said slot to the other.

3. A fallout meter comprising a rotary plate, flat sector-shaped collecting members carried by said plate, a flat plate having an unobstructed upper surface positioned closely above and parallel to said rotary plate, means for supporting said rotary plate and said flat plate in a substantially horizontal position, means for producing relative rotation between said rotary plate and said flat plate about an axis perpendicular to said flat plate and surface, and an elongated slot in said flat plate having its centerline positioned substantially radially relative to said axis of rotation, the sides of said slot being substantially radial, whereby the ratio of the width of the slot to the length of the relative movement of said flat plate and rotary plate will be uniform throughout the length of said slot.

4. A fallout meter comprising a rotary plate, flat sector-shaped collecting members carried by said plate, a flat plate having an unobstructed upper surface positioned closely above and parallel to said rotary plate, means for supporting said rotary plate and said flat plate in a substantially horizontal position, means for producing relative rotation between said rotary plate and said flat plate about an axis perpendicular to said flat plate and surface,

and an elongated slot in said flat plate having its centerline positioned substantially radially relative to said axis of rotation, the sides of said slot being parallel, whereby the ratio of the width of said slot to the length of relative movement between said flat plate and rotary plate will decrease radially outwardly along said slot.

5. A fallout meter comprising a flat plate, an endless belt beneath said plate having its upper run parallel to said plate, collecting members carried by said endless belt so disposed that they lie parallel to said plate on said upper run, an elongated slot in said plate extending transversely to said endless belt, said slot being of uniform width throughout its length, means for driving said endless belt at a uniform speed, and means for supporting said plate in a horizontal position.

6. A fallout meter comprising a flat plate, an endless belt beneath said plate having its upper run parallel to said plate, collecting members carried by said endless belt so disposed that they lie parallel to said plate on said upper run, an elongated slot in said plate extending transversely to said endless belt, said slot being tapered from one end to the other, means for driving said endless belt at a uniform speed, and means for supporting said plate in a horizontal position.

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RICHARD C. QUEISSER, *Primary Examiner.*

C. A. CUTTING, ROBERT EVANS, *Examiners.*