

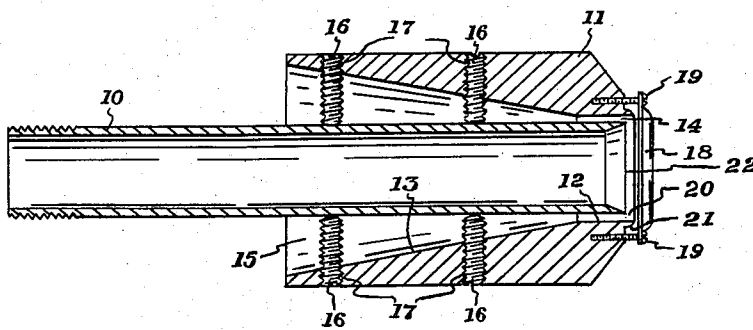
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ANNULAR IMPACTOR SAMPLING DEVICE

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ANNULAR IMPACTOR SAMPLING DEVICE

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3 Claims. (Cl. 73—28)

The invention relates to an aerosol sampling device based on the impaction principle, and capable of sampling at high rates by which is meant rates of the order of 400 litres per minute or more.

There is an important need to detect alpha emitting materials in the form of aerosols, e.g., airborne plutonium, in areas affected by escapes or spills in industrial and laboratory processes. The problem of detecting some alpha emitting materials in the form of aerosols has been difficult because the activities that must be measured are very low, and because activity due to natural radon decay products, is often sufficient to completely mask that due to undesirable concentrations of more toxic contaminants. The practice until now has been to sample air with some filtering device and permit the active deposit to decay for an hour or more. Differentiation between various alpha emitters is also possible by a measurement of pulse energy but the practical difficulties of sample preparation have so far rendered this technique impractical for routine use.

It has been noted that radon decay products in the air are preferentially associated with the smaller dust particles with 90% of radon decay product activity on particles of less than 0.035 micron-diameter. In contrast, it is known that if material is rendered airborne by mechanical disruption from the solid or liquid state the bulk of the material is in the larger particle sizes with only a very small fraction of the mass in sizes of less than 1 micron diameter. This is the condition which exists when alpha emitting materials are handled in practice. On this basis, it is desirable to provide a separation of airborne particles into two groups respectively greater and less than one micron diameter, thereby providing a sample of active dust from plant spills substantially free from radon decay products.

Devices are available which effect a separation between dust particles smaller and greater than one micron diameter, but this in itself is not sufficient. It is necessary to provide for rapid detection of highly toxic contaminants such as plutonium, which involves a high sampling rate of the order of 400-1000 litres per minute of air in contrast to the maximum rate of about 20 litres per minute for presently available instruments. The high sampling rate is also important for materials in other fields, such for example as beryllium dust, pathogenic organisms and allergy inducing airborne proteins. Dangerous amounts of any of these materials cannot be collected in a reasonably short time with conventional impactors.

It has been found that a scaling up of existing impactor-type sampling devices to sample air at the required high rate does not provide adequate impaction. Moreover the resulting device would require a large and heavy blower because the efficiency of the air flow in existing impactor type samplers is low so that a large amount of power is wastefully expended.

An object of the invention is therefore to provide a device which samples gases efficiently on the impaction principle and does so at high rate of flow of the order

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indicated above, and a further object is to provide a device of such construction as to provide the required jet velocity with a relatively small and low powered blower moving air at the required high rate whereby the device is reasonably portable. Such a device according to the invention comprises a sampling tray, a hollow member having a substantially cylindrical wall adapted to be connected at one end to a source of suction, means positioning the hollow member with the other end spaced from the sampling tray to form therebetween a substantially uninterrupted radial passage substantially aligned with the wall of the hollow member and communicating with the interior of the hollow member, and means surrounding the hollow member and defining a surrounding annular jet orifice tapering over at least a major portion of its length and communicating with the said radial passage which is defined by the cylindrical hollow member and the sampling disc or tray.

According to the preferred form of the invention the surrounding annular jet orifice has a forward portion communicating with the radial passage and a rear portion tapering thereto, the forward portion having its inner and outer walls substantially parallel to the axis of the hollow member, and the rear tapered portion having its inner wall substantially parallel to the axis of the hollow member.

According to a further feature of the invention, the inner surface of the wall of the hollow member is bevelled to a sharp edge at the end thereof adjacent to the sampling tray.

Other features and objects of the invention will appear from the following description with reference to the attached drawing which is a longitudinal sectional view of a sampling device according to the invention.

In the drawing the reference numeral 10 indicates a substantially cylindrical-walled hollow member adapted to be connected to a source of suction capable of drawing air at a rate of the order of at least about 400 litres per minute and suitably within the range of 500 to 1000 litres per minute, e.g. 700 litres per minute. As pointed out above, it is an object of the invention to provide a sampling device which is reasonably portable which means that the source of suction should likewise be portable in addition to being capable of drawing air at the required rate. A readily available air mover which meets these requirements is the conventional vacuum cleaner blower. In order to achieve impaction of most particles down to one micron diameter, stream velocities of 50 to 80 meters per second are required in the jet orifice. These velocities, in turn, correspond to pressure heads of 1.2 to 3.1 centimeters of mercury. The domestic vacuum cleaner blowers are capable of sucking 700 litres per minute at a head of 2.8 centimeters or mercury, which is adequate for the purpose. On the basis of a jet velocity of 68 meters per second, and with an air flow of 700 litres per minute a total jet area of 1.7 cm.² is required.

In view of the above the outer dimension of the hollow member 10 is conveniently 2.6 centimeters to fit an adapter to be received in the attachment opening of a standard size domestic vacuum cleaner. Surrounding the hollow member 10 is a member 11 formed with a bore which has a substantially cylindrical section 12 adjacent one end and a substantially conical section 13 constituting the remainder of its length. The cylindrical section 13 of the bore 12 is greater in diameter than the hollow member 10 whereby, when the two members are positioned as shown in the drawing, there is defined between them an annular jet orifice 14 the walls of which are substantially parallel to the axis of the hollow member 10, while the remaining portion 15 of the annular jet orifice surrounding the hollow member 10 is tapered. The member 11 may be spaced from the hollow member 10

by studs 16 threaded in bores 17, the relative positions of the two members 10 and 11 being adjusted by the studs 16 so that the dimensions of the passages 14 and 15 may be uniform throughout. An alternative construction for mass production would be to use spacing fins soldered or welded into slots instead of studs.

At the end of the device adjacent the jet orifice 14 there is provision for a sampling tray 18 which may be attached to the member 11 by suitable means e.g., screws 19, the sampling tray being in any event spaced from the adjacent end of the hollow member 10 so as to define therebetween a radial passage 20 in communication both with the annular passages 14 and 15 and with the bore of the hollow member 10. As illustrated the member 11 may be formed with a cylindrical lip 21 forming a seating or mounting for the tray 18 and the end of the member 10 is preferably bevelled to a sharp edge 22. The size of the passage 20 (which is the distance between the edge 22 and the end of the lip 21) may be adjusted by moving the member 10 lengthwise, on loosening the studs 16 slightly, and should be 0.25 to 0.35 centimeter so as to provide a jet velocity of 60 to 75 meters per second when the capacity of the blower is 700 litres per minute, and, as in the embodiment illustrated, the passage 15 is 8.5 centimeters deep with an inlet diameter of 5.8 centimeters, the passage 14 is 1.5 centimeters long and has a diameter of 2.9 centimeters, and the diameter of the member 10 is 2.6 centimeters so that the member 11 is spaced from the member 10, 0.15 centimeter.

OPERATION

The sampling tray is lightly coated with a sticky material and put in place as illustrated. The nature of the sticky material does not seem important, a thin layer of vaseline or silicone grease being acceptable. Air is drawn through the impactor for two to five minutes by means of the vacuum cleaner. The tray is then removed and counted with an alpha-sensitive scintillation counter. It has been found that the counter efficiency is slightly different than that for standard source trays. This results from the ringlike deposit close to the tray rim leading to a lower geometry than for standard sources well centered on the tray. The factor to be allowed for abnormal geometry of the annular deposit may be found by cutting the rim off several of the trays after the initial count, dividing this rim into segments which can be centered under the counter, and recounting. Once the counter efficiency has been determined the activity of unit volume of air is readily found from the air flow rate for the sampling unit. The device possesses the advantage that the flow rate remains constant provided no change occurs in the efficiency of the blower. This may be contrasted with filter samplers where the flow rate is sensitive to the nature of the filter paper and will change with time as the pores of the paper become blocked.

The use of the device for the sampling of β or γ active particulates, other than daughters of gaseous fission products, requires modification only of the final counting procedure. For other uses including the sampling of large volumes of relatively dust free air for inactive material, the contents of the tray can be subjected to chemical examination. Alternatively, a glass disc can be placed in the tray for subsequent microscopic examination.

Sampling efficiency for various particle sizes.—The following table gives the results of trials:

TABLE I.—EFFICIENCY OF ANNULAR IMPACTOR FOR VARIOUS PARTICLE DIAMETER (MICRONS)

Trial	0.6 to 1.1	1.1 to 2.4	2.4 to 3.4	3.4 to 4.5	4.5 to 7.2	7.2 to 9.0	9 to 12
1.....	.46	.77	.78	.81	.97	.96	1.00
2.....	.62	.73	.85	.78	.73	1.00	1.00
3.....	.65	.95	.91	1.00	1.00	1.00	1.00
4.....	.77	.81	.96	.98	.97	1.00	1.00
Mean.....	.63	.82	.88	.89	.92	.99	1.00

It is apparent that the minimum particle diameter effectively sampled by the sampling device of the present invention (referred to for convenience as the annular impactor) lies in the vicinity of 0.5 micron (the theoretical impactation efficiency falls off approximately as the square of the particle diameter for small particle size).

Field tests

Airborne plutonium dusts.—A number of annular impactor samples followed by tubular filter samples were taken where it was expected that there was plutonium air contamination. Samples showing alpha counts are listed in Table II.

TABLE II.—ALPHA ACTIVITY OF AIRBORNE PLUTONIUM SAMPLES¹

Trial	Impactor Disc, cts./min./m. ³	Tubular Filter Following Impactor, cts./min./m. ³	Sampling Efficiency, Percent
38.....	287	.....	.....
39.....	270	.....	.....
40.....	130	.....	.....
41.....	142	.....	.....
42.....	99	.....	.....
52.....	51	2.4	95
53.....	39	4.3	90
58.....	73	7.6	91
59.....	47	6.0	89
60.....	21	1.4	94
61.....	65	6.4	91
62.....	40	2.0	95
63.....	52	2.0	96
64.....	50	1.7	97
66.....	21	0.7	95
72.....	25	3.1	89
74.....	77	6.1	92
75.....	14	3.5	80
77.....	3.9	0.4	90
79.....	5.6	0.7	89
80.....	18	2.0	90

¹In nearly all cases at least 24 hours' delay occurred before counting to permit effective decay of radon daughters present.

Efficiency of rejection of airborne radon decay products.—Annular impactor followed by tubular filter samples were taken in areas where no contamination from airborne Pu was expected. Well ventilated upper floor rooms and ill ventilated basement rooms were included in order to get a range of radon daughter concentrations. Results are summarized in Table III.

TABLE III.—ALPHA ACTIVITY OF AIRBORNE RADON DECAY PRODUCTS

Trial	Delay between Sampling and Counting, Mins.	Impactor Disc, cts./min./m. ³	Filter following Impactor, cts./min./m. ³	Sampling Efficiency, Percent
48.....	15	1.7	29	6
49.....	20	1.7	15	10
50.....	15	1.9	26	7
51.....	25	1.4	17	8
70.....	25	0.2	2.4	8
81.....	17	7.3	31	19
82.....	23	3.8	38	9
83.....	20	0.7	52	1
84.....	19	1.1	12	8
85.....	20	0.4	6.3	6
86.....	18	0.7	11	6
87.....	13	3.9	59	6
88.....	20	1.2	18	6
89.....	15	7.1	65	11
90.....	33	2.4	16	13

Samples were counted as soon as possible after being taken, the delay time ranging from 13 to 33 minutes. They were recounted at a later period and in general showed the decay rate expected for radon decay products, confirming that the bulk of the activity was due to radon daughters. A slower decay over longer periods of time suggested that thoron daughters may be present in small concentrations.

Trial 90 was carried out in the decontamination center and indicated the presence of small concentrations of airborne long lived alpha emitters in addition to the

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natural alpha activity. Results of counting after different delay times are given in Table IV. It is apparent that the impactor disc count largely represents airborne alpha activity arising from the decontamination work whereas only the natural alpha emitters are sampled by the following filter tube. These figures illustrate very well the power of the annular impactor to discriminate against natural alpha emitters present in the air.

TABLE IV.—DECAY OF SAMPLE TAKEN IN PRESENCE OF COMPARABLE CONCENTRATIONS OF NATURAL AND LONG LIVED ALPHA EMITTERS

[Trial 90, 10 minute sample with filter tube following impactor run at 700 litres/minute.]

Time	Annular Impactor Disc, cts./min.	Filter Tube, cts./min.
0945-0955	sampling	sampling
1018-1023	16.6	110
1118-1123	12.4	39
1418-1423	12.2	1.8

Thus a sampling device is provided according to the invention which, in conjunction with a relatively low powered and light blower, e.g. a standard vacuum cleaner type blower, is capable of sampling air at a rate of the order of 700 litres/minute, and is highly efficient in sampling particles above one micron diameter and is relatively inefficient for particles below one-half micron.

The device can be used for sampling both alpha and beta-gamma active material, and is particularly suitable for sampling airborne Pu or the long lived alpha emitters of high toxicity in the presence of a high background of Rn or Tn decay products. This follows from the consistently high sampling efficiency of the order of 90 percent for dusts generated by normal technical processes, contrasted with the low sampling efficiency of the order of 10 percent for radon decay products.

What I claim as my invention is:

1. A device for sampling gases at high rate of flow comprising means for mounting a sampling tray, a hollow member having a substantially cylindrical wall adapted to be connected at one end to a source of suction, means positioning the hollow member with the other end spaced

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from the sampling tray to form therebetween a substantially uninterrupted radial passage substantially aligned with the wall of the hollow member and communicating with the interior of the hollow member, and means surrounding the hollow member and defining a surrounding annular jet orifice having a forward portion communicating with said radial passage and a rear portion tapering thereto, said forward portion having its inner and outer walls substantially parallel to the axis of the hollow member, and said rear tapered portion having its inner wall substantially parallel to the axis of the hollow member.

2. A device for sampling gases at high rate of flow comprising means for mounting a sampling tray, a hollow member having a substantially cylindrical wall adapted to be connected at one end to a source of suction, means positioning the hollow member with the other end spaced from the sampling tray to form therebetween a substantially uninterrupted radial passage substantially aligned with the wall of the hollow member and communicating with the interior of the hollow member, and means surrounding the hollow member and defining a surrounding annular jet orifice tapering over at least a major portion of its length and communicating with the radial passage, the inner wall of the surrounding passage being substantially parallel to the axis of the hollow member, and the inner surface of the wall of the hollow member being bevelled to a sharp edge at the end thereof adjacent to the sampling tray.

3. A device for sampling gases as claimed in claim 1 in which the inner surface of the wall of the hollow member is bevelled to a sharp edge at the end thereof adjacent to the sampling tray.

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