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A Portable Continuous Sampling Instrument for Airborne Beta/Gamma Contamination, Incorporating an Automatic Warning Alarm.

by

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Abstract

A portable air sampling instrument has been developed that simultaneously assesses any airborne particulate beta/gamma activity collected, and gives an alarm if a certain preset level is achieved.

The development work was initiated because a need existed for some kind of a "watch dog" air sampler that could be used on routine work of a low risk nature, and which would give an audible alarm if airborne contamination arose.

In practice alarms have been received at concentrations low enough to ensure that operators to date have received no measurable internal contamination.

This report describes the instrument design, method of operation, testing procedures and results.

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Contents

1. Introduction

Instruments commonly used for sampling of airborne contamination rely on a system whereby a given volume of environmental air is drawn through a filter, which is then assessed after some period of time, giving a post event result.

Other air samplers exist which continuously sample and more or less immediately assess any airborne contamination present. In the main these instruments sample gases and/or particular contamination, and are usually fairly bulky instruments.

We came to the conclusion that a need existed for some kind of a "watch dog" sampler that could be used on routine work of a low risk nature, particularly in isotope laboratories, and which would continuously sample for particulate contamination and give an audible alarm if airborne contamination arose.

An instrument of this nature should also be physically small, relatively light, rugged and simple in construction and economical to produce.

Working to these specifications the instrument section of the Risø Health Physics Dept., have produced such an instrument (Fig. 1).

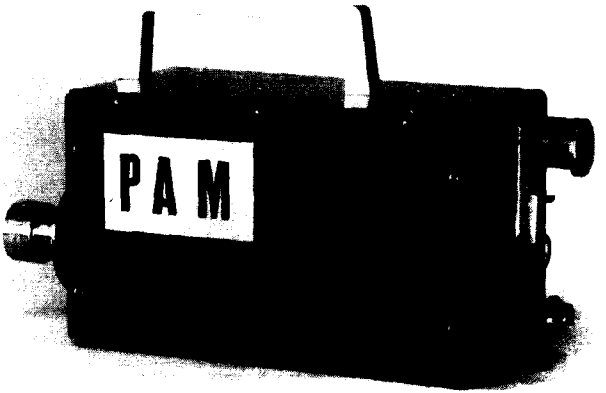

Fig. 1 Photograph showing the continuous air monitor. The dimensions are 20 x 11 x 9 cm.

2. Apparatus

The complete system is housed in a metal box of size 20 x 11 x 9 cm and weighing approximately 4 kg, the bulk of the weight being due to the lead shielding of the detector.

The instrument utilises an air-ejector principle, previously described by Stephenson[1], working on low pressure compressed air. A pressure of app. 5 kg/cm^2 is able to pull air through a filter with a flow of up to 70 litres per minute. The volume of the air sampled can be calculated knowing the duration of the sampling period and the flow rate. The flow rate is read from a shunting calibrated flow-meter attached to the monitor ranging from 0 - 80 litres/minute. The air consumption varies with air pressure available and the load of the filter paper. The pressure/flow characteristics of the air-ejector system is indicated in Fig. 2.

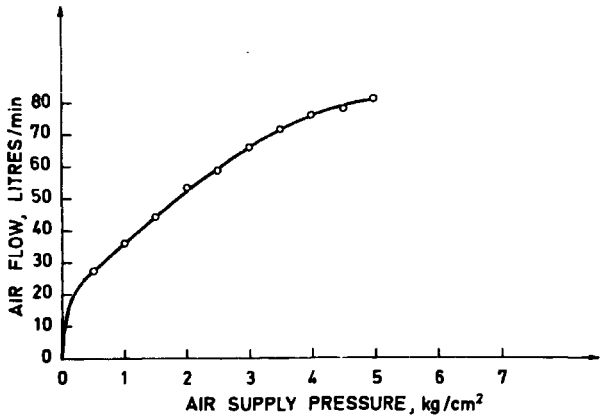

Fig. 2 Suction flow in sampling hose as a function of compressed air pressure.

Sampled air is drawn through an adaptor provided for attachment of sniffer hose and then through a detachable filter holder (Fig. 3). An interchangeable glass fibre filter is positioned in front of a low-energy end-window G.M. tube. Air borne radioactivity deposited on the filter thus representing the integrated activity as a function of the time will affect an audible alarm at certain preset alarm levels.

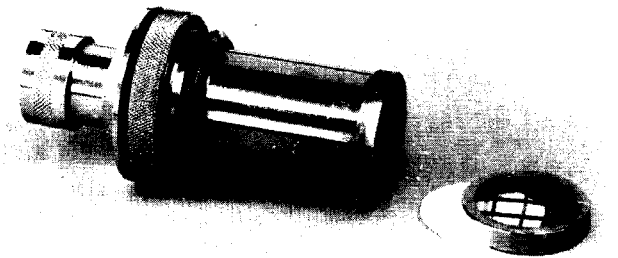

Fig. 3 Photograph showing the detachable filter holder.

The electronic alarm system is based on a commercially available personal dose rate alarm monitor (Graetz Electronik type 2-400 mR/h) to which has been connected an end-window G.M. tube (Philips Miniwatt type 18515). The monitor allows for preset dose rates from 2 to 400 mR/h in 8 steps.

The filter and G.M. detector are both shielded with 1 cm lead to give some selectivity against external radiation fields. A schematic diagram of the entire system is shown in fig. 4.

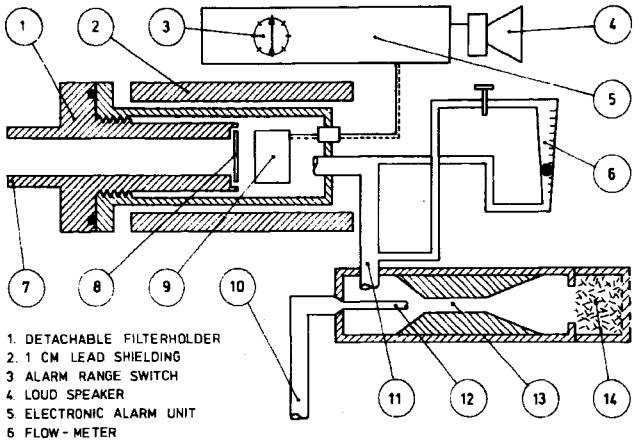

Fig. 4 The air sampler. Schematic diagram.

3. Evaluation procedures

The instrument has been subjected to a number of evaluation tests, as follows.

Tests:

1. 8 tests were carried out with the instrument sampling contaminated air that had been sprayed into a glove box. The instrument was started at the same time that spraying commenced and stopped when an alarm was achieved. The reaction time, box concentration and collected activity were recorded.

2. After the alarm had been received, in all cases on the most sensitive range, sampling continued through all the ranges up to the maximum, with the alarm times being noted for each range, the final collected amount was measured.

For seven of the above tests, 3 ml NaCl with a concentration of (ave) 0.77 µCi/ml Na-24 was used on each occasion, and 1.1 µCi/ml K-42 for the remaining test. The solution was sprayed from an atomiser which produces a particle size within the respirable range and at a rate commensurate with the sampling rate.

3. The alarm response of the instrument to isotopes with different beta and gamma energies was spot checked by introducing to it filter papers previously contaminated with varying amounts of activity. These tests were continued, as for test 2, through all the ranges.

4. The influence of natural airborne activity on the instrument was also checked by allowing it to sample environmental air from rooms under low ventilation, after week-end shutdown periods, and before other work commenced.

Results:

1. Test 1 indicated that an alarm was received after an average of 0.6 µCi had been sprayed into the glove box. If this were all airborne it would be equivalent to a concentration of 2×10^{-6} µCi/cc, however we believe that there was a certain static attraction to the walls of the glove box, the true concentration could be significantly less. An intermittent alarm was received after (ave) 5 minutes which included build-up and mixing time within the box.

2. Progression through the ranges required increasing amounts of activity to be collected as was expected, but no direct linear relationship appeared. This was considered to be related to non-uniform concentration of the airborne contamination.

3. Basic levels determined in this test together with those determined under operational conditions are shown in table 3. In this case a more satisfactory range relationship was obtained.

... Background contamination levels on these occasions did not have any significant effect on the instrument, reaching only a maximum of 960 dpm. Higher levels would of course bring the instrument closer to alarm point, which, on same occasions, may be advantageous.

4. *Operational Sampling*

In addition to these tests the instrument has been used under operational conditions. Some of these results are given below.

Table 2

Operational sampling

Isotope	Airborne conc. (dpm/m^3)	Alarm level (dpm)
S^{35}		2.2×10^5
"		1.6×10^5
"	In the order of	1.8×10^5
"	2.2×10^5	1.4×10^5
"	dpm/m^3	2.7×10^4
P^{32}	unknown	4.2×10^5
I^{131}	-	3×10^3
"	-	2×10^4

In the time the instrument has been in routine service it has proven its worth on a number of occasions. Once for example, during the flame sealing of glass ampoules containing S-35 an alarm was received, and the operator donned a respirator in order to complete the work. On completion of the work body contamination up to 10 x maximum permissible level was determined but no internal contamination was received.

On another occasion, again with S-35, during routine glove box working, an alarm was received and the operator evacuated the area. The airborne contamination level within the area continued to rise to 2,5 x MPC before declining. Due to an early warning at a low level and prompt evacuation the operator received no contamination whatsoever.

5. Discussion

Sampling at the operators breathing zone is usually possible with an extension hose. In all cases with the isotopes checked to date, the alarm level is such that a person inhaling approximately 50 % of this level (breathing rate 20 litres/minute) can be expected to have ultimately received only a negligible fraction of a body burden up to the time of alarm. This has been demonstrated in practice in the actual events where airborne contamination has occurred.

Following I.C.R.P.'s lung model the inhaled fraction could be expected to be further reduced by 75 % (Table 3).

Table 3

Possible body burdens derived from alarm levels

Isotope	Alarm level (lowest range) (dpm)	Inhaled fraction (50 %) (µCi)	Ultimate lung concentration (25 %, ref. I.C.R.P.) (uCi)	Max permissible body burden (µCi)
S-35	2.9×10^4	6.8×10^{-3}	1.7×10^{-3}	90
P-32	4.4×10^5	0.1	2.5×10^{-2}	6
I-131	2.0×10^4	4.6×10^{-3}	1.2×10^{-3}	0.7
Ca-137	9.6×10^3	2×10^{-3}	5.0×10^{-4}	30
Hg-203	9.6×10^3	2×10^{-3}	5.0×10^{-4}	4
Ca-47	7.4×10^3	1.7×10^{-3}	4.0×10^{-4}	5
Na-24	1.1×10^6	0.23	6.0×10^{-2}	7
K-42	4.4×10^6	1.0	2.5×10^{-1}	10

6. Conclusions

We consider that the sensitivity of the instrument to beta radiation is such that it can also be used for alpha emitting isotopes that have a significant beta emission, uranium for example.

The sampler fulfills in the main our requirements for the isotopes checked and can be used in areas where relatively low dust loading occurs. Its use in other areas i.e., production lines, has not been evaluated but tests are planned. It is also considered that with slight modification it can be used as a "go/no go" emergency sampler under field conditions, using a cylinder of compressed air as motive force.

Making the instrument as sensitive as is reasonable means that it is also influenced by external radiation, which, whilst having the effect of making the instrument even more sensitive may also be an embarrassment if to many false alarms accur. Usually the operator would be aware of such a situation, but in some cases extra shielding may be required and/or an extended sampling hose.

Acknowledgement

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Reference

1. Stephensen J., H.P. Div. UKAEA, Harwell Report Sept. 1959.