THE LABORATORY APPRAISAL OF IONISATION CHAMBER SMOKE DETECTORS

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A paper at the Paris conference in 1977 described the approach which the National Radiological Protection Board (NRPB) was to adopt in the United Kingdom with regard to the radiological testing of products that irradiate the public (1). The paper summarised early results of tests on ionisation chamber smoke detectors (ICSDs). Since that time, there has been a steady supply of detectors for evaluation. At the time of writing 47 detectors have been received, most of which utilised americium-241 foil sources. One detector received utilised krypton-85 and some utilised radium-226 foil sources. The test programme which was originally proposed in 1976 (2) has been modified in the light of experience, and the results have formed part of the input to the Nuclear Energy Agency (NEA) in the drafting of recommendations on these devices (3). These were published in 1977 and the NRPB evaluation procedure follows that described in the document. The present paper describes some of the Board's experimental methods and experiences and its interpretation of some of the NEA criteria. The evaluation consists of four sections; visual inspection, dose rate measurements, surface contamination measurements and destructive testing. These will be discussed in turn.

The visual inspection is intended to detect any shortcomings in design, with particular regard to access to the source(s). The recommendations require that under normal conditions of use, direct access to the sources shall be impossible and that the construction of the ionisation chamber for single-station ICSDs shall be sufficiently tamper-proof. While none of the detectors examined so far permit direct access to the sources, several have been considered to be insufficiently tamper-proof. The interpretation of this term within the UK is that the source(s) should only be accessible by means of a special tool or by damaging the detector. For example, the securing of the ionisation chamber by the use of plain screws would be considered unacceptable although the use of special screws would be acceptable. The use of rivets, solder, glue or certain types of plastic clip would be considered acceptable if their removal constituted significant damage to the device. Construction is of particular importance in the domestic situation since there can be no statutory control over use.

The requirement of the recommendations with regard to dose rate is that irrespective of the radionuclide the dose equivalent rate at any accessible point may not exceed 1 μ Sv h^{-1} (0.1 mrem h^{-1}) at 0.1m from the surface of the device. Dose equivalent rates from those detectors containing radium-226 have been measured directly using a calibrated GM counter, and that from the detector utilising krypton-85 was measured using thermoluminescent dosimetry. However, for detectors which utilise americium-241 there is a significant contribution to the dose equivalent from low energy x-rays. In consequence the total dose equivalent rate is dependent upon the materials which shield the source, the methods of construction and the internal dimensions of the device. It is therefore necessary to measure the

photon spectrum using a Si(Li) detector, in order to calculate the total dose equivalent rate. The assessed dose equivalent rates for different types of detector which have the same source activity vary by a factor of three. Most of the detectors examined have dose equivalent rates of less than 10% of the recommended maximum, the two exceptions being the ones with the most active sources. The detectors which contained activities of radium-226 in quantities comparable with those used for americium-241 sources exceeded the limit as did detectors utilising krypton-85. The dose equivalent rate at 10cm from the surface of most americium-containing detectors is below the detection limit. In consequence measurements are routinely made at 0.05m and the results extrapolated to 0.1m. Some of these results are compared in Table 1.

TABLE 1. Dose rates at 0.05m from outer casing

Nuclide	Activity kBq	Dose rate $\mu Sv\ h^{-1}$
Am-241	33.3	6.0×10^{-3}
	37.0	8.5×10^{-3}
	33.3	6.1×10^{-3}
	37.0	1.0×10^{-2}
	37.0	1.3×10^{-2}
	33.3	1.8×10^{-2}
	29.6	2.4×10^{-2}
Ra-226	37.0	1.5+
	1.85	1×10^{-1}
Kr-85*	18500	2×10^{-1}

The standard deviation in the results for Am-241 is 1.2×10^{-3} $\mu Sv\ h^{-1}$

* Dose rate measured at 0.1m from the surface of the device
+ β dose rate 2.0 $\mu Sv\ h^{-1}$ at 0.05m

The preferred method of surface contamination assessment is the wipe test, which permits several components of each detector to be independently checked. The wipes are performed using an alcohol-moistened cotton wool swab. A comprehensive wipe-testing programme results in a large number of samples, and for this reason the activity transferred to each swab is measured by liquid scintillation counting, which allows an automatic throughput of a large number of samples with a detection limit of 0.2 Bq (5 pCi). The results obtained on the inactive areas have almost invariably been below the limits of detection.

Wipe tests also play a major part in the integrity assessment during the final part of the evaluation, the destructive testing programme. Where possible, the source and holder are wiped separately both before and after the test, but where dismantling might

invalidate the subsequent test, only the post-test wipes are carried out. Most of the tests (impact, puncture, drop, pressure, temperature, vibration) have produced few problems with regard to wipe testing, although they were designed to simulate conditions of normal use and credible abuse.

The current test programme differs from the earlier proposals (2) in several aspects. It was found that the sulphur dioxide corrosion test was unrealistically severe. The same conclusion was reached by NEA and the test was not included in the recommendations. However, it was apparent that in tests such as corrosion and fire, there was a likelihood of inactive deposits on the source. A policy of carrying out two consecutive wipe tests was therefore adopted for these tests. In addition, in the case of corrosion tests, activity was frequently found in the liquid beneath the sample, indicating that wipe tests alone were an insufficient criteria of leakage.

The earlier programme contained two fire tests - one at 600°C to simulate a domestic fire and one at 1200°C to simulate a hot industrial fire.

With the 600°C experiment it was possible to define a pass-fail criterion based on leakage and wipe tests and to identify material incompatibility problems. The 600°C test continues to provide the most interesting results. The use of a closed flow system and representative samples continues to give reproducible results. Standard counting methods are used to determine total leakage, and further qualitative information about source behaviour is obtained by alpha spectrometry and autoradiography. Alpha spectra in particular correlate well with the results of wipe testing. The results of 600°C fire tests are summarised in Table 2. The data serves to illustrate the effects of different holder materials, methods of fixing the source and different types of plastic. The range of results quoted refer to the first wipe taken.

TABLE 2. Summary of the results of the 600°C fire test

Holder material	Range of activity transferred to wipes, Bq	Comments
Stainless steel	0.3 - 370	No dispersion
	3589	Plastic housing contains fire retardant
Aluminium	0.6 - 163	No dispersion
Tin plated	148 - 3145	Extensive dispersion in tube and some in filters
Brass	555 - 12950	Extensive dispersion throughout apparatus
Source soldered on brass holder	81	Activity found in the vapour trap

The higher temperature in the 1200°C test was sufficient to melt the source and cause some dispersion of activity within the combustion tube. Several experiments were performed at the higher temperature, whereupon it was decided to curtail the test since no adequate pass-fail criteria could be defined. The NEA included a test at this temperature, defining a criterion in terms of activity which escapes from the combustion tube. This test is being incorporated into the NRPB programme and those samples which were subjected to it proved satisfactory in terms of the NEA criterion. Activity was detected remote from the combustion tube in only one instance, when 28 Bq was found in the vapour trap.

At the time of writing, the Board continues to act in an advisory role with regard to consumer products, although it is likely that this will change in the future. Nevertheless, manufacturers and distributors have willingly submitted samples for evaluation, normally prior to distribution within the UK, were equally willing to make modifications as a result of the Board's findings, and were agreeable to the results being published in a recent Board report (4).

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