Radioactivity: Instrumentation for leak tests and contamination checks

Routine leak tests and contamination checks are the responsibility of the Radiation Protection Supervisor (Schools). This person must ensure that the detection equipment in use is suitable and working correctly. Professional testing and calibration, by an accredited testing house, is expensive and unlikely to be necessary under normal circumstances for schools working with the *Standard School Holding* of radioactive materials[1].

This leaflet describes Geiger-Muller (GM) tubes and counting systems suitable for carrying out regular leak tests and contamination checks on radioactive sources and materials used in school science. These procedures require sensitive and efficient equipment. A method for checking the operation and efficiency of a GM counting system is described (ie, basic calibration as required by ISO 9978[2]).

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1. GM tubes unsuitable for leak tests or contamination checks

Some GM tubes, which work well for standard practical investigations, may not detect very low levels of ionising radiation efficiently. Hence they may not be suitable for leak tests or contamination checks. The following types of tube are usually **unsuitable** for leak tests or contamination checks:

- GM tubes with small windows (less than 15 mm diameter);
  these include the popular *Atomic Energy Authority (AEA) Radcount* (now discontinued),
  the *Science Enhancement Programme (SEP) Geiger Counter*
  and most tubes supplied for use with dataloggers.
- GM Tubes with non-removable plastic protection over the window;
  integral protective covers often reduce the effective window area significantly.

2. GM tubes suitable for leak tests or contamination checks

A GM tube with an end detection window greater than 15 mm diameter, which is capable of detecting alpha and beta emissions, is necessary for leak tests and contamination checks. It is essential that any protective cap over the window is removed during counting, to expose the whole area of the window.

⚠ If provided, a protective cover should be fitted over the GM window during normal laboratory use. Extra care should be taken to avoid damage to the exposed window, during leak tests, contamination checks and calibration processes.

Centronic (in the UK) and *LND Incorporated* (in the USA) make the most common type of GM tube, used in schools for many years – the ZP1481 (previously MX168) and LND 72233 respectively. This type of tube is available from science education suppliers and may be used effectively for leak tests and contamination checks.

Technical information about these tubes is provided at the end of this leaflet in section 5.

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1 The role of the RPS (Schools), the procedure for carrying out leak tests and contamination checks and details of the Standard School Holding of radioactive materials are explained in CLEAPSS guide *L93 Managing Ionising Radiations and Radioactive Substances in Schools, etc* (September 2008).

2 *International Standard: Radiation Protection – Sealed Radioactive Sources – Leakage Test Methods*, ISO 9978:1992, International Organisation for Standardisation.

3. Suitable counting units for leak tests or contamination checks

A reliable cumulative counting unit (or scaler), incorporating a power supply for the GM tube, is essential. A unit that functions only as a rate meter (eg, displaying only counts per second) is not suitable. Computer-based datalogging counting systems may be unsuitable, because they can be prone to unreliable operation and/or may only provide a ratemeter facility. Some units enable the input to be counted for predetermined periods of time. This is a useful feature, removing the need to use a stopwatch. The usual counting period for leak tests and contamination checks is 2 minutes.

4. Using a standard test source to check a GM counting system

Confirmation that a ZP1481 type GM tube and counter is operating efficiently can be achieved in the school laboratory, using a simple standard test source made with potassium chloride. The natural radioactivity of all potassium compounds is due to the presence of 0.0117% of potassium-40 (mean beta energy 560.2 keV).

A specified mass of potassium chloride, filling specified dimensions, is used to make the standard test source. CLEAPSS is trying to arrange for a source of this type to be manufactured and made commercially available to schools. In the meantime, the source may be constructed as shown below.

The extremely low activity of potassium compounds means that the test source is not legally defined as a radioactive source and should **not** be kept in the radioactives store.

4.1 Making a standard test source

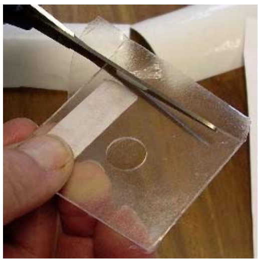
Components required

- Transparent acrylic, 2mm thick, cut to around 50 mm square[3];
- Pure (laboratory grade) potassium chloride;
- Self-adhesive clear plastic book-covering film. It is essential to use the exact product specified below[4] as other film may have a different thickness or density;
- Self adhesive paper label with wording below and an identifying code (eg, TS 1).

K-40, naturally occurring in 300 mg potassium chloride. Test source: _____.

Procedure

<table>
<tr>
<td>

1</td>
<td>
2</td>
<td>1. Make a 13 mm diameter hole in the acrylic and attach the label. If drilled directly with a standard drill bit, acrylic plastic shatters easily. Wear eye protection. Firmly clamp the plastic between two sheets of wood. Position and secure firmly on a pillar drill table. Drill with a standard 13 mm drill bit, using light pressure and lifting the drill bit regularly to clear the shavings and swarf.
2. Cover the labelled side of the slide with the self-adhesive film. Turn the slide over so the open side of the hole is uppermost.</td>
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<tr>
<td>
3</td>
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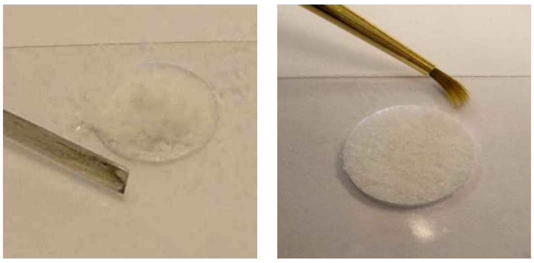
4</td>
<td>3. Use a pestle and mortar to crush the dry potassium chloride so that it has the consistency of caster sugar.
4. Weigh 300 ± 5 mg of the crushed potassium chloride. The balance must be able to resolve to 1 mg.</td>
</tr>
</table>

3 Transparent acrylic/Perspex® sheet 2mm thick may be available in the school's technology department. It is often sold in DIY shops or may be purchased from many outlets on line, eg, www.ukplastics.co.uk

4 "Cover Clear® Standard" 50 micron thick transparent polypropylene gloss self-adhesive film, manufactured by Tenza Technologies Ltd, (www.tenzatech.com/docs/coverclear.pdf) School libraries may have stock of Cover Clear® Standard. It is widely available from stationers.



5

5. Carefully pack all the potassium chloride evenly in the hole in the slide, using a spatula and a fine brush.

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6. Cover the top of the slide with another piece of self-adhesive film so the potassium chloride is encapsulated in the slide.
7. The potassium chloride forms a disc source. It has an indefinite life and only needs replacing should the plastics physically deteriorate or become damaged.

The completed test source should be kept safely in a small, sealable plastic bag or similar container (to avoid damage or contamination). Store out of sunlight to avoid UV degradation of the plastics.
It must not be labelled as radioactive and should not be kept in the radioactives store.

4.2. Checking the GM counting system

Carry out these checks prior to annual leak tests and contamination checks. Work well away from any other radioactive sources. **Keep a Test Record, as shown in section 4.3.**

Apparatus required

- GM tube in holder with lead;
- Counting unit (scaler);
- Clamp and stand;
- Standard potassium test source (procedure 1);
- Normal school plutonium or americium sealed radioactive source (procedure 2).

Procedure 1 – Measuring comparative beta efficiency

1. Position the GM-tube vertically so the end window is pointing uppermost. Clamp the tube holder, not the tube itself.
2. Remove the protective end cap carefully (usually white or blue with a ‘spider’s web’ grille). The window is fragile and the GM tube will be ruined, if it is damaged.
3. If the GM voltage on the counter is adjustable, set it to 450 volts.
4. Rest the standard test source on the GM tube, so the source rests on the metal rim, with the disc of potassium chloride directly covering the centre of the GM window.
5. Note the count, over a period of 1000 s, in the Test Record.
6. Remove the test source well away from the tube and record the background radiation counted over 1000 s. This should be 350 to 500 counts. Try moving another area of the lab, if it is higher.
7. Replace the protective cap on the tube.

Procedure 2 – Check for alpha sensitivity

Follow standard operating procedures when using radioactive sources. Position an alpha-emitting school sealed source (americium-241 or plutonium-239) about 10mm from the GM-tube window. Check that the count rate increases and then decreases considerably when a piece of paper is placed in front of the source. Note that americium-241 also emits significant gamma radiation and the GM tube will still detect this through the paper.

4.3 Recording and processing the results

The record of the test should include the exact combination of monitoring equipment used. If no serial number or unique identifier is present on a particular piece of equipment, a suitable label should be added. This complete counting system must then be used whenever leak tests and contamination checks are necessary.

Test record for a Geiger-Muller counting system	
Equipment used	**Serial no or unique identifier**
GM Tube (with protective cap removed, if fitted)	
GM Tube holder	
Connecting lead	
Counting unit (scaler)	
Operating voltage (ideally set to 450V)	volts
Standard test source used	**Serial no or unique identifier**
K-40, naturally occurring in 300 mg KCl	
Measurements taken	**Actual count for 1000 seconds**
K-40 test source resting on GM tube window (t)	
Background (b) (typically be 350 to 500 counts in 1000s)	
Comparative beta efficiency of system[5]	
=100 (t – b)/540 (should be at least 70%)	= _______ %
Comparative beta efficiency	Pass/Fail (delete as appropriate)
Check for alpha detection	Pass/Fail (delete as appropriate)
Overall result (ie, 2 tests above passed)	Pass/Fail (delete as appropriate)
Test carried out by:	
Signed:	**Date:**

4.4 If the instrumentation fails its test

If the beta efficiency is below 70%, (or considerably above 100%), or the alpha sensitivity test is failed, maintenance or replacement of some or all parts the system is likely to be needed.

Before purchasing a new GM tube, check that it is:

- operating at the correct voltage (usually 450V);
- well away from other radioactive sources during the tests;
- not contaminated (clean it carefully with a damp soft tissue);
- free from additional covering or protection over the window;
- Connected via a good lead to a properly-functioning counter (scaler). See comments below.

Before purchasing a new GM tube, it is advisable to ensure that the holder, lead and counting system work properly, when used with another tube known to be working correctly.

Failure of components or electrical connections in the holder, lead or counting unit sometimes results in incorrect or intermittent readings. If the system still does not work with a good tube, substitution of individual parts of the system, one at a time, should locate the problem. In order to do this, a similar system might need to be borrowed from another school.

[5] An explanation of comparative beta efficiency and the formula used in the calculation is given in section 5.

5. Technical information

ZP1481 and LND 2233 GM tubes

The standard GM tube, used in most schools, is the Centronic ZP1481 (formerly the Philips ZP1481, and before that the Mullard MX168). It has a detection window diameter of about 18mm. It is available from educational suppliers and from the current manufacturer, Centronic[6]. The tube has a very long working life, if handled carefully. Many still work well after 40 years. It is shown here with and without its protective cover, which should be removed only when performing leak tests or contamination checks.

The American equivalent of the ZP1481 is the LND 72233, manufactured by LND Incorporated[7] supplied to some schools in the UK.

All these types of GM tube plug into a special “B2A” socket, usually marked A (anode) and C (cathode)

The performance of this type of tube is good over quite a wide beta energy range; tests on new tubes showed over 60% intrinsic beta efficiency with low-level activity calibration disks of Tc-99 (mean beta energy 84.6 keV) and Cl-36 (mean beta energy 251.2 keV) very close to the GM window. All measurements were taken with the GM operating at 450 volts with the protective end cap removed. The intrinsic efficiency of the tube is therefore sufficient to detect the beta that would accompany a leak of Co-60 (mean beta energy 96.4 keV) and from Cs-137 (mean beta energy 187.1 keV).

In tests with new ZP1481 type GM tubes, using a low-level Am-241 calibrated source very close to the window, with the protective cap removed, the intrinsic alpha efficiency exceeded 35%. (In contrast to alpha and beta, the ZP1481 intrinsic efficiency for high energy gamma photons is only a few percent.)

Comparative efficiency measurement of a ZP1481 GM tube

This is the efficiency of the tube under test compared to a new, correctly operating GM tube of the same type.

Background radiation, measured with a correctly-operating ZP1481 tube, is typically 350 to 500 counts in 1000s If the background radiation is much above this, the efficiency test will be invalidated.

Tests on new ZP1481 GM tubes, using the standard Potassium-40 test source described in this leaflet typically gave 540 counts in 1000s above background radiation The radiation from the test source is principally beta. Therefore the comparative beta efficiency of the tube under test is calculated as:

100 $\times$ (count for 1000 seconds with test source – background count for 1000 seconds) / 540

The comparative beta efficiency of the tube under test should be better than 70%.

A slightly lower value can be tolerated, but much less means that tube will no longer be sensitive enough for leak tests or contamination checks and should be replaced. It is possible for the efficiency to slightly exceed 100%, due to variations in tube manufacture and tolerances in constructing the test source.

If the calculated efficiency significantly exceeds 100%, this also indicates that the tube is reaching the end of its life. Halogen-quenched GM tubes such as the ZP1481 have a life expectancy of 5×10^{10} counts. Towards the end of their life, they may start to ‘multiple pulse’ and incorrectly detect a higher background count. If the system indicates a much higher than expected background and the beta efficiency is well over 100%, the tube should be replaced.

A separate calibration for alpha efficiency is not necessary; simply a check that alpha is detected. If a thin end-window GM tube such as the ZP1481 detects beta efficiently, it will detect alpha quite efficiently too.

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6 www.centronic.co.uk

7 www.lndinc.com