Uncertainties of sealed source leak testing

1. Introduction

The method and required limits for sealed source leak testing are defined in the ISO 9978 standard.

Two methods are used for the leak testing:

a) A wet wipe is made and the surface contamination of the wipe is measured with a portable surface contamination meter.

b) A wet wipe is made and the wipe is counted in the LB770.

There are diverse sources of uncertainty in this measurement. The highest source of uncertainty is the collection efficiency (F) of the wipe. For 1 Bq of removable contamination on the source surface, the activity transferred to the wipe has the value of F Bq. The international standards recommend that an F value of 10% should be used, and as this is a conservative estimate for the leak test, this value is used in the IAEA working instruction. However, the value of F could lie in a range between 5% and 20%, depending on how the wipe was made and the characteristics of the source surface. This large uncertainty is considered to be a “dominant uncertainty”.

It is proposed to adopt a procedure for “acceptable uncertainty limits” similar to that used for individual monitoring for photons. These are characterized by the “trumpet curve” suggested by the PTB. For source leak testing, the proposed adaptation would be as in the figure below. For alpha and beta source leak testing, the upper acceptance limit is at plus 150% over the whole measurement range. The lower acceptable limit starts at zero near the detection limit of 0.01 Bq of removable alpha or beta radiation, and at around 1 Bq levels out at minus 60%.

![Proposed acceptance levels for leak tests for alpha and beta emitters](image)
2. Uncertainty evaluation

2.1 Collection efficiency

The collection efficiency is the highest source of uncertainty in this measurement method. Collection efficiency varies with both the wipe method, the surface wiped and the material which is contaminating the surface.

As the leak test will be performed on a number of surfaces (mostly smooth, metallic or plastic based surfaces) a collection efficiency of 10% is assumed. The type B uncertainty in the collection efficiency is considered to have a rectangular probability distribution, and is considered to be the dominant uncertainty.

Following the methodology for uncertainty evaluation established in the NIST site, http://physics.nist.gov/cuu/Uncertainty/typeb.html, the value of the lower limit, \( a_- \) is considered to be 0.05 and the value of the upper limit, \( a_+ \) is considered to be 0.15. The best estimate of the value of the quantity is then \( (a_+ + a_-)/2 \) or 0.1.

\( U_j \) is given by \( (a_+ - a_-)/2 \) which is then divided by the square root of 3, giving \( u_j \) as 0.029, or 29% of 0.1.

2.2 Surface contamination measurement with portable meters

The evaluation of surface contamination measurements using portable meters is given in the document “Uncertainty calculation - workplace monitoring of surface contamination using portable monitors, John Hunt, 2005-10-03”. This report gives an alpha contamination uncertainty (k=1) of 36% for alpha emitters and 25% for beta emitters.

2.3 Counting the wipe in the LB770

2.3.1 Counting uncertainty

The counting time of 10 minutes reduces the statistical uncertainty in the count rate to approximately 5%, with a normal probability distribution. The uncertainty in the calibration of the LB770 is taken as 10%, also with a normal probability distribution.

2.3.2 Reference source uncertainty

The traceable reference sources used with the LB770 counter have a maximum total uncertainty of 5%, as given in the calibration certificate. This uncertainty has a normal probability distribution.

2.3.3 Self Absorption

The self-absorption for the alpha particles in this type of filter has not been extensively documented. Values from the literature range from 20% to 50% self-absorption. The value assumed for the present calculation is 50% with a rectangular probability distribution and an uncertainty of 20%. The value of 50% is derived from the ISO standard “Evaluation of surface contamination.” ISO 7503-1, 1988.

The summary of the uncertainty budget for the LB770 is given in Table 1 below.
### Table 1: Summary of the uncertainty budget for counting the wipe.

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>(i)</th>
<th>Uncertainty</th>
<th>Probability</th>
<th>Divisor</th>
<th>u(i)</th>
<th>[u(i)]²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dx(i) %</td>
<td>distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counting statistics</td>
<td>1</td>
<td>5</td>
<td>normal</td>
<td>1</td>
<td>5.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Calibration</td>
<td>2</td>
<td>10</td>
<td>normal</td>
<td>1</td>
<td>10.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Reference source</td>
<td>3</td>
<td>5</td>
<td>normal</td>
<td>1</td>
<td>5.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Self absorption</td>
<td>4</td>
<td>20</td>
<td>rectangular</td>
<td>1.73</td>
<td>11.56</td>
<td>133.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Combined</td>
<td>standard</td>
<td>uncertainty</td>
<td>%</td>
<td>16.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expanded</td>
<td>uncertainty</td>
<td>(k=2)</td>
<td>%</td>
<td>33.68</td>
</tr>
</tbody>
</table>

#### 2.4 Summary of the leak test uncertainty budget

2.4.1 Direct measurement with portable surface contamination meters

For alpha emitters, the uncertainty would be represented as: Measurand ± 68%. The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=1, which provides a level of confidence of approximately 68%. The uncertainty is dominated by an expanded uncertainty of 29% due to the collection efficiency of the wipe.

For beta emitters, the uncertainty would be represented as: Measurand ± 54%. The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=1, which provides a level of confidence of approximately 68%. The uncertainty is dominated by an expanded uncertainty of 29% due to the collection efficiency of the wipe.

2.4.2 Measurement with the LB770.

The uncertainty would be represented as: Measurand ± 46%. The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=1, which provides a level of confidence of approximately 68%. The uncertainty is dominated by an expanded uncertainty of 29% due to the collection efficiency of the wipe.

#### 3. References
