# The Assessment of Uncertainty in Radiological Calibration and Testing

## GPG 49

## Calibration of Surface Contamination Monitors

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x}_i$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Standard deviation of mean of M | 3.45 % | normal | 1 | 1.10 | 3.80 | 5 |
| Standard deviation of mean of B | 23 % | rectangular | √3 | 0.098 | 1.30 | ∞ |
| Standard uncertainty of calibration source emission rate, E | 0.24 % | normal | 1 | 1.0 | 0.24 | ∞ |
| Semi-width of source area, A | 1.41 % | rectangular | √3 | 1.0 | 0.82 | ∞ |
| Semi-width of voltage factor, $f_V$ | 10 % | triangular | √6 | 1.0 | 4.08 | ∞ |
| Semi-width of source-detector separation factor, $f_d$ | 2.6 % | rectangular | √3 | 1.0 | 1.50 | ∞ |
| Semi-width of calibration source non-uniformity factor, $f_u$ | 10 % | rectangular | √3 | 1.0 | 5.77 | ∞ |
| Uncertainty of backscatter factor, $f_{bs}$ | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Combined uncertainty | - - - | normal | - - - | - - - | 8.27 | ∞ |
| Expanded uncertainty, ($k$=2) | - - - | normal | - - - | - - - | 16.5 | ∞ |

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x}_i$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Standard deviation of mean of M | 3.45 % | normal | 1 | 1.10 | 3.80 | 5 |
| Standard deviation of mean of B | 23 % | rectangular | √3 | 0.098 | 1.30 | ∞ |

If calibration sources are sufficiently active, combined uncertainty due to source and background counts should be relatively small.

UKAS labs comparison indicates that a combined uncertainty of 0.5% is normal.

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x}_i$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Standard uncertainty of calibration source emission rate, E | 0.24 % | normal | 1 | 1.0 | 0.24 | ∞ |

UKAS labs comparison data indicate that the typical uncertainty provided for almost all ISO8769 calibration sources is of the order of 1.5%

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x}_i$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Semi-width of source area, A | 1.41 % | rectangular | √3 | 1.0 | 0.82 | ∞ |

Example assumed the length and the breadth of the active area (10 cm x 10cm) were only known to ± 1 mm

In reality, by visual inspection, the length and breadth are probably the stated values with a maximum uncertainty of, say, 0.2 mm. Most sources used are 10 cm x 15 cm.

0.2 mm in 10 cm ≡0.2%, 0.2 mm in 15 cm ≡0.13%

Semi-width uncertainty in area = $[(0.2\%)^2 + (0.13\%)^2]^{½} = 0.24\%$

Assume rectangular distribution – divide by √3

Uncertainty on calibration factor = 0.14%

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x_i}$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Semi-width of voltage factor, $f_V$ | 10 % | triangular | √6 | 1.0 | 4.08 | ∞ |

Example assumed a change of 10% in response for a 50v change in HT.

In reality, this need to be determined by the operator for the instrument concerned.

For calibrations, the factors on the certificate apply for the voltage set. If the user is not going to change the HT, this source of uncertainty doesn’t apply.

If comparisons are being made with type-test data, then this uncertainty MAY be important – if the calibrator has made adjustments or determined a plateau so that the HT may not be reset to exactly the factory setting.

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x_i}$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Semi-width of source-detector separation factor, $f_d$ | 2.6 % | rectangular | √3 | 1.0 | 1.50 | ∞ |

Example assumed, for a $^{14}C$ source at a 3 mm source-detector separation, the change in response was 2.6 % / mm. It illustrated the calculation that assumed that the deviation from the declared 3 mm separation is no greater than 1 mm but that all values are equally probable between 2 and 4 mm, a rectangular distribution.

In reality, for well-defined measurement jigs, the difference from 3 mm is probably not more than 0.2 mm – can be checked simply with calipers. If so, the uncertainty in the calibration factor would be not greater than 0.3% (for $^{14}C$).

| Source of uncertainty | Uncertainty ($\partial \boldsymbol{x}_i$) | Probability distribution | Divisor | $c_i$ | $u_i(y)$ ( % ) | $v_i$ or $v_{eff}$ |
|---|---|---|---|---|---|---|
| Semi-width of calibration source non-uniformity factor, $f_u$ | 10 % | rectangular | √3 | 1.0 | 5.77 | ∞ |

Can be reduced significantly - if you know the emission distribution.

If the source area and the probe area are the same, the uniformity uncertainty contribution is effectively zero *(if we ignore non-uniformity of the probe detection efficiency across its area).*

The effect increases as the probe area gets progressively smaller than the source area.  Need to consider each detector probe separately – but this can be a simple task if the source uniformity distribution is known.

Not unreasonable to expect that the uncertainty due to this effect could be reduced to less than 2%.

- Revision of ISO8769 should help
- More in-depth analysis of UKAS labs comparison data should provide useful guidance

| | GPG 49 example | Potential |
|---|---|---|
| Source of uncertainty | $u_i(y)$ ( % ) | $u_i(y)$ ( % ) |
| Standard deviation of mean of M | 3.80 | 0.5 |
| Standard deviation of mean of B | 1.30 | - |
| Std. uncert. of calibration source emission rate, E | 0.24 | 1.5 |
| Semi-width of source area, A | 0.82 | 0.14 |
| Semi-width of voltage factor, $f_V$ | 4.08 | n.a. |
| Semi-width of source-detector separation factor, $f_d$ | 1.50 | 0.3 |
| Calibration source non-uniformity factor, $f_u$ | 5.77 | 2.0 |
| Uncertainty of backscatter factor, $f_{bs}$ | n.a. | n.a. |
| Combined uncertainty *(k=1)* | 8.27 | 2.6 |

# Message

GPG 49 - Example on how to treat uncertainties

- NOT recommended values

Need to produce own data and uncertainty budgets

Overall uncertainties for calibration factors COULD be of the order of 2 – 3 % (k=1)