Attachment I

Counting Statistics
For Laboratory and
Portable Instruments

Minimum Detectable Activity (MDA)

MDA is the minimum detectable (*quantifiable*) activity in dpm at a specified confidence level. Additional conversion factors (C) may be applied to convert dpm to any other activity units that may be desired (e.g., µCi, kBq, etc.). MDA depends on the counting device, counting times (controllable by procedure) and background counting rate. It is not specific to an individual sample. The MDA of a detection system can be prospectively established in the sample collection and counting procedure by specifying sample and background counting times, and by specifying some maximum acceptable background counting rate. Detector efficiency is established during calibration.

$$\text{MDA} = \frac{k_1^2 + 2k_1\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{(t_s)(E)(C)}$$

Where:
R_b = background count rate in cpm
t_s = sample count time in minutes
t_b = background count time in minutes
E = detector efficiency in counts per disintegration
A = area wiped
C = conversion factor from dpm to other desired activity unit, if applicable
k_1 = the one-sided confidence factor = 1.645 at 95% confidence

In nuclear counting programs, MDA is usually calculated at the 95% confidence level (k_1 = 1.645).

MARSSIM sets the first term of the numerator equal to 3 instead of 2.71.

$$\text{MDA}_{95\%} = \frac{3 + 3.29\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{(t_s)(E)(C)}$$

Where:
R_b = background count rate in cpm
t_s = sample count time in minutes
t_b = background count time in minutes
E = detector efficiency in counts per disintegration
C = conversion factor from dpm to other desired activity unit, if applicable. For these calculations, C = 1.

LLD for Wipe Samples

When assaying samples, including wipe samples, the more correct term to use is lower limit of detection (LLD) because sample parameters (e.g., area wiped in this case), in addition to detector and procedural variables, are now part of the equation. For wipe samples, the equation is modified as follows:

$$LLD_{95\%} = \frac{3 + 2k_1\sqrt{R_b t_s\left(1 + \frac{t_s}{t_b}\right)}}{(t_s)(E)\left(\frac{A}{100}\right)(C)}$$

This extra term in the denominator accounts for the actual area wiped. A sample area of 100 cm^2 ($\sim 4" \times 4"$ or 10 cm$\times$10 cm) was used for these samples.

k_1 = 1.645 at CL=95%

R_b = 31 cpm

t_s = 1 minutes

t_b = 1 minutes

E = 80% (worst case)

A_{Active} = 100 cm^2

C = 1 (i.e., no unit conversion factor used)

$$\frac{3 + 3.29\sqrt{0.31 * 1\left(1 + \frac{1}{1}\right)}}{(1)(0.80)\left(\frac{100}{100}\right)(1)} = \frac{5.59}{0.8} = 7\,\text{dpm}/100\,\text{cm}^2$$

An LLD of 7 dpm shows that the DCGL concentration of total contamination can easily be seen with 95% certainty.

LLD for Direct Static Surface Measurements (Ludlum Model 43-68 + Model 2224-1)

Performing direct contamination measurements is the same as counting wipe samples, except the sample is the floor or component being measured. Detector area (A) now comes into play, instead of the area wiped. The area of the Ludlum Model 43-68 is 126 cm^2. The LLD will be in terms of dpm/100 cm^2.

$$\mathrm{LLD} = \frac{k_1^2 + 2\ k_1\ \sqrt{R_b\ t_s\left(1+\frac{t_s}{t_b}\right)}}{(t_s)\ (E)\ \left(\frac{A}{100}\right)(C)}$$

Given:
k_1 = 1.645 at CL=95%

R_b = 268 cpm

t_s = 5 minutes

t_b = 5 minutes

E = 3.9%

A_{Active} = 126 cm^2

C = 1 (i.e., no unit conversion factor used)

At 95% confidence this becomes

$$\mathrm{LLD}_{95\%} = \frac{3+3.29\sqrt{268*5\left(1+\frac{5}{5}\right)}}{(5)(0.039)\left(\frac{126}{100}\right)(1)} = \frac{173.34}{0.246} = 705\,\mathrm{dpm}/100\,\mathrm{cm}^2$$

An LLD of 705 shows that we can detect concentrations of total contamination that are orders of magnitude less than even the DCGL for removable contamination with 95% certainty.

LLD for Direct Static Surface Measurements (Ludlum Model 43-37 + Model 2224-1)

Performing direct contamination measurements is the same as counting wipe samples, except the sample is the floor or component being measured. Detector area (A) now comes into play, instead of the area wiped. The area of the Ludlum Model 43-37 is 584 cm^2. The LLD will be in terms of dpm/100 cm^2.

$$\text{LLD} = \frac{k_1^2 + 2\ k_1\sqrt{R_b\ t_s\left(1+\frac{t_s}{t_b}\right)}}{(t_s)\ (E)\left(\frac{A}{100}\right)(C)}$$

Given:
$k_1 =$ 1.645 at CL=95%

R_b = 521 cpm

t_s = 1 minutes

t_b = 5 minutes

E = 5.5%

A_{active} = 584 cm^2

C = 1 (i.e., no unit conversion factor used)

At 95% confidence this becomes

$$\text{LLD}_{95\%} = \frac{3 + 3.29\sqrt{521 \times 1\left(1+\frac{1}{5}\right)}}{(1)(0.055)\left(\frac{584}{100}\right)(1)} = \frac{85.26}{0.32} = 265\,\text{dpm}/100\,\text{cm}^2$$

An LLD of 265 dpm/100 cm^2 shows that concentrations of total contamination can be detected that are orders of magnitude less than even the DCGL for removable contamination with 95% certainty.

SCANNING MDA FOR COUNT-RATE METERS[1]

At the 95% confidence level, the equation for MDA using a count rate meter is

$$MDA_{95\%} = \frac{4.65\sqrt{\dfrac{R_b}{2\tau}}}{(E)\left(\dfrac{A}{100}\right)}$$

where:

MDA = dpm/100 cm^2
R_b = background count rate (cpm)
τ = detector time constant (min)*
(from mfr's tech manual; = 4 sec fast, 22 sec slow)
NOTE: time constant ≠ response time.
E = detector efficiency in counts per disintegration
A = active detector area in cm^2

The detection sensitivity of scanning is dependent on a number of other factors, such as detector scan rate, size of contaminated area, amount of activity present and surface-to-detector distance. A rough estimate of the MDA for a scan survey can be calculated by substituting the audibly discernable increase in count rate for the numerator in the above equation. Therefore,

$$MDA = \frac{D_i \times R_b}{E \times \dfrac{A}{100}}$$

where:

D_i = Audibly discernable increase in instrument counting rate (multiples of R_b)
E.g., 2 = able to discern 2× background from R_b; 3 = able to discern 3× background from R_b.
R_b = Background counting rate (cpm)
E = Instrument counting efficiency (counts per disintegration)
A = Active detector area in cm^2

An experienced surveyor may be able to discern an increase of 25% to 50% at background counting rates of several hundred cpm or more. At low background counting rates an increase of two or three times background might be required before an identifiable audible difference can be discerned. The health physicists who performed the scanning surveys at Chemtura are able to discern (conservatively) **twice** background at a minimum.

Standard practice for Radiation Safety Associates, Inc. personnel is to scan at a rate no faster than 1 detector width per second, and maintain a surface-to detector distance of 1 cm.

[1] From Oak Ridge Associated Universities text book (http://www.orau.org/ptp/5849/5849-5.pdf) “Scanning.”

Scan Survey Sensitivity—Ludlum 43-37 Floor Monitor

The health physicists who performed the scanning surveys at Chemtura are able to discern (conservatively) **twice** background at a minimum. Therefore the scanning MDA at the 95% confidence level for the Ludlum 43-37 floor monitor is:

$$MDA = \frac{2 \times R_b}{E \times \frac{A}{100}}$$

Where:

Rb = 521 cpm
E = 5.5%
A = 584 cm^2

$$MDA = \frac{2 \times 521\,\text{cpm}}{0.055 \times \frac{584}{100}} = \frac{1042}{0.3212} = 3{,}244\,\text{dpm}/100\,\text{cm}^2$$

Scan Survey Sensitivity—Ludlum 43-68 Hand-Held Detector

The health physicists who performed the scanning surveys at Chemtura are able to discern (conservatively) **twice** background at a minimum. Therefore the scanning MDA at the 95% confidence level for the Ludlum 43-68 hand-held monitor is:

$$MDA = \frac{2 \times R_b}{E \times \frac{A}{100}}$$

Where:

Rb = 268 cpm
E = 3.9%
A = 126 cm^2

$$MDA = \frac{2 \times 268\,\text{cpm}}{0.039 \times \frac{126}{100}} = \frac{536}{0.0491} = 10{,}908\,\text{dpm}/100\,\text{cm}^2$$