"FROM THE TRENCHES"

with Beth Hall and Rollie Cantu

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DETECTION SENSITIVITY AND MDA (Part 1)

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Introduction

Ludlum Measurements, Inc. frequently receives calls from people who perform environmental monitoring with questions regarding release limits, survey techniques, and detection limits and the method for determining them. While Ludlum is not the source authority on regulatory limits or instructions on how to perform environmental monitoring, calculation of detection limits does depend upon the inherent characteristics of the instrument used to perform the monitoring.

The most prevalent detection limit is the MDA (minimum detectable activity). A good definition of MDA as used in the field of nuclear measurements is the smallest amount of activity distinguishable from background which can be quantified at a given confidence level (which in the nuclear industry is nearly always 95%). MDA is an *a priori* (before the fact) calculation designed to give an indication of the basic capabilities of a counting system. It has been referred to as an "advertising level." Another way of thinking about it is a "Minimum *Quantifiable* Activity." Just because a result is less than the calculated MDA does not mean activity distinguishable from background is not present; it just means that there is not enough to quantify an activity with great precision. MDA is for a counting system and is not specific to an individual sample or measurement.

Another closely related detection limit is the LLD (Lower Limit of Detection). There are many different (and conflicting) definitions for LLD (as there are for MDA); however, we will save a brief treatment of LLD for the next installment (part II). This article, Part I, will focus on MDA. A 95% confidence level (which is standard in the nuclear industry) is used in all equations and calculations. The equations are given in several similar forms for what we hope will be clarity. If you are still not sure which one is appropriate, Part II will give examples for you to find the one closest to your specific application.

Equations for Calculating MDA

If you've made it this far into the article you've probably seen at least a couple of different equations for calculating MDA. In truth they all will give nearly the same results and are in most cases mathematically identical. The best all-encompassing form of the MDA equation is:

$$MDA = \frac{2.71 + 3.29\sqrt{R_b t_s \left[1 + \frac{t_s}{t_b}\right]}}{(t_s)(E)}$$

Equation 1

where:

MDA = minimum detectable activity in dpm

R_b = background count rate in cpm

t_s = sample counting time in minutes

t_b = background counting time in minutes

E = detector efficiency in counts per disintegration

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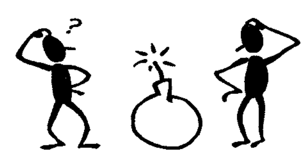

The table contains the relevant values for Ludlum's analog ratemeter instruments. The response time (and thus the time constant) of digital ratemeters varies with the current count rate. Refer to Ludlum Report articles, published in 1994-1995, to determine the response time for digital ratemeters.

Instrument Model	Response time (seconds)	Time Constant (minutes)	Value to use as "t" in MDA calculations (twice the time constant)
Model 177	Fast = 2.2 sec.	0.0161 min.	0.0323 min.
	Slow = 22 sec.	0.161 min.	0.323 min.
Models 2, 3, 12, 14C, 16, 18, and 2221	Fast = 4 sec.	0.0293 min.	0.0587 min
	Slow = 22 sec.	0.161 min.	0.323 min.

MODEL 44-9-18

Telescoping Pancake G-M Detector

December 1998

The Model 44-9-18 is a telescoping pancake GM detector that will extend from 23 to 36 inches. The 44-9-18 is compatible with most survey meters, ratemeters, and scalers. With a thin entrance window of 1.7 ± 0.3 mg/cm² mica, it will detect alpha, beta, and gamma radiation. The flexible tubing used allows the detector to be adjusted to almost any angle.

SPECIFICATIONS:

WINDOW AREA:
Active - 15 cm² Open - 12 cm²

EFFICIENCY (4pi): Typically 5%-^{14}C; 22%-$^{90}Sr/^{90}Y$; 19%-^{99}Tc; 32%-^{32}P; 15%-^{239}Pu

SENSITIVITY: Typically 3300 cpm/mR/hr (*^{137}Cs gamma*)

ENERGY RESPONSE: Energy-dependent

DEAD TIME: Typically 80μs

OPERATING VOLTAGE: 900 volts

CONSTRUCTION: Anodized aluminum handle with beige polyurethane enamel painted detector housing and SS protective screen (*79% open*)

TEMPERATURE RANGE: -4°F(-20°C) to 122°F(50°C)

SIZE: 1.8" (4.6 cm)H X 2.7" (6.9 cm)W X 23" (58.4 cm)L, Max. telescoping length 36"(91.4 cm)

WEIGHT: 1.5 lb (0.7kg)

PRICE: $ 245.00 each

If you would like more information on this product please call our Sales office at 800-622-0828.

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In the case where the sample counting time is the same as the background counting time, the equation can be simplified to:

$$MDA = \frac{2.71 + 4.65\sqrt{(R_b)(t)}}{(t)(E)}$$

Equation 2

where:
MDA, R_b, and E are as defined above
t = sample and background counting time in minutes

In many instances we want the MDA to be in terms of a specific area. For samples such as smears for removable contamination the above equations are understood to be in terms of dpm per smear. For surface measurements we usually want the MDA in terms of dpm per 100 cm². For this, an additional factor can be included in the denominator to adjust the MDA for the area of the detector you are using:

$$MDA = \frac{2.71 + 3.29\sqrt{R_b t_s \left[1 + \frac{t_s}{t_b}\right]}}{(t_s)(E)\left(\frac{A}{100}\right)}$$

Equation 3

where:
MDA, R_b, t_s, t_b and E are as defined above
A = detector area in cm²

And

$$MDA = \frac{2.71 + 4.65\sqrt{(R_b)(t)}}{(t)(E)\left(\frac{A}{100}\right)}$$

Equation 4

where:
MDA, R_b, E and A are as defined above
t = sample and background counting time in minutes

Using MDA Equations with Ratemeters

Determining MDA for instruments that count a sample or surface for a pre-set time is relatively straightforward using the above equations. Sometimes people get stuck, however, in calculating MDA for a ratemeter because there is no clear sample and background counting "time." Fortunately, it has been accepted that in ratemeter applications, twice the instrument's *time constant* can be substituted for the sample and background counting times.

An instrument's time constant is not the same as an instrument's response time, although they are related. The response time is the value we are most familiar with, and it is defined as "the time interval required for the instrument reading to change from 10% to 90% of the final reading (or vice versa) following a sudden significant change in the radiation field at the detector." Another way of thinking about response time is as the amount of time over which the currently indicated value is averaged.

The time constant, on the other hand, is defined as "the time involved in the charging or discharging of an inductor or capacitor; one time constant is the length of time required to reach 63% of the full charge or discharge." As described in a three-part series, published in three 1994 and 1995 issues of the Ludlum Report, the time constant can be approximated by multiplying the response time by 0.44. The calculated time constant, however, will be in seconds, so you must divide that number by 60. Alternately, to approximate from response time (in seconds) directly to time constant (in minutes) in a single step, divide the response time by 0.00733.

The table on page 2 contains the relevant values for Ludlum's analog ratemeter instruments. The response time (and thus the time constant) of digital ratemeters varies with the current count rate. Refer to the Ludlum Report articles mentioned above to determine the response time for digital ratemeters.

References will be published in Part II