ANSI N323 Calibration Standard for Portable Radiological Instruments

Presented to Air Monitoring User Group

Las Vegas, Nevada

May 4-6,2010

Why This Presentation to This Group

1. Portable survey instruments are often used to assess air sample media in the field.
2. Detectors used for air sample counting are often similar type, or the same as those used for surface measurements.
3. Many issues associated with portable instrument calibration are also encountered with air monitoring and sample counting calibration.

Why This Presentation to This Group

4. Examples include:
   - Use of certified, traceable calibration sources
   - Defining factors for correlating a calibration result for interpreting field measurements
   - Documenting and reporting requirements for calibration points (e.g., CAMs)
   - Laboratory QA/QC requirements
5. Morgan Cox suggested this.

I. Introduction

A major point that must be recognized <u>and</u> understood with regard to selection, calibration, and use of portable instruments for detection and assessment of radiation conditions is that two distinct cultures exist and the two do not necessarily have the same requirements for successful completion of a radiological assessment.

- Radiation Control (Radcon)
- Environmental Assessment

Radiation Control (Radcon)

- Application: Primary focus is radiological source term assessment for specification and design of personnel radiation protection and/or source term removal.
- Issues that must be addressed by Radcon assessments involve personnel risk vs. operational interfaces associated with component maintenance, source removals, decon, and waste handling/disposal.

Environmental Assessment

- Application: Assessment of the levels of residual radioactivity associated with surfaces and components for unrestricted release in support of reuse, recycle, or disposal.
- Limits associated with unrestricted release are usually near natural background.

Differences between Radcon and Environmental Cultures

- Radcon:
  - Most factors used for measurement assessment result in conservative results.
  - Even if non-conservative, safety factors applied to radiation protection and source handling result in adequate (conservative) operation.
- Environmental:
  - Measurements are typically at low levels, near background.
  - Significance of the measurements more applicable to political and economic risks as opposed to real public or environmental impact risks.
- Note:

  Operational “green-tagging” is more akin to Environmental than to Radcon in its significance.

II. Background – Basis for Developing ANSI N323B

- Instrument calibration and use prior to 2002 was based on recommendations and requirements contained in ANSI N323 and ANSI N323A-1997 for calibration and ANSI N42.17A for performance requirements.
- The lower range of applicability for both standards was 1.0µGy/hr (100µR/hr).
- Instruments that had a low range that responded to background levels of radiation (< 100µR/hr) were calibrated on the low range for electronic response only. No source calibration was performed.
- ANSI N323B was developed to extend the range of applicability for near-background calibration.

Source vs. Electronic Pulse Calibration

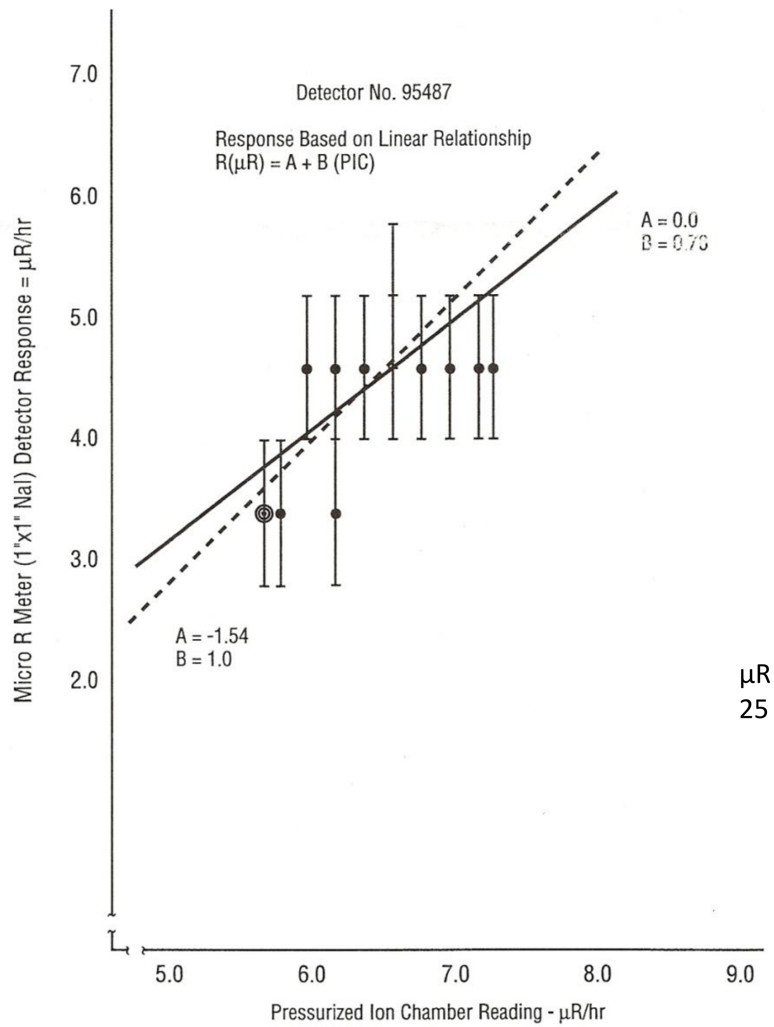
- The following examples illustrate the consequences of performing an electronic test <u>only</u> on the low range of the detector.
- μR Meter response comparison with PIC

  Meter No. 1 – 25% lower

  Meter No. 2 – 50% lower
- Count-rate meter response

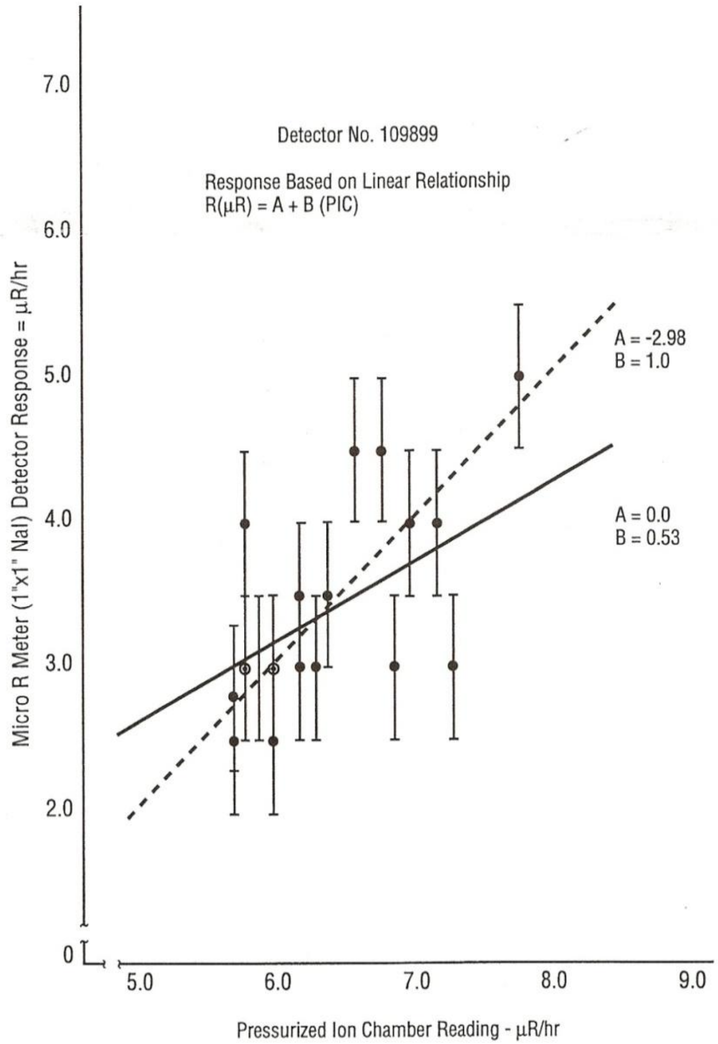
  Variation between the two meters was a factor of two (2)

Response of MicroR Meter to Background



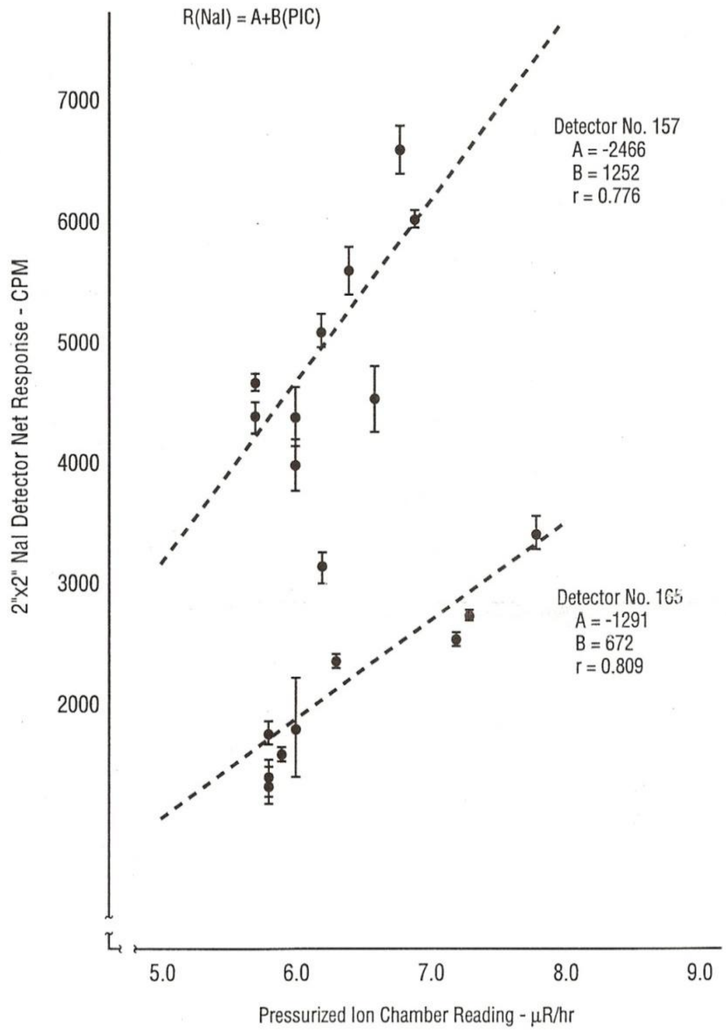
μR meter response
25 % lower than PIC

Response of MicroR Meter to Background



μR meter response
50 % lower than PIC

Response of 2"x2" NaI Detector to Background



Scanning system-no calibration lab certification

Electronic Pulser vs Radiation Source Response Test

Source	Detector Type	Pulse Duration	Pulse Height
Pulser	---	0.05 µS	0.12 mV
Technitium-99	Scintillator	2.9 µS	0.055 mV
Technitium-99	Gas Proportional	3.9 µS	0.17 mV
Strontium-99	Scintillator	2.9 µS	0.09 mV
Strontium-99	Gas Proportional	3.9 µS	0.155 mV
Thorium-230	Scintillator	8.3 µS	0.375 mV
Thorium-230	Gas Proportional	6.9 µS	0.45 mV

III. Beta and Alpha Sample Counting

$$S_0 = \frac{R_T - R_B}{\varepsilon_i * \varepsilon_S} \; - \; \text{dpm}$$

R_T = Total count rate in cpm

R_B = Background count rate in cpm

ε_i = Instrument efficiency for alpha or beta radiation in cpm per dpm

ε_s = Source correction factor to account for differences between the calibration/check source and the residual activity, such as backscatter, self absorption, geometry, etc. (unitless)

Beta and Alpha Counting Summary

- The detector only responds to the 2π surface source activity.
- To convert the response of the detector to surface activity the efficiency (ε_i) of the detector (cpm/dpm) must be known.
- If the calibration source has the same surface effects (backscatter, self absorption, etc.) as the surface to be measured, the relationship between the 2π calibration and the unknown 4π surface activity is a factor of 2 ($\varepsilon_s = 0.5$).
- If the unknown surface effects are different from the calibration, additional corrections to ε_S are necessary.
- The following example illustrates the effects of not properly considering surface effect differences.

Effects of Calibration Source Design

Two ^{137}Cs "calibration" sources of different composition and geometry were used to determine the detector efficiency for analyzing air sample and smear activity, collected on a 47mm filter paper, set within a metal counting planchet.

1. Backscatter source description

   Activity deposited on nickel plate with source activity 47.7mm in diameter, covered with 3.5mg/cm^2 mylar, and certified by 2π beta analysis.

2. Filter paper source description

   Activity deposited as droplets on to 50mm filter paper from certified liquid. The deposit side was coated with a protective film of unknown composition and thickness.

Effects of Calibration Source Design

^{137}Cs $t_{½}$ = 30.17 yr

Beta Energy and Abundance

(1) 0.154 MeV (93.5%)

(2) 1.176 MeV (6.5%)

Gamma Energy and Abundance

(1) 0.662 MeV (85%)

Calibration Source Descriptions – At Calibration

Parameter	Backscatter Source	Filter Paper Source
Calibration Date	7/12/1979	7/11/1979
Surface Emission Rate	5180 dpm Certified Measurement	unknown
Total Emission Rate	7400 dpm (1)	3000 dpm (2) (Certified liquid?)

(1) Derived for backscatter factor of 0.40

(2) Written on the face of the source

Effects of Calibration Source Design

- Both sources were placed on the metal planchet and the results used to derive a “calibration factor” to be used to analyze filter paper samples. The filter paper source was inserted with the coated surface facing the detector.
- The filter paper source was closer to filter paper samples to be analyzed. However, the coating on one side of the source and the “non-traceable” source strength made this source of questionable application.
- The backscatter source had a protective coating not encountered with filter paper samples to be counted, did not reproduce the self-shielding characteristics of filter papers, and utilized a backscatter factor that was appropriate for the higher energy, but less abundant beta particle. This source did, however, have a traceable verified surface emission rate.

Effects of Calibration Source Design

- The response of a pancake Geiger-Mueller detector-scaler planchet beta counting system was noted for each source. The responses noted were:

  Backscatter source: response ≈ 30%

  Filter paper source: response ≈ 15%

- The filter paper source was used by a regulator and the backscatter source was used by the operator.
- The operator was cited for using a "calibration" that was non-conservative by a factor of two.

Effects of Calibration Source Design

- In response to the citation, the operator conducted an extensive evaluation of the two sources and the counter response that should be applicable to filter paper counting. This included source characteristics verified by gamma analysis of the ^{137}Cs activity.
- The focus of the testing was on the filter paper source to determine its self-absorption and backscatter characteristics with respect to the planchet counting system for applicability to filter paper counting. The attenuation thickness was determined by weight and size, and verified by measurement with calibrated beta attenuator discs.
- The effective coating thickness was determined by comparing detector response to the coated and uncoated sides. This analysis permitted determination of the 2π source emission rate for both sides of the source.
- Comparison between filter paper source and typical filter paper sample discs are shown on the following table.

Effects of Calibration Source Design

- Comparison between Source and Sample Characteristics

Parameter	Sample	Source
Diameter	47mm	50mm
Paper Thickness	$10mg/cm^2$	$26mg/cm^2$
Coating Thickness	--	$4.5mg/cm^2$

- The total of 4π activity of the filter paper source was compared to a gamma analysis and was consistent with the decay-corrected activity written on the source. This permitted a coated and uncoated surface emission rate determination, assuming uniform distribution of the activity within the filter paper.
- Using the surface emission rate for each source, the instrument efficiency (ε_i) for the pancake GM was determined.

Source	ε_i
Backscatter	0.439
Filter paper, coated side	0.443
Filter paper, uncoated side	0.443

Effects of Calibration Source Design

- Correcting for filter paper sample counting conditions (ϵ_S), by assuming the sample activity is primarily on the surface facing the detector, then accounting for backscatter from the planchet and self absorption within the filter paper results in an $\varepsilon_S \approx 0.55$ (typical for ^{137}Cs beta and Whatman paper).
- Total counting efficiency $\varepsilon_i * \varepsilon_S \approx 25\%$.
- This value was verified by counting several air samples and performing both a total beta analysis using a gas flow proportional counter and a gamma spectrum analysis and comparing the results to beta counting using the pancake GM counter.

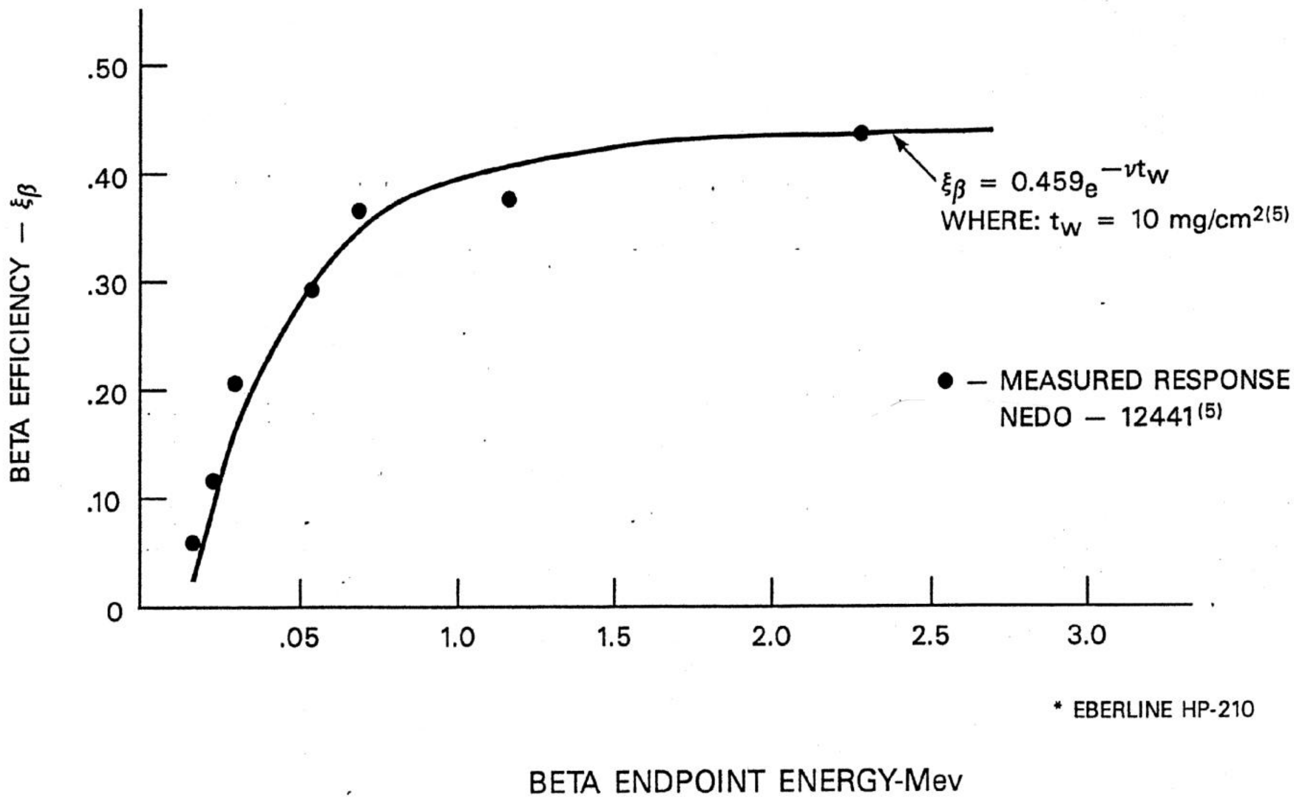
Effects of Calibration Source Design

- Correlation between GM counter analysis and both total beta and gamma spectrum for several air samples obtained in situ confirm the efficiency determination for the GM counter.
- The samples were analyzed for total beta activity using a gas flow proportional counter and analyzed for ^{137}Cs activity using gamma spectrometer analysis.

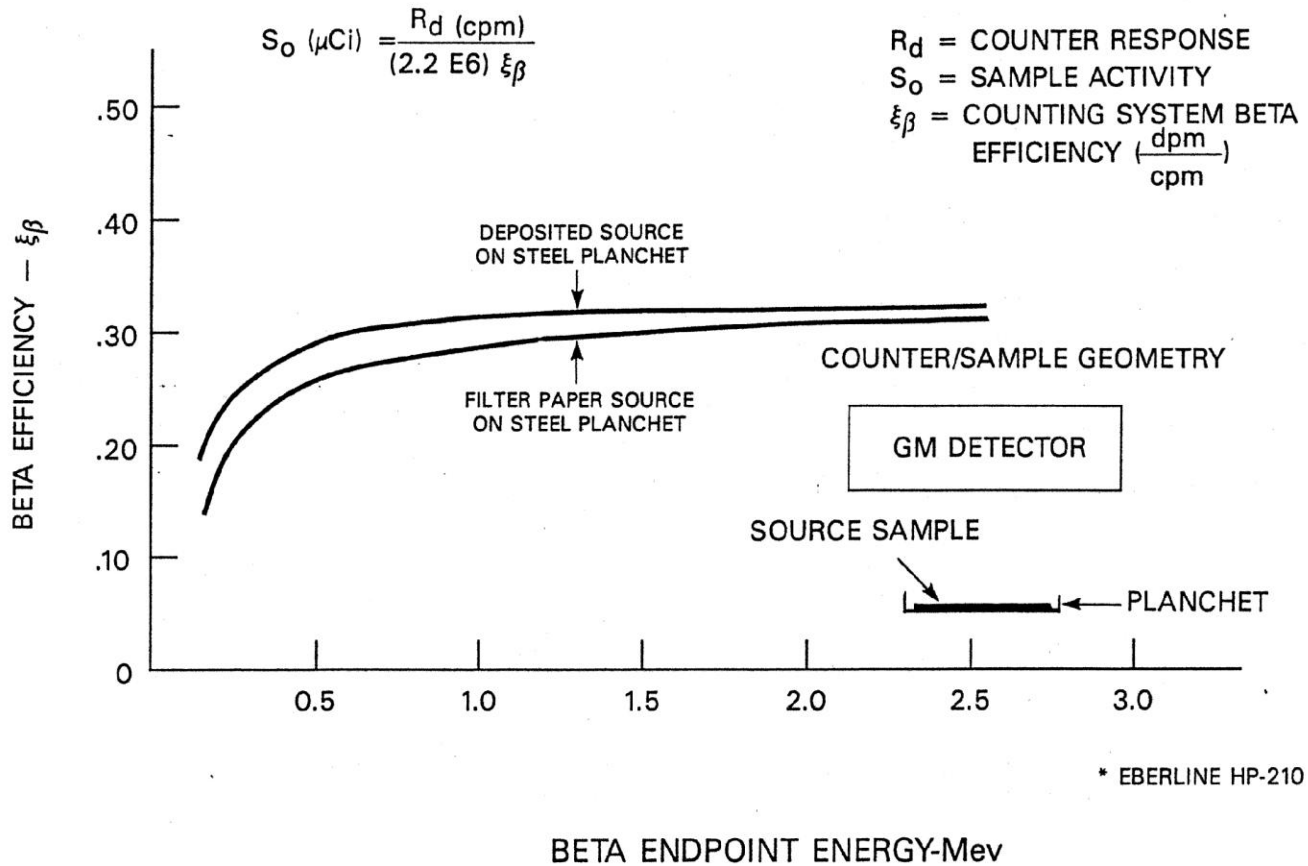
^{137}Cs (dpm) GeLi Analysis	Total Beta-dpm Gas Proportional	GM Response-cpm	ε_0
1996	6370	1548	24.3%
38040	30410	9645	25.4%
1146	904	278	24.3%

- Note: The first sample contained more beta activity that the cesium contribution but the GM response to total beta remained consistent for a beta energy mix similar to cesium.

RESPONSE OF PANCAKE GM DETECTOR TO BETA CHECK SOURCE*



BETA DETECTION EFFICIENCY FOR SAMPLE COUNTING USING PANCAKE GM*



* EBERLINE HP-210

IV. Summary-Instrument Calibration

1. Calibration source requirements for count and dose rate meters
   - The calibration source shall be certified to NIST or international-equivalent standards.
   - Perform the calibration for surface activity measurements using a certified surface emission rate (2π) only. Total activity certification (4π) rarely, if ever, represents field measurement conditions.
   - The calibration source should have the same radioactive emission characteristics, e.g., emission particle type and energy, as the anticipated field radiation/radioactive material.
   - For near-background measurements, the emission rate of the calibration source should be ≤ 50 times the applicable standard for unrestricted use.

Instrument Calibration

2. Instrument calibration requirements
   - Instrument calibration requirements for near background measurement should currently be based on the performance requirements in ANSI N323B.
   - The most sensitive range of the instrument should be calibrated or verified using a radiation source.
   - Electronic calibration for the meter (only) fails to reproduce the electronic input from a detector. Electronic pulsers generate pulses that are typically 10's to 100's of microsecond duration whereas most alpha and beta detectors generate pulses that are typically 10's to 100's of milliseconds in duration.
   - The difference between electronic pulse and radioactive source response could be as much as a factor of two (2) or more.

Instrument Calibration

2. Instrument Calibration Requirements (continued)
   - For near background calibration of dose rate meters, a transfer instrument, e.g., a Reuter-Stokes PIC, may be used by direct comparison.
   - Calibration for surface activity and air sample measurements should be based on the following:
     - Particle energy that is within ± 10% of the anticipated activity to be measured.
     - Alternately, calibration may be based on a curve generated from at least three sources with energies that bracket the energy of interest.
     - Calibration should <u>not</u> be based on extrapolation outside the energy range tested.

Instrument Calibration

2. Instrument Calibration Requirements (continued)
   - The effects of interfering radiation on the response of the detector should be known or determined during calibration, e.g., gamma response of alpha and beta detectors.
   - For combination alpha-beta detectors, the interference between the two electronic channels (i.e., crosstalk) must be evaluated.
     - Ideally crosstalk between channels should be < 10% for alpha into beta and < 1% for beta into alpha.
     - Experimental results indicate relationships between crosstalk and both source energy and cable length between detector and meter that significantly exceed this "ideal".
     - Beta measurements in the presence of equivalent alpha activity (i.e., uranium) may over-predict (false positive) that activity by as much as 50%.