Rad Monitor Set Points and the RETS

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10 CFR 20 Limits
(Per Site Limits)

Liquids

Offsite Concentrations Limited To:

10 Times Appendix B, Table 2, Col 2 Values*

* Extreme Part 20 Trivia:

- Reference to Table 2 (Arabic numeral) is New Part 20
- Reference to Table II (Roman numeral) is Old Part 20

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Tech Specs (Per Site Limits)

Gases

Noble Gas Dose Rate Limited To:

500 mrem/year Total Body

3000 mrem/year Skin

Radioiodine, Tritium and Particulate Dose Rate Limited To:

1500 mrem/year To Any Organ

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Tech Specs
(Per Site Limits)

Gases

Radioiodine, Tritium and Particulate Dose Rate Limited To:

1500 mrem/year To Any Organ

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10 CFR 50 Appendix A

General Design Criteria For Nuclear Power Plants

General Design Criteria 60

- Effluent Releases Must Be Controlled

General Design Criteria 64

- Effluent Releases Must Be Monitored

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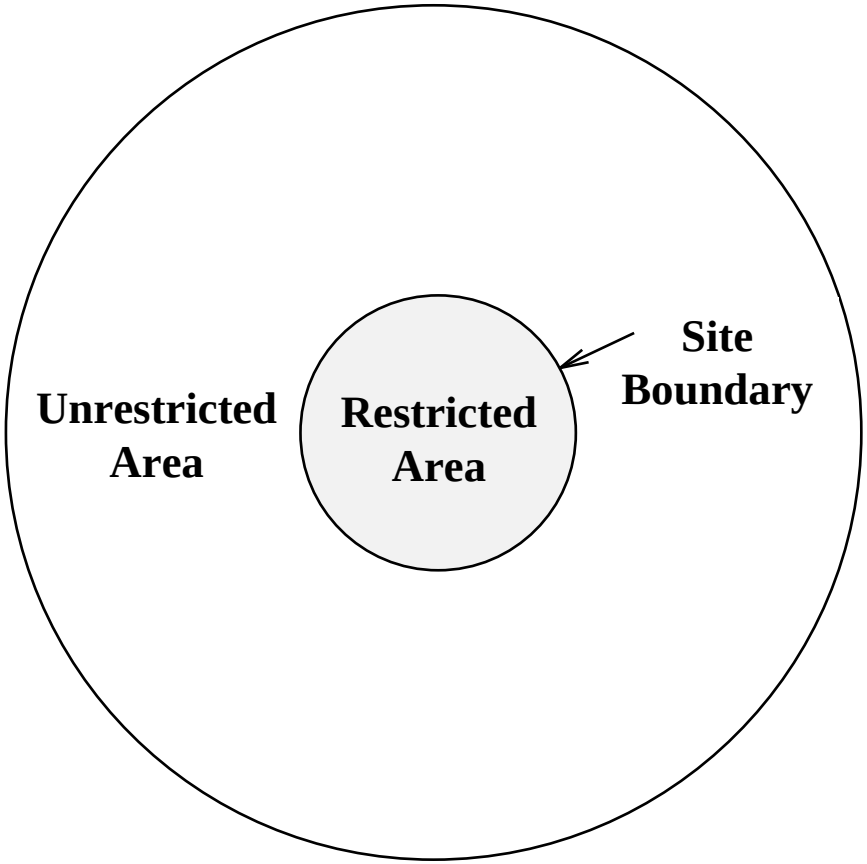
Liquid Effluents



Site Boundary Concentrations Limited To:

- 10 Times 10 CFR 20, App B, Table 2, Col 2

Dose in Unrestricted Area to Member of Public Not To Exceed:

- 1.5 mrem/qtr and 3.0 mrem/yr Total Body
- 5.0 mrem/qtr and 10 mrem/yr Any Organ

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Liquid Effluent Implementation Methodology

10 CFR 20 Concentration Limits

Calculate Liquid Effluent Monitor Set Points to Terminate Release in the Event Concentration Exceeds 10 Times 10 CFR 20 Limits at the Site Boundary

NOTE!: For Purposes of Set Point Determination, the 10 CFR 20 Concentration Limits are Considered to be *Instantaneous Concentration Limits*

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Liquid Effluent Implementation Methodology

10 CFR 50 Dose Limits

- Calculate Cumulative Total Body and Organ Doses to Real Individual Based on Existing Pathways
- Dose is calculated at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicate the maximum potential exposures.

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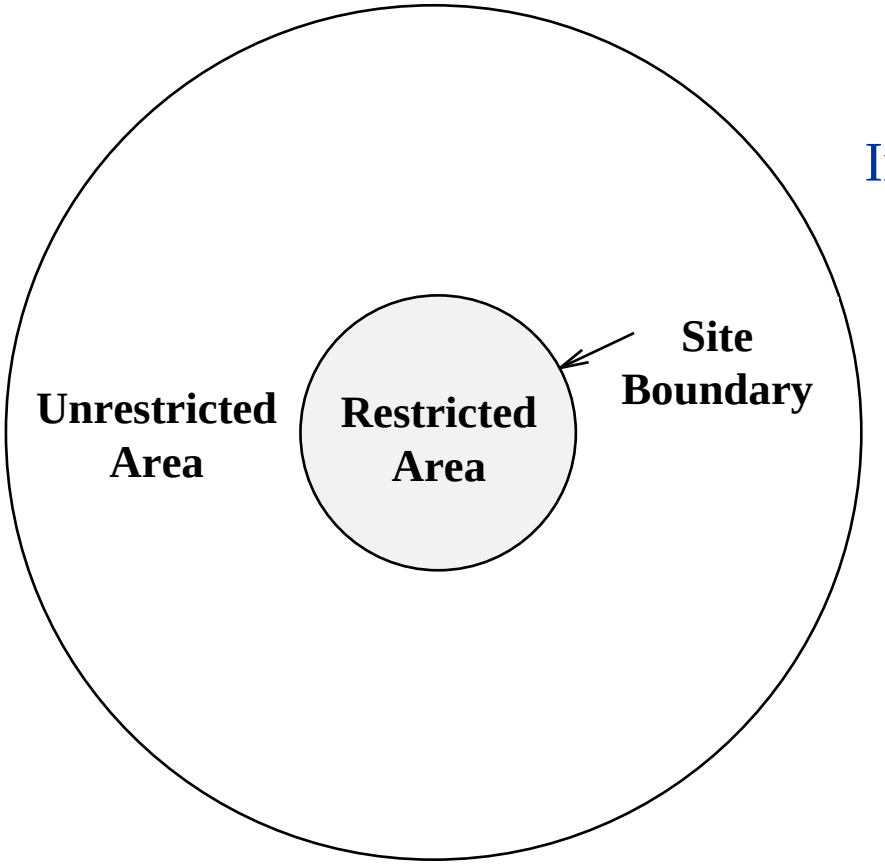
Gaseous Effluents



At the Site Boundary

Instantaneous Dose Rates Limited To:

- Noble Gas:
  - •500 mrem/yr Total Body
  - •3000 mrem/yr Skin
- Radioiodines, Tritium and Particulates:
  - •1500 mrem/yr Any Organ

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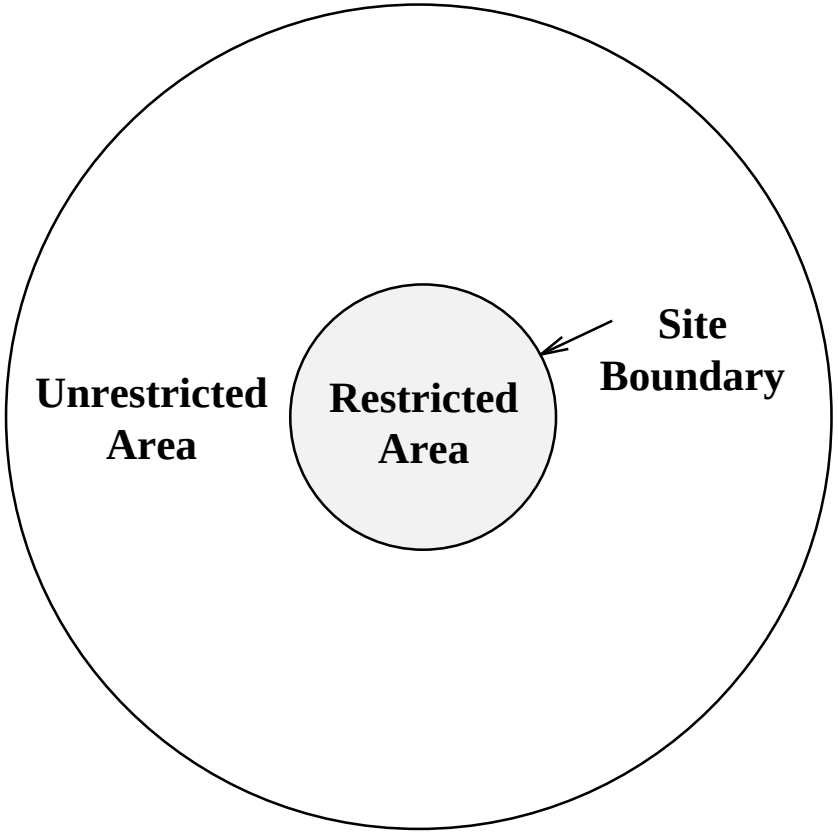
Gaseous Effluents



At or Beyond the Site Boundary

Noble Gas Air Dose Limited To:

- 5 mrad/qtr and 10 mrad/yr Gamma
- 10 mrad/qtr and 20 mrad/yr Beta

Dose to Individual in the Unrestricted Area From Radioiodines, Tritium and Particulates Limited To:

- 7.5 mrem/qtr and 15 mrem/year

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Gaseous Effluent Implementation Methodology

Tech Spec Airborne Concentration Limits (Driven by "Old" 10 CFR 20)

Calculate Rad Monitor Set Points to Limit Instantaneous Noble Gas Dose Rates To:

500 mrem/year Total Body

3000 mrem/year Skin

Calculate Radioiodine, Tritium and Particulate Dose Rates to Verify Compliance With:

1500 mrem/year Organ Dose Rate

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Effluent Trivia

Where did the 500, 1500 and 3000 mrem numbers come from?

- "Old Part 20 was based on the dose methodology of Publication 2 of the International Commission on Radiological Protection (ICRP 2)
  - ICRP 2 Worker Limits Were:
    - 5 Rem Total Body
    - 15 Rem to Any Organ
    - 30 Rem to Skin
  - The 15 and 30 Rem numbers are not found in the old Part 20!
- Public Limits Were Set at 1/10 of the Worker Limits:
  - 500, 1500 and 3000 mrem.

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More Effluent Trivia

- Part 20 Revised to Incorporate ICRP 26 and ICRP 30
- Current Part 20 Dose Limit to Member of Public is now 100 mrem – except…
  - Dose is apportioned as 50 mrem internal and 50 mrem external.
  - This means that the ECLs of App B, Table 2, Col 2 are based on 50 mrem.

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Why are limits like they are?

- Liquid Concentration Limits: 10 x ECL
  - New Part 20 Dose Limit ~ 1/10 of Old Part 20
    - 500 mrem CDE (Committed Dose Equivalent)
    - 50 mrem TEDE (Total Effective Dose Equivalent)
  - New Part 20 Concentration Limits ~ 1/10 of Old Part 20 Concentration Limits
    - Old Part 20 – MPC (Maximum Permissible Concentration)
    - New Part 20 – ECL (Effluent Concentration Limit)

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Why are limits like they are?

- Gaseous Dose Rate Limits:
  - Remain Unchanged
  - Connection Broken Between New Part 20 and Dose Rates Limits (500, 1500 and 3000 mrem/yr)
  - Gaseous Dose Rate Limits are Now Tech Spec Only Limits

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And More Effluent Trivia

- Revision to Part 20 Failed to Consider Impact on RETS/REMP
  - Recognized that pushing down concentration and dose rate limits by factor of 10 would have substantial impact on licensee.
- Rationale
  - Cannot release at the current concentration limits very long before challenging App I dose limits.
  - Example: Dose rate of 3000 mrem/yr exceeds App I limit in less than 24 hours.

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Gaseous Effluent Implementation Methodology

10 CFR 50 Dose Limits

- Calculate Cumulative Total Body and Organ Doses to Real Individual Based on Existing Pathways
- Dose is calculated at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicate the maximum potential exposures.

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Liquid Effluent Monitor Set Point Calculations

10 CFR 20 Requires the Total ECL Fraction to be:

$$\frac{C_A}{ECL_A} + \frac{C_B}{ECL_B} + \frac{C_C}{ECL_C} \leq 1$$

Total ECL Fraction = Required Dilution Factor

Actual Dilution Factor is:

$$DF = \frac{Dilution\ Flow + Waste\ Flow}{Waste\ Flow}$$

Note that the ECL values defined here are 10 times the 10 CFR 20, Appendix B, Table 2, Column 2 values.

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Liquid Effluent Monitor Set Point Calculations

Therefore:

$$\sum_i \frac{C_i}{ECL_i} \leq \frac{Dilution\ \ Flow}{Waste\ \ Flow}$$

OR

$$Total\ \ ECL\ \ Fraction\ \ =\ \ RDF\ \ \leq\ \ DF$$

Alternately

$$\sum_i \frac{C_i}{ECL_i} \leq \frac{Dilution\ \ Flow + Waste\ \ Flow}{Waste\ \ Flow}$$

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Liquid Effluent Monitor Set Point Calculations

The concentration of liquid effluent at the site boundary can be controlled by:

1. The effluent concentration in the waste stream.
2. The effluent discharge flow rate.
3. The dilution flow rate.

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Liquid Effluent Monitor Set Point Calculations

Minimum Dilution Flow Rate Set Point

$$F_{\min} \geq Total\ ECL\ Fraction \times f(Assumed\ Waste\ Flow)$$

Maximum Waste Flow Rate Set Point

$$f_{\max}(Maximum\ Waste\ Flow) \leq \frac{F(Assumed\ Dilution\ Flow)}{Total\ ECL\ Fraction}$$

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Liquid Effluent Monitor Set Point Calculations

$$c_{\max} = \sum_i c_i \frac{DF(actual)}{Total\ ECL\ Fraction}$$

OR

$$c_{\max} = \sum_i c_i \frac{F(actual)/f(actual)}{Total\ ECL\ Fraction}$$

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Liquid Effluent Monitor Set Point Calculations

Correction for Monitor Insensitivity to Non-Gamma Emitters

$$c_{\max} = \sum_g c_g \frac{DF(actual)}{Total\ ECL\ Fraction} \times RF$$

Should Include an Administrative Safety Factor (SF > 1)

$$c_{\max} = \sum_g c_g \frac{DF(actual) \times RF}{Total\ ECL\ Fraction \times SF}$$

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The Tritium Problem

- Tritium concentration in liquid effluents is high compared to gamma emitter concentration.
- Traditional methodology may result in Set Point values barely above background.
- Increased probability of false alarms.

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The Tritium Problem

- Modify traditional Set Point methodology.
- Assumes tritium concentration in the liquid effluent stream will never exceed a predetermined maximum.
- Reasonable assumption since Tritium is not concentrated by plant processes.
- Can result in more operationally reasonable Set Point values.

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Correction for Tritium

Introduce a Tritium Correction Factor (TCF) defined as:

$$TCF = \left[1 - \left(\frac{C_{H-3}/ECL_{H-3}}{DF_C/WF_C}\right)\right]$$

Where:

$C_{H\text{-}3}$ = Conservative estimate of H-3 concentration.

$ECL_{H\text{-}3}$ = H-3 effluent concentration limit.

DF_C = Conservative Dilution Flow estimate.

WF_C = Conservative Waste Flow estimate.

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Set Point Modification

Set Point equation is modified as follows:

$$C_{\max} = K_{mon} \times \sum_{g} C_g \times \left[\frac{\{\text{Dilution Flow}\}/\{\text{Waste Flow}\}}{\sum_{i \neq H-3} \frac{C_i}{ECL_i}} \right] \times TCF$$

Note that the Total Effluent Concentration Limit Fraction (denominator) ***excludes*** Tritium.

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Example - 1

Nuclide	Concentration uCi/ml	ECL uCi/ml	ECL-Fraction	
H-3	2.00E-03	1.00E-02	2.00E-01	
Co-60	1.00E-07	3.00E-05	3.33E-03	
Sr-90	7.00E-07	5.00E-06	1.40E-01	
Cs-137	1.00E-07	1.00E-05	1.00E-02	
Total Conc	**2.00E-03**		**3.53E-01**	**Total ECL**
Total Gamma	**2.00E-07**			**Fraction**

Dilution Flow = 50,000 gpm Waste Flow = 100 gpm

Monitor Response = 7.0E+06 cps per uCi/ml

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Example - 2

Maximum Allowable Concentration for Mix = 2.8E-00 uCi/ml

Standard Set Point Methodology

Monitor Set Point = 2000 cps

Monitor will alarm at gamma concentration = 2.8E-04 uCi/ml

Total concentration at alarm will be = 2.8E-00 uCi/ml

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Example - 3

TCF Set Point Methodology

Assume:

Conservative Dilution Flow	= 5000 gpm
Conservative Waste Flow	= 100 gpm
Conservative H-3 Conc	= 1.0E-02 uCi/ml
Tritium Correction Factor	= 0.98

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Example - 4

TCF Set Point Methodology

Monitor Set Point = 4700 cps (compare to 2000 cps)

Monitor will alarm at gamma concentration = 6.4E-04 uCi/ml

Total concentration at alarm will be = 4.9E-03 uCi/ml

Worst case concentration will be = 1.3E-02 uCi/ml

(Remember We've Claimed H-3 cannot exceed 1E-02)

Compare to concentration limit 2.8E+00 uCi/ml

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The TCF Methodology

- Methodology provides operationally reasonable liquid monitor Set Point while providing appropriate conservatism.
- Most effective in situations where Tritium concentration is high compared to gamma emitter concentration.
- Should evaluate methodology using site specific source term to determine suitability.

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Controlling Airborne Effluent Dose Rates

- Dose Rate Limits Act to Control Airborne Concentration
- Dose Rate Due to Noble Gas
  - Controlled By Online Monitor
  - Set Points Based On Dose Rate (not concentration)
- Dose Rate Due to Radioiodine, Particulates and Tritium
  - Not Considered Technically Feasible to Monitor Online (some sites do)
  - Compliance Demonstrated by Calculation – Not Set Points

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Noble Gas Dose Rate Set Points

- Applicable in the Unrestricted Area
  - Does not include areas over bodies of water (NUREG 0133).
  - May include areas within the site boundary used for residential quarters, commercial, institutional and recreational facilities.
- For sites with tall stacks (elevated releases) the highest NG dose rate is not generated by immersion but by plume shine.

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Noble Gas Dose Rate Set Points

- Depends on Release Height
- Typical Exposure Mechanism is by Immersion in Semi-Infinite Cloud
  - External Dose (Total Body Dose)
  - Gamma Dose
  - Beta Dose
- But Don’t Forget Plume Shine

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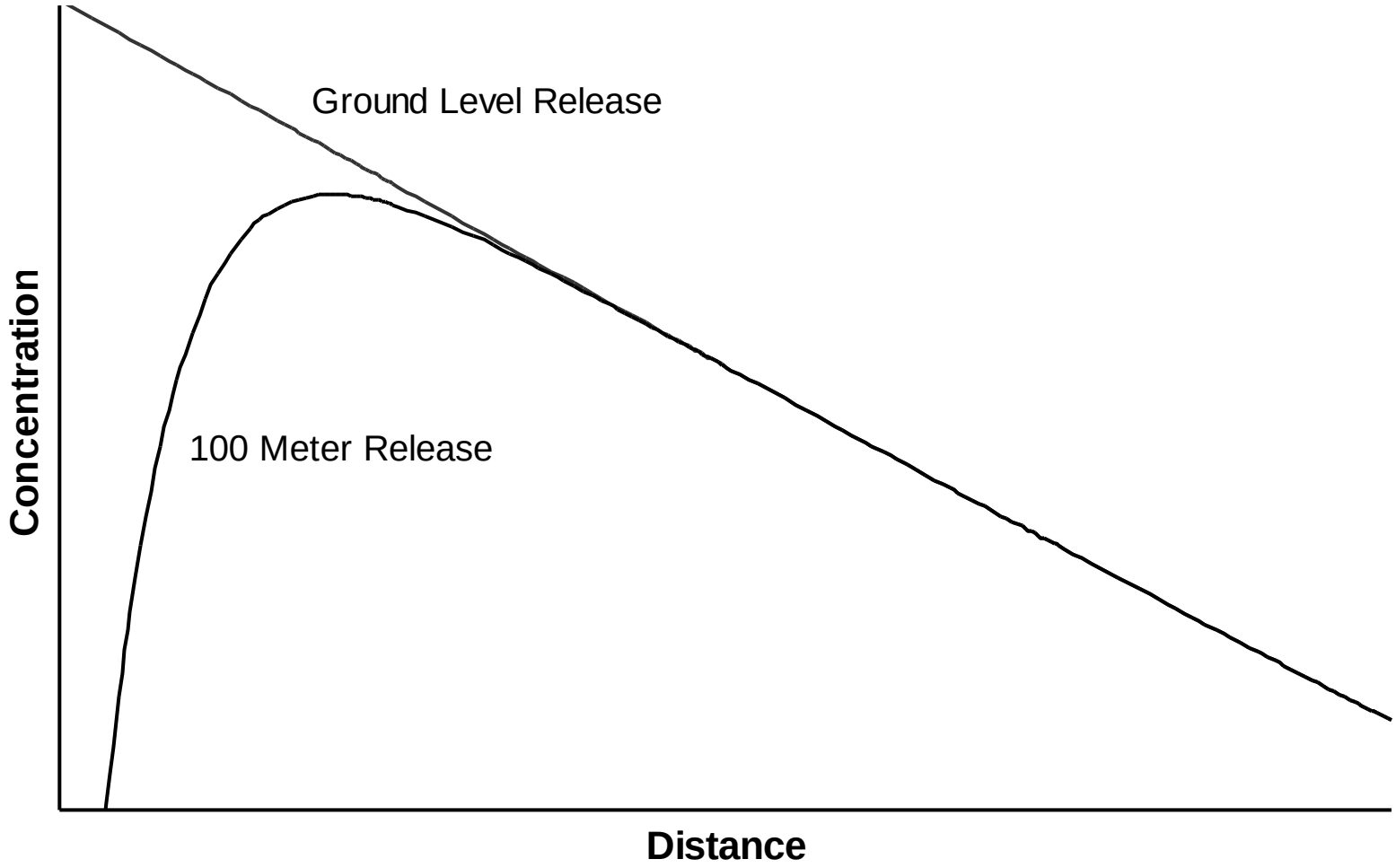
Concentration vs. Release Height



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Noble Gas Dose Rate Set Points

- Releases of Noble Gases from Elevated Release Stacks
  - Greater than 80 Meters – Free Standing (cooling towers don't count)
  - Highest Dose Comes from Plume Shine
  - No Significant Beta Dose Due to Air Shielding

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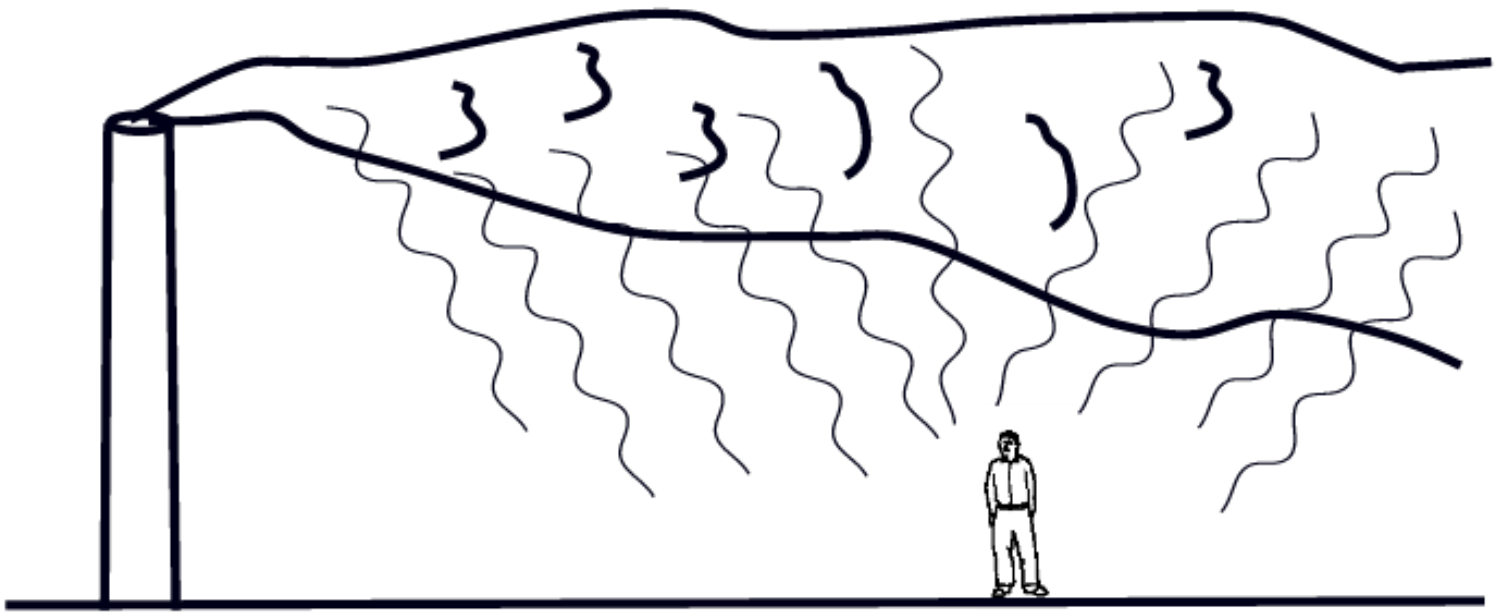
Plume Shine Dose from Elevated Release



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RPT Dose Rate

- Applicable in the Unrestricted Area
  - Does not include areas over bodies of water (NUREG 0133).
  - May include areas within the site boundary used for residential quarters, commercial, institutional and recreational facilities.
- For sites with tall stacks (elevated releases) the highest RPT dose rate may occur *beyond* the site boundary.

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Noble Gas Dose Rate

The dose rate to the total body due to immersion in a semi-infinite (or finite) cloud of noble gas is given by:

$$\textit{Total Body Dose Rate}\ (\textit{mrem / year}) = \overline{\chi/Q}\sum_i K_i \dot{Q}_i$$

The dose rate to the skin due to immersion in semi-infinite (or finite) cloud of noble gas is given by:

$$\textit{Skin Dose Rate}\ (\textit{mrem / yr}) = \overline{\chi/Q}\sum_i \left[L_i + 1.1 M_i\right] \dot{Q}_i$$

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NG Dose Rate Set Point Methodology

- Similar to Liquids – Scale Parameter to Be Controlled by Ratio of Dose Rate Limit to *Actual* Dose Rate
- Can Derive Set Point To Control:
  - Release Rate uCi/sec
  - Concentration uCi/cc
  - Flow Rate cc/sec

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Noble Gas Monitor Set Points – uCi/cc

The alarm/trip Set Point based on the skin dose rate limit is:

$$\frac{3000\ \boldsymbol{mrem}\ /\ \boldsymbol{year}}{\left(\overline{\chi/Q}\right)\sum_i\left[L_i + 1.1M_i\right]\dot{Q}_i} \times \sum_i \frac{\dot{Q}_i}{VF} \times \boldsymbol{Monitor\ Sensitivity}$$

The alarm/trip Set Point based on the total body dose rate limit is given by:

$$\frac{500\ \boldsymbol{mrem}\ /\ \boldsymbol{year}}{\left(\overline{\chi/Q}\right)\sum_i K_i\dot{Q}_i} \times \sum_i \frac{\dot{Q}_i}{VF} \times \boldsymbol{Monitor\ Sensitivity}$$

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Additional Points for Set Points

- Set Point Methodology Must
  - Account for Background
  - Insure Termination (Trip) Prior to Exceeding the Limits
  - Address Monitor Set Point During Periods of No Discharge

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Important Point for Set Points

- The Limits Being Controlled by Set Points are SITE LIMITS
- This means for simultaneous releases the total dose rate (or concentration) for the site cannot exceed the limits.
- Normally Need Only Apply to Gas Set Points
  - An “Allocation Factor” is used to apportion the dose rate among release points.

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ODCM and Set Point Methodologies

- All Set Point Methodologies Should be Documented in the ODCM
- Guidance Requires: "The alarm/trip Set Points (for effluent monitors) ... shall be determined and adjusted in accordance with the methodology and parameters in the ODCM."

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Factors Influencing Effluent Stream Monitoring

- Characteristics of the Effluent
  - Radiological
  - Physical
  - Chemical
- Environmental Factors
- Make sure all these are covered by the QA program

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Radiological Characteristics

- Radionuclide Concentration
- Half-Lives
- Type of Radiation Emitted
  - Gamma, X-rays (Fe-55), Beta
- Energy of Radiation
  - Detector Response is Strongly Dependent on Energy

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Sensitivity of Set Points to Source Term

Dilution Flow / Waste Flow = 500

Ce-144	2.00E-05 uCi/ml
Co-60	3.00E-05 uCi/ml
Cs-137	2.00E-05 uCi/ml
I-131	3.00E-05 uCi/ml

Total Concentration = 1.00E-04 uCi/ml

Set Point = 4.85E-04 uCi/ml

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Sensitivity of Set Points to Source Term

Dilution Flow / Waste Flow = 500

Ce-144	1.00E-05 uCi/ml
Co-60	6.00E-05 uCi/ml
Cs-137	3.00E-05 uCi/ml
I-131	0.00E-05 uCi/ml

Total Concentration = 1.00E-04 uCi/ml

Set Point = 1.89E-02 uCi/ml

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Physical and Chemical Characteristics

- Temperature
- Pressure
- Humidity
- Size and Distribution of Suspended Particles
- Effluent Flow Rate
- Plate Out
- Corrosiveness
- Combustibility

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Environmental Factors

- Temperature
- Mechanical
- Chemical
- Background Radiation
- Humidity
- Electromagnetic Effects
  - Power Transients, Magnetic and RF Fields, Ground Loops…

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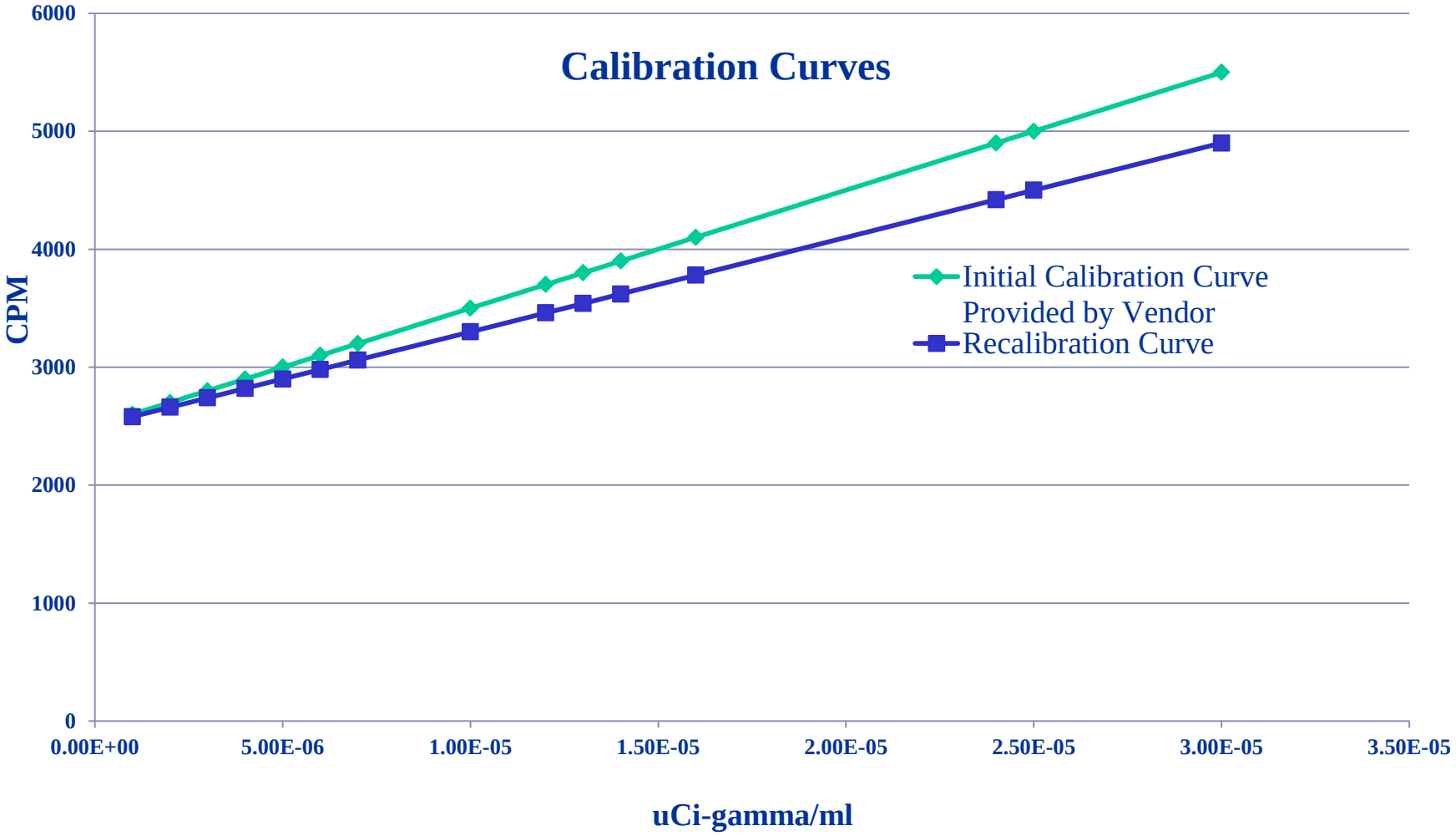
Monitor Response Curve



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Monitor Response and Source Term

- RG 1.21

  "Periodic correlations should be made during operation to relate monitor reading to the concentrations and/or release rates of radioactive material…"

- Correlations should be based on isotopic grab sample analysis.

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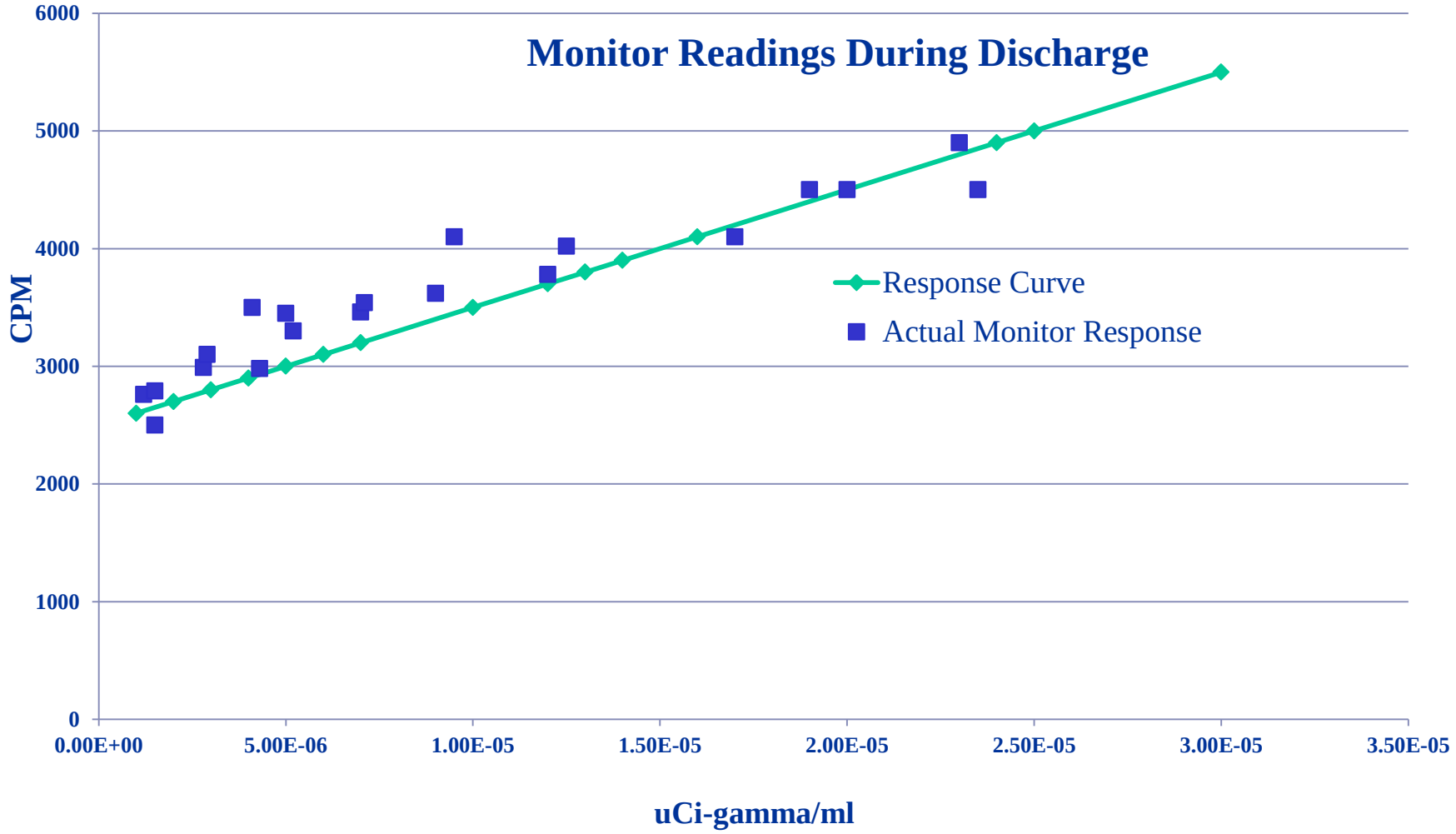
Expected vs. Actual Monitor Response



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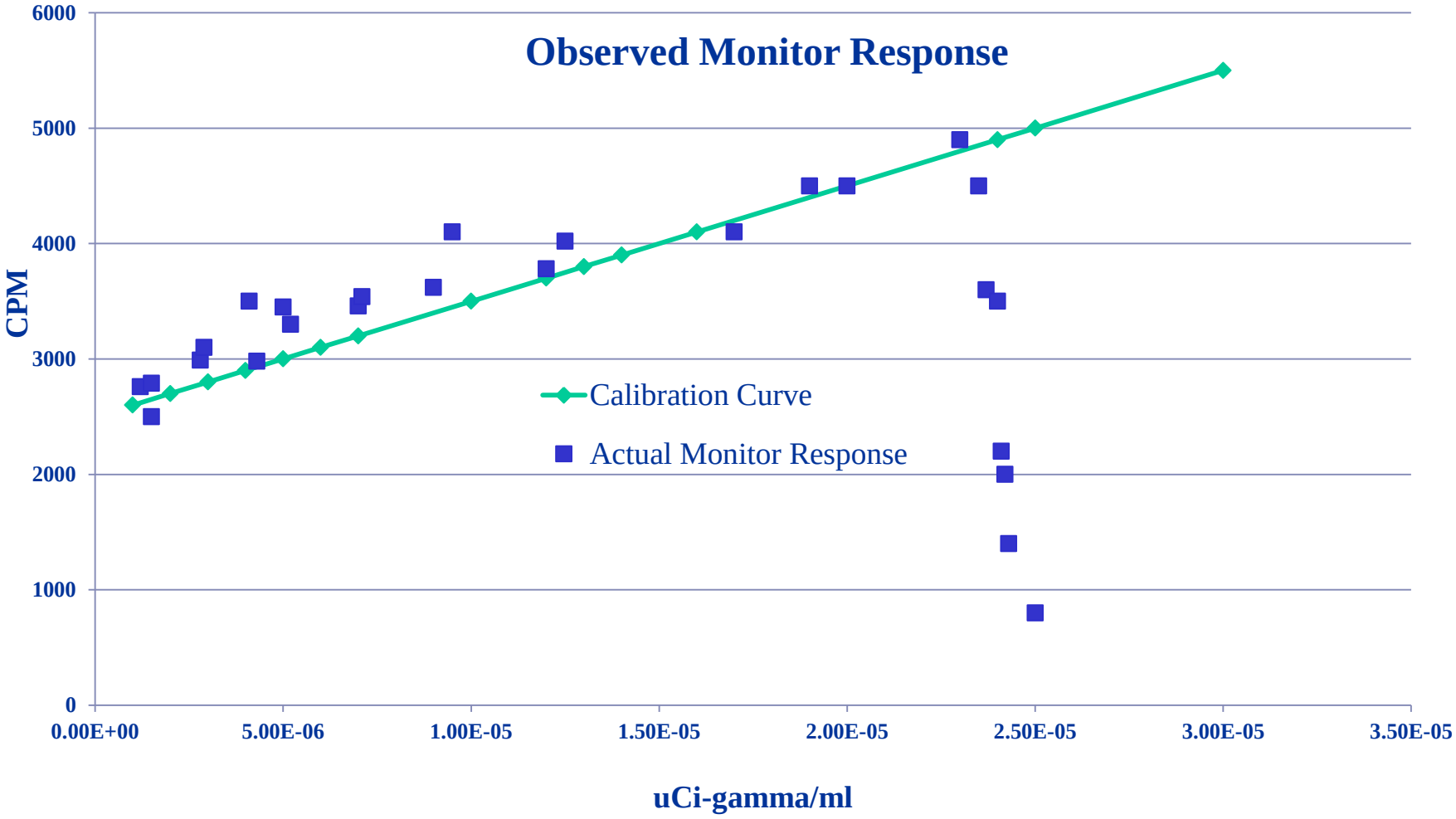
Unexpected Monitor Response



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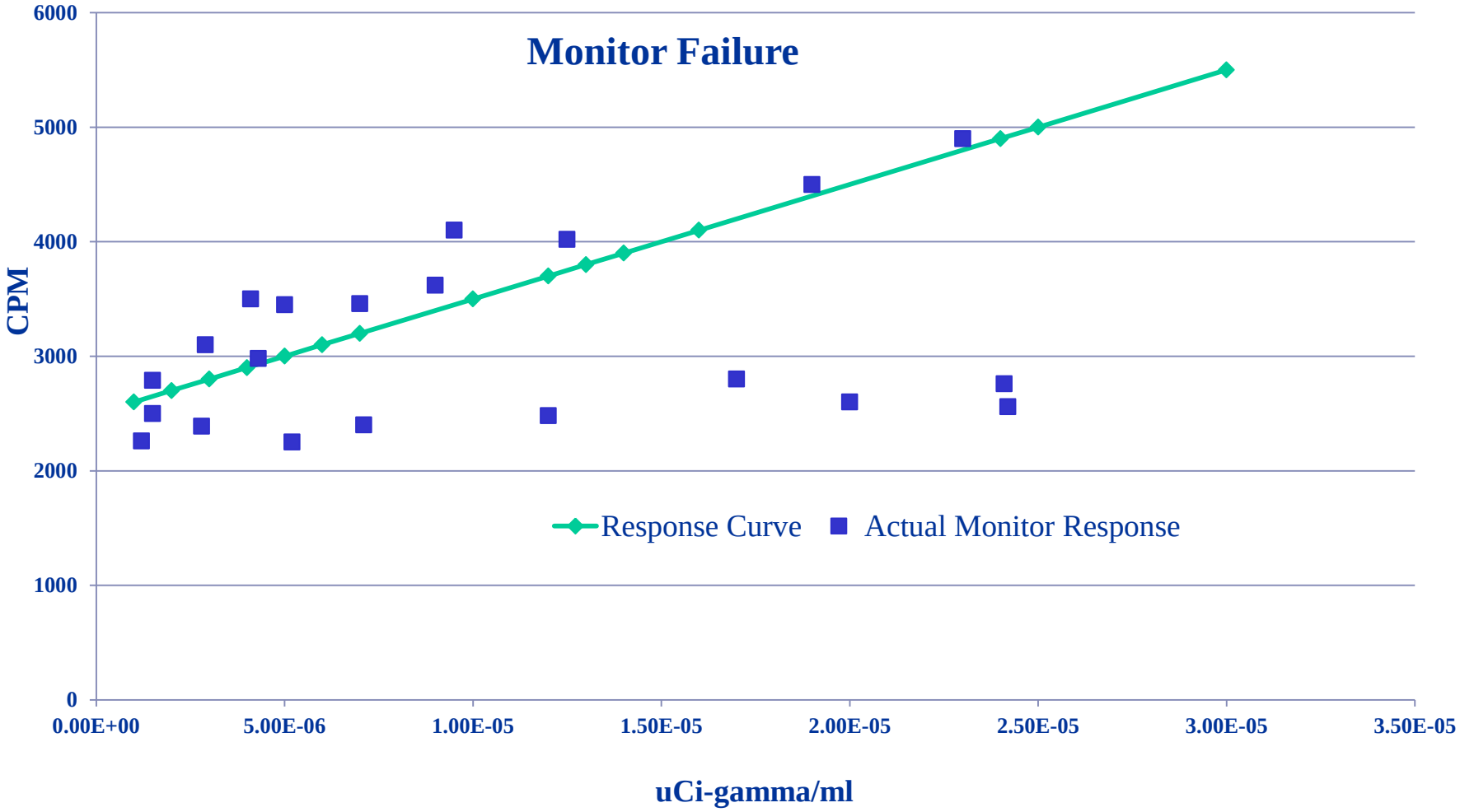
This is Why You Always Check



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Set Point Methodology Must…

- Be Fully Documented in the ODCM
  - Should be able to calculate values from ODCM.
  - Address set points used during times of no release.
- Insure Alarm/Trip ***Prior*** to Exceeding Limits
- Deal With Simultaneous Site Releases
- Your Set Points Should Not Be "In the mud."
  - Handle Non-Gamma Emitters
  - Appropriately Deal With Background

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Representativeness of Samples Equals Big Headache

- Must Be Able to Demonstrate
  - Gases
    - Isokinetic Flow
  - Liquid
    - Appropriate Mixing
- Check Out Reg Guide 1.21
- On Occasion Sample At
  - Start, Middle, and End of Releases

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Rad Monitor Paranoia

- Make Sure You Understand How Your Set Point Methodology Works
- Routinely Review Monitor Readings
- Determine Source of All Unexpected Readings/Alarms

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