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Effluent Radiation Monitoring Systems (RMSs)

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Outline

- Why talk about this?
- Challenges
- Regulatory Framework
- Setpoints
- Normal Operation of RMSs
- In-service Calibration
- 4 Keys to Assess Reliability of RMSs
- Other Uses of RMSs

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Why Talk About This?

- No one notices RMS until something…
- Easy to read cpm or uCi/sec
- What does the reading mean?
- How accurate is the reading?
- What if isotopic composition changes?
- What if the RMS is inoperable?
- Who is responsible? For what?
- What else can RMSs do?

The Challenge

- Many people are involved with RMSs
  - System Engineering, Design Engineering, Ops, Chem, HP, I&C, Maintenance, EP
- Who decides operability?
- Who decides “reliability?”
- What is reliability?
- If it is operable, is it reliable?

Assessing Reliability

- Each user assesses reliability
- Users = Ops, Chem, HP, EP, I&C
- End user (for this discussion) is:
  - RECP owner
  - Chemist or HP (typically)
- What is important to RECP?
- What does the RECP staff need to know?

Regulatory Framework, Item #1

- Primary Calibration
  - Tech Spec / ODCM
  - NUREG-1301/1302
  - Controls 3.3.3.9 and 3.3.3.10
  - A.K.A. -- Initial Channel Calibration
  - NIST traceable sources
  - System Engineer (vendor?, end user?)

Regulatory Framework, Item #2

- Secondary Calibration
  - Tech Spec / ODCM
  - NUREG-1301/1302
  - Controls 3.3.3.9 and 3.3.3.10
  - A.K.A. -- Subsequent Channel Calibration
  - Use sources related to the primary calibration
  - I&C (specialist?, end user?)

Regulatory Framework, Item #3

- "QA/QC" to verify normal operation
  - Quality Assurance Program (QAP)
  - RG 4.15, (Rev 1, page 2, Section B)
    - Identify deficiencies & take corrective actions
    - Provide confidence in results (to validate)
  - NUREG-1301/1302 (Tech Spec / ODCM)
    - Functional Checks, COT, Source Check, …
  - RG 1.21, Rev 1 (page 5, 11.c)
    - Routine Checks (see NUREG 1301/1302)
    - Show RMS is "functioning properly" (normal)

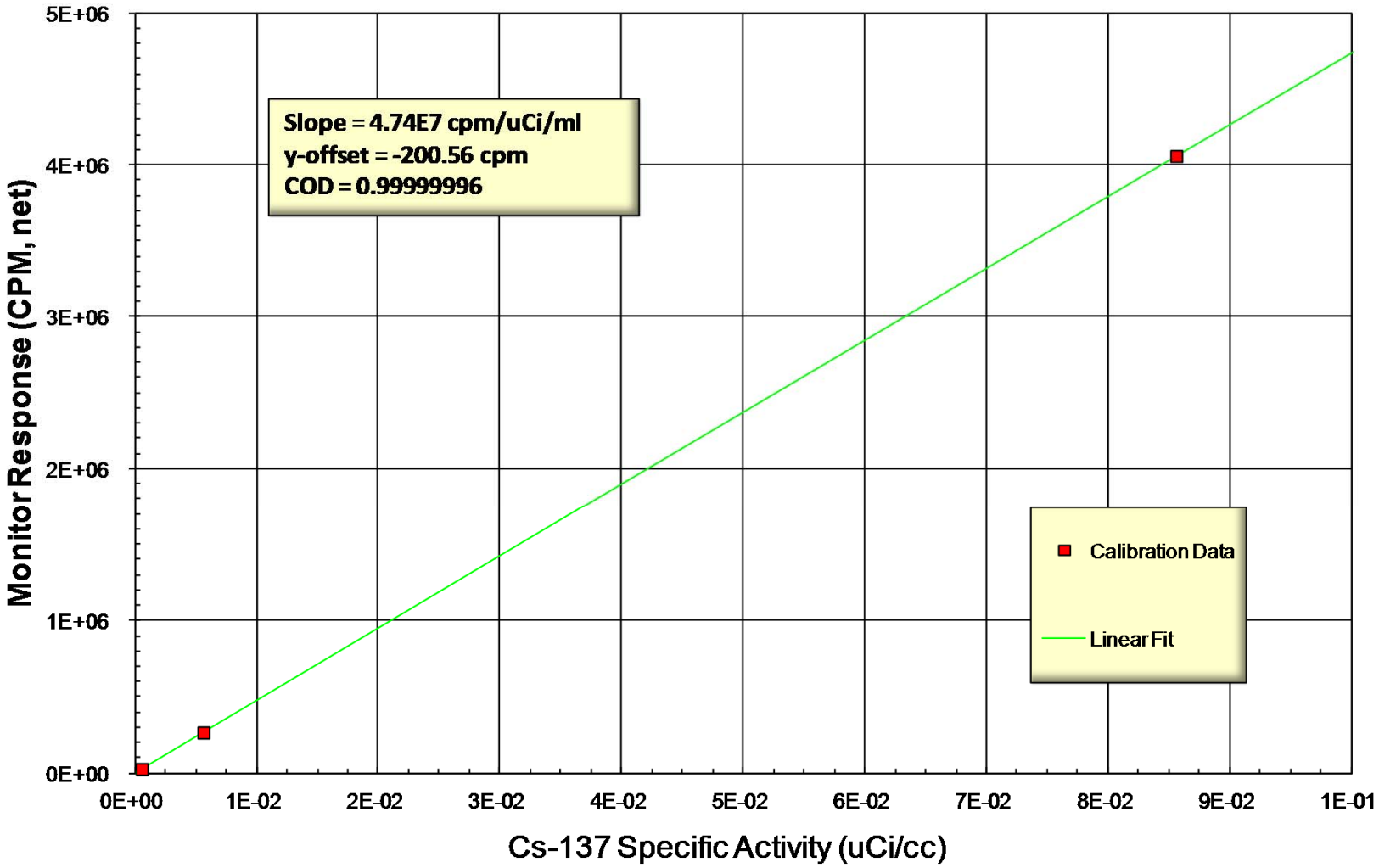
Regulatory Framework, Item #3 (Continued)

- RG 1.21 (Continued)
  - Establish a relationship between:
    - RMS readings (actual), and
    - grab samples from the release path
  - Let's call it → "Monitor Correlation"
- "Normal Operation" may be defined as whenever actual readings = predicted
- QA/QC by I&C, Operations, End User?

Regulatory Framework, Item #4

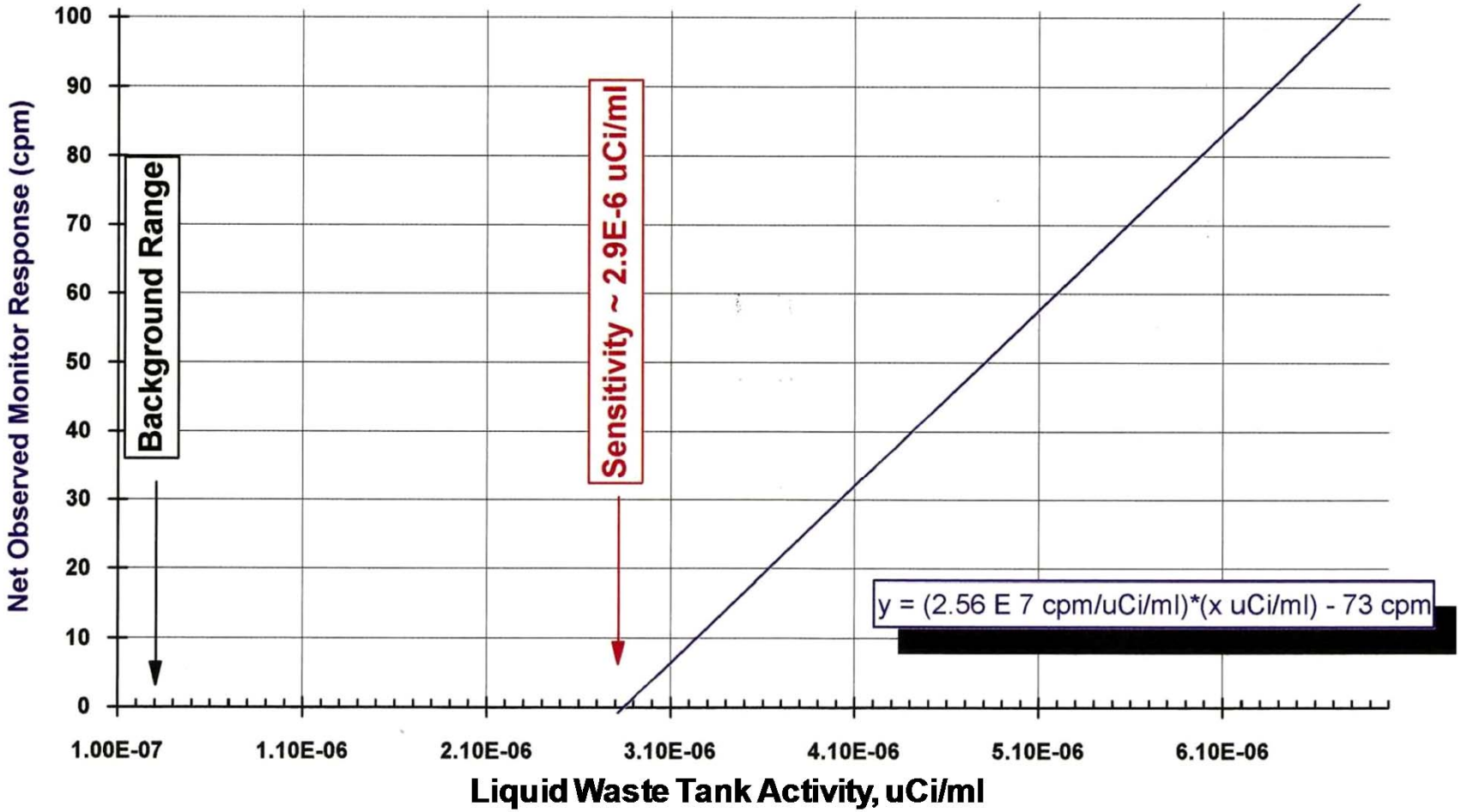
- "In-service Calibration"
  - RG 1.21, Rev 1 (page 5, 11.c)
  - Calibration based on grab samples
  - If actual RMS reading ≠ predicted…
  - Is RMS outside "normal operation?"
  - Correction may be needed (Calibration)
  - Force actual reading = predicted reading
  - A method to redefine "Normal Operation"
  - Who does this? (End User?)

Typical Linearity Graph For NaI Detector



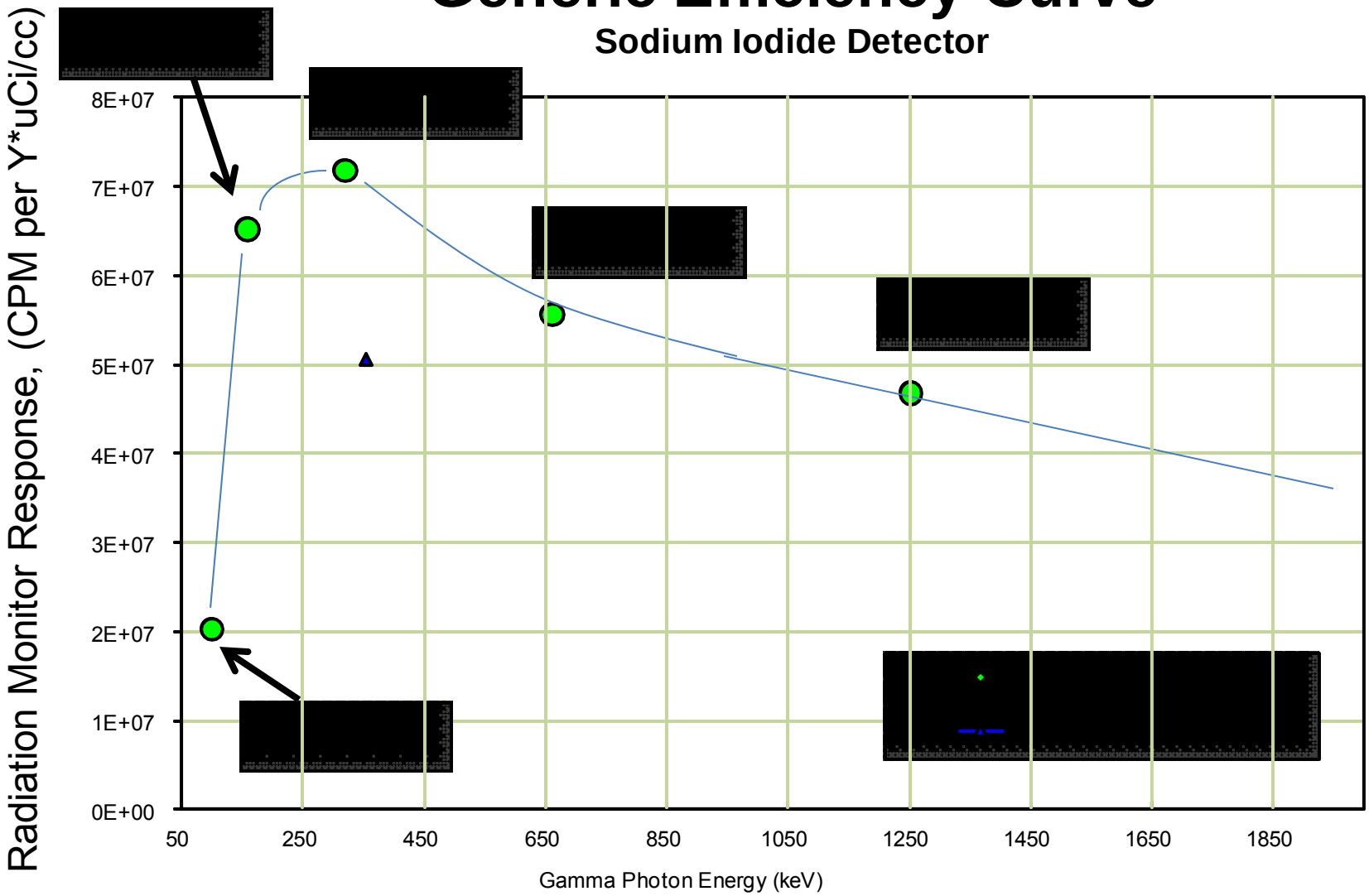
Radiation Monitor Sensitivity

Typical Sodium Iodide Detector



Generic Efficiency Curve

Sodium Iodide Detector



Example Setpoint Calculation

- $S_{fix} = K_{SF} \{ F_d/F_u \sum [A_{iL} * E_i] + Bkg \}$
- Use the calculation in your ODCM
- S_{fix} = Fixed setpoint, cpm
- K_{SF}= Safety factor, fraction of limit, unitless
- F_d = Flow rate, dilution water, gpm
- F_u = Flow rate, undiluted radwaste, gpm
- A_{iL} = Activity limit for nuclide i, uCi/ml
- E_i = Detector efficiency for nuclide i, cpm per uCi/ml
- Bkg = RMS Background, cpm

Example Calculation

Nuclide Name	Mixture, f (%)	MPC (uCi/ml)	product of other MPCs	efficiency (cpm/uCi/ml)	sp.act. equal to 1 MPC (uCi/ml)	Rad. Mon. (CPM)	Conc. Factor	Rad.Mon. cpm at the setpoint
Co−58	25%	9E−05	4.86E−40	6.57E+07	4.191E−07	27.5	3333.3	91787
Cs−137	25%	2E−05	2.19E−39	4.47E+07	4.191E−07	18.7	3333.3	62449
I−131	16%	3E−07	1.46E−37	7.08E+07	2.682E−07	19.0	3333.3	63304
Ag−110m	3%	3E−05	1.46E−39	1.58E+08	5.029E−08	7.9	3333.3	26488
Cs−134	13%	9E−06	4.86E−39	1.17E+08	2.179E−07	25.5	3333.3	84997
Co−60	4%	3E−05	1.46E−39	9.29E+07	6.706E−08	6.2	3333.3	20766
I−133	3%	1E−06	4.37E−38	5.72E+07	5.029E−08	2.9	3333.3	9589
Nb−95/Mn−54	2%	1E−04	4.37E−40	4.86E+07	3.353E−08	1.6	3333.3	5432
Sb−125	9%	1E−04	4.37E−40	4.99E+07	1.509E−07	7.5	3333.3	25097
Total all nuclides	100.00%				1.676E−06	117.0		389909

Calculate the gross specific activity of this radionuclide mixture which corresponds to 1 MPC ======>	1.6765E−06 uCi/ml	(10CFR20, Appx. B, Note 1)
Flow rate of dilution water ========>	400000 gpm	(ODCM, Eq. 2L, pp. 18−19)
Flow rate of undiluted radwaste ====>	120 gpm	(ODCM, Eq. 2L, pp. 18−19)
Background cpm ==========>	0 cpm	(ODCM, Rev. 0, Eq. 1L, pp 17−20)
Ksf (Fraction of 1−MPC)=======>	0.5	(ODCM, Rev. 0, Eq. 1L, pp 17−20)
The new setpoint for this monitor ==>	1.95E+05 cpm	(ODCM, Rev. 0, Eq. 1L, pp 17−20)

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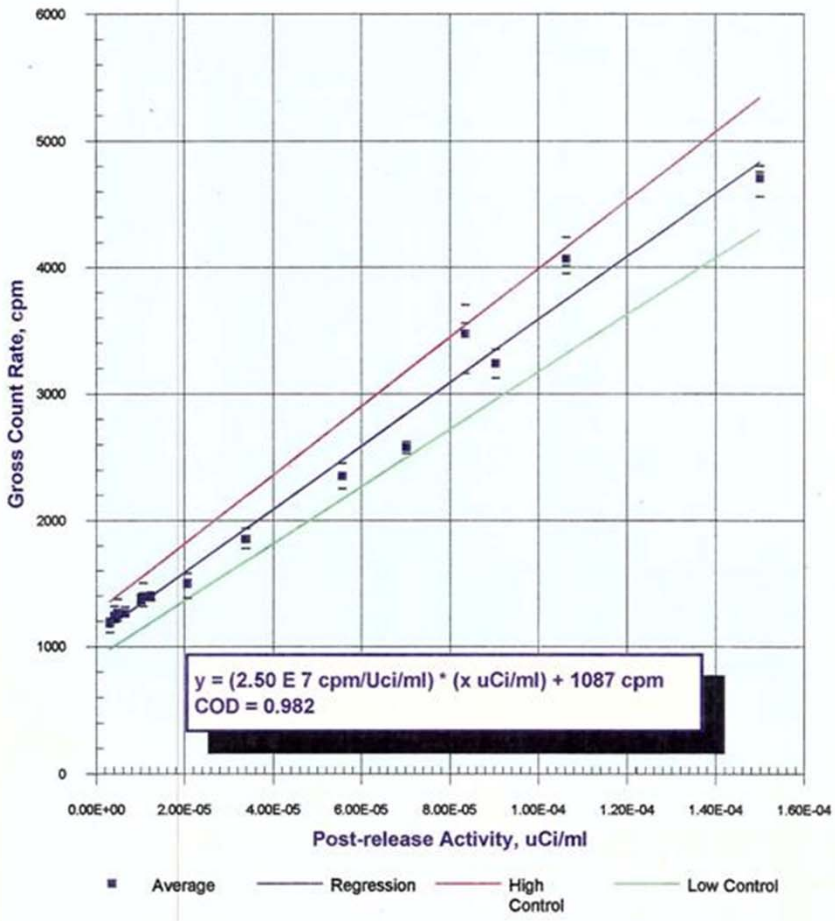
Recap

- Primary Calibration is done
- Secondary Calibration is done
- Setpoint calculation is done
- Nuclide efficiencies are calculated
- RMS is operational (Done! Right?)
- RMS is ready to monitor discharges
- Now, routine (QA/QC) checks are used to verify “normal operation”

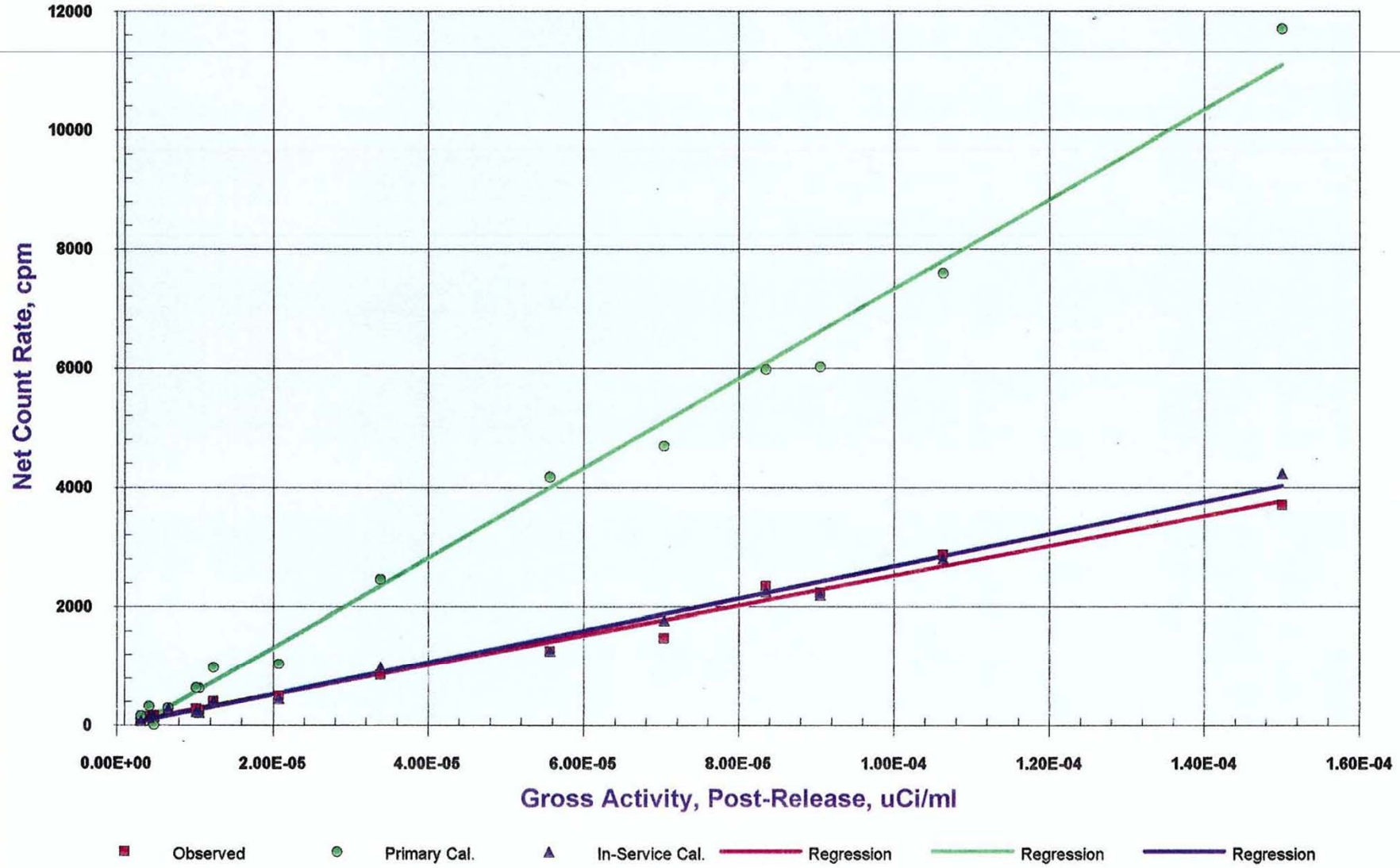
Normal Operation

- What is “normal operation?”
- RG 1.21 guidance says to correlate:
  - Observed RMS responses (from actual tank discharges) to
  - Actual activity in grab samples (from lab gamma isotopic analysis)
- Yields a “Monitor Correlation” for RMS

Normal Operation
For Generic Radiation Monitor

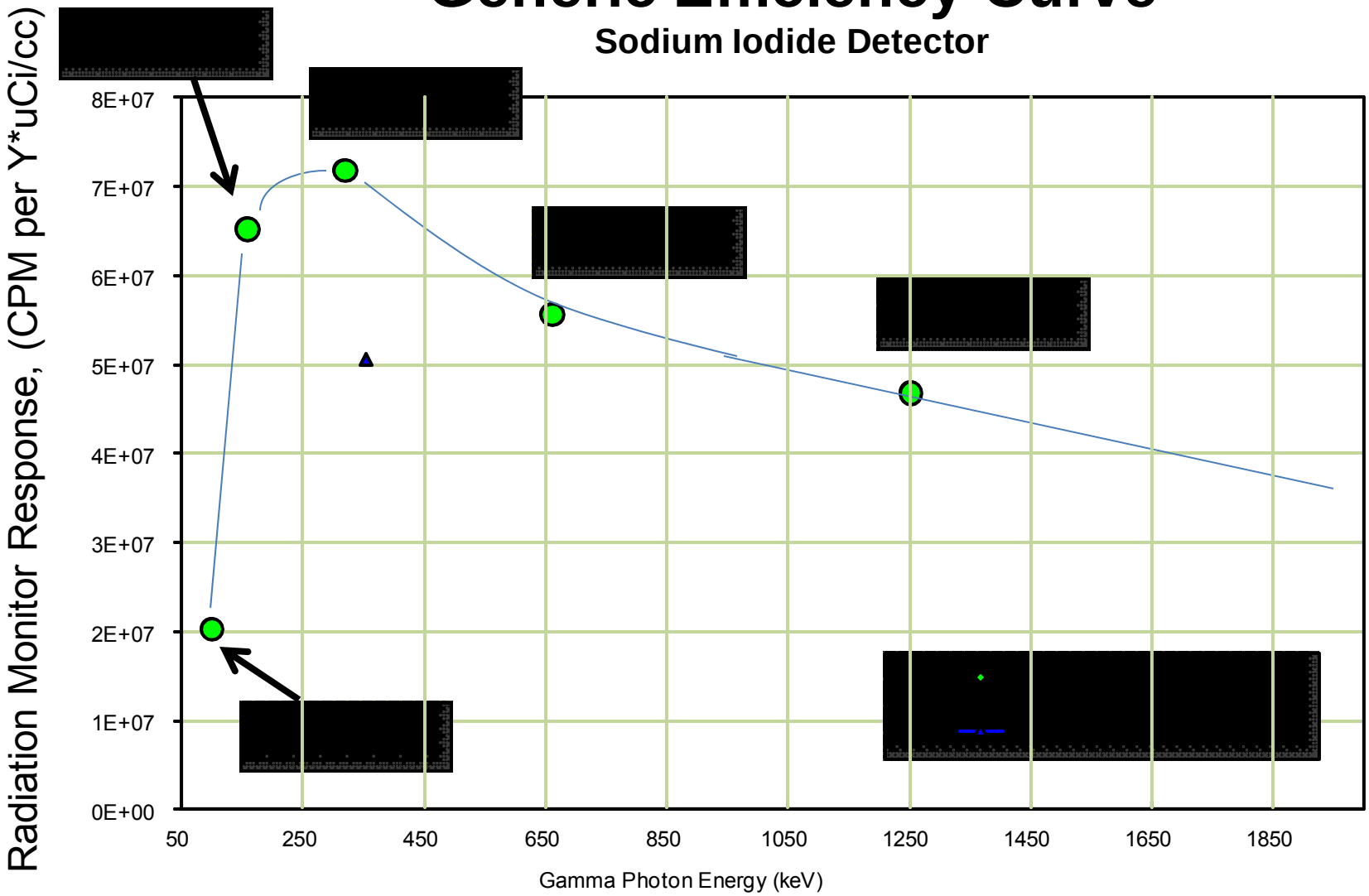


In-Service Calibration



Generic Efficiency Curve

Sodium Iodide Detector



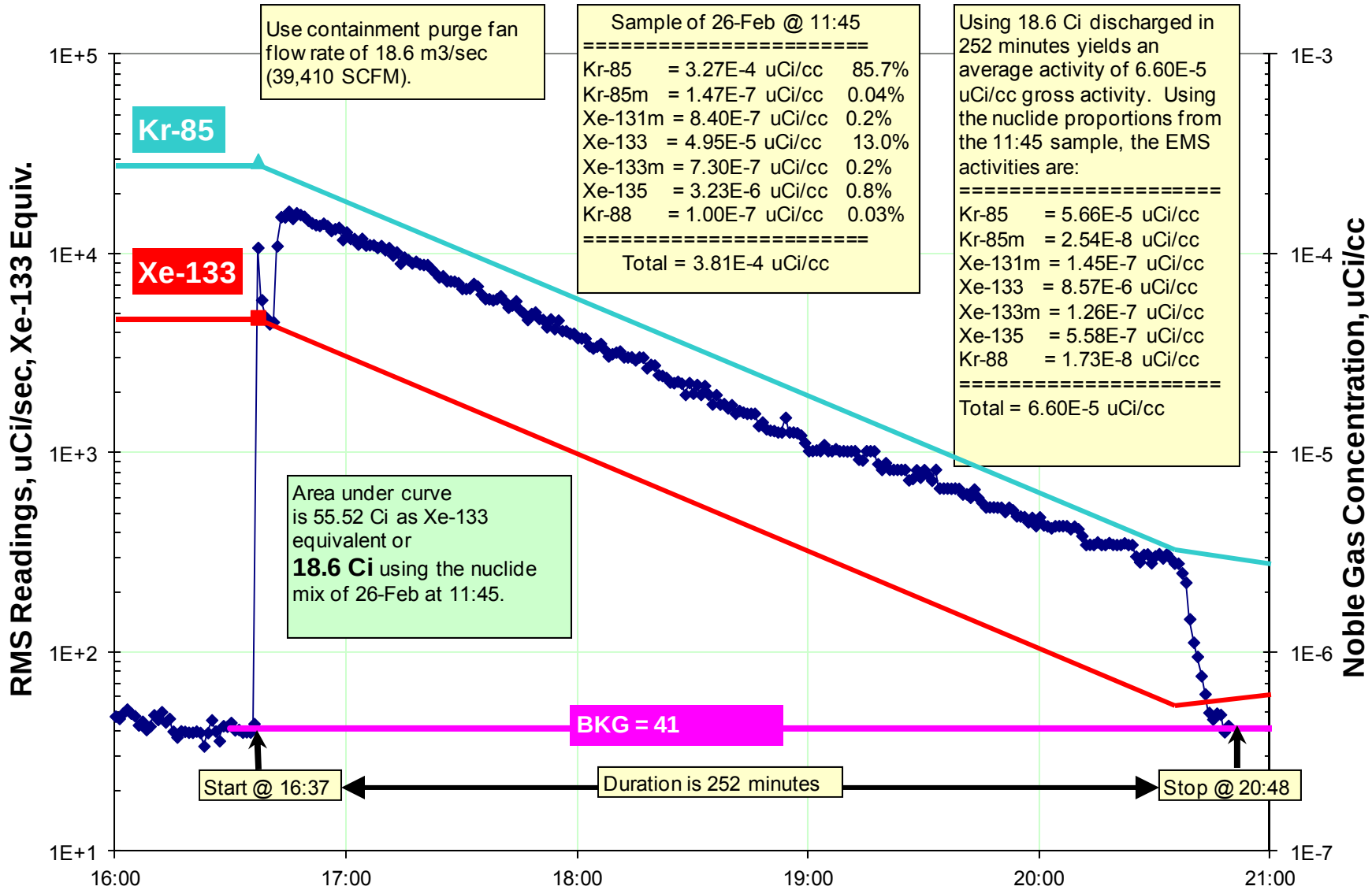
4 Keys to Assessing Reliability

- Primary Calibration
  - Linearity, Sensitivity, Efficiency, Setpoints
- Secondary Calibration
  - "Transfer Cal," Linearity, cpm/uCi/ml
- "QA/QC" (to verify normal operation)
  - Functional Checks
  - Monitor Correlation
- "In-service Calibration"
  - A method to re-define normal operation

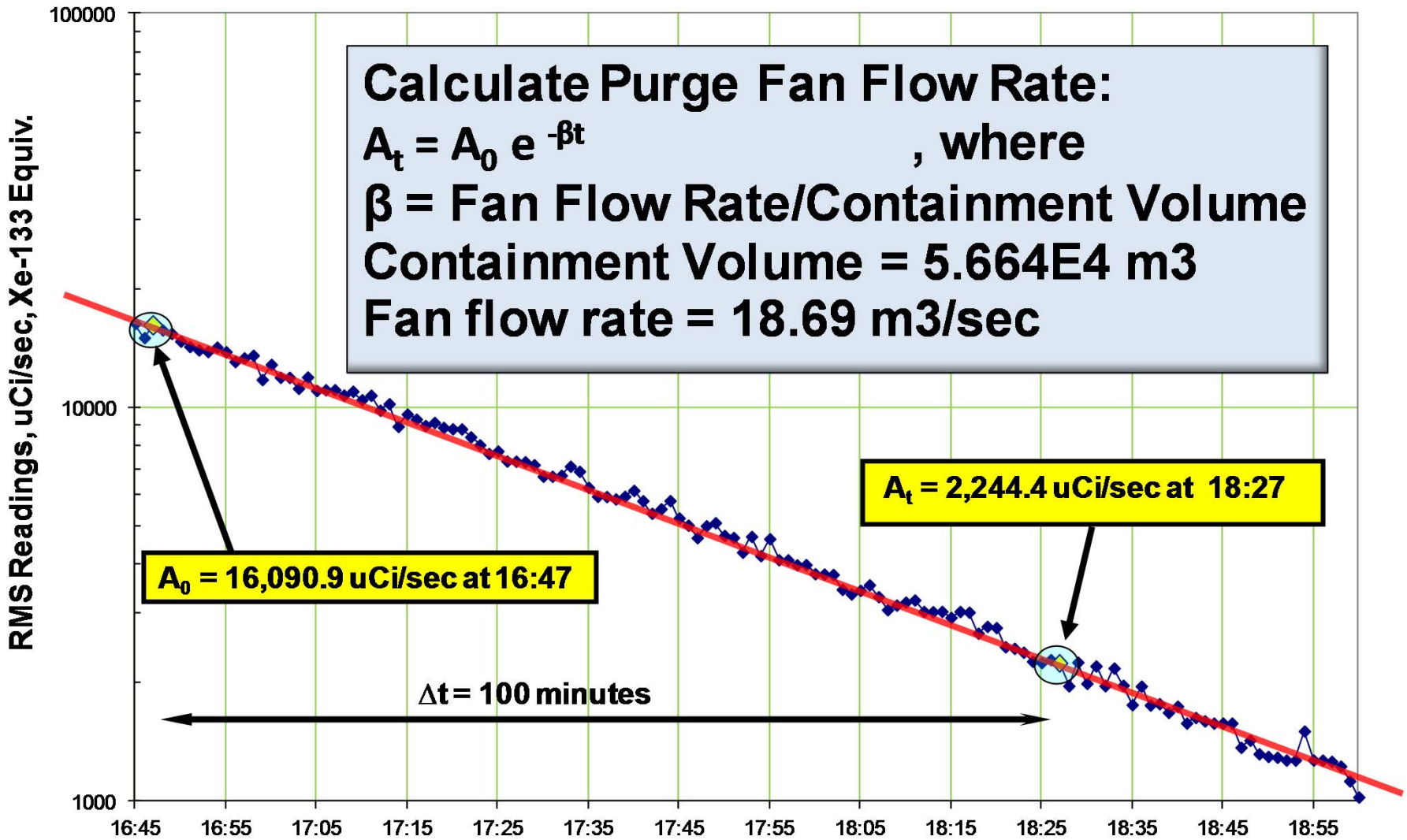
Other Uses for RMSs

- Determine flow rates
- Account for RMS spikes
- Account for activity discharged in RFO

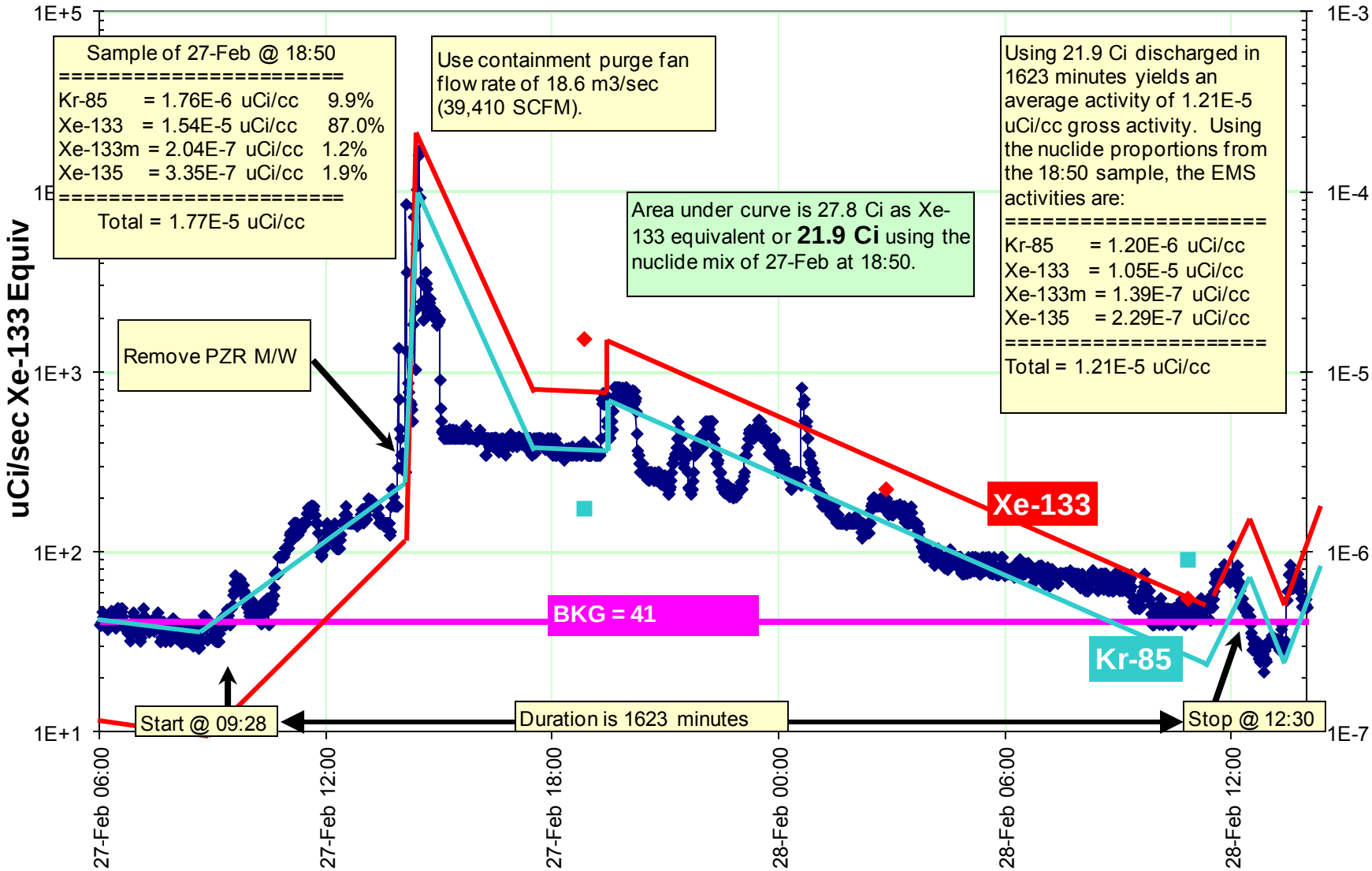
Containment Purge #1



Containment Purge #1 (Excerpt)



Containment Purge #3



Convert RMS Response to Activity

- Example calculation (solve for A_{iu}):

$$RR_{XeEq} = c\ F_u \sum [\ A_{iu} * E_i\ ] + Bkg$$

RR_{XeEq} = RMS Response, Xe-133 Eq, uCi/sec

- c = Conversion Constant, 1E6cc/m3
- F_u = Flow rate, undiluted radwaste, m3/sec
- A_{iu} = Activity of nuclide i, uCi/cc
- E_i = Detector efficiency , uCi Xe-Eq/uCi nuclide i,
- Bkg = RMS Background, uCi/sec Xe-Eq

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Summary

- RMSs provide a wealth of information
- Who is monitoring the RMS?
- I've highlighted 4 keys to assess RMS reliability (from regulatory framework)
- These 4 keys can often resolve RMS issues identified by NRC inspectors

Questions

Acronyms & Abbreviations

- NRC = Nuclear Regulatory Commission
- Cal = Calibration
- RMS = Radiation Monitoring System
- uCi/sec = microcuries per second
- RECP = Radioactive Effluent Control Program
- Ops = Operations
- Chem = Chemistry
- HP = Health Physics
- EP = Emergency Planning
- I&C = Instrumentation and Control
- ODCM = Offsite Dose Calculation Manual
- A.K.A. = Also known as
- NIST = National Institute for Science and Technology
- cpm = counts per minute
- Tech Spec (or TS) = Technical Specifications
- RG = Regulatory Guide
- RFO = Refueling Outage
- COT = Channel Operability Test

Acronyms & Abbreviations

- COD = Coefficient of determination for linear regression