DISCLAIMER & COPYRIGHT NOTICE

DISCLAIMER

This work of authorship and those incorporated herein were prepared by Contractor as accounts of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Contractor, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, use made, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency or Contractor thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency or Contractor thereof.

COPYRIGHT NOTICE

This document has been authored by a subcontractor of the U.S. Government under contract DE-AC05-00OR-22800. Accordingly, the U.S. Government retains a paid-up, nonexclusive, irrevocable, worldwide license to publish or reproduce the published form of this contribution, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, or allow others to do so, for U. S. Government purposes.
Proposed Guidance and Specification for a Process-Specific Minimum Accident of Concern

Peter L. Angelo
B&W Y-12 LLC
Y-12 National Security Complex

NCSD 2013
Wilmington NC
Sept 28-Oct 3 2013
The Analogy for a Hazard in the Near Field

The near field represents the closest distance to an imminent hazard with “acceptable outcome”.

A criticality hazard in the near field will most likely be greater than the MAC

“The Luckiest Man”
The Main Ideas

1. Significant background from past ANS papers provides **timeline** for process specific MAC

2. Proposed excursion thresholds are derived from recent kinetic and past experiment evaluations

3. The near field excursions encapsulate the “**Time Period of Interest**”

4. Existing ANS-8.3 Appendix B guidance for detector radius of coverage can be **AUGMENTED**

5. Apply specific guidance to HEU scenarios

6. **Risk Informed Insight** – ‘deterministic wiggle room’
Timeline for Considerations

- NCSD 1993 – “Ground Zero” – Malenfant/Barbry
- ICNC 1995 – Distribution of fissions and CDF (upper bound)
- NS&E 1999, 2001 – Nomura papers, SRS MAC
- ANS 2004 – Barbry “most credible minimum accident”
- NCSD 2005 – 2 papers on process-specific MAC
- ANS 2007 – Adjoint MC and CAAS MAC contours
- ANS 2009 – Dose in air, tissue D*(10), effective dose H*(10)
- NCSD 2009 – “Realism and Risk acceptance, “minimum spike excursion”
- ICNC2011 - ANS-8.3 Appendix B Sustained Reaction, MAC comparison to experiments (Duluc)
- NCSD2013 – ANS-8.3 Appendix B Rapid Transient, “adequate protection” for near field
Source and Target in Near and Far Field

Near Field – Reference MAC  Far Field – Detector Response
“Marginal Utility” of Dose Rate in Air, SR and RT

- **Sustained Reaction** – **Non responsive rate based CAAS** below a minimum reactivity value ~ 1/3 the delayed critical range. Large D*(10) 1-2 Gy if 60 s delay – (ICNC2011)

- **Rapid Transient** - **Non responsive rate based CAAS** for excursions extending into prompt critical range. (NCSD 2013)

- **Above $0.75** delayed critical, D*(10) > 0.2 Gy, H*(10) > 15 Sv unmoderated

- **Below $0.35** delayed critical D*(10) 0.2 > Gy, H*(10) > 5 Sv for a poorly moderated system.
Transforming the MAC “Coordinate System”

- Transform from “square waves” (SR and RT) to “inverse period” and upper bound total fissions over Time Period of Interest (TPI)

- Same threshold units (fissions/sec)

- Independent of air response, no 60 sec delay assumed

- Based on experiments, accident history, kinetics evaluations

- Initial human recognition of alarm

- “Acceptable near field outcome”
Proposed Excursion Thresholds

• Excursion Threshold I -
  – *Credible Slow Excursions* –
  – bounded by $2 - 4 \times 10^{15}$ fissions over the slowest CRAC
  – Inverse period $0.1$ s$^{-1}$ (ICNC 2011) (no slow cookers), 5 sec TPI
  – $0.35 - 0.75$

• Excursion Threshold II -
  – *Credible Fast Excursions*
  – bounded by $1 - 2 \times 10^{15}$ fissions , 3-5 Sec TPI
  – Inverse period of $1$ s$^{-1}$ (NCSD 2013)
  – $0.75 - 1.0$

• Excursion Threshold III -
  – *Credible Spike Excursions* –
  – bounded by $1 \times 10^{14}$ fissions over a $1000$-s$^{-1}$ inverse period.
  – (NCSD 2009)
  – greater than $1$ reactivity.

• Consistent with Delafield and Clifton SRD R309
Tying Excursion to Detector Radius of Coverage

\[ D_r(R) = D_{2m} \times \left(\frac{2}{R}\right)^2 \times T_{air} \times \varepsilon \quad \text{Eq. (1)} \]

\[ D_{tot}(R, t_{tot}) = [E_{Tot}]_{2m} \cdot f\left(\frac{D}{E}\right)_{2m} \cdot \left(\frac{2}{R}\right)^2 \cdot T_{air} \quad \text{Eq. (2)} \]

\[ E_{Tot} = E_{Thresh \ (I,II,III)} + E_{TPI} \quad \text{Eq. (3)} \]

\[ t_{Tot} = t_{Thresh \ (I,II,III)} + TPI \quad \text{Eq. (4)} \]

\[ P_{Thresh} \sim E_{Thresh \ (I,II,III)} \cdot \omega(t_{thresh}) \quad \text{Eq. (5)} \]

\[ D_{TPI} = f\left(\frac{D}{E}\right)_{2m} \cdot P_{threshold} \cdot \int_{t_{thresh}}^{TPI} \exp^{\omega(t)} \cdot t \, dt \quad \text{Eq. (6)} \]
Application to CIDAS Detector Radius of Coverage

1. **Determine/Choose** reactivity insertion

(Exploit time dependent kinetics information)

2. **Increment** 1 s interval for 280 nGy.

3. **Note** threshold P, E, ω, time

4. **Determine** total fissions for TPI

5. **Solve** Eq. 1-6 for Radius of Coverage
Radius of detector coverage increases over 0.2 Gy/min in air with $0.5 \text{ (best est.) } 5 \text{ sec TPI}$

310 m Solution, 270 m Mod metal-water
Application to Uranium Systems – 10 L Volume

**β/Δ vs Critical Volume**

**Heat Capacity C_p vs Critical Volume**

**β/Δ vs Critical Concentration - HEU Metal-Water Mixtures**

**Heat Capacity C_p vs Critical Concentration**
Integrate Excursions Thresholds with Uranium System

• **Process Specific Scenario 1:** 2-4e15 fissions/sec **TPI 5 s**
  – Excursion Threshold I – inverse period 0.1 s\(^{-1}\)
  – HEU Solutions/fully moderated (homogenous) mixtures
  – *(critical volume >10 L):*

• **Process Specific Scenario 2:** 1-2 e 15 fissions/sec **TPI 3 s**
  – Excursion Threshold II – inverse period 1 s\(^{-1}\)
  – HEU Poorly Moderated H/X ~10
  – *(critical volume <10 L):*

• **Process Specific Scenario 3:** 1e17 fissions/sec
  – Excursion Threshold III – inverse period 1000 s\(^{-1}\)
  – HEU unmoderated metal
Risk Informed Insight noted by *ANS Standards Board Policy Manual* as an initiative to better apply standards

“Probabilistic” or “Heuristic” input into a **deterministic** value (e.g. MAC). **NOT RISK-BASED**

**Substantiation** of Numeric Values – ASB Policy Manual

“reference to another (ANSI) standard”


Complimentary view of risk (ANSI/ISO 31000):

“Risk is the **effect of uncertainties** on objectives”
Summary and Conclusions

• Proposed guidance and specification requires stakeholder involvement, concurrence

• Transform ANS-8.3 Appendix B guidance (SR, RT) to realistic exponential excursion guidance

• Couple ANS-8.3 Appendix B Radius of Coverage equation to excursion kinetics

• Evaluate for a specific material form and type (e.g. HEU)

• Risk informed insight—input into final decision making

• Identify Objectives and “Effect of Uncertainties on Objectives”