On the Use of Nature of Process Arguments

Tracy Stover, John Lint, Joshua Butler, Jaclyn Fitzpatrick, Tara Smith, Kevin McCann, Brett Clinton, and Brittany Williamson

Tracy E. Stover, Ph.D., P.E.

Principal Engineer, Savannah River Nuclear Solutions

American Nuclear Society Annual Meeting 2019

June 9-13, 2019

Introduction

- **Debate and Discussion Expected!**
- **Used here to defend why scenarios once considered credible are not**
  – Not used to change facility hazard categorization
- **Presentation Outline**
  – Background
  – Examples
  – Conclusions (or lack thereof)

Introduction

- **ANS/ANSI Standards and common handbooks – no prescriptive guidance**
- **(1997) DOE-STD-1027-1992 Change Notice 1**
  - If a facility contains more than a ANS 8.1 single parameter mass of fissile material, it shall initially be classified as Hazard Category 2 however credit can be taken if segmentation or nature of the process precludes a criticality.
- **(2007) Supplemental Guidance**
  - Guidance on what can and cannot be considered nature of process.
  - Consider "planned activities, operational upsets, and derivative design basis abnormal conditions". Such abnormal conditions which would change the environment of the material and cause the need for criticality controls would likely fail to be identified as not credible by nature of the process.

Introduction

- **(2019) DOE-STD-1027-2018 Change Notice 1**
  - Can consider: fissile material quantity, form, shape, and collocation with moderators and reflectors.
  - Can credit: fundamental chemistry, physics and distribution of the materials being evaluated, limitations on what can enter the facility
  - Cannot credit: engineered or administrative controls with-in the facility.
- **Note the time span – 27 years since first issuance of 1027.**
- **There is no concrete, universally accepted method for making a nature of process argument, and this talk does not purport to establish one.**

Introduction

- **SRNS Methodology and Program**
  - A nature of process argument is applicable if the form of the fissile material is inherently safe with regard to criticality safety for both normal conditions and any credible abnormal condition.
  - No criticality controls are needed on any parameter of the process to prevent a potential criticality accident.
  - All process changes must be evaluated to determine if the nature of process argument can be maintained.
  - Align with DOE-STD-1027-92 Change Notice 1, DOE-STD-1120-2005 Vol. 1, and NNSA Technical Bulletin 5-02 June 2005
  - Assess hazardous material inventory and segmentation first
  - Not applicable to Hazard Category 3 facilities
  - May adjust single parameter minimum mass limit based on fissile form
  - May credit TSR level security or accountability restrictions on material

Nature of Process Considerations

- **Process Considerations**
  - First of a kind operations or operations which must initiate rapidly without time for extensive analysis → very conservative analysis warranted
  - Well understood, mature processes with sufficient time to examine them → reanalyzed with practical, real-world considerations.
  - Not restrict to just single parameter fissile masses or similar simplistic process parameters
  - Understanding of the chemistry and non-nuclear physics can be the most productive means of assessing nature of the process
- **Facility Design Considerations**
  - Not restrict to just favorable geometry fissile containers or similar design features.
  - Understanding how each component of a process is designed and involved can prove another path to determining criticality not credible

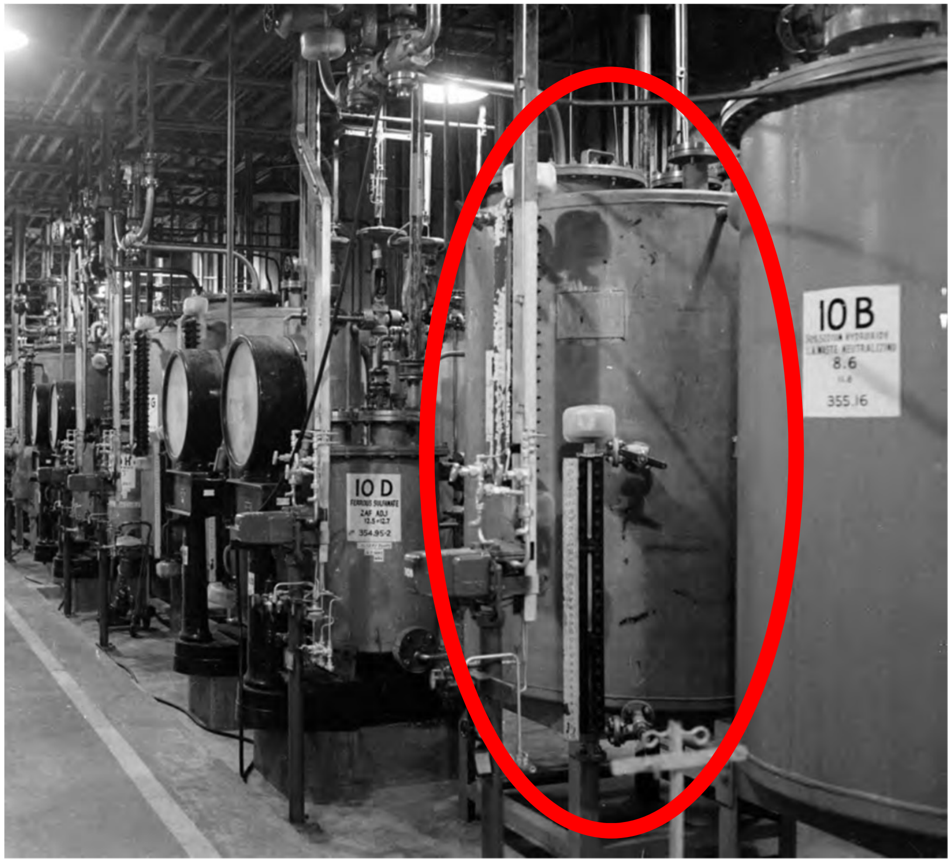
And now some examples…

Application Examples

- **5-Gallon HEU Solution Containers**
  - Used for leaks and maintenance
  - Concern of overconcentration in “large” arrays
  - Continuous monitoring with concentration limit line
  - Normally use 1 container, historically not more than 5, less than 20 on-site
  - Calculation show need at least 588 optimally arranged
  - Limited periods of freezing in South Carolina and U does get entrained in ice
  - Maximum initial fissile concentration

Application Examples

- **Solvent Head Tanks**
  - Separations process uses 7.5 vol.% TBP in an organic diluent
  - Limits the amount of U that can be extracted to organic phase
  - Postulated upsets involve over dilution or over concentration to TBP
  - Chemical engineering evaluation performed
  - Based on chemicals available and head tank volume
  - Even at the solubility limits, have to be incorrectly made up between 8 and 16 times
  - Not made up more than twice per cycle evolution



Application Examples

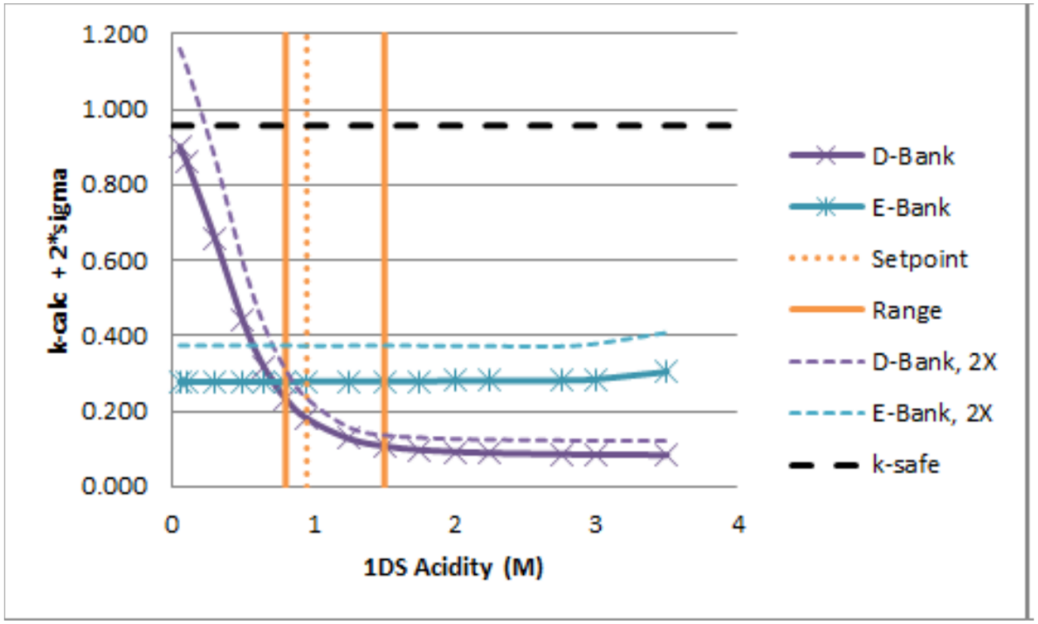
- **HFIR / RHF Chemistry**
  - Previously assumed all material optimally concentrated in one well
  - Controls on neutron poison and one core at a time
  - Given dissolver dimension, maximum concentration of acid available, fissile mass in each type of core, and the extremely high aluminum content.
  - Before the dissolver solution could reach a critical concentration all of the acid would be used up and the remaining pieces of cores could not dissolve.
  - 5 HFIR or 4 RHF cores per batch with no controls

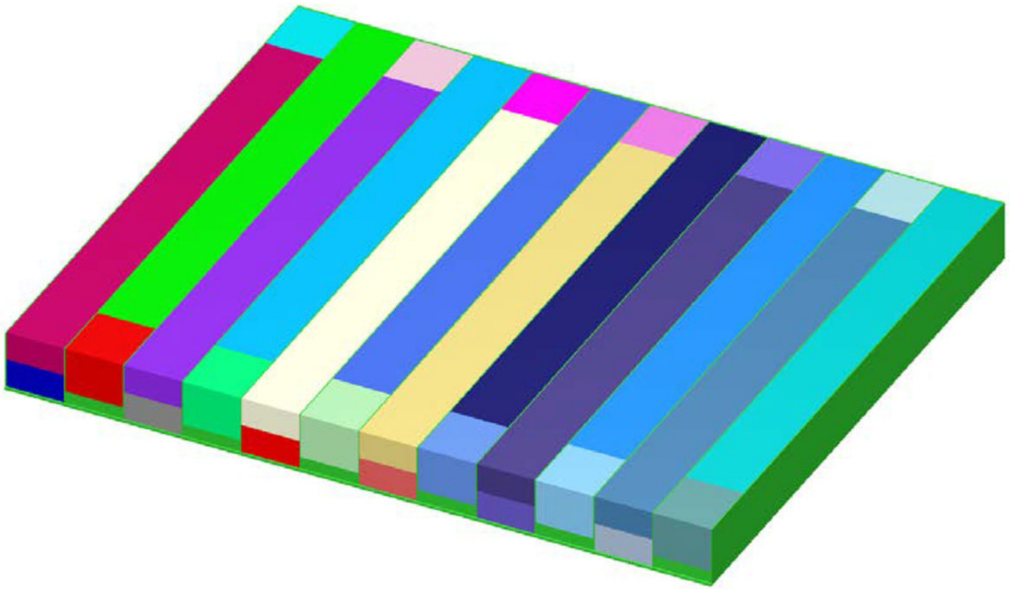
$$3.75\ \frac{mol\ acid}{mol\ Al}$$

$$4\ \frac{mol\ acid}{mol\ U}$$

Application Examples

- **Acid Concentration Upsets and Reflux**
  - Acid may become diluted or concentrated leading to a reflux of material
  - Occurred in 1978 at Idaho Processing Plant
  - Controls were in place using sampling, administrative responses, and active engineered interlocks
  - High consequence event
  - Advanced modeling using SEPHIS and SCALE for beyond credible abnormal conditions
  - Reflux → new steady state but no criticality concern
  - Chemistry inputs validated by SRNL





Application Examples

- **Uranium Solubility and Outside Sumps**
  - Undetected leak = slow, low volume not easily detected by instrumentation
  - Potentially collect in sump and evaporate to critical concentration
  - Historic samples of sumps indicated <15 g U-235.
  - Sumps open to rainfall and transferred to a general purpose evaporator which is controlled by sampling to < single parameter fissile mass.
  - January 1961 through August 2017 was evaluated
    - *Only October 1963 and October 2000 had 0 inches*
  - Annual minimum of 28.08 inches rainfall
  - Max credible undetected leak would take 3.9 months to reach a minimum critical mass
  - SRNL determined solution from an undetected leak reach the sump (the liquid in which is typically rainfall), the majority would remain soluble due to the contribution of nitric acid from the leak
    - *Thus be flushed to the evaporator regularly*
  - Event is not credible, also saves workers from handling high concentrate acid

Application Examples

- **Freezing of Large Outside Uranyl Nitrate Storage Tanks**
  - Large = 5500 to 163000 gallons
  - Cold weather = October through March
    - *Assumes freezing point of 32 F though real point is lower*
  - Temperature date between 1961 and 2017 were reviewed
    - *Below freezing for 1 day – 68 periods*
    - *Below freezing for 2 days – 33 periods*
    - *Below freezing for 3 days – 20 periods*
    - *Below freezing for 4, 5, or 6 days – 1 period each*
  - It would take multiple consecutive days below freezing to freeze the tank
  - Assumes concentration of material in remaining liquid, neglects U entrainment in ice which limits concentration
  - No reports of freezing solution in operating history of facility
  - Program to heat certain tanks when ambient is less than a minimum temperature is not necessary for preventing this event (may required for other reasons)

Application Examples

- **Dissolver Insert Plug Configuration**
  - Dissolution of spent research reactor fuels
  - Bundles of assemblies charged to dissolver wells, 10 spots
  - Potential to over mass the system with all 10-wells open
  - Controls on charging, mass per bundle, and neutron poison developed
  - Well was modified with 5-well plug that prevents 5 of the wells from being charged with fuel
  - State of the equipment, verified in place, difficult to remove
  - Assume plug is in place (protected by procedure steps marked for criticality)

Application Examples

- **Dissolver Insert Plug Configuration**
  - Review fuel types and used highest reactivity one
  - Use chemistry study for maximum U concentration in any well
  - Over mass events not credible in 5-well configuration
  - May charge all 5 wells with no restriction on fuel type
  - No neutron poison needed (retain as uncredited defense in depth)
  - Additionally, overconcentration scenarios were reduced to a single bounding event

Discussion and Conclusions

- **Conclusions (or lack thereof) and Recommendations**
  - Examples above removed approximately 20 postulated scenarios from facility safety basis and showed others did not need to be added
  - Removal of controls and downgrade of equipment
  - Personnel involved can do their work without the risk of being exposed to a criticality accident.
  - Process or facility for which that determination is made does not require criticality safety controls.
  - Nature of process arguments require a **case-by-case** evaluation and an understanding of the process behavior.
    - *There is no one-size-fits all definition or stringently prescribed approach*