Effects of Nitric Acid on Criticality Safety Analysis

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Introduction

- Outline:
  - Savannah River Site (SRS) & H-Canyon
  - Nitric Acid Basics
  - Dissolving in H-Canyon
  - Moderation
  - Reflection
  - Interaction
  - Results

Savannah River Site & H-Canyon

- SRS
  - 310 mi^2 complex (~800 km^2)
  - Owned by the Department of Energy
  - Managed and operated by Savannah River Nuclear Solutions
- H-Canyon
  - The only operating nuclear chemical separations plant remaining in the United States
  - Heavily shielded
  - Employs remote operations

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Nitric Acid Basics

- $HNO_3 + H_2O$
- 100% HNO_3 has a molarity of 23.9 M
- As the molarity increases, the density increases
  - 100% HNO_3 has a density of ~1.5 g/cm^3
- As the molarity increases, the hydrogen density decreases

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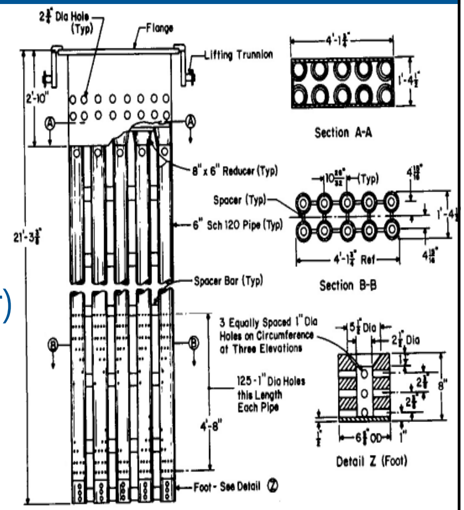
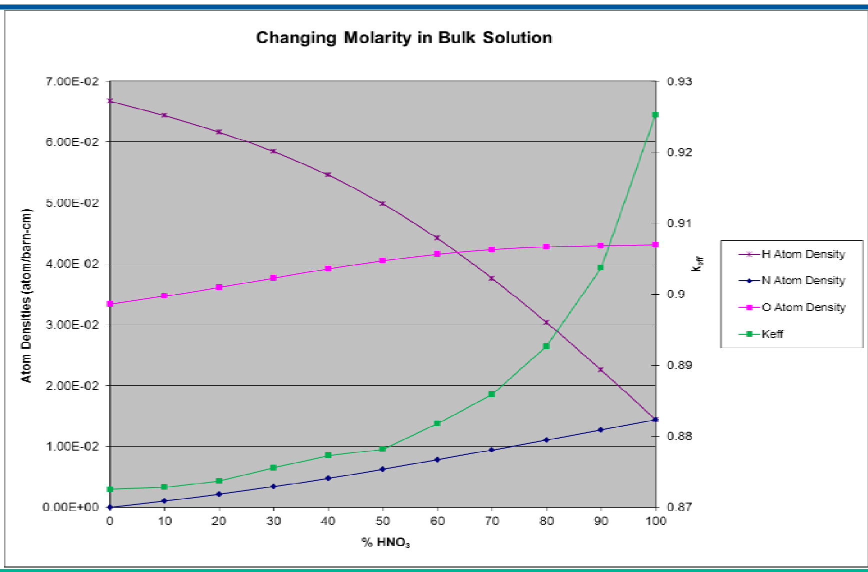
Dissolving

- 2 tanks
  - 8' d x 8' h (2.5 m x 2.5 m)
  - 12' d x 8' h (3.5 m x 2.5 m)
- 10-well insert
- 2 regions of interest
  - Inside the wells (moderator)
  - Bulk solution (moderator & reflector)



Bulk Solution



Moderation

- **Hydrogen atom density is typically a good indicator of effectiveness as a moderator**
- **Average lethargy gain per collision**

$$\xi = 1 - \frac{(A-1)^2}{2A} \ln\left(\frac{A+1}{A-1}\right)$$

Moderator	A (g/mole)	N (atoms/barn-cm)	σ_s (barns)	σ_a (barns)	ξ
H_2O	**63.00**	**0.03333**			**0.9256**
H	1.008	0.06665	20.47	0.332	1.000
O	15.99	0.03333	3.78	0.00019	0.1200
HNO_3	**18.01**	**0.01437**			**0.5546**
H	1.008	0.01437	20.47	0.332	1.000
N	14.01	0.01437	10.01	0.075	0.1362
O	15.99	0.04312	3.78	0.00019	0.1200

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Moderation

- **Moderating Power**

$$\text{Moderating power} = \xi\Sigma_s$$

- **Moderating Ratio**

$$\text{Moderating ratio} = \frac{\xi\Sigma_s}{\Sigma_a}$$

Moderator	ξ	Σ_s (barns)	Σ_a (barns)	Moderating power	Moderating ratio
H_2O	0.9256	1.490	0.02214	1.380	62.32
HNO_3	0.5546	0.6011	0.005858	0.3334	56.91

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Reflection

- Density of water, ~1.0 g/cm^3
- Density of HNO_3, ~1.5 g/cm^3

Moderator	Σ_s (barns)
H_2O	**1.490**
H	1.364
O	0.1260
HNO_3	**0.6011**
H	0.2942
N	0.1439
O	0.1630

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Interaction

- Because nitric acid is a worse reflector, interaction between the wells is increased
- However, nitric acid is still a very good moderator
- Interaction between the wells is increased, and k_{eff} goes up

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Results

- In the bulk solution, nitric acid is a moderator & reflector
  - As molarity increases, k_{eff} increases
- In the wells, nitric acid is only a moderator
  - As molarity increases, k_{eff} decreases slightly
- The molarity effects in the wells are the dominating effect
- Overall, as nitric acid molarity increases, k_{eff} goes decreases
- Understanding the physics is very important!

Questions?