Recent Improvements to the Criticality Safety Evaluation Exercise - First Week

This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy

Introduction

- NCSP Hands-On Training & Education Course pilot in 2011
  - The course has been presented several times since
  - Participants have provided very positive feedback
  - Continuous improvement mindset
    - Recently revised the criticality safety evaluation (CSE) exercise
      - LANL, PNNL, SNL, and ORNL
      - Electro-Refining (ER) operation originally used
        - Process too complex for time allotted
        - Students not able to assess subcriticality with the simple tools available
        - Metal process seen as an inappropriate focus

Schedule – First Week

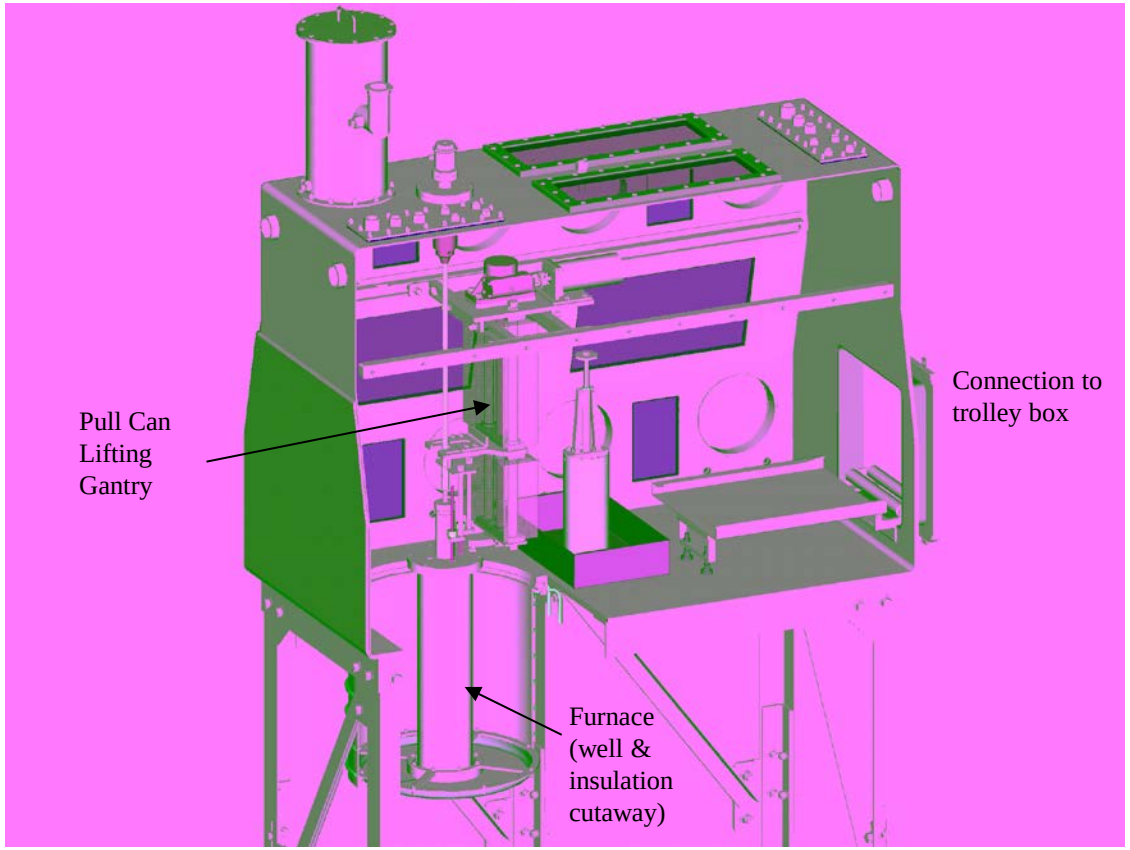
Monday		
7:30	LANL Badge Office	Obtain badge reader access
8:30	Study Center	Welcome and Introduction to LANL
8:45	Study Center	Module 0 Section 2: DOE Requirements, Nat'l Standards and NCSP
9:45	Study Center	Module 3: Process Facility Accidents
10:45	Study Center	Module 1: NCS History, Fundamentals
11:45		Lunch
12:45	Study Center	Module 1 con't: NCS Fundamentals, Time Behavior, Safety Margin
2:45	Study Center	Module 2: Parameters
4:30	Study Center	Evaluation Exercise Introduction
5:15	Study Center	Hand out Quiz
5:30		End of Day
Tuesday		
8:00	Study Center	Module 5: ANSI/ANS Standards Overview
11:30		Lunch
12:30	Study Center	Module 6: DOE Requirements, Nat'l Standards and NCSP
1:30	Study Center	Module 7: Criticality Safety Evaluations
3:30	Study Center	Evaluation Exercise: Preparation for Walkdown
4:30	Study Center	PF-4 Tour preparation and visitor acknowledgement form
5:00		End of Day

Wednesday		
8:00	Study Center	Module 8: Human Factors
9:00	Study Center	Module 3 con't: Process Accidents
10:15	Study Center	Module 4: Hand Calculation Methods Part 1
11:00	Study Center	Hand out quiz
11:00		Lunch
12:30	TA-55 Access Center	TA-55 Entry Procedures
1:30	TA-55	Evaluation Exercise: Walkdown and Tour
5:15		End of Day
Thursday		
8:00	Study Center	Module 4: Hand Calculation Methods Part 2
9:00	Study Center	Evaluation Exercise: Evaluation Development
11:15	Study Center	Class Photo
11:30		Lunch
12:30	Study Center	Module 9: NDA
5:00		End of Day
Friday		
8:00	Study Center	Evaluation Exercise: Final Discussions and Hand out example
10:00	Study Center	Module 10: DOE Requirements, Nat'l Standards and NCSP
11:00	Study Center	Module 3 con't: Process Accidents
12:00		Lunch
1:00	Study Center	Review for Exam
2:00	Study Center	Exam
3:00	Study Center	Students Turn in feedback forms, handout NCERC binders

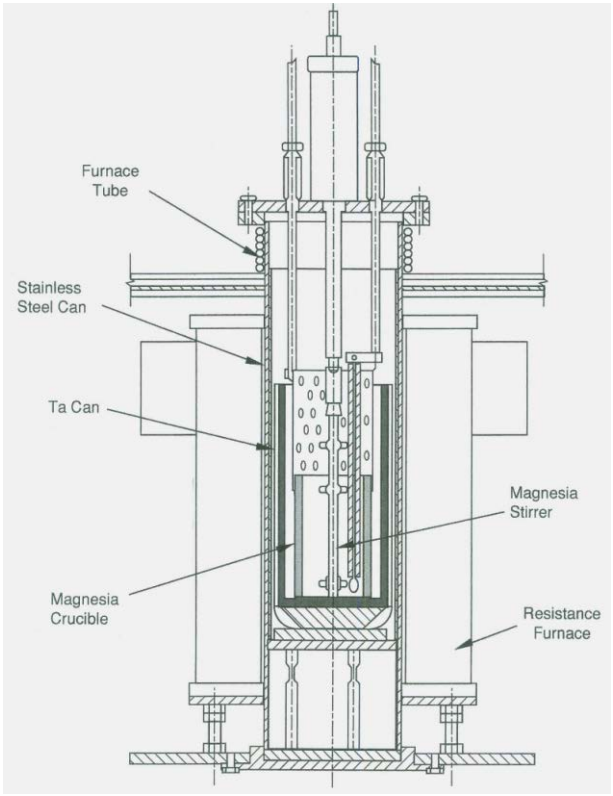
Electro-Refining (ER) Process

- ER Process involves:
  - Hands-on Pu metal transfer
  - Preparation for and loading into the furnace
  - The ER operation itself
  - Breakout
  - Product and waste removal
- Process utilizes two cooling water systems
  - Negative Pressure Circulating Chilled Water System inside glovebox
  - Positive Pressure Circulating Chilled Water System outside glovebox

ER Process (Cont.)



ER Glovebox



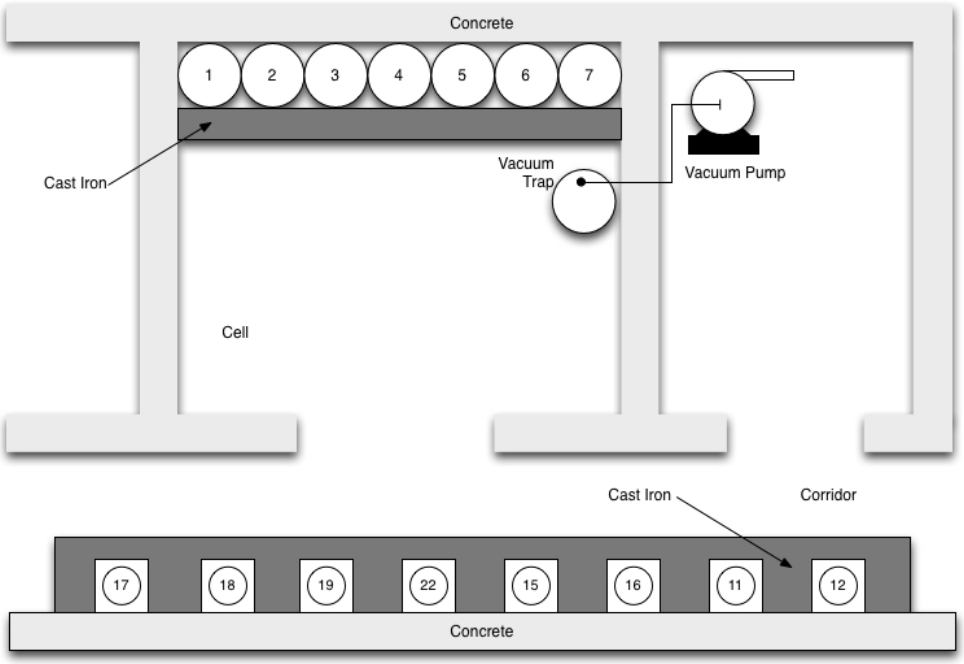
Furnace With Tube

Metal Process Inappropriate Focus

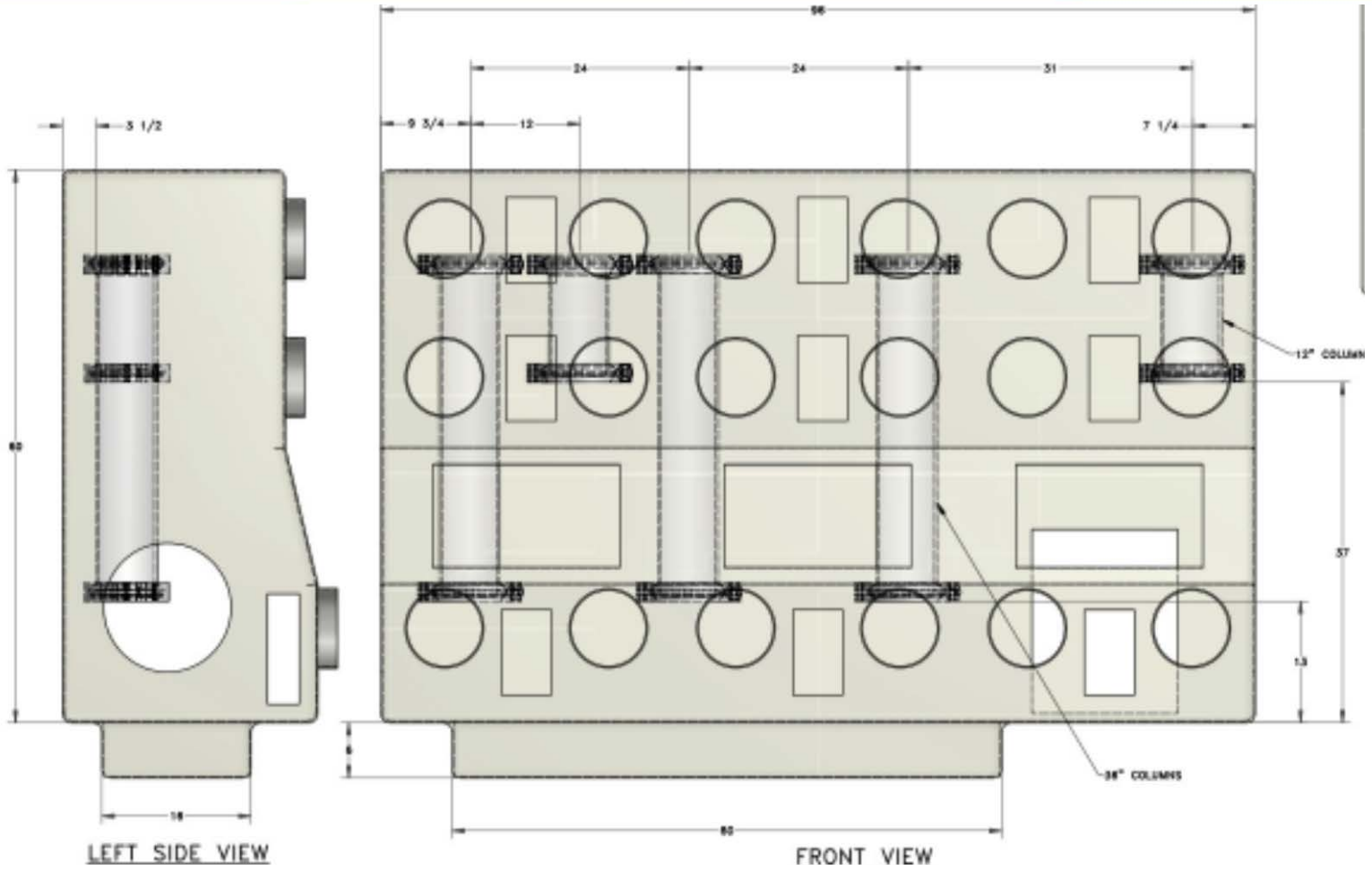
- Module 3 - Criticality Accidents
  - Objective:
    - Introduce LA-13638 “A Review of Criticality Accidents” published in 2000
      - 21 of the 22 process criticality accidents involved solutions or pseudo-solutions
    - Understand the common characteristics of the process criticality accidents and lessons learned
      - Unfavorable geometry vessels should be avoided in areas where high-concentration solutions might be present
      - All accidents have been dominated by design, managerial, and operational failures
    - Etc.

1953 Mayak Accident

- Solution transfer, staging, and sampling process
  - Unfavorable geometry process vessels
  - Unfavorable geometry vacuum transfer system
  - Heavy reliance on administrative controls
- Accident occurred with only 842 grams

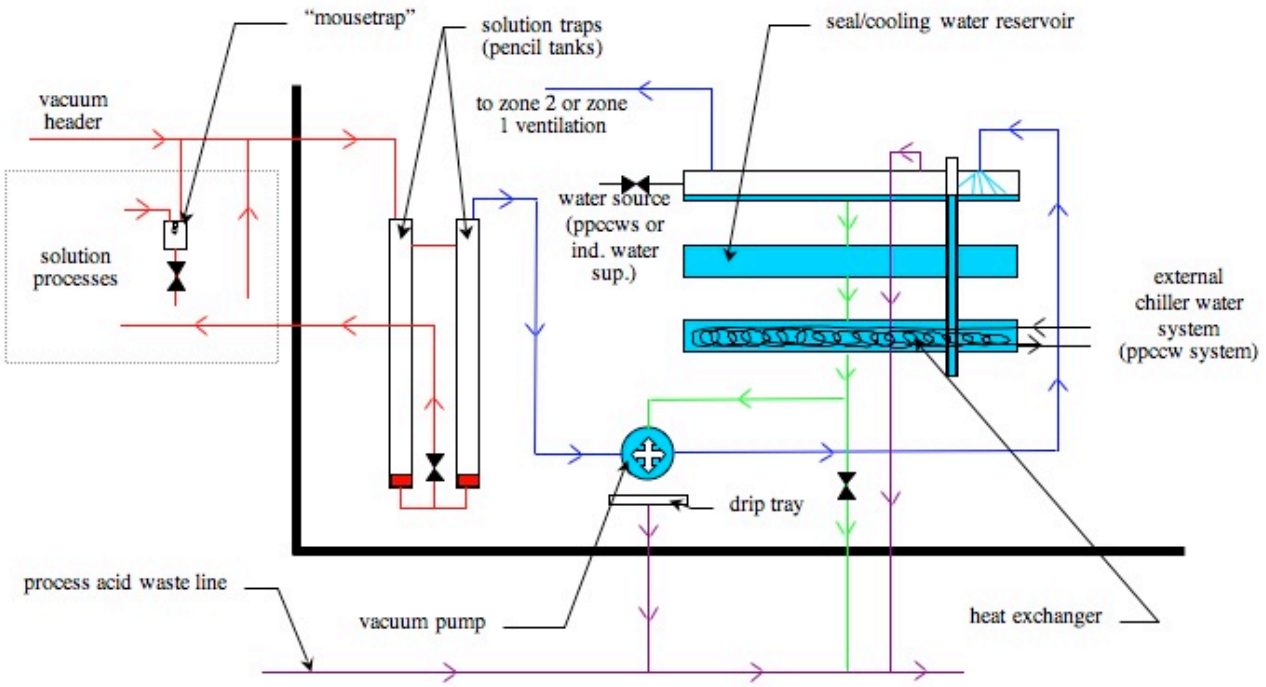


Solution Transfer, Staging, Sampling



Vacuum Solution Transfer System

- Favorable geometry traps
- Favorable geometry pump
- Favorable geometry seal water system

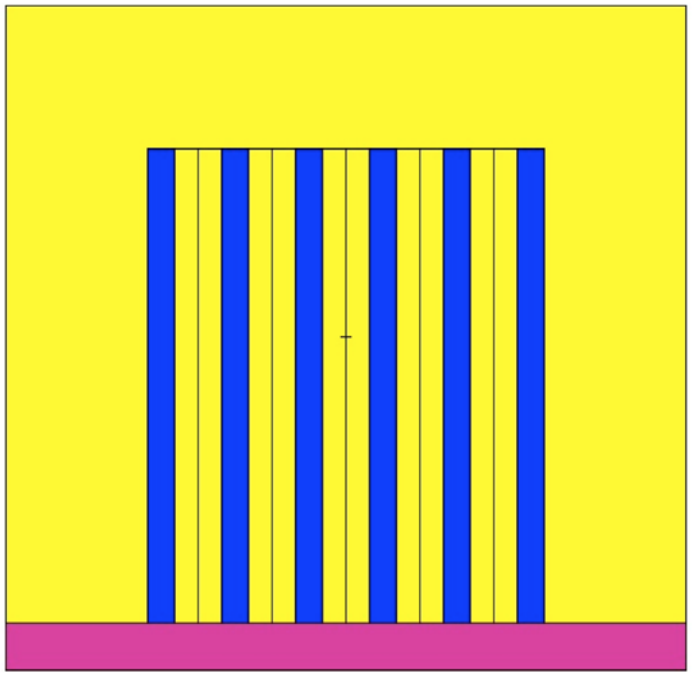


Vacuum Solution Transfer System

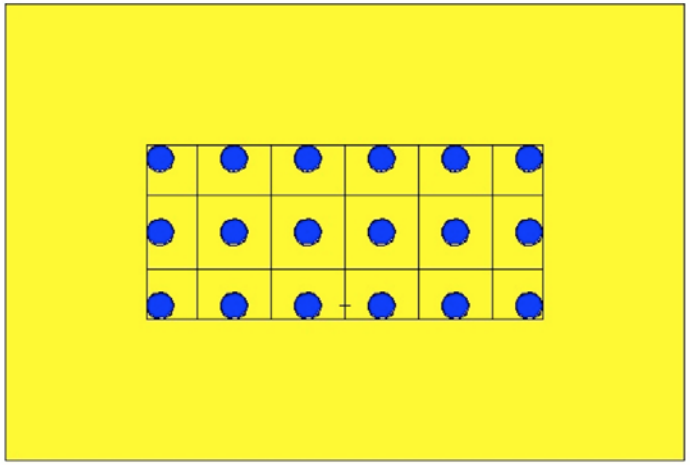
Reference Material – Tools

- LANL issued LA-UR-14-20507, *Parametric Studies for Practical Limit Development for Plutonium Solution Systems Involving up to 3 x 6 Arrays of 6-Inch Columns*
  - Arrays of columns (bare and water flooded/reflected)
    - Various configurations, spacing, Pu concentration, ^{240}Pu content
  - Single columns (bare and water reflected)
    - Various Pu concentration, ^{240}Pu content, precipitation
  - Hand-carried items held up next to column
    - 4,500 g Pu[0] α-phase metal
    - 6-liter container with 500 g Pu[0]/l metal/water mixture

Reference Material – Tools (Cont.)



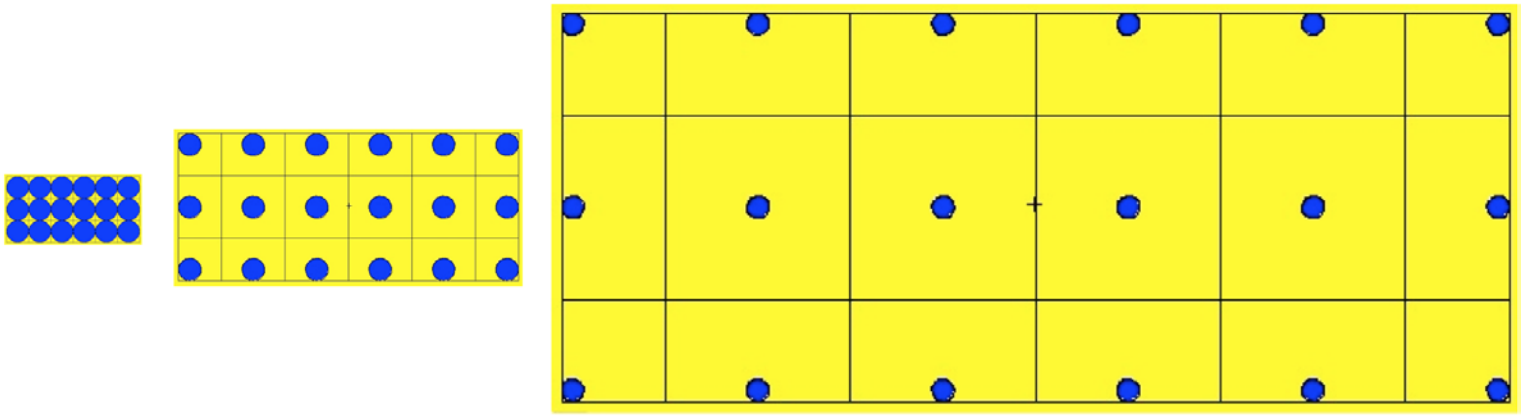
Side View



Top-Down View

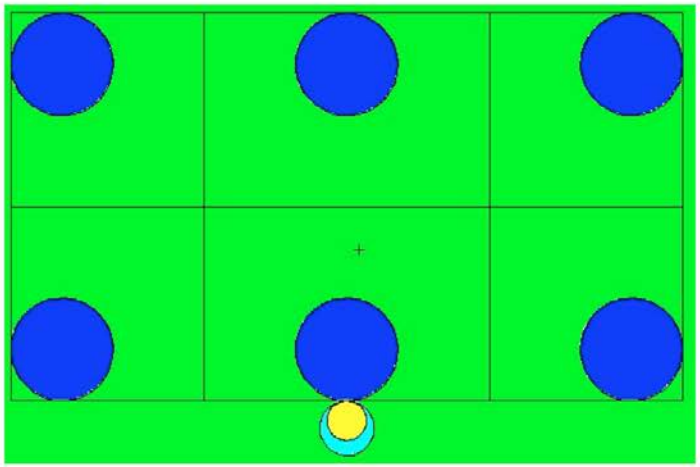
- 3 x 6 Array of Columns on a 12-Inch Thick Slab of Concrete

Reference Material – Tools (Cont.)

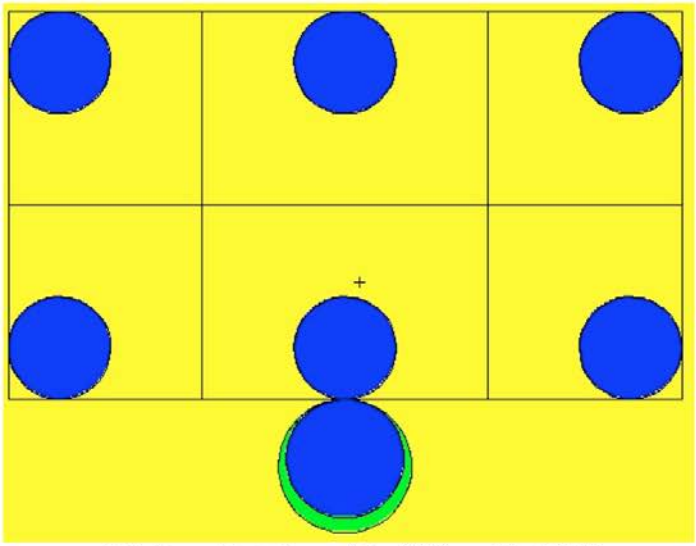


- 3 x 6 Array of Columns with Various Edge-To-Edge Spacing

Reference Material – Tools (Cont.)



4,500-g α-phase Pu[0] Metal



6-Liter Bottle with 500-g Pu[0]/l

- 2 x 3 Array of Columns, 12-Inch Edge-To-Edge Spacing, with Hand-Carried Item

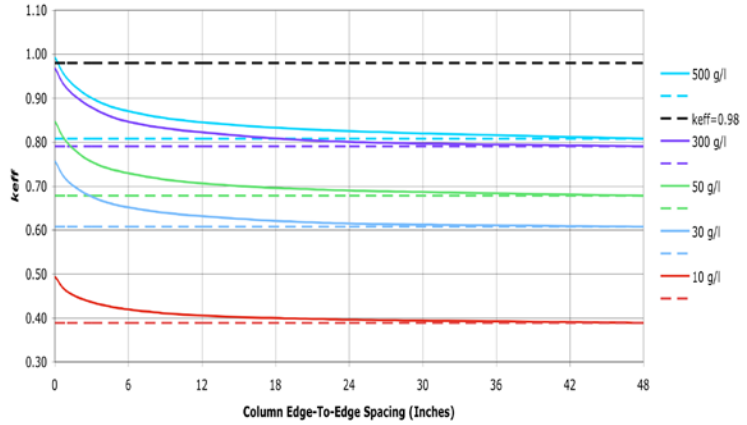
Reference Material – Tools (Cont.)

- Results presented in tabular form and in plots

1 x 4 Array

Table 3 – 1 x 4 Array of Columns.

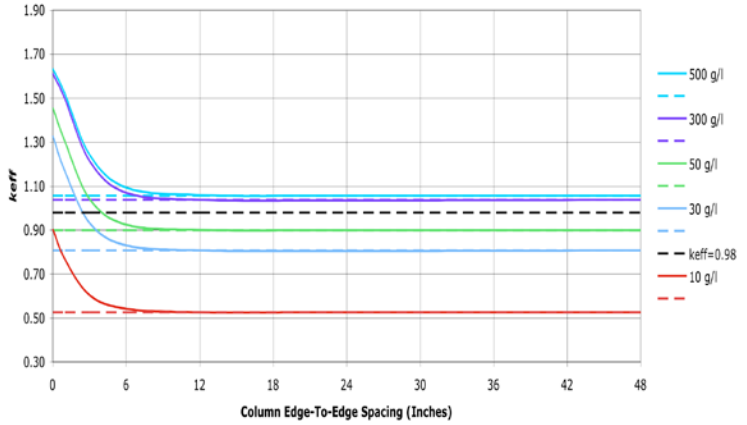
E-T-E Spacing (in)	*keff* @ 10 g Pu[0]/l	*keff* @ 30 g Pu[0]/l	*keff* @ 50 g Pu[0]/l	*keff* @ 300 g Pu[0]/l	*keff* @ 500 g Pu[0]/l
0.0	0.495	0.758	0.848	0.969	0.993
1.0	0.460	0.713	0.799	0.922	0.945
3.0	0.437	0.677	0.755	0.879	0.901
6.0	0.420	0.652	0.730	0.846	0.871
12.0	0.406	0.632	0.706	0.822	0.846
24.0	0.397	0.615	0.690	0.801	0.826
48.0	0.389	0.608	0.679	0.791	0.808



Array of Columns in Water

Table 35 – 3 x 6 Array of Columns in Water.

E-T-E Spacing (in)	*keff* @ 10 g Pu[0]/l	*keff* @ 30 g Pu[0]/l	*keff* @ 50 g Pu[0]/l	*keff* @ 300 g Pu[0]/l	*keff* @ 500 g Pu[0]/l
0.0	0.906	1.330	1.457	1.613	1.635
1.0	0.767	1.167	1.302	1.497	1.520
3.0	0.605	0.933	1.042	1.214	1.243
6.0	0.542	0.831	0.925	1.070	1.094
12.0	0.526	0.808	0.901	1.038	1.060
24.0	0.527	0.806	0.900	1.036	1.057
48.0	0.526	0.808	0.900	1.038	1.057



Reference Material – Tools (Cont.)

- Module 4 – Hand Calculation Methods
  - Two new practical exercises developed
  - Worked in class after applicable presentation
    - Single unit methods
    - Array methods
  - Two questions directly applicable to the CSE exercise
    - Using Buckling Conversion, address column leaking into the well
    - Using Solid Angle, address subcriticality of columns
      - Bare
      - Flooded

Course Improvements

- Aligns the CSE exercise complexity with the allotted time
- Students can visually observe all process equipment
- Process relies on a Solution-Assay Instrument (SAI), which is a non-destructive assay (NDA) technique
- Sufficient analysis tools provided
- Real-world examples using hand-calculation techniques applied