Lawrence Livermore National Laboratory

# Nuclear Accident Dosimetry Exercises at CEA-Valduc


**Andrew Wysong**

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**Lawrence Livermore National Laboratory, P.O. Box 808, L-198, Livermore, CA 94551-0808**

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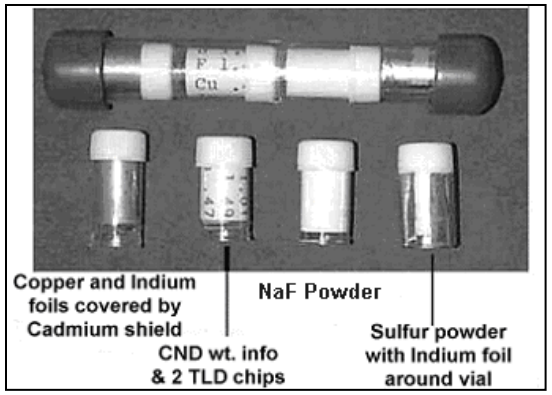
# Outline

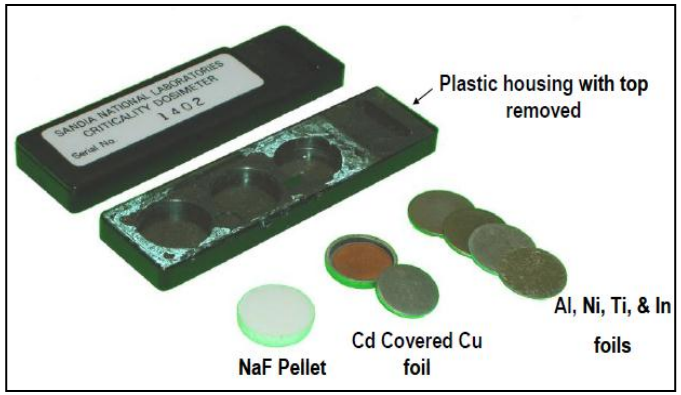
## Topics

- Nuclear Accident Dosimetry Systems
- 2009 SILENE Reactor Exercise
- 2010 CALIBAN Reactor Exercise
- NAD Exercise Results
- Lessons Learned
- Future Work

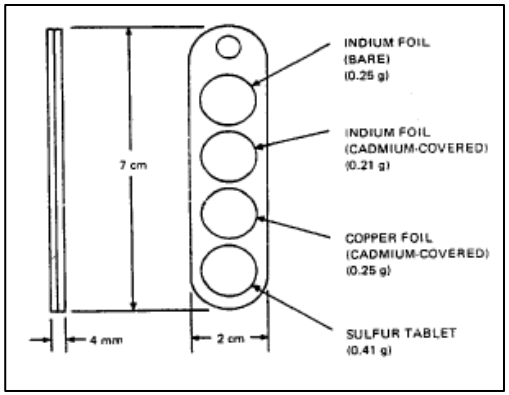
# Nuclear Accident Dosimetry Systems



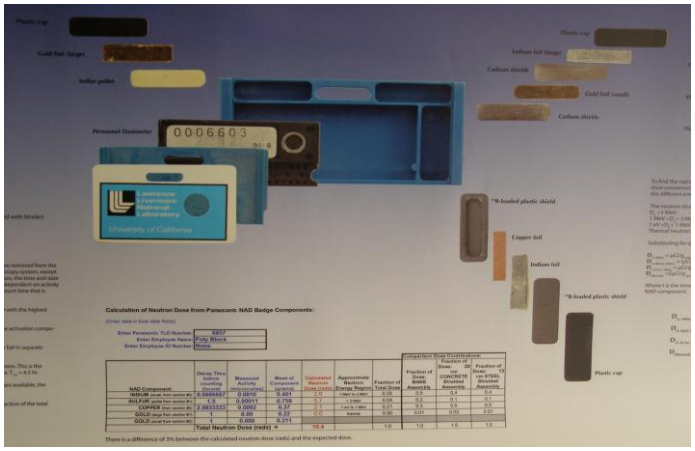

SRS



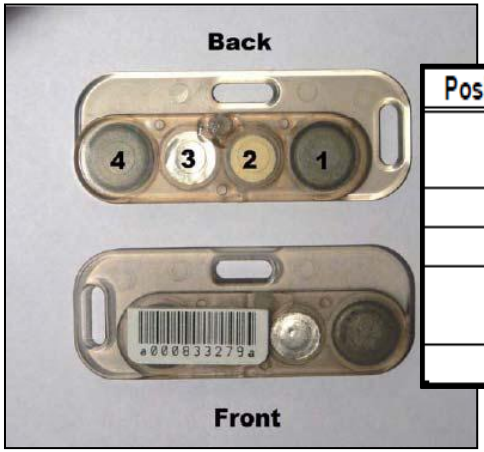

SNL




LANL



LLNL




| Position in PNAD | Description |
|---|---|
| 1 | Indium (Cd shielded)[a] |
| 2 | Sulfur Pellet |
| 3 | Indium (Bare) |
| 4 | Copper (Cd shielded)[a] |
| -- | TLD-700 Chip |

PNNL



Note: Y-12 System Not Pictured

# 2009 NAD Exercise

## Participating Laboratories

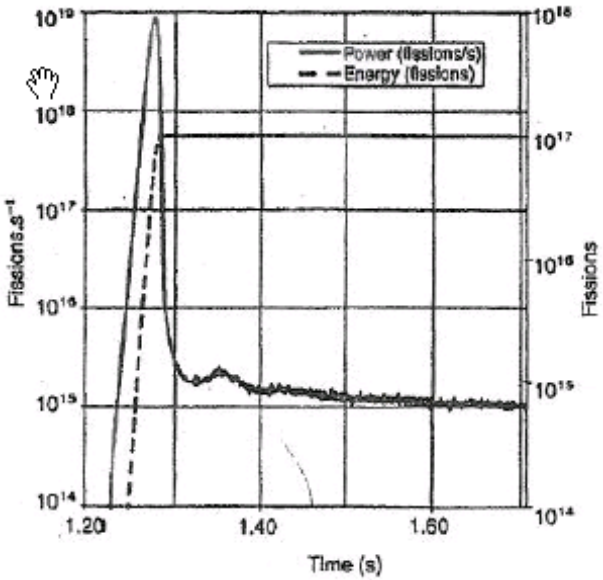


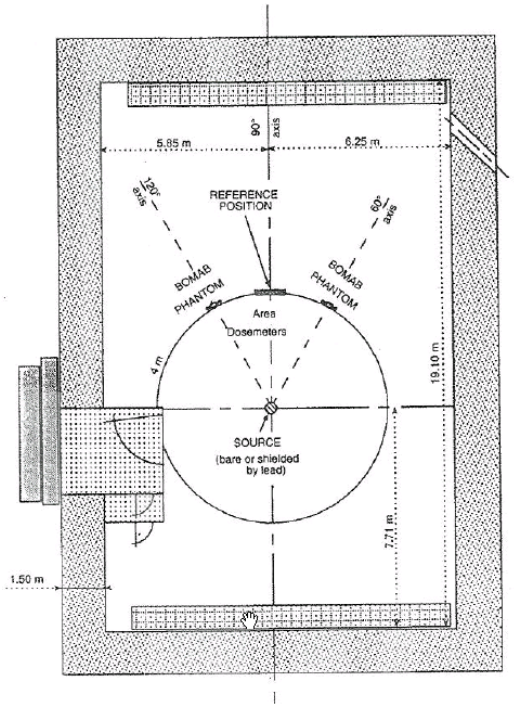


# SILENE Reactor

## SILENE Reactor

- Uranyl-nitrate solution reactor
- Operates in three modes: **pulse**, free evolution, steady state
- Pulse mode initiated by rapid withdrawal of control rod
- Reaction stops due to bubbling of liquid and then liquid is quickly evacuated from reactor core
- Operated bare and with a lead shield



# 2009 Exercise Setup

- Three Pulses
  - Pulse 1 – Lead Shield
  - Pulse 2 – No Shield, High Yield
  - Pulse 3 – No Shield, Low Yield
- Phantom Arrangement
  - Setup at 2 m, 4 m, and 6 m distances
  - Bibs contained dosimeters on front, side, or rear of phantom

# 2010 CALIBAN NAD Exercise

## Participating Laboratories

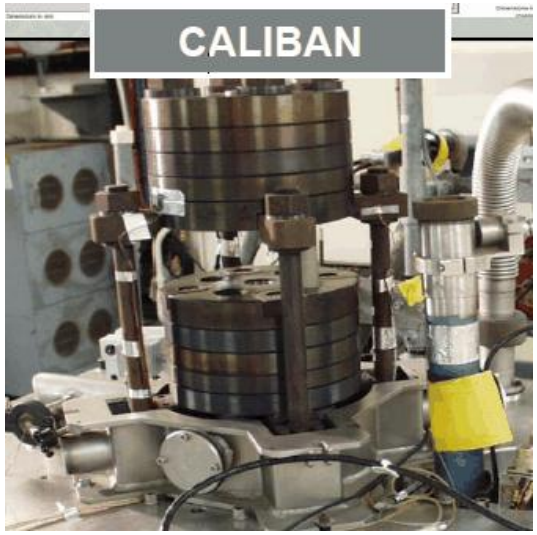
- All 2009 Participants Returned
  - LLNL
  - LANL
  - PNNL
  - SRS
  - Y-12
- New Participant

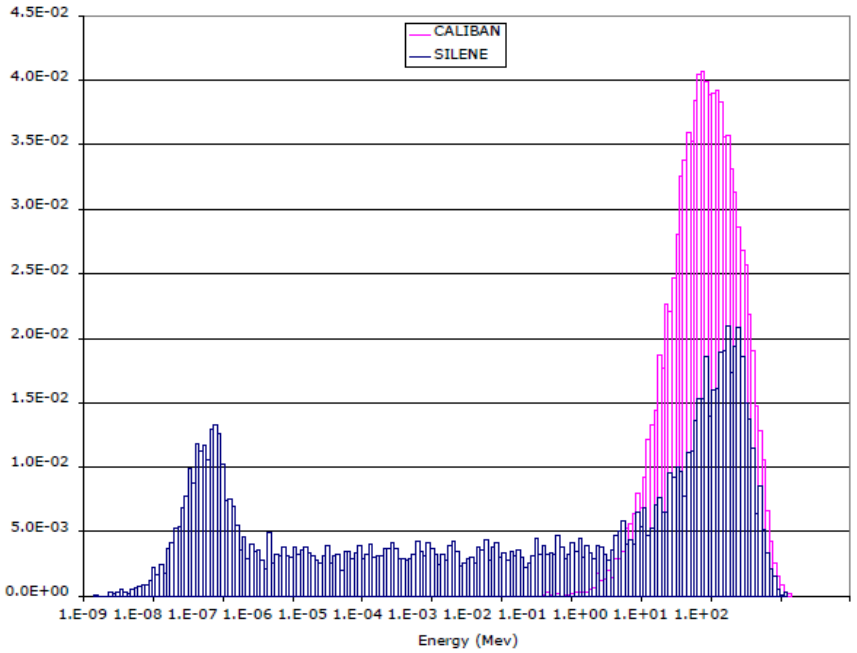

- Many other organizations expressed interest but could not be accommodated until exercises are established with Godiva

# CALIBAN Reactor

## CALIBAN Reactor

- Un-reflected HEU metal fast burst reactor (similar to SPR)
- Operated in pulse mode
- Pulse mode initiated by rapid insertion of control rods
- Solid core composition
  - 10 fuel discs & 4 control rods
  - 93.5% HEU metal alloyed with 10 wt% Mo



# 2010 Exercise Setup

- Two Pulses
  - Pulse 1 – No Shield, Low Yield
  - Pulse 2 – No Shield, High Yield

- Phantom Arrangement
  - Setup at 2 m, 2.5 m, 3 m, and 4 m distances
  - Bibs contained dosimeters on front, side, or rear of phantom and in air

# Exercise Results - Neutron

## US Laboratory Exercise Results

### Neutron Dose (Rad)

| Year | Pulse | Shield | Distance (m) | Reference | LLNL | Y-12 | LANL | PNNL | SRS | SNL |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 1 | Lead | 2 | **690** | 791 | 800 | 650 | 634 | 546 | NR |
| | | | 4 | **190** | 232 | 290 | 270 | NR | NR | NR |
| | | | 6 | **110** | 109 | 160 | NR | NR | NR | NR |
| | 2 | None | 2 | **320** | 344 | 340 | 310 | 367 | 425 | NR |
| | 3 | None | 6 | **150** | 159 | 180 | 150 | 78 | 154 | NR |
| 2010 | 1 | None | 2 | **510** | 490 | 310 | 560 | NR | NR | 433 |
| | | | 4 | **170** | 220 | 310 | 200 | NR | 175 | 153 |
| | 2 | None | 2 | **720** | 707 | 440 | 760 | NR | NR | NR |
| | | | 2.5 | **500** | 580 | 460 | NR | NR | NR | 502 |
| | | | 4 | **240** | NR | 430 | 330 | NR | 273 | NR |

# Exercise Results – Neutron

## US Laboratory Exercise Results

### Neutron Dose Ratios to Reference Values

| Year | Pulse | Shield | Distance (m) | Reference | LLNL | Y-12 | LANL | PNNL | SRS | SNL |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 1 | Lead | 2 | **1** | 1.15 | 1.16 | 0.94 | 0.92 | 0.79 | NR |
| | | | 4 | **1** | 1.22 | 1.53 | 1.42 | NR | NR | NR |
| | | | 6 | **1** | 0.99 | 1.45 | NR | NR | NR | NR |
| | 2 | None | 2 | **1** | 1.08 | 1.06 | 0.97 | 1.15 | 1.33 | NR |
| | 3 | None | 6 | **1** | 1.06 | 1.20 | 1.00 | 0.52 | 1.03 | NR |
| 2010 | 1 | None | 2 | **1** | 0.96 | 0.61 | 1.10 | NR | NR | 0.85 |
| | | | 4 | **1** | 1.29 | 1.82 | 1.18 | NR | 1.03 | 0.90 |
| | 2 | None | 2 | **1** | 0.98 | 0.61 | 1.06 | NR | NR | NR |
| | | | 2.5 | **1** | 1.16 | 0.92 | NR | NR | NR | 1.00 |
| | | | 4 | **1** | NR | 1.79 | 1.38 | NR | 1.14 | NR |

According to ANSI/HPS N13.3, *Dosimetry for Criticality Accidents*, nuclear accident dosimetry systems should be able to provide sufficient data to calculate the dose within ± 25%. Results in green meet this performance criterion while results in red do not.

# Exercise Results - Gamma

## US Laboratory Exercise Results

### Gamma Dose (Rad)

| Year | Pulse | Shield | Distance (m) | Reference | LLNL | Y-12 | LANL | PNNL | SRS | SNL |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 1 | Lead | 2 | **50** | 221 | 180 | 420 | 276 | 262 | NR |
| | | | 4 | **30** | 46 | 80 | 160 | NR | NR | NR |
| | | | 6 | **20** | 28 | 50 | NR | NR | NR | NR |
| | 2 | None | 2 | **380** | 432 | 330 | 420 | 467 | 494 | NR |
| | 3 | None | 6 | **210** | 172 | 160 | 180 | 187 | 295 | NR |
| 2010 | 1 | None | 2 | **70** | 64 | 100 | 85 | NR | NR | 72 |
| | | | 4 | **40** | 18 | 70 | 130 | NR | 109 | 64 |
| | 2 | None | 2 | **100** | 87 | 130 | 130 | NR | NR | NR |
| | | | 2.5 | **80** | 116 | 140 | NR | NR | NR | 136 |
| | | | 4 | **60** | NR | 100 | 170 | NR | 132 | NR |

# Exercise Results - Gamma

## US Laboratory Exercise Results

### Gamma Dose Ratios to Reference Values

| Year | Pulse | Shield | Distance (m) | Reference | LLNL | Y-12 | LANL | PNNL | SRS | SNL |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 1 | Lead | 2 | **1** | 4.42 | 3.60 | 8.40 | 5.52 | 5.24 | NR |
| | | | 4 | **1** | 1.53 | 2.67 | 5.33 | NR | NR | NR |
| | | | 6 | **1** | 1.40 | 2.50 | NR | NR | NR | NR |
| | 2 | None | 2 | **1** | 1.14 | 0.87 | 1.11 | 1.23 | 1.30 | NR |
| | 3 | None | 6 | **1** | 0.82 | 0.76 | 0.86 | 0.89 | 1.40 | NR |
| 2010 | 1 | None | 2 | **1** | 0.91 | 1.43 | 1.21 | NR | NR | 1.03 |
| | | | 4 | **1** | 0.45 | 1.75 | 3.25 | NR | 2.73 | 1.60 |
| | 2 | None | 2 | **1** | 0.87 | 1.30 | 1.30 | NR | NR | NR |
| | | | 2.5 | **1** | 1.45 | 1.75 | NR | NR | NR | 1.70 |
| | | | 4 | **1** | NR | 1.67 | 2.83 | NR | 2.20 | NR |

According to ANSI/HPS N13.3, *Dosimetry for Criticality Accidents*, nuclear accident dosimetry systems should be able to provide sufficient data to calculate the dose within ± 25%. Results in green meet this performance criterion while results in red do not.

# Lessons Learned

- **Insufficient Operational Experience**
  - Instrumentation and personnel have changed resulting in personnel with no practical experience
  - Training of dosimetry personnel on their dosimetry system should be formalized and increased across complex

- **Detector Technology Has Advanced**
  - Nuclear accident dosimetry technology is substantially unchanged
  - Neutron activation analysis imposes time restraints on short lived isotopes
  - Difficulty in accounting for complex power history
  - Measurements require expert interpretation
  - NAD systems could take advantage of current technology or new technology to eliminate process steps and lessen reliance on experts

- **Gamma Dose TLD Needs Investigation**
  - Results from all laboratories (particularly pulse 1 – 2m) were far too high
  - Additional testing is necessary to resolve this anomaly

# Lessons Learned

- **Throughput of Activated Foils is the Limiting Factor**
  - Counting irradiated samples must be done before activation of sample becomes too low and information is gone
  - To achieve good statistics these counts require time
  - Crosstalk of samples due to multiple teams added an additional complication

- **A Thorough and Reoccurring Testing Program is Needed**
  - Every participating laboratory expressed a strong desire for continued opportunities to test and refine their dosimetry system as well as train operations personnel to demonstrate regulatory compliance and competency
  - ANSI/HPS N13.3 *Nuclear Accident Dosimetry* is being rewritten with these participating labs taking the lead

# Future NAD Exercises

- **2013 Godiva NAD Experiment at Nevada National Security Site (NNSS)**
  - **Laboratory participants were limited by equipment and setup available at CEA-Valduc**
  - **LLNL is coupling the experience of the past two NAD exercises in France with operational experience at NNSS to develop a counting laboratory for upcoming NAD experiments using Godiva.**
  - **Godiva radiation field in DAF must be characterized to provide reference values**
  - **Counting Laboratory will feature all the proper safety equipment, workspace, hand tools, and utilities (i.e. power)**
  - **Counting Laboratory should provide a fume hood to allow processing of irradiated dosimetry elements (e.g. crushing, melting, burning sulfur)**
  - **Counting Laboratory should include moveable shielding to minimize crosstalk**
  - **Routine exercises should be provided in the future for training of dosimetry personnel**
  - **NNSA should consider hosting an OECD International Intercomparison Exercise**

**All laboratory reports can be found at http://ncsp.llnl.gov/**