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Experiment Logistics for an International Blind Intercomparison Exercise for Nuclear Accident Dosimetry at the Armed Forces Radiobiology Research Institute's TRIGA Reactor

P. Angus, A. Cook, M. Gadd, B. Lawson, P. Maggi, S. Mitchell, S. Murphy, C. Percher, D. Roberts, A. Romanyukha, A. Smolinski, A. Tamashiro, F. Trompier, F. Vanhavere, K. Veinot, D. Ward

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Lawrence Livermore National Laboratory

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IER-602 CED-3A Report

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March 25, 2024

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[3]Los Alamos National Laboratory
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[6]Hanford Site
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[9]Institut de Radioprotection et de Sûreté Nucléaire
[10]Belgian Nuclear Research Centre
[11]Y-12 National Security Site
[12]Sandia National Laboratories

Executive Summary

This document is the Experimental Set-up and Design (CED-3a) Report for IER-602, "Dosimetry Exercise with Armed Forces Radiobiology Research Institute (AFRRI) - Exercise" The report discusses the structure of the exercise consisting of three reactor exposures, identifying the participating laboratories and their points of contact. The report also includes details of all dosimetry each laboratory will submit to be placed in proximity to AFRRI on aluminum plates or BOMAB phantoms. Each laboratory lists the counting and spectroscopy equipment to be utilized at AFFRI. The exercise is tentatively scheduled for one week in June, 2024 (FY24 Q4).

Contents

1 Introduction

The purpose of this exercise is to test participants' nuclear accident dosimeters (NADs) and personnel to the requirements established by ANSI/HPS-N13.3-2013 (R2019) *Dosimetry for Criticality Accidents*. IER-602 is the first nuclear accident dosimetry exercise taking place at the Armed Forces Radiobiology Research Institute (AFRRI) in Bethesda, MD, a Department of Defense (DOD) facility. This effort expands the available high-dose neutron exposure test beds and establishes a nuclear accident intercomparison collaboration between the DOD and Department of Energy (DOE). Previous work at AFRRI included a scoping meeting in early 2023 (IER-484 CED-3A), and a characterization effort in August 2023 (IER-484 CED-3B).

There are eleven laboratories planning to participate in this NAD blind intercomparison exercise. Six laboratories are from the Department of Energy (DOE), which includes Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Hanford, Sandia National Laboratory (SNL), Savannah River Site (SRS), and the Y-12 National Security Complex (Y-12). The five remaining laboratories are the Atomic Weapons Establishment (AWE), the Institut de Radioprotection et de Sûreté Nucléaire (IRSN), the Naval Dosimetry Center (NDC), the Norfolk Naval Shipyard (NNSY), and the Belgian Nuclear Research Center (BNRC). All laboratories except BNRC have participated in the previous blind intercomparisons.

2 AFRRI Overview

Details of the AFRRI TRIGA reactor pertaining to its use as a test bed for nuclear accident dosimetry can be found in the IER-484 CED-2 report.[1] The AFRRI points of contact are

- Andrew Cook: andrew.cook@usuhs.edu; 310-295-3922
- Andrew Smolinski: andrew.smolinski@usuhs.edu; 301-295-1288

A brief summary is provided in this document. There are two exposure rooms available at the AFRRI TRIGA reactor. Exposure Room 1 (ER1) was used for the 2023 characterization for IER-484 and will be used for this intercomparison. Nine locations, shown in Figure 1, were marked and characterized in the IER-484 CED-3B effort. This provides a room large enough to house multiple Bottle Man-akin Absorption (BOMAB) phantoms and stands for "free-in-air" dosimeters. The reactor core is centered 120 cm above the floor of the exposure room, which is near midline to the BOMABs. There are two ion chambers mounted on the ceiling of ER1. These are denoted as MC4 and MC2. MC4 is at 0 degrees near the back of the room at approximately 4 m and MC2 is offset at about -5 degrees between the 2 and 3 m distance from the core protrusion. The ion chambers are used for irradiation constancy. Each experimental run first requires a setup run to determine integrated charge on the ion chamber for a given irradiation dose target. The dose measured is normalized to the ion chamber readings to extrapolate different dose values for different ion chamber measurements. An example of the ion chamber measurements, reproduced from IER-484 CED-3B is shown in Figure 2.

[1] Wilson, C. et al. *Final Design for the Characterization of the Leakage Radiation Field from the TRIGA Reactor at the Armed Forces Radiobiology Research Institute*. IER-484 CED-2 Report. AWE Report No. 22/19 (2019).

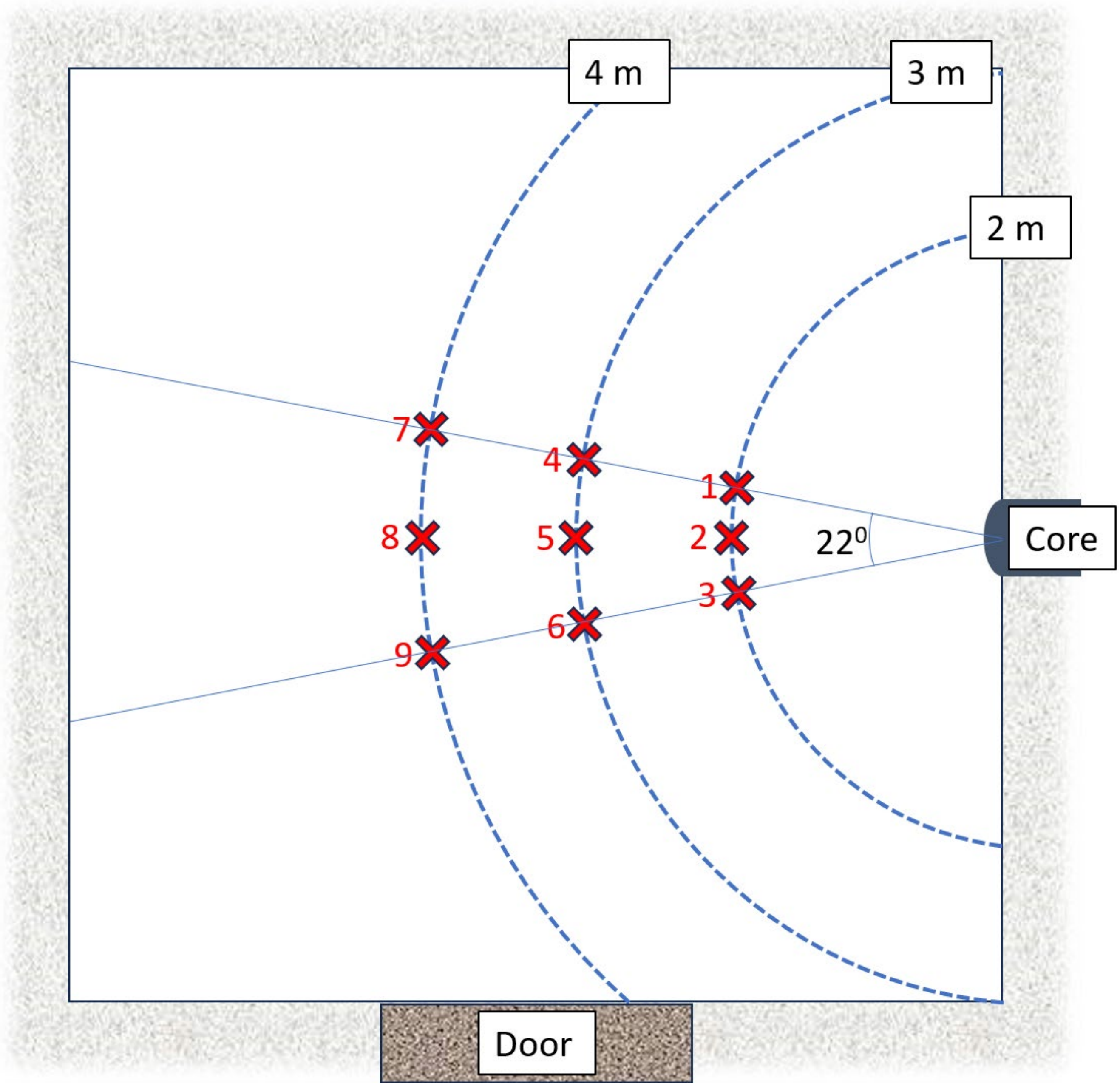

Figure 1: Map of irradiation position for ER1.

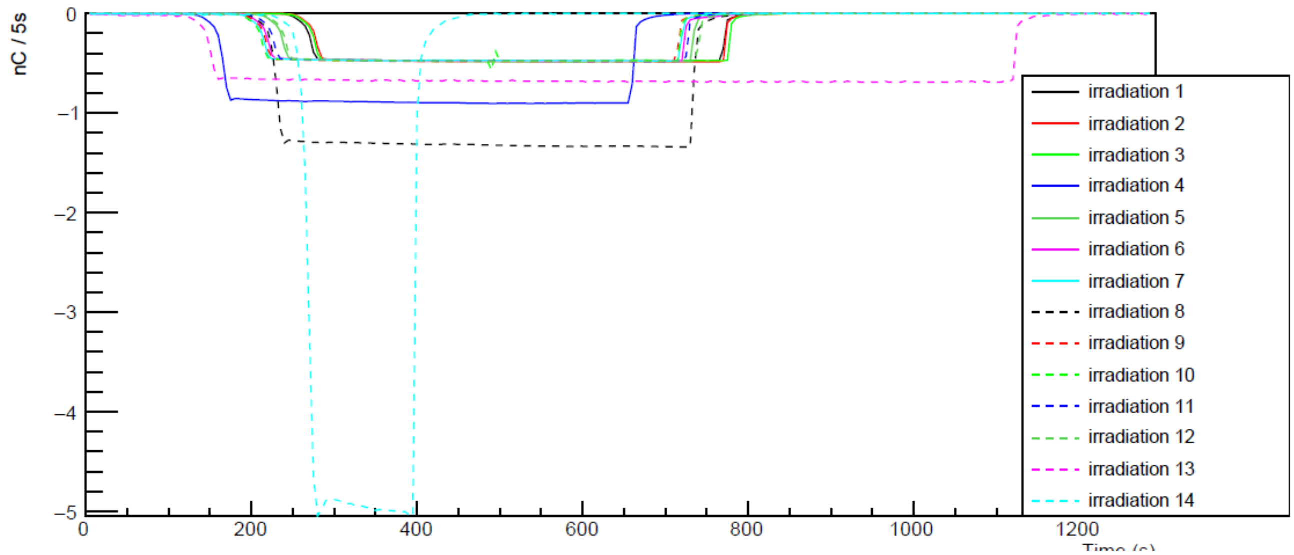

Figure 2: Ion Chamber Measurements from IER-484 CED-3B

3 Schedule, Scope and Responsibilities for IER-602

The intercomparison exercise is scheduled for the week of June 24, 2024 at AFFRI.AFRRI will operate the TRIGA reactor and provide hazards control and safety oversight. LLNL will provide reference dosimetry values, test stands, and phantoms needed for the experiment.

AFRRI will operate the reactor and manage access to the exposure area. All radiological activities will be performed under their broad scope NRC license 19-08330-02. The Intercomparison Coordinators (ICs) will supervise the set-up of dosimeters to be placed in the exposure room, as well as placement of phantoms and support structures. Placement will correspond to locations where reference values have been established. This role is currently assigned to Paul Maggi and Scarlet Mitchell of LLNL.

After irradiation, the phantoms and stands will be removed from the exposure room by AFRRI personnel. The ICs will remove the NADs and provide any requested dose measurements from the BOMAB, or samples of hair or saline. The NADs will be distributed to the respective labs under control of AFRRI radiological workers.

As the lead laboratory, LLNL, in conjunction with AFRRI, will assist each participating organization with travel logistics, training, and receipt of all NAD system components including counting equipment. This responsibility includes assisting foreign national participants, to obtain access to AFRRI. At the conclusion of the exercise, AFRRI will return all equipment to the participants. Each participating organization is responsible for providing a summary report of their exercise results.

4 Experiment Logistics and Execution

4.1 Exercise Summary

The purpose of this exercise is to examine the performance of each program to ANSI/HPS N13.3-2013 (R2019) *Dosimetry for Criticality Accidents*. This will be a blind exercise, conducted similarly to IER-584, testing the following aspects of a NAD program:

- Quick Sort Performance
- Biological Dosimetry Methods

- Preliminary NAD performance (within 24 hrs)
- Final NAD performance
- Identification and correction of orientation dosimeter response

This exercise will consist of six square-wave reactor exposures: three for setup and three for experiment. Dosimetry will only be deployed on the second of each exposure pair.

4.1.1 Proposed Irradiation Schedule

Friday, Jun 21:
- Start detector setup with lab leads

Monday, June 24:
- Full orientation at AFRRI. Includes site specific radiation safety training and escort policies
- Receive personnel dosimetry (whole body + extremity) from AFRRI Health Physics Department
- Labs provide dosimeters to ICs for Tuesday's irradiations.

Tuesday, Jun 25:
- Setup run for Experiment Run 1(approx. 7:00)
- Stands, phantoms, and dosimeters moved to ER1.
- Experimental Run 1 (approx. 9:00)
- Exposed NADs provided to labs (approx. 10:00)
- Target values provided to labs by IC mid afternoon
- Labs provide dosimeters to ICs for Wednesday's irradiations (afternoon)

Wednesday, Jun 26:
- Setup run for Experiment Run 2 (approx. 10:00)
- 24 hour results due for Experimental Run 1 (approx. 10:00)
- Experimental Run 2 (approx. 12:00)
- Labs provide dosimeters to ICs for Thursday's irradiation (afternoon)

Thursday, June 27:
- 24 hour results due for Experimental Run 2 (approx. 10:00)
- Setup run for Voluntary Experiment Run 3 (approx. 11:00)
- Experiment run 3 (approx. 13:00)

Friday, June 28:
- Exercise closeout meeting
- Finish packing equipment for shipment

The exercise will consist of three square wave exposures. The first exposure will be a "known" exercise where participants will be given the location, distance, orientation and delivered dose of the dosimeters approximately four hours after the initial delivery of the NADs. They will be provided with irradiation start and stop times immediately following the exposure.

The second exercise is a limited information scenario. Participants will only be provided with the irradiation start and stop times upon NAD retrieval. Other information will be kept private from the participants for the first 24 hours post irradiation.

The third exercise is a research-oriented exposure to allow for testing of new or modified technologies or other exposure geometries. The ICs will communicate with the labs to determine the dose level and the setup locations. No information will be blinded from the participants. Participation is optional for this exposure. In the nuclear accident community, there has been a recent interest to investigate the utility of measuring activated personal items, such as keys, belt buckles, or watches. As such, this irradiation will include a minimum of two BOMAB phantoms wearing pocketed lab coats for simulated personal item storage.

Each laboratory will submit up to 15 dosimeters for the first and second irradiation. Each laboratory will submit their uniquely identified dosimetry to the ICs. The coordinators will place the dosimetry on a Bottle Manikin Absorption (BOMAB) phantoms (Figure 1) and aluminum plates (Figure 2) keeping track of the dosimetry identification and placement locations. Coordinators will be non-participatory in dosimeter readouts and results generation.

Three BOMABs will be deployed for each of the first two irradiations. Each phantom can hold up to 22 dosimeters, 11 on the front and 11 on the back. A small number of dosimeters from each participant will be placed in varying orientations, including on the backside of the BOMABs. The BOMABs will be filled with saline solution to simulate sodium concentration in the human body. Additionally, each BOMAB will have small packets of hair taped to the surface of the phantom's head. The BOMABs will be set up for quick sorting measurements and participants will also be given samples of hair and 10 ml samples of saline for analysis.

Three stands will be deployed for each of the first two irradiations, located at the same distance as the BOMABS. Each stand will hold three aluminum plates where up to 11 dosimeters can be placed on a plate and 3 plates can be placed on a stand, up to 33 dosimeters in total. All dosimeters deployed on a plate will be oriented towards the reactor.

Participants will have up to 2 dosimeters placed per BOMAB and a maximum of 3 dosimeters per laboratory may be placed on the stand at a height as close as possible to the height of the corresponding dosimetry placed on the adjacent BOMAB phantom. Participants will be informed whether dosimeters were placed on BOMABs or plates upon receipt of the dosimeters post irradiation.

LLNL will place dosimeters on to phantoms and will photograph the placement of all dosimetry on phantoms and plates prior to setup in the exposure room. Once the phantoms and stands are moved into the exposure room, LLNL will fine tune placement, ensuring dosimetry is still in the correct locations. The BOMABs will be arranged to minimize shielding measurement points further away from the reactor. Additional setup photos will be taken at this time.

Post irradiation, AFRRI will remove the plates and the BOMABs into the exposure room staging area. The ICs will remove the dosimeters and sort them according to participant. Each participant will then be presented with their irradiated dosimeters and informed of their placement on BOMBABs or plates.

Participants will report dosimetry results as they become available. Limited information will be released by the coordinators during the first 24-hours post irradiation. At the end of the 24-hour period, participants will provide their best dosimetry determinations.

Upon the conclusion of the exercise, the positioning of each participant's dosimeters will be given. The participants will have three weeks after the exercise to perform additional analysis, make corrections (e.g. for shielding, rotation, etc), and provide revised dose estimates. Shielded dosimeter results (e.g., backside of BOMABs) will be required at this time.

Figure 3: BOMAB on stand with dosimetry placed on front and backside.

Figure 4: Dosimetry placed on aluminum plates on a rolling stand.

Workspace is provided on the first and second floors of the AFRRI reactor building. 15 possible work areas and two fume hoods are located on the second floor; four additional work areas are located on the first floor near the exposure room. The labs will be distributed based on required space and proximity considerations to minimize counting interference.

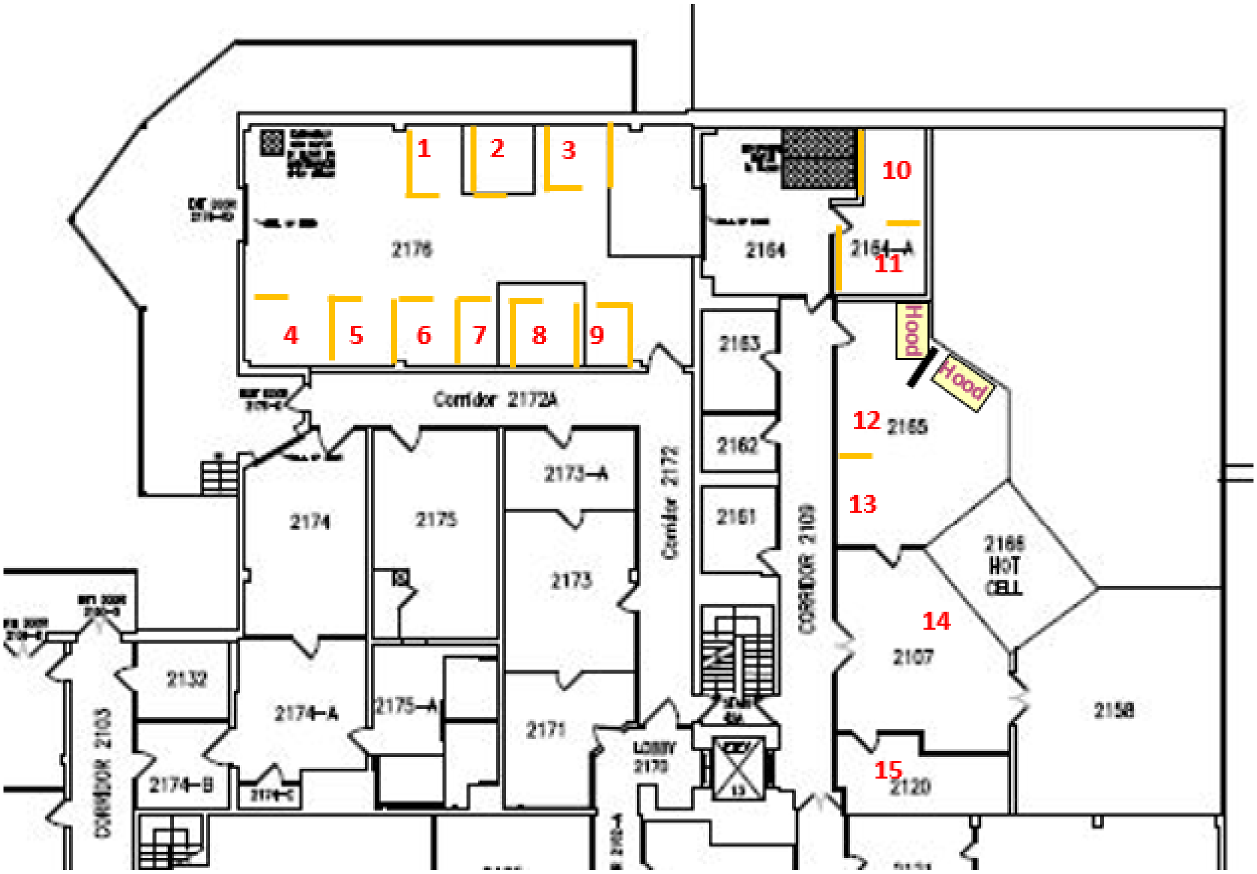

Figure 5: Room layout of the second floor of the AFRRI reactor building. Red numbers indicate the 15 possible work areas.

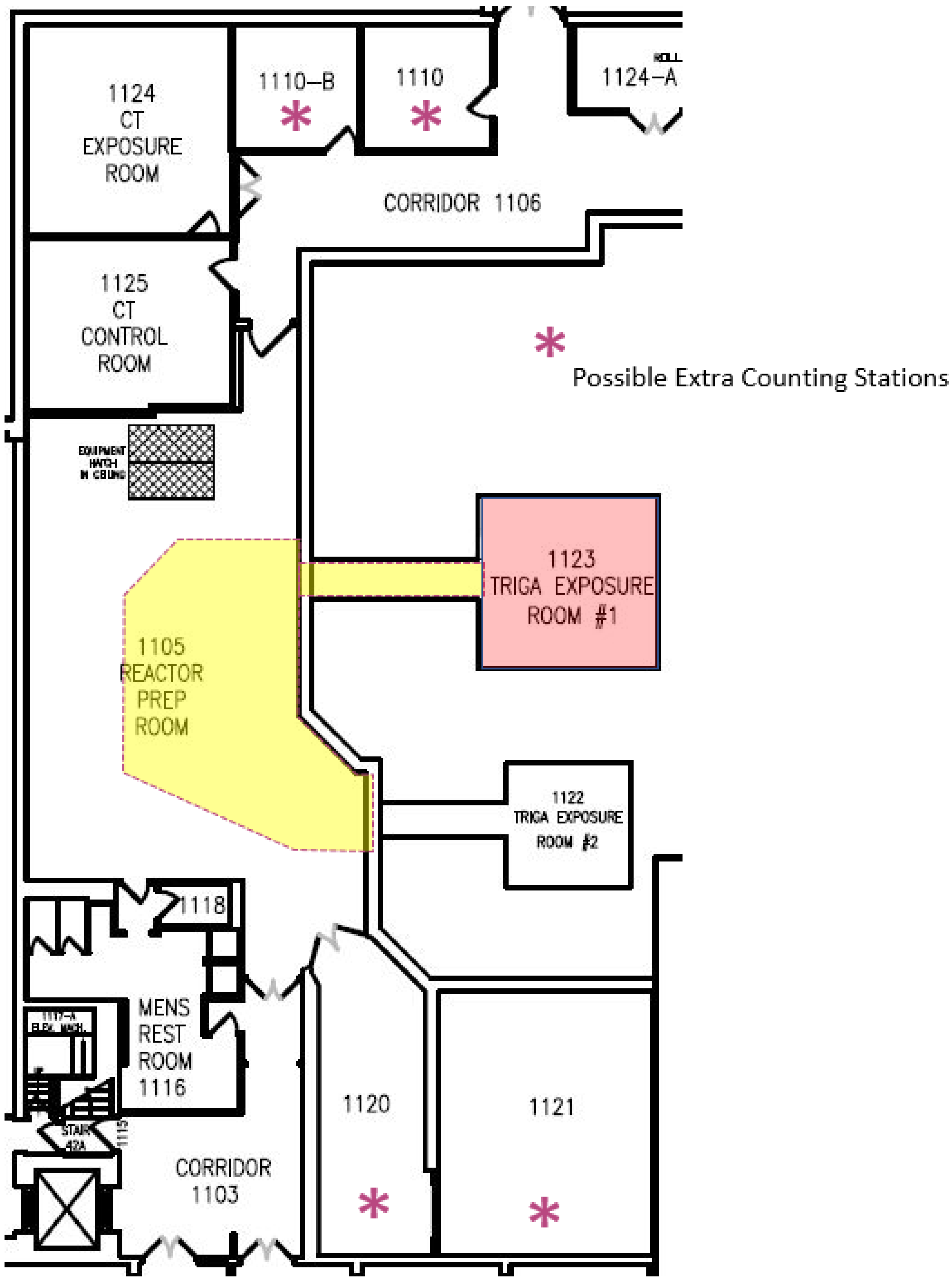

Figure 6: First floor of AFRRI reactor building. Astricks indicate possible work areas, if needed.

4.2 Dosimetry Descriptions by Laboratory

There are eleven laboratories that elected to participate in the IER-602 NAD exercise at AFRRI. For each participating laboratory, the subsections below provide:

- An official point-of-contact and list of participants
- A description of their equipment to be placed into the exposure for irradiation

An additional subsection describes general equipment that will be provided by LLNL or AFRRI for use during the exercise.

4.2.1 Atomic Weapons Establishment (AWE)

Philip Angus is the point of contact for AWE. His contact information along with the other AWE participants is specified below:

- Philip Angus: Philip.Angus@awe.co.uk
- Nick Vessey: Nicholas.Vessey@awe.co.uk
- Yarl Yeadon: Karl.Yeadon@awe.co.uk
- Liam Buchanan: Liam.Buchanan@awe.co.uk

The primary AWE NAD is the Harwell MKIV Criticality locket. The dosimeter will be deployed free-in-air on aluminum plates and placed on BOMABs. The dosimeter consists of sulfur, indium, gold, cadmium and plastic. PIN diodes will be collocated with the lockets. AWE will deploy site passes containing indium disks used for triage. AWE will also participate in biological dosimetry methods using blood and hair activation.

AWE will utilize the following additional equipment:

- 2x Transpec portable gamma spectrometers
- 1x iSolo beta counter
- BP4/19 hand held beta/gamma probes
- 2x laptops
- PIN diode Reader

4.2.2 Hanford Site

Sean Murphy is the program lead for the Hanford external dosimetry program, which includes nuclear accident dosimetry. His contact information as well as the other Hanford participants is below:

- Sean Murphy: sean_j_murphy@rl.gov, 509-396-1253
- Don Steward: donald_stewart@rl.gov, 509-521-0413
- Rob Ludwigsen: robert_l_ludwigsen@rl.gov, 509-713-0933

Hanford will deploy their standard PNAD and FNADs for both on-phantom and free in air measurements. The Hanford NAD is a four-foil dosimeter purchased from Shieldwerx, which is comprised of a bare and cadmium cover indium foil, a cadmium covered copper foil, and a sulfur pellet as shown in Figure 7. Hanford will also deploy the Hanford Combination Neutron Dosimeter (HCND) as a part of the FNAD assembly (Figure 8).

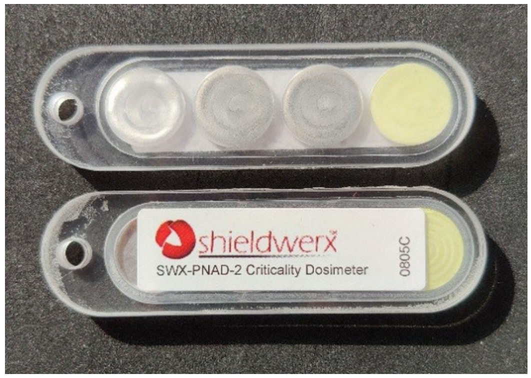

Figure 7: Shieldwerx NAD

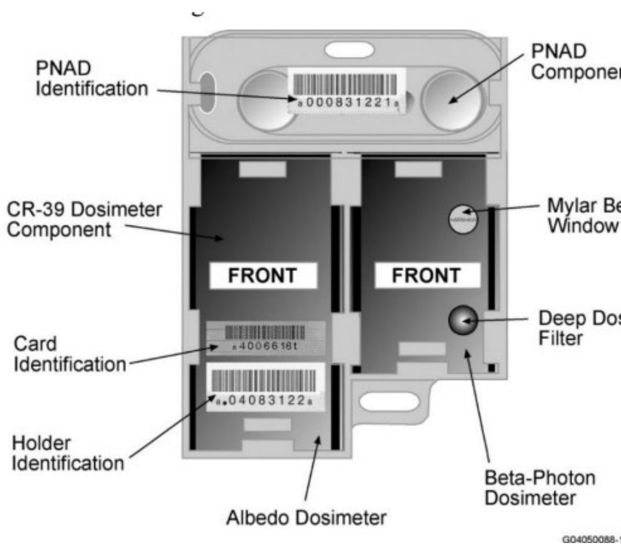

Figure 8: HCND

Haford will utilize the following additional equipment:

- 2x ORTEC HPGe detectors
- 4 Osprey NaI detectors
- 2 benchtop beta counters (Ludlum 2200 or similar)
- Handheld GM pancake probe (Ludlum M26 or similar)
- Laptops
- Hot plate

4.2.3 Institut de Radioprotection et de Sûreté Nucléaire (IRSN)

Francois Trompier is the point of contact for Institut de Radioprotection et de Surete Nucleaire (IRSN). His contact information along with the other IRSN participants is specified below:

- Francois Trompier: francois.trompier@irsn.fr
- Yoann Ristic: yoann.ristic@irsn.fr
- Aurélie Bardelay: aurelie.bardelay@irsn.fr

IRSN will deploy the following PNADs:

- SNAC 2 (Neutron spectrometer with activation foils) (Figure 9, left)

- SNAC50
- IRSN CAD (Figure 9, center)
- Silicon Diode (Figure 9, right)
- Thermoluminescent dosimeter (TLD)

Figure 9: SNAC 2 (left), IRSN CAD (middle), Silicon Diode (right)

IRSN will utilize the following additional equipment:

- A Silicon Diode reader
- A NaI spectrometer
- Laptop computers
- Electrical adaptors and transformers
- A beta counter

4.2.4 Naval Dosimetry Center

Alex Romanyukha is the point of contact for Naval Dosimetry Center (NDC). His contact information along with the other NDC participants is specified below:

- Alex Romanyukha[2]: alexander.romanyukha@usuhs.edu

Naval Dosimetry Center will deploy the NCL-03 neutron criticality dosimeter (Figure 10). This dosimeter is based on the neutron activation of foils consisting of gold, cadmium, indium, and sulfur. NDC will also utilize electron paramagnetic resonance (EPR) analysis of alanine.

[2] Starting March 25, 2024, Alex will be working for AFRRI, not the NDC. He may still maintain connections with NDC.

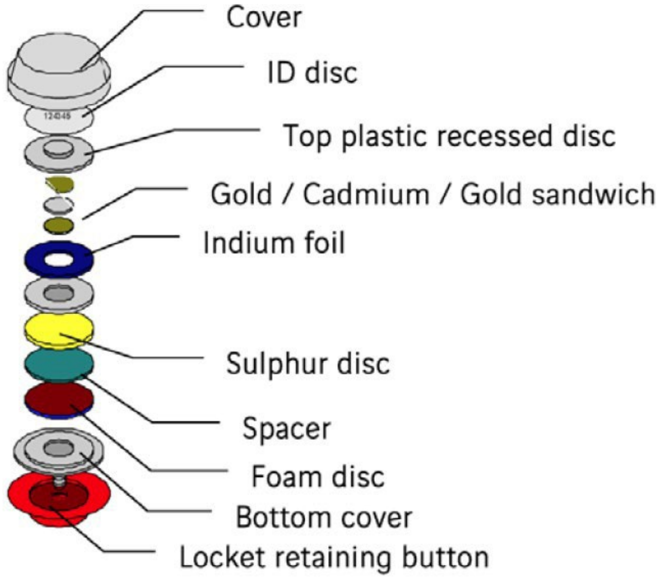

Figure 10: Expanded diagram of NCL-03 neutron criticality dosimeter

NDC will utilize the following additional equipment:
- 1 Falcon 5000
- 1 iSolo
- 2 laptops

4.2.5 Norfolk Naval Shipyard

Brian Lawson is the point of contact for Norfolk Naval Shipyard. His contact information along with the other NNSY participants is specified below:
- Brian J. Lawson: brian.lawson@navy.mil
- Christopher Ward: christopher.r.ward1@navy.mil
- Caleb Nixon: caleb.nixon@navy.mil

NNSY will submit the DT-702/PD dosimeter for irradiation free in air and on front and back of BOMAB phantoms. The DT-702/PD dosimeter case contains metal radiation filters that will be analyzed by radioactivity measurements for activation by neutrons. The dosimeter elements in the DT-702/PD dosimeter are LiF:MCP. The dosimeters must be processed using a Thermo Model 8800 TLD reader. These readers are available at Navy sites and can process dosimetry within 24 hours of an accident. Immediate processing may be possible due to proximity of AFRRI to the Naval Dosimetry Center.

NNSY will utilize the following additional equipment:

- Canberra Falcon 5000 with an electrically cooled Ge(Li) detector
- Specialized tools to open DT-702/PD dosimeter cases to remove the dosimeter card containing the four LiF:MCP dosimeter elements
- Hand tools to remove metal radiation filters from dosimeter cases for radioanalysis

4.2.6 Lawrence Livermore National Laboratory

Paul Maggi is the IER-602 point of contact and program lead for LLNL's NAD program. Catherine Percher is the Nuclear Criticality Safety Program (NCSP) Task Manager for LLNL. Scarlet Mitchell is the program manager for the exercise. Their contact information, together with that of the other LLNL participants is specified below:

- Paul Maggi: maggi4@llnl.gov, 925-424-4685
- Scarlet Mitchell: mitchell89@llnl.gov, 925-423-6770
- Catherine Percher: percher1@llnl.gov, 925-423-9345
- Dave Heinrichs: heinrichs1@llnl.gov, 925-424-5679
- Mike Firpo: firpo2@llnl.gov, tel. 925-424-6496
- Brian Champine: champine1@llnl.gov, 1-925-423-5123
- Paige Witter: witter1@llnl.gov, 1-925-424-2976
- Raj Maharjan: maharjan2@llnl.gov, 1-925-424-3730

LLNL will deploy the LLNL PNADs on the BOMABs and the stands. LLNL will also utilize the testing of hair sulfur activation and blood sodium activation to estimate dose. The LLNL PNAD (Figure 11) consist of a Panasonic UD-810 TLD, gold, indium and copper foils, a sulfur pellet, cadmium and borated plastic shields, and plastic caps inside a plastic case.

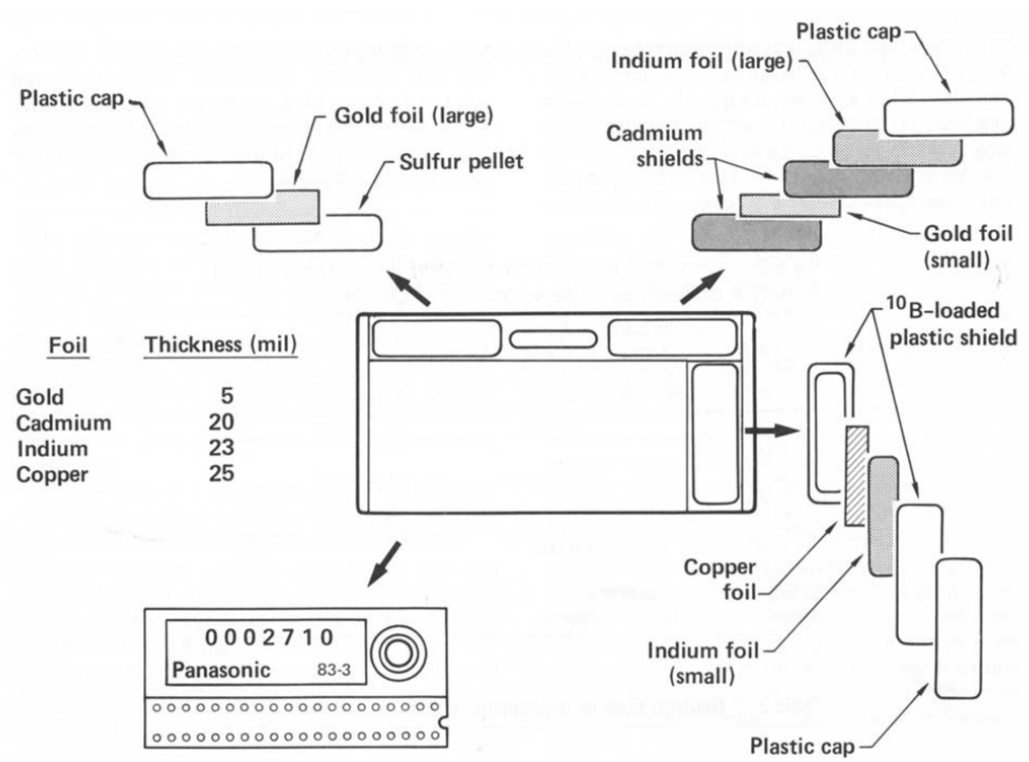

Figure 11: LLNL Personal Nuclear Accident Dosimeter

LLNL will also utilize the following additional equipment:

- Canberra Industries Falcon 5000 Portable HPGe Gamma Spectroscopy System
- Canberra Industries iSolo Alpha/Beta Counting System
- Laptop computers
- Canberra AEGIS Portable HPGe Gamma Spectroscopy System

4.2.7 Los Alamos National Laboratory

Milan Gadd is the LANL program lead for LANL's criticality accident dosimetry program. His contact information together with that of the other LANL participants is specified below:

- Milan Gadd: milang@lanl.gov, 505-667-2713
- Betsy Hillmer: emeek@lanl.gov, 505-665-1302
- Francisco Garcia: garciaf@lanl.gov, 505-665-8888
- Josh Chandler: jchand20@lanl.gov, 505-665-9731
- Scott Engeman: scottengeman@lanl.gov, 505-665-1313
- Laurel Sharisky: lsharisky@lanl.gov, 505-667-3050

Los Alamos will deploy PNADs and FNADs on movable stands for free-in-air measurements. The LANL Personal Nuclear Accident Dosimeter (PNAD) consists of bare and cadmium-covered indium foils, a cadmium-covered copper foil, and a sulfur tablet as shown in Figure 12. LANL 8823 whole-body dosimeters (Figure 13) will be deployed with the PNADs to determine photon dose. The 8823 dosimeter contains two 4-element Harshaw thermoluminescent dosimeter cards. One card contains three TLD-700 elements and one TLD-400 element. The second card is contained in a cadmium "box" in an albedo/anti-albedo configuration and uses a combination of TLD-600 and TLD-700 elements. The Los Alamos Criticality Dosimeter (LACD), which is deployed in fixed locations where there is a potential for criticality accidents. Figure 12 shows the dosimeter package used for intercomparison exercises. This package differs in appearance but not function from the LACD deployed at LANL facilities. Elements of the exercise LACD are bare and cadmium-covered indium and gold foils, a cadmium-covered copper foil, and a sulfur tablet.

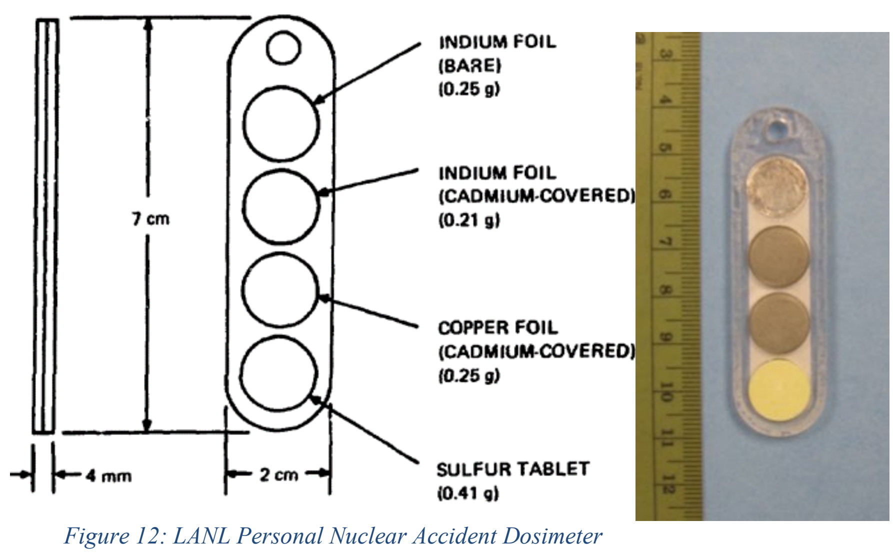

Figure 12: LANL Personal Nuclear Accident Dosimeter

Figure 13: LANL 8823 Whole-Body Dosimeter

Figure 14: Los Alamos Criticality Intercomparison Dosimeter

LANL will also utilize the following additional equipment:

- Model 2M2/2 Saint-Gobain Crystals 2x2 NaI(Tl), Kromek GRA1+ CZT detector, and Bicron 2XM.75BC408/2A plastic scintillator. Data acquisition will be performed using Canberra Inspector-2000, Ortec DigiBase, Kromek K-Spec, Canberra Genie-2000, or Ortec GammaVision MCA emulation software, as appropriate, installed on a laptop computer. The photon detectors are shielded by steel or 1" thick lead collimators lined with copper.
- A Ludlum Instruments Model 44-1 plastic scintillator detector connected to an Eberline E-600 Digital Survey Meter (battery power)
- A Canberra iSolo or similar alpha/beta counting system
- A SHP-380AB (dual scintillator) detector connected to a Thermo/Eberline E-600 or RadEye digital survey meter (battery power)
- A SHP-270 Geiger-Mueller detector connected to an Eberline E-600 or RadEye digital survey meter (battery power)
- Laptop computers

4.2.8 Sandia National Laboratories

Dann Ward is the point-of-contact for Sandia National Laboratories (SNL). His contact information is specified below:

- Dann Ward (POC): dcward@sandia.gov, 505-844-8325
- Nathan Elliot: nrellio@sandia.gov, 505-506-0032
- Luis Valdivia: lvaldiv@sandia.gov, 505-208-1862
- John Killbane, email:

SNL will deploy the SNL Criticality Dosimeter (Figure 15) and CaF_2:Mn TLDs (Figure 16). The CaF_2 TLDs will be returned to SNL for analysis. SNL will also deploy Arrow-Tec Direct Reading Pocket Dosimeters (Figure 17) Models W740 (0 – 100 R) and 742 (0 – 200 R). The SNL Criticality

Dosimeter[3] is a sealed plastic housing containing a NaF pellet, Al, Ni, Ti and In bare foils, and a Cd covered Cu foil.

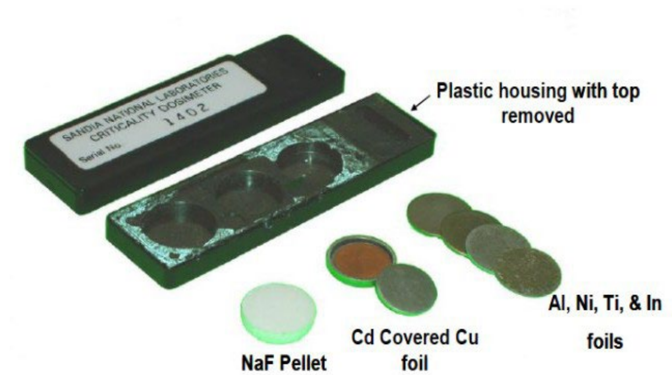

Figure 15: SNL Criticality Dosimeter

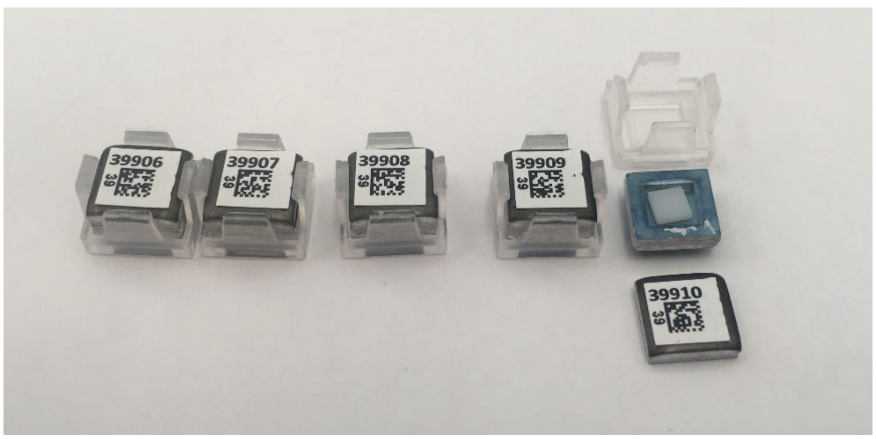

Figure 16: CaF2 TLDs showing aluminum buildup material around the chip.

Figure 17: Examples of Arrow-Tec Direct Reading Pencil Chambers

[3] *Personal Nuclear Accident Dosimetry at Sandia National Laboratories*, SAND96-2204.

SNL will also utilize the following additional equipment:

- Canberra Industries Falcon 5000[4] Portable HPGe Gamma Spectroscopy System
- An Eberline E600[5] with a Model SHP270 Geiger-Müller probe

4.2.9 Savannah River Site

David Roberts is the SRS program lead for the SRS criticality accident dosimetry program. His contact information together with that of the other SRS participants is specified below:

- David Roberts: david-w.roberts@srs.gov, 803-507-6907
- Stephanie Blazer: stephanie.blazer@srs.gov, 803-646-7817
- Jessica Hattaway: jessica.hattaway@srs.gov, 803-952-7907
- Joy Epps: joy.epps@srs.gov, 803-679-7958

SRS will deploy Criticality Neutron Dosimeters (CND), InLight Model 2T dosimeters, nanoDot dosimeters. Dosimeters will be placed BOMAB phantoms as wells as movable stands for free-in-air measurements. Saline samples will be obtained from BOMAB phantoms and used to perform ^{24}Na analysis.

The SRS uses a three-phase criticality dosimetry system established to respond to a criticality accident. In the first phase, all potentially exposed personnel are screened by probing the worker's abdomen since sodium in the blood would be activated by neutron exposures. The second phase involves determining the preliminary neutron dose by analytically quantifying ^{24}Na activation in blood. The third and final phase consists of a more accurate dose determination using a criticality neutron dosimeter capable of measuring dose over a wide range of energies.

Specifications for the CND's components are described in Table 2. A diagram of the current CND is shown in Figure 18. The CND's components are assembled in a 3-5/8 inch long by 1/2 inch diameter mylar tube. A clip is attached so it can be placed on the wearer's pocket. Indium, copper, and cadmium foils were shaped into hollow cylinders to lessen directional effects. These foils, along with specific amounts of sodium fluoride, sulfur and TLD-700 chips, are contained in four small polystyrene vials.

[4] http://www.canberra.com/products/hp_radioprotection/pdf/Falcon-SS-C38597.pdf
[5] http://www.equipcoservices.com/pdf/manuals/eberline_e-600.pdf

Table 1: CND Components

Vial No.	Material Contained	~Size (in.) or Weight (g)
1	Cadmium shield*	1 piece of 1 x 5/8 x 1/32 in. 2 pieces of 3/8 dia. x 1/32 in.
	Indium foil* (Cd-covered)	15/16 x 5/8 x 0.005 in.
	Copper foil* (Cd-covered)	15/16 x 5/8 x 0.005 in.
2	Sodium fluoride powder	1.50 gram ± .20 gm**
3	Indium foil (bare foil around outside of vial)	1 7/16 x 5/8 x 0.005 in.
	Sulfur powder	1.00 gram ± .20 gm**
4	Paper (not shown)	~1.2 x 5/8 in.
	Harshaw TLD-700 chips	2 chips

Plastic tube (UV resistant polycarbonate):	3.8 ± .2 " long 0.5" ± 0.05" inside diameter 0.062" ± .005 wall thickness Acutech Inc. or Equivalent
Vials (with caps):***	5/8" to 1"-long 3/8" minimum inside diameter 1/2" maximum outside diameter
Tube Caps (2):	.625" inside diameter x .5" inside length, Black StockCap Inc. P/N 064062 or Equivalent
Tube Clip:	Dosimeter Type Clip J. F. Maguire P/N 6203 w/black strap or Equivalent

* The weight of each foil will be permanently inscribed on each foil to the nearest hundredth of a gram.

** The actual weight will be recorded to the nearest 100th of a gram on a numbered piece of paper inside the CND.

*** Each vial will be labeled with the dosimeter number.

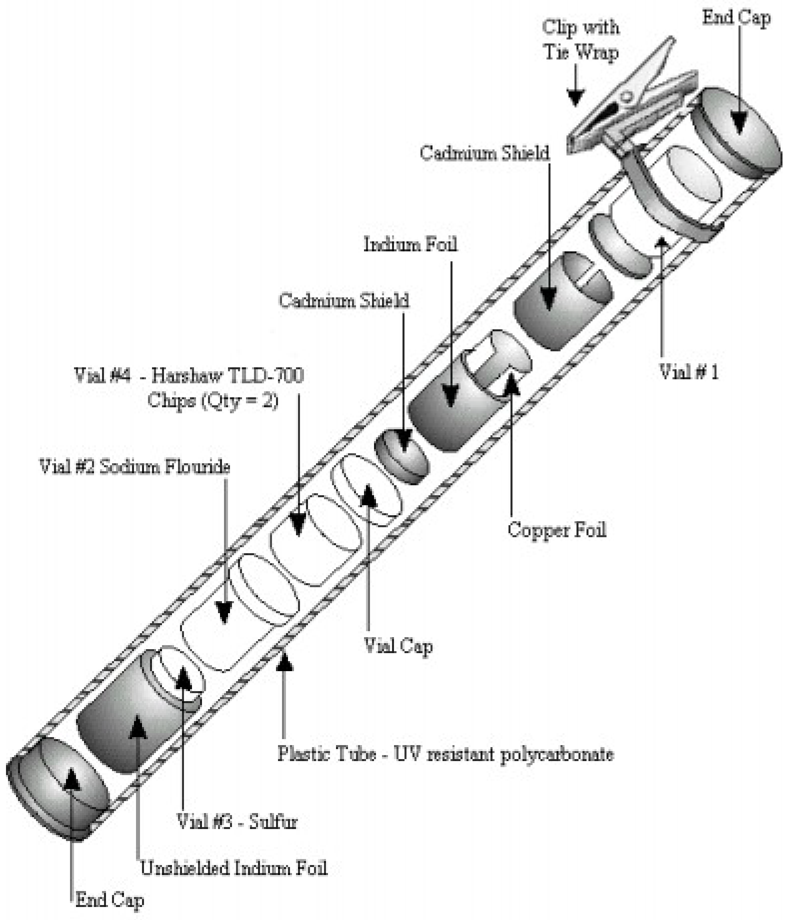

Figure 18: SRS CND

SRS will also utilize the following additional equipment:

- Falcon 5000 portable electronically cooled HPGe detector
- Mirion HPHe detector
- Harshaw TLD Reader
- Canberra Colibri Easy-Count Alpha-Beta counting system

4.2.10 Y-12 National Security Complex

Ken Veinot is the criticality accident dosimetry team lead for Y-12. Their contact information together with that of the other Y-12 participants is specified below:

- Ken Veinot: 865-241-6165, Ken.Veinot@pxy12.doe.gov
- Alexander Detweiler: Alexandra.detweiler@pxy12.doe.gov
- Regan Frye, regan.frye@pxy12.doe.gov, 865-241-8763

The Y-12 National Security Complex criticality accident dosimetry program is comprised of multiple stages. The first is triage-type screening, which includes monitoring for activation of sodium in the body. This screening consists of whole-body surveys using portable field type instrumentation (e.g., G-M instruments) and portable gamma spectrometers (FLIR Identifinder) with customized nuclide libraries to include ^{24}Na peak data.

All personnel entering areas of the facility that have the potential for criticality accidents are required to wear a whole body dosimeter, namely the Harshaw Model 8805 four-element thermoluminescent dosimeter (TLD), as shown in Figure 19. These TLDs include three gamma and one neutron and gamma sensitive elements. Personnel who routinely work in areas having significant neutron fields are also equipped with a Harshaw Model 8806 neutron TLD that includes two gamma sensitive elements and two neutron and gamma sensitive elements, as shown in Figure 20.

Figure 19: Harshaw 8805 Beta-Photon Dosimeter Used at Y-12

Figure 20: Harshaw 8806 Neutron Dosimeter Used at Y-12

In the event of criticality accident alarm system (CAAS) outage personnel are required to wear electronic dosimeters to provide contingency monitoring. The approved dosimeter is the Mirion DMC-3000 shown in Figure 21.

Figure 21: Mirion Technologies DMC-3000 Dosimeter Used at Y-12

Triage-type monitoring is central to the Y-12 criticality accident dosimetry program response plan. These measurements are performed using the Ludlum Model 3 with Model 44-9 pancake-type G- M probe and/or the Ludlum Model 2224 with Model 43-93 dual alpha-beta scintillator. This initial survey of personnel provides adequate measurement of sodium activation following neutron exposures. If this initial survey indicates activity, a screening using the FLIR Identifinder is performed to determine if the source of the activity is contamination or ^{24}Na . Personnel identified to have been significantly exposed to neutron fluence are sent to the REAC/TS facility in Oak Ridge. To test this triage system, Y-12 will perform surveys on BOMAB phantoms containing traceable quantities of sodium that were exposed to known-doses of neutron exposure in the training event. Surveys performed at various times post-accident allows for detection capabilities to be determined since the ^{24}Na has a known half-life. Initial personnel dose estimates will be determined using the Model 44-9 G-M and Model 43-93 detector measurements using established conversion factors and assumptions on neutron:photon dose ratios.

TLD measurements will be performed on phantoms. These TLDs will be processed upon return to the

Y-12 site. However, testing from previous inter-comparison studies[6,7] indicates that information on order-of-magnitude exposure can be obtained by surveying the TLD holders using field instruments. Therefore, Y-12 personnel will perform surveys for activated filtration components contained in the dosimeter holders using field survey equipment. This equipment may include the Model 3 with 44-9 detector and the Ludlum Model 2224 with Model 43-93 dual alpha- beta scintillation probe.

Y-12 employs the Mirion DMC-3000 electronic dosimeter for CAAS-contingency monitoring. As part of the inter-comparison LANL personnel will deploy these units at various distances from the critical assembly to validate their use. These irradiations may be performed on-phantom or free- in-air as conditions permit.

Y-12 will also utilize the following additional equipment:

- Ludlum Model 3 with Model 44-9 pancake-type G-M probe and/or the Ludlum Model 2224 with Model 43-93 dual alpha-beta scintillator
- FLIR Identifinder with customized nuclide libraries to include ^{24}Na peak data
- AEGIS HPGe detector

4.2.11 Belgian Nuclear Research Center (BNRC)

Filip Vanhavere is the point of contact for the BRNC's nuclear accident group. He and the other participant from BNRC's contact information is:

- Filip Vanhavere: filip.vanhavere@sckcen.be
- Jeroen Willems: Jeroen.willems@sckcen.be

The SCK CEN criticality dosemeter makes use of the same badge as the TNO TLD based photon/beta personal dosemeter used at the SCK CEN dosimetry laboratory. It has a diameter of 4 cm and a thickness of 0.9 cm and consists of a polycarbonate holder (blue and grey parts) with PEEK detector holders for the two top detector positions (black parts) and four 2 mm thick aluminium filters in front of and behind the two bottom detector positions that were used for optimizing the TLD response. The criticality dosimeter is shown in Figure 22.

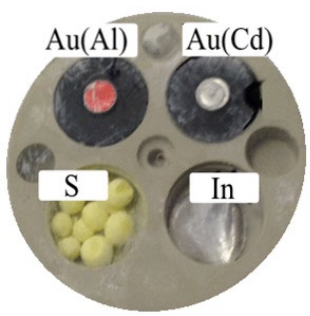

Figure 22: SCK CEN Criticality Dosimeter

The criticality dosemeters contain four activation detectors. There are two gold foils with 2 mm diameter and 0.05 mm thickness. One of the gold foils is inside a small aluminum box, while the other

[6] RCO/TBD-097 "Results from 2010 Caliban Criticality Dosimetry Intercomparison", K.G. Veinot and M.L. Souleyrette; 2011.

[7] RCO/TBD-092 "Results from 2002 and 2009 Silene Criticality Dosimetry Intercomparisons", K.G. Veinot and M.L. Souleyrette; 2010.

is inside a small cadmium box. Both boxes have a thickness of about 0.5 mm and are placed in the two black PEEK detector holders in the two positions at the top. The opening on the bottom left contains about 0.5 g of sulphur pellets, while the opening on the bottom right contains an indium foil with 10 mm diameter and 0.125 mm thickness.

For the photon component of the irradiations, SCK CEN will also bring Landauer InLight photon dosemeters (Figure 23) based on optically stimulated luminescence in Al_2O_3:C and Mirion Instadose+ dosemeters based on direct ion storage.

Figure 23:Landauer InLight and Mirion Instadose+ photon dosimeter

SCK CEN will additionally also bring the Thermo Scientific EPD-N2 (Figure 24) active personal photon and neutron dosemeter to investigate how it reacts to the high intensity field.

Figure 24: Thermo Scientific EPD-N2

The SCK CEN criticality dosemeters will be irradiated on the front and back of the BOMAP phantoms and on the plates.

4.3 General Equipment

The following equipment will be provided by LLNL for use by all participants during irradiation measurements:

- 8 BOMAB phantoms with saline solution and support stands (Figure 1)
- 8 Avenger A5033 Roller 33 stands with 1 - 3 aluminum mounting plates (Figure 2)

The following equipment will be provided by AFRRI for use by all participants:

- Work space for participant quick sort readout activities using participants quick sort equipment/methods
- Lab benches with encapsulated lead bricks or mobile shield walls for shielding
- Lab chairs

- A balance (0.1 mg – 200 g)
- Access to two radiological fume hoods
- Planchets, glassine envelopes, pens, tape, plastic bags, lab coats, gloves
- 60Hz/120V electrical connections (NEMA 5-15R style)
- Digital Camera
- Conference/meeting area with computer based overhead projection and marker boards
- Multiple radioactive check sources

5 Planning for FY2024

5.1 Experiment Initiation (CED-3a)

No later than May 20th, 2024, all participants will ship their equipment to AFRRI. Foreign nationals will need to ship sooner to ensure timely arrival. The shipping address is

Armed Forces Radiobiology Research Institute
4301 Jones Bridge Road
Bethesda, MD 20814
ATTN: Andrew Cook / Your Name
301-295-3922

Participants will be allowed to send one or two individuals the week prior to the exercise to setup equipment.

AFRRI will assist the participants with the shipping, receiving and return of their equipment. Each laboratory is responsible for unpacking, setup, operation and repackaging of their equipment.

5.2 Evaluation and Publication of Data (CED-4a)

AFRRI will return all equipment including irradiated dosimetry elements to all participants as soon as possible to enable timely completion of counting measurements that can only be performed at the "home" laboratory (e.g., evaluation of TLDs).

Coordinators will provide dosimetry placement details to participants upon return. Participants

will have three weeks from conclusion of the exercise to report revised results.

After receipt of revised results participants will receive dosimetry placement details and expected doses.

Coordinators will evaluate participant results and release report of the results.