Summary of Neutron Assessments in the Nuclear Power Industry

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Radiation Safety & Control Services, Inc.

RSCS Overview

- Company Founded in 1989 by 3 CHPs
- Headquartered in Stratham, New Hampshire with branch offices in Atlanta, San Diego, and UK
- Diverse Professional Staff of 59 FTE’s includes 25 CHP / Sr. HPs & 7 HP Specialists
- Mature Programs & Procedures including Quality Assurance processes for nuclear work
- Acquired Millennium Services in 2014
- www.radsafety.com

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RSCS Overview

- Calibration Division
  - Gamma and neutron calibrations
  - Repair of almost all types of instrumentation
  - Calibration and repair of contaminated instrumentation
- Engineering & Sales Division
  - Radiation simulation systems
  - Custom instrumentation design and fabrication
  - Sales and installation of Instrumentation
- Environmental & Geotechnical Division
  - Buried pipe corrosion studies and tritium monitoring
  - Post Fukushima modification support
  - Advanced CAD and GIS implementation and support
- Health Physics Division
  - Provide a wide variety of support in all areas of health physics from assessments to specialty measurements
  - Release Programs for equipment and license termination
  - Simulation modeling for complex systems
  - Decommissioning and license termination
- Staffing Division
  - Outage staffing for all positions
  - Support personnel from junior technicians to project managers

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Summary of Studies

- Since 2010 completed 29 campaigns
- 18 PWR containments
- 4 BWR drywells
- 11 Spent Fuel Transfers
- 15 ISFSI Pads
- 1 Power Ascension

Reasons to Perform

- Reactor head modifications
- Reactor shielding modifications
- Dosimetry changes (TLD, OSL, CR-39, Panasonic)
- Instrumentation changes
- Change of calibration facility
- Changes in work that contribute to neutron dose

Methodology

- The goal of a study is to calculate a neutron correction factor to correct the response of neutron measuring devices to a reference measurement to reflect the neutron energy spectrum of the location.
- This is nothing more than a ratio of the responses.
- These factors can be for:
  - Personnel Dosimetry
  - Electronic Dosimetry
  - Neutron Survey Instrumentation

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Methodology - Phantoms

- ANSI/HPS N13.11-2009 requires material to be made from Polymethyl Methacrylate (PMMA or Acrylic) and be no less than 30x30cm square and no less than 15cm thick for photon/neutron.
- Neutron dosimeters be no less than 10cm from the edges.
- Water filled phantoms are theoretically the best choice but are not practical in the field. The difference is small and the benefits outweighs it. Imagine carrying a ~3 gallon fish tank in containment…

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Methodology - Phantoms

- Custom 30x30x15cm PMMA phantom.
- Mountings for tripods or stainless stands that can be adjusted for height.
- Tether points to satisfy engineering controls.
- Sliding faceplates are great for safety and dose savings.

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Methodology - Dosimeters

- Dosimeters should be mounted parallel to the face of the phantom within an area 10cm from the outer edge.
- Lanyard clips should be removed to allow them to lay flat and maximize space.
- 3-6 dosimeters can be fit on one phantom face depending on the number of EDs used.
- Fixed into a configuration and placed inside of a Ziploc bag or whirl pack to keep them together and prevent contamination.
- The bag is secured to the phantom using tape.
- EDs should be placed in a manual mode with no alarms

Methodology - Instrumentation

- For reference measurements we used the Farwest FWAD TEPC (Tissue Equivalent Proportional Counter)
- Data logs the LET spectrum on a minute by minute basis using 2 MCAs and that data is converted into neutron dose rates.
- Can apply multiple sets of quality factors to the same set of data to make everything future compatible.
- Rem500 has also been used since it works on similar principles but provides less versatility in the data.
- Multi-detector or moderator spectrometers can be used but can be heavy and dose intensive due to multiple measurements needed.

Methodology - Locations

- Choose locations to represent the work being done that contributes to personnel receive neutron dose.

What to look for:

- Sufficient Neutron Dose Rates to meet minimum dose within the job duration.
- Space for equipment.
- Safe travel path.
- Ability to tether.
- Uniform field.

What to Avoid:

- Streaming.
- Neutron Field gradients.
- High gamma dose rates with low neutron dose rates.
- High transient neutron fields on travel path.
- High Risk areas for safety and Rx trip.

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Methodology - Locations

- **Containment**
  - Several locations representative of neutron dose to worker.
  - Refueling floor, outside bioshield entrances, sample collection areas.
- **Drywells**
  - Setup outside airlocks and piping penetrations.
- **Spent Fuel Transfer**
  - Setups on upper and/or lower levels, depends heavily on platform setups and ongoing work.
  - Done during the drying phase since it is the only time there is sufficient neutron dose rates.
  - Difficulty is to not impact the schedule.
  - Welding can interfere with the TEPC due to EMF.
- **ISFSI Pad**
  - Setup at vent locations.
  - Irradiation times range from days to over a month.

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Methodology - Data

- Once all the data is collected the dosimeters are sent off to be processed using both the current in use factor and with no factor applied.
- This lets us benchmark the dosimeters and if there is a change needed then we can recalculate a new factor.
- Convert all measurements into neutron dose rate so you can compare easily between all measuring devices.
- Apply the correct quality factor set to the TEPC data.

$$Correction\ Factor = \frac{reference\ measurement}{instrument\ measurement}$$

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BWR Result Summary

- Locations where neutron dose is present can vary from outside hatched to piping penetrations.
- Neutron dose rates where measurements took place were less than 10 mrem per hour and not high occupancy.

Site (Dual Units counted together)	Albedo	CR-39	Remball	Neutron ED
1	5.2	1.4	1.5	
2	1.6		3.4	3.2
3	0.7	0.3	0.5	
4	7.8			3.0

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PWR Result Summary

- Albedo Dosimetry always over responds in containment and varies greatly based on location.
- The larger the scatter the component the larger the over response.
- CR-39 by location inside containment varies greater than albedo dosimeters.
- Spectral measurements show average neutron energies from 19-92keV.

Site (Dual Units counted together)	Albedo	CR-39	Remball	Neutron ED
1	5.2	0.6	2.2	2.3
2	1.4		1.8	2.4
3	67.0		6.7	
4	4.5		2.3	1.0
5	10.0	0.5	3.0	
6	27.0		5.3	
7	4.2			3.9
8	9.1		3.0	1.6
9	6.3	0.6	2.5	1.4
10	7.7		4.5	2.4
11	2.2		5.6	3.5

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Spent Fuel Transfer Canisters Result Summary

- Upper level locations are difficult to collect measurements due to welding and ongoing drying. Oftentimes very limited space.
- Average neutron energy is higher than in containment due less scatter. Neutron Dose Rates range from 2 to 15 mRem per hour.

Site (Dual Units counted together)	Albedo	CR-39	Remball	Neutron ED
1	10.0	1.1	1.4	
2	7.3	1.9		2.0
3		1.7	3.1	
4	5.3	0.8	0.5	
5	15.0			1.4
6	11.6			1.0
7	5.3		2.7	1.7
8	6.3		1.7	0.5
9	3.0	1.8		1.3

Independent Spent Fuel Storage Installations Result Summary

- Dose rates can vary from 0.03 to 5 mRem per hour, most are less than 0.5 mRem per hour.
- Not a significant dose concern compared to other activities.
- Large thermal component causes the albedo dosimeters to greatly over respond.

Site (Dual Units counted together)	Albedo	CR-39	Remball	Neutron ED
1	15.9	0.7	1.5	2.1
2	10.2	2.8		
3	54.0			
4	47.0			
5	29.0			
6	164.0			
7	5.4		2.2	
8	3.2			
9	5.6	0.6	3.3	
10	23.0			1.7
11	92.0			2.4
12	23.6		5.8	8.2
13	5.6	1.5	3.6	
14	8.1	1.0		0.7
15	2.9		2.5	0.6

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How Much Dose?

- Containments are the most dose intensive and vary greatly. They require longer stay times since exiting between each measurement may not be an option.
- Difficult for ALARA since your goal is to find and measure neutron fields.
- Maximize dose savings by prepping as much as possible ahead of time and optimize trips between locations and low dose waiting areas.
- Received ~650mRem over the past 6 years from neutron studies.

Measurement	mRem Per Measurement Set Per Person	
	Min	Max
Containment	8	250
Drywells	1	15
Spent Fuel Teansfer	1	7
ISFSI	0	1

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Implementation

- Compare the dosimeter responses and correct if needed. ANI recommends a factor of 2. This can be difficult especially if conducting a variety of activities.
- Adjust site instrumentation to match through the use of cal factors or factors applied later when documenting surveys.
  - Dosimetry can be corrected through the NVLAP vendor.
  - EDs can be corrected during calibration, in software to manage RWP, or manually entered.
  - Instrumentation can be corrected during calibration or by the technician during job coverage or surveys.
- Make it practical and reasonable for implementation.

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Questions?

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