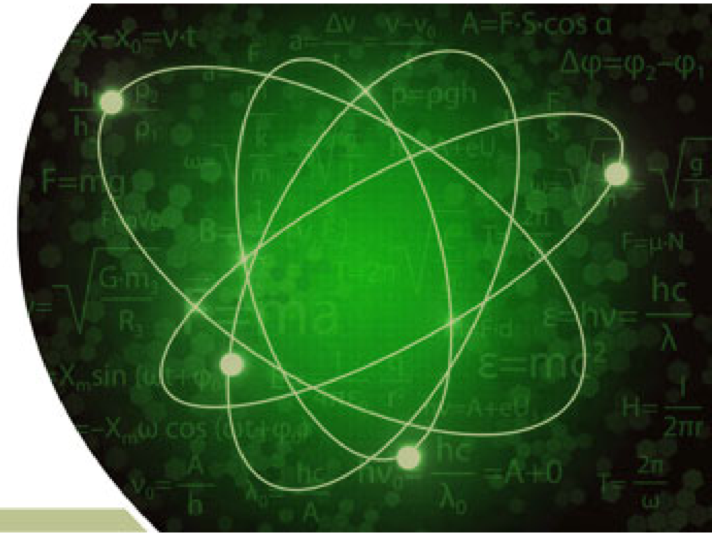
ANS Annual Meeting

2019 THE VALUE OF NUCLEAR



Minimum Accident of Concern for Uranyl Sulfate Solutions

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Background

- The SHINE medical isotope production facility is currently preparing an operating license application for submission to the NRC.
- The facility uses low-enriched uranyl sulfate solution as an irradiation target for medical isotope production.
- Solution preparation and extraction activities involve direct handling of unirradiated and remote handling of irradiated fissile material.
- Consequently, the use of a criticality accident alarm system for the facility is warranted.

Criticality Accident Alarm System

- Specific detection requirements are determined by the regulatory schema for the facility.
- In the case of SHINE, the specific requirements are identified in 10 C.F.R. 70.24:
- *"The monitoring system shall be capable of detecting a criticality that produces an absorbed dose in soft tissue of 20 rads of combined neutron and gamma radiation at an unshielded distance of 2 meters from the reacting material within one minute. Coverage of all areas shall be provided by two detectors."*

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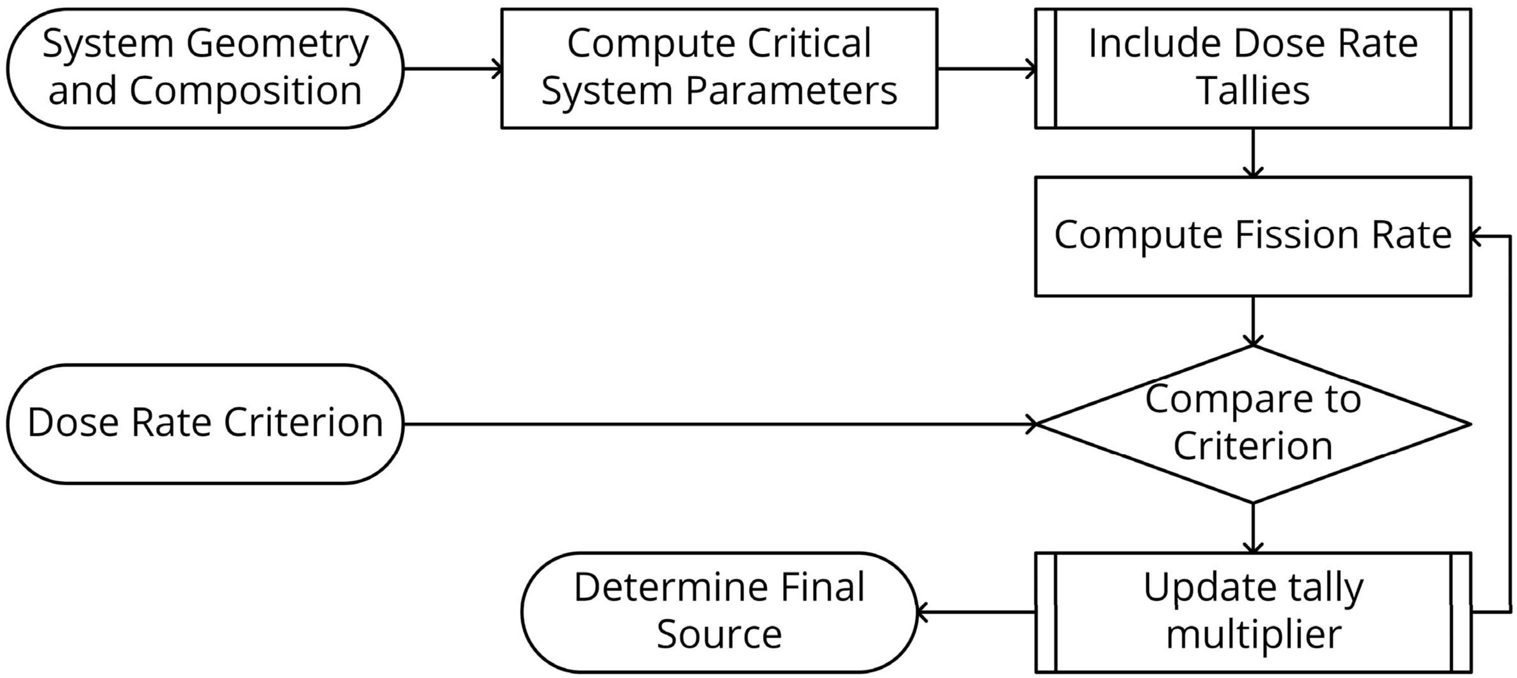
Minimum Accident of Concern

- The minimum accident of concern is a hypothetical representation of the smallest accident with regard to fission yield and dose rate that a CAAS is required to detect.
- Given that the dose rate in the case of the SHINE facility is prescribed by regulations, the work presented here was conducted by setting the dose rate and focusing on the minimum fission yield for the cases in question.

Methods



System Geometry and Composition
Compute Critical System Parameters
Include Dose Rate Tallies
Compute Fission Rate
Dose Rate Criterion
Compare to Criterion
Determine Final Source
Update tally multiplier

Important Assumptions

- Neutron capture gammas contribute to the prompt gamma source.
  - This assumption is conservative because the prompt gamma source is used to determine the delayed gamma source.
- The dose criterion will be met within 1 second
  - Because the dose criterion is very low relative to the expected yield of a critical system, this is a reasonable assumption.
  - A brief discussion of the kinetics of criticality is available in LA-13638, “A Review of Criticality Accidents”
  - No consideration is given in this calculation for the delay between actual criticality and the resultant power spike, which can be on the order of tens of seconds for solution systems.

Source Validation

- Two candidate sources were independently derived:

Calculated SHINE Systems	$[U^{25}]$ (g/liter)	Critical Spherical Radius (cm)	Calculated Fission Rate (fissions/sec)
SHINE Case 1	126	18.48	5.00E+14
SHINE Case 2	20	34.86	5.20E+15

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Source Validation

- It was desired to compare the computed results to experimental data to aid in determination of which source was more appropriate
- Data from the "*Consequences Radiologiques d'un Accident de Criticité*" (CRAC) were used as a basis of comparison for fission yield.
- A basis for comparison was established by use of buckling conversion for the cylindrical CRAC systems to equivalent spherical systems.

Source Validation

300-mm Experiments	[U^{235}] (g/l)	Solution Height (cm)	Equivalent Spherical Radius (cm)	Peak Power (fissions/sec)	Average Power (fissions/sec)
CRAC D 01-02	48.4	198	19.11	1.60E+15	3.33E+14
CRAC D 05-02	56.9	68	18.48	1.10E+15	2.34E+14
CRAC D 08-03	189	27.5	15.74	7.80E+14	1.52E+14
CRAC D 11-03	303	26.19	15.49	9.80E+14	1.52E+14
800-mm Experiments					
CRAC D 37-02	19.9	46.77	34.73	5.00E+15	1.22E+15
CRAC D 39-02	28.5	27.24	24.12	6.20E+15	1.00E+15
CRAC D 40-02	54.7	18.61	17.52	7.40E+15	1.04E+15

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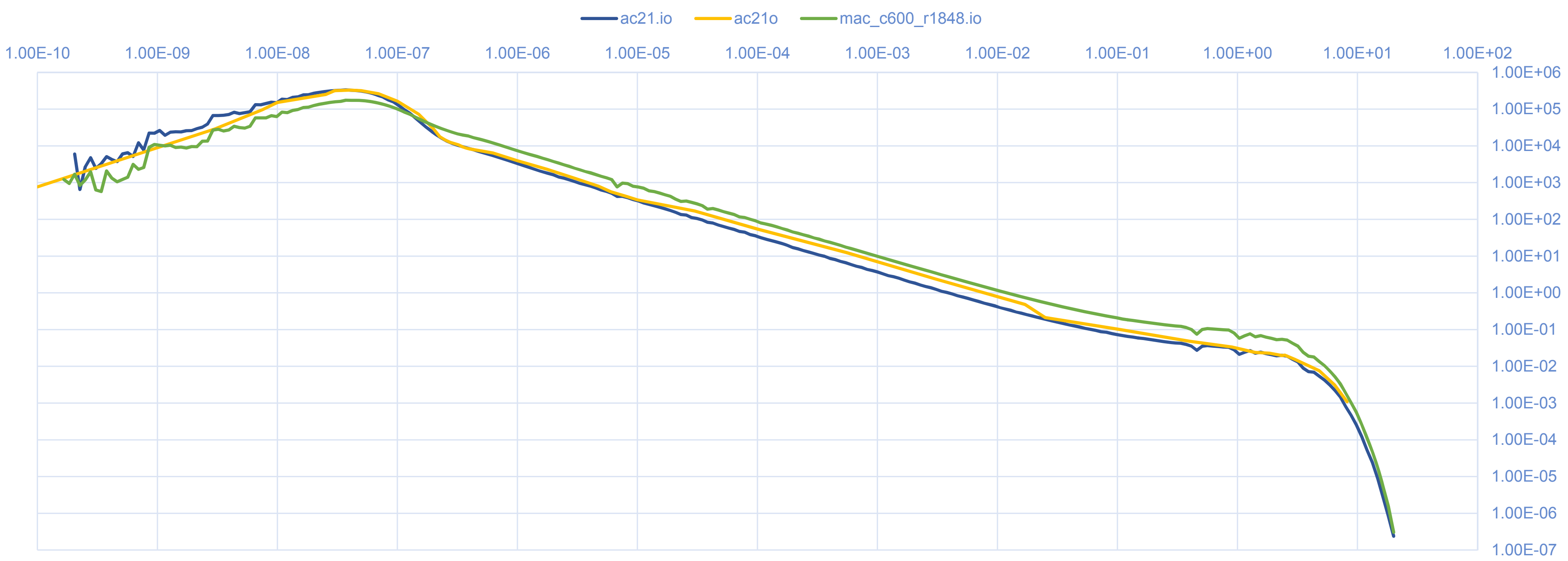
Source Validation

	[U235] (g/l)	Equivalent Spherical Radius (cm)	Peak Power (fissions/sec)	Average Power (fissions/sec)
CRAC D 05-02	56.9	18.48	1.10E+15	2.34E+14
SHINE Case 1	126	18.48	5.00E+14	-
CRAC D 37-02	19.9	34.73	5.00E+15	1.22E+15
SHINE Case 2	20	34.86	5.20E+15	-

Additional Results

- In addition to the fission yield, particle tallies were used to collate data regarding the neutron and gamma fluxes.
- These data are used in subsequent calculations for detector placement to preclude the need for criticality (kcode) calculations while placing detectors

Neutron Spectrum



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Gamma Spectrum

Future Work

- The next obvious step for SHINE is to finalize detector placement within the facility using the derived MAC data.
- With regard to future criticality work, refinement of critical data with respect to uranyl sulfate solutions is a high priority.
- Benchmark data from the Homogeneous Reactor Experiment (HRE) is a high-value target
- As the facility comes on-line, subcritical measurement data will become available for use by the criticality safety group.

Acknowledgments

- Dr. R.A. Borelli – University of Idaho
- Dr. Charles Henkel & Brian Matthews – Nuclear Safety & Technology Services

Additional Topics of Discussion

- Is the current MAC definition and regulatory requirement sufficient and implementable to support emerging and future fissile material operations? Are there alternative approaches available?
- Is the detection requirement in general compatible with new and future detection technologies?
- What experimental capabilities exist to validate and certify new detection technology?