Project 3 D&D

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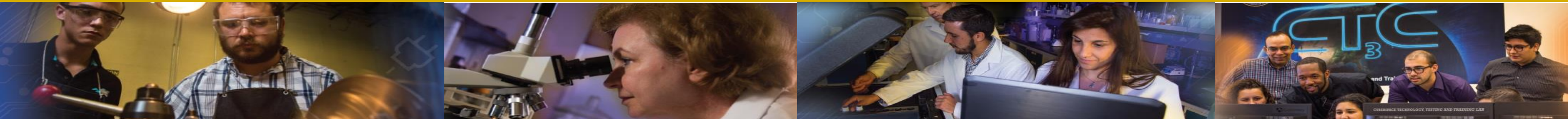

D&D Mission Sets and Research Areas

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- Adapting COTS-based Intumescent Technologies for D&D Applications (TRL-5 to TRL-7)
  - Incombustible Fixative Coating ISO SRS 235-F PUFF Facility
  - Incombustible Foam Fixatives as "Plugs" to Decommission Piping
  - Passive Thermal Insulators for Waste Packaging

- Empirically quantifying operational performance of fixative technologies
  - Open Air Demolition activities (e.g.: impact and environmental stressors)
  - Safety Basis contingency scenarios (e.g.: fire and extreme heat stressors)

- Leveraging ASTM International's E10.03 Subcommittee to develop standards and testing protocols for D&D technologies
  - Foundation for a "standards-based" technology test and evaluation program

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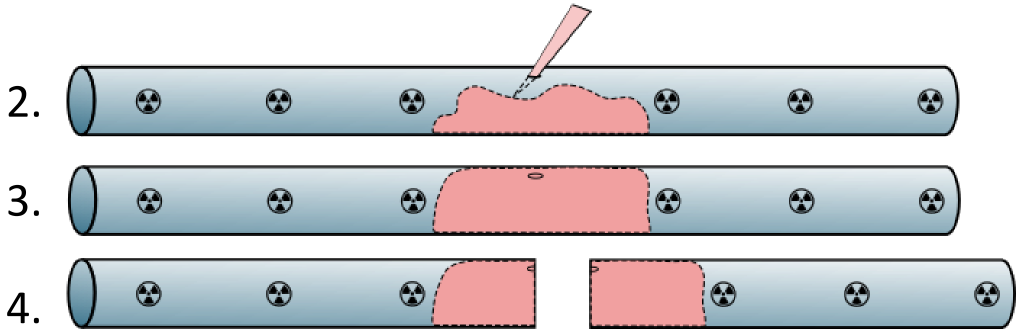
Application #1: Incombustible Fixatives SRS 235-F Onsite Hot Demonstration

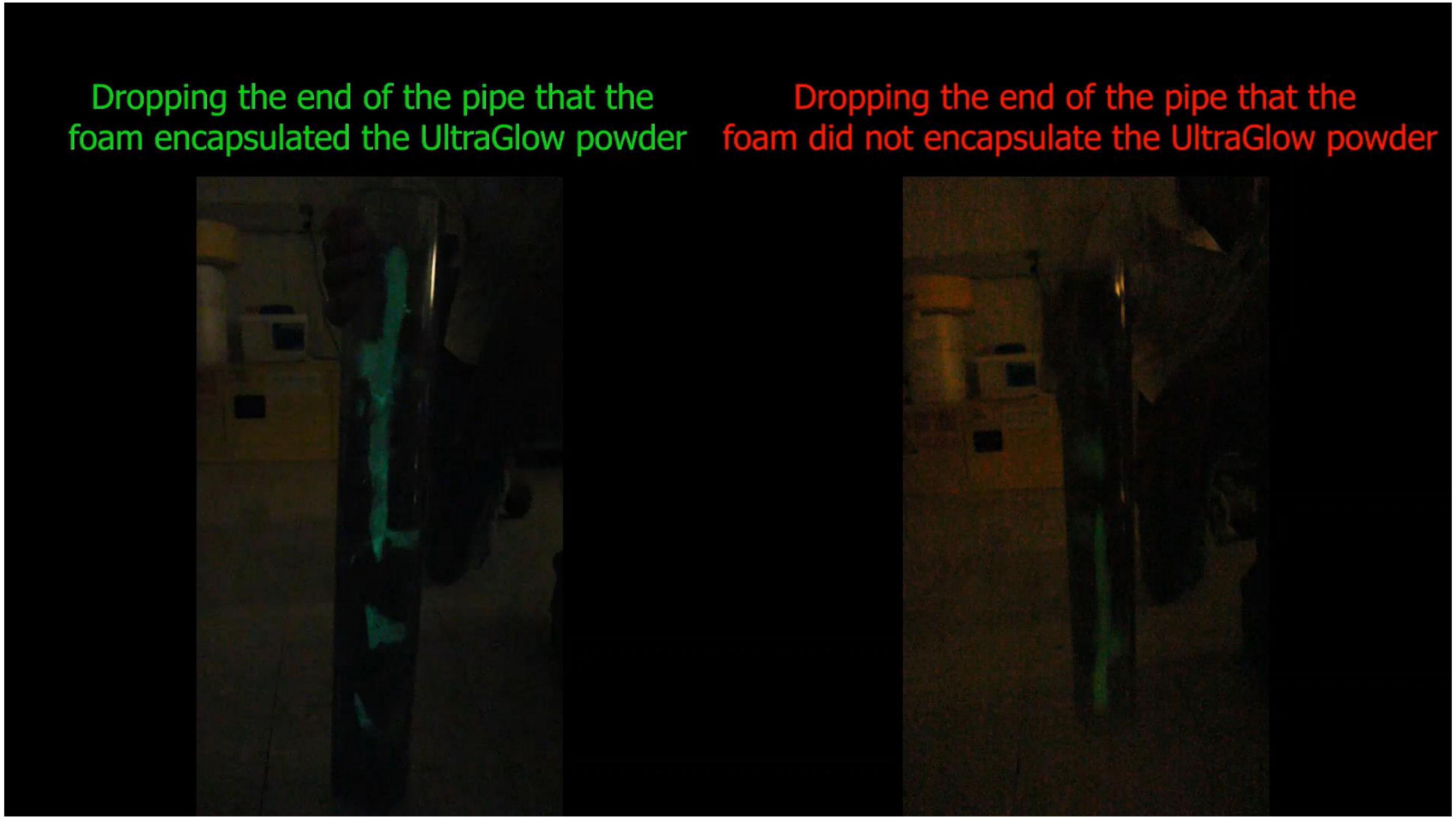
- Down-selected COTS-based intumescent technology successfully deployed in Process Cell #7 and the entry hood of Process Cell #1 at the SRS 235-F PUFF Facility
  - FIU / SRNL / SRS collaborative effort
  - TRL-5 to TRL-7 in 3 years
  - Highlighted in DNFSB 2018 Annual Report
  - Targeting joint (FIU / SRNL / SRS) closeout report in Year 10
  - Engage vendor to open new market for product

Application #2: Intumescent Foams as "Plugs" for Nuclear Pipework



- Concept of Operations:
  - Place fire resistant plugs at strategic cutting points along pipework
  - Serves as a barrier to segregate / trap / immobilize contamination to mitigate potential release while cutting, packaging and storing

Basic Proof of Concept Demonstration



Down-Selection Process Identified Frontrunner

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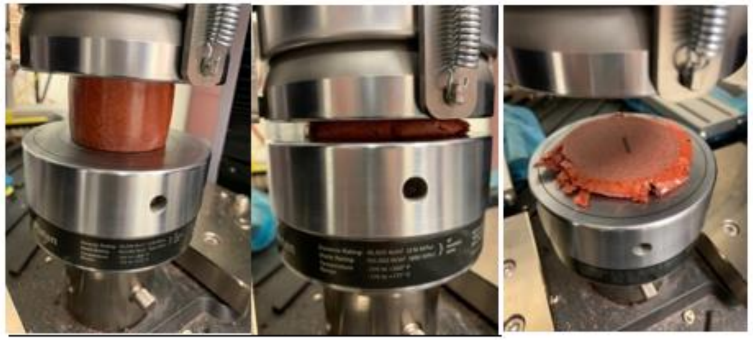
- Mechanical testing performed by DOE Fellow, Tristan Simoes-Ponce, during summer internship at SRNL
- Compression Test:
  - Used best-fit testing protocol ASTM D1621-16.

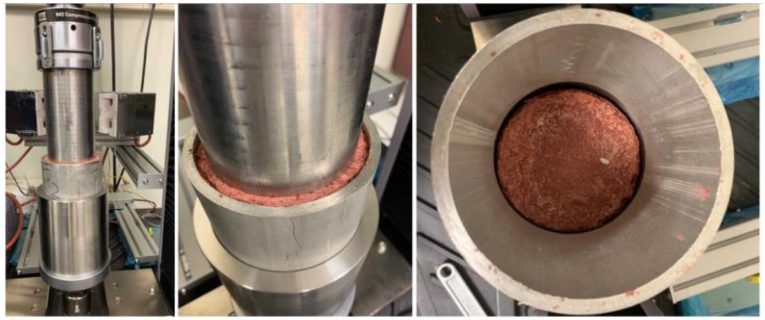
Intumescent Foam – Cylindrical Samples	Concrete
2169 psi	2500 psi (residential) 4000 psi (commercial)

- 304-SS Pipe Adhesion Test: Initial Trial
  - Up to ≈ 2,800 lb. before foam delaminated from pipe
- Continued to immobilize contamination after exposure to extreme thermal stressors
- Defined operational parameters and additional testing is required

Compression



Pipe Adhesion



Fire Testing

Non-Destructive Evaluation to Confirm Uniform Application of Foam Plug

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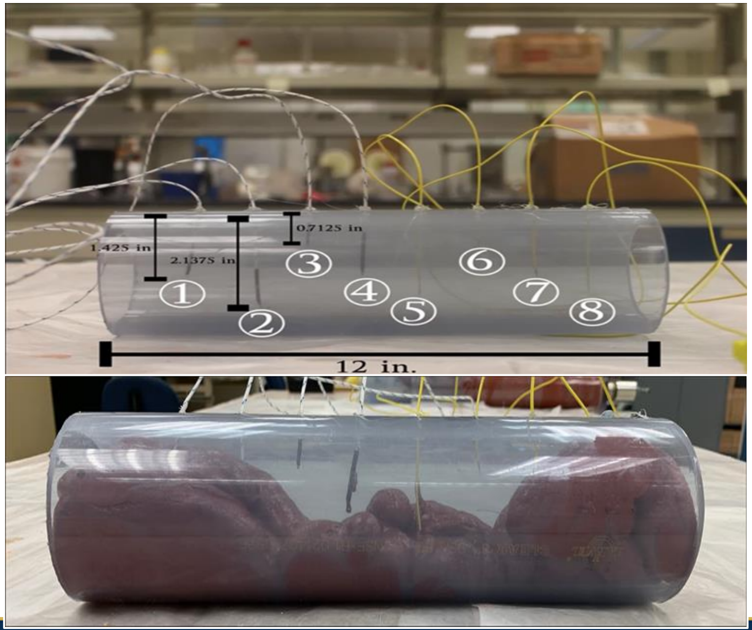
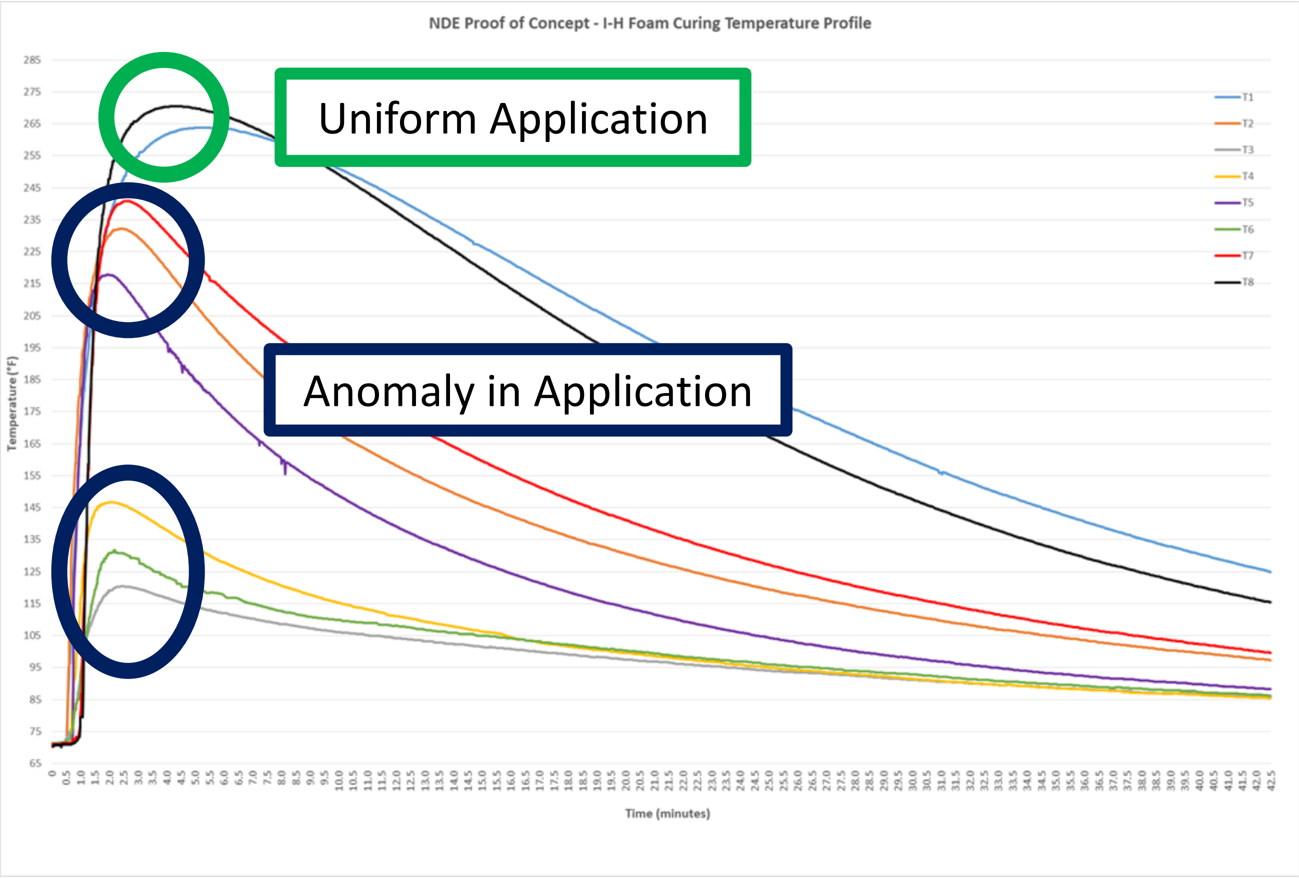
Proof of Concept Experiment #1

- **Hypothesis:** Is there a correlation between curing temperature profile and anomalies in application?
- **Confirmed:** Anomalies in application display much lower temperatures.

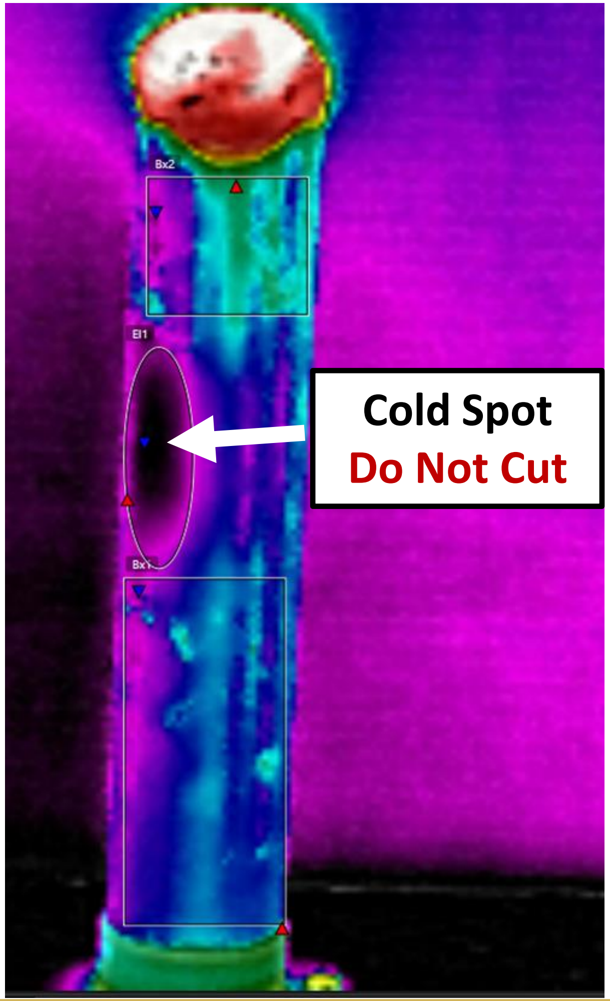


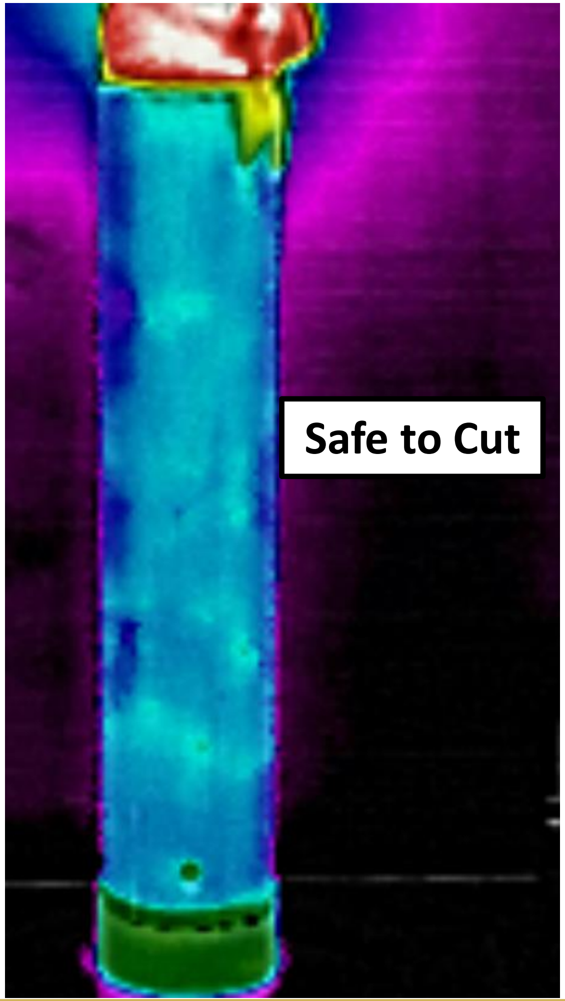


Non-Destructive Evaluation to Determine Uniform Application of Foam Plug

Proof of Concept Experiment #2

- **Hypothesis:** Can we combine advancements in thermal imaging systems with understanding of foam curing temperature profiles to identify anomalies in application in 304-SS pipe?





- **Confirmed:** Able to identify anomalies up to 3/8" steel wall thickness.

The Path Forward - Roadmap to TRL-7

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TRL-5:

- **Component and/or breadboard validation in a relevant environment**
  - *Proof of concept validated and specific COTS-based technology identified - Completed 2019*

TRL-6:

- **System or prototype demonstration in a relevant environment**
  - *Testing will be focused on refining and validating key operational parameters to support approval by safety basis personnel for an operational test and evaluation - Completed 2020*

TRL-7:

- **System prototype demonstration in an operational environment**
  - *Close collaboration with SRNL and/or INL will hopefully yield an opportunity to apply the foam system in an operational environment in 2021*

Validation:
Fire Resistance
Mechanical Limits
Curing Temperature Limits
Extent of Contamination Immobilization
NDE by Thermography

Increase scale and introduce more challenging operationally relevant scenarios

Collaborate with SRNL and leverage ASTM practices and principals to define the operational requirements

Application #3: Passive Thermal Insulator for Packaging Containers

- Potential applications in mitigating container pressurization of radioactive waste during a fire scenario
- Intumescent Coating: serves as an excellent thermal insulator in initial proof of concept tests
- Next round of testing scheduled for August 8, 2019
- Working with SRNL to refine operational requirements and concept of operations with site personnel

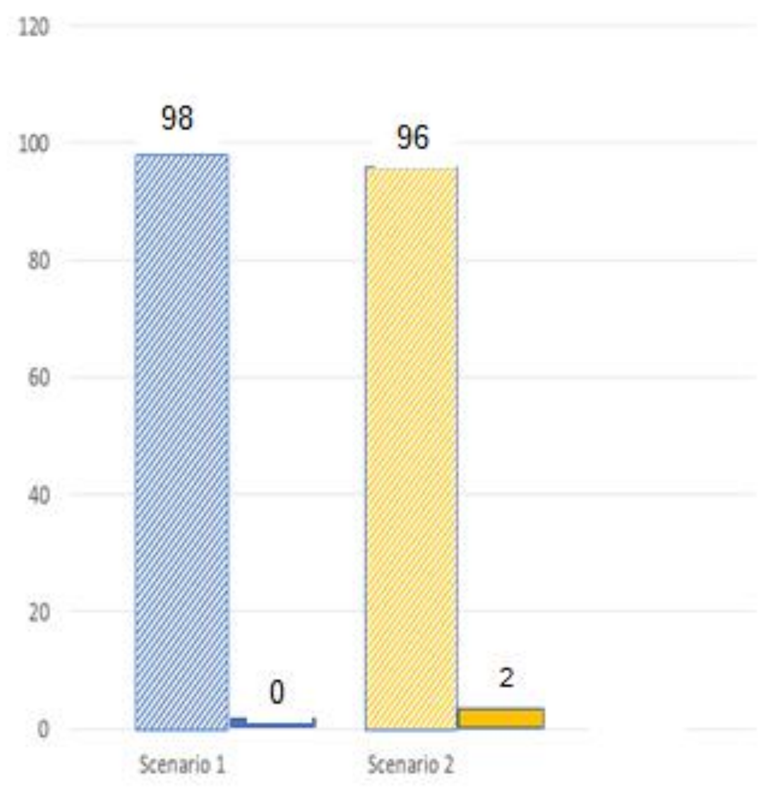
No Coating

Intumescent Coating

Potential Power of International Standards in Facilitating Technology Acceptance in D&D Space

- Choose between the two technologies based on the given information:
  - Technology 1: Fixative intended to stabilize residual radioactive material when exposed to a fire. $0.75 / square foot.
  - Technology 2: Fixative intended to stabilize residual radioactive material when exposed to a fire. $0.75 / square foot. Met ASTM E84, NFPA 701, and UL723 fire test standards.

- Choose between the two technologies based on the given information:
  - Technology 1: Fixative intended to stabilize residual radioactive material when exposed to a fire. $0.75 / square foot.
  - Technology 2: Fixative intended to stabilize residual radioactive material when exposed to a fire. $1.00 / square foot. Met ASTM E84, NFPA 701, and UL723 fire test standards.



Linking Standards Development with Operational Requirements

- Sets foundation for uniformed evaluation of technology performance against defined operational requirements
- 4 x ASTM standards for fixative technologies formally approved to date
- Referenced in Test Plans across DOE EM Complex
- Increased recognition by community on critical role of standards
  - Awarded Best in Track / Paper of Note at WM'19

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Empirically Quantifying Fixative Performance Against Operational Stressors

- **Fire and thermal** hazards often receive the most attention as the consequences can be severe and may lead to significant release
- During demolition, **impacts from debris** are unavoidable yet there is no current means of assessing their effects on fixatives
- **Water** is used as a dust suppressant during demolition; however, many polymer fixatives are water soluble or easily delaminate when subjected to water
- Uniform, peer-accepted testing protocols facilitate comparison of performance against these stressors

Example of Thermal Stressor

Example of Water Stressor

Experimental Design for Quantifying Release under Operationally Relevant Stressors

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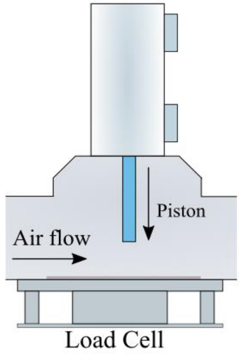
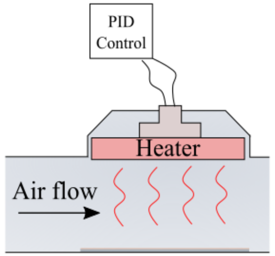
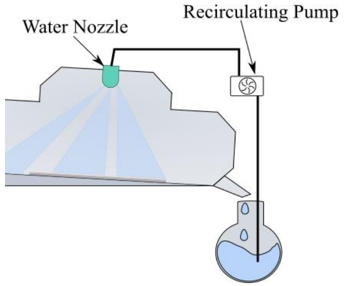
Standardized Contamination:

- Needs to represent site contamination
  - Soluble salts such as cesium nitrate can be used as a surrogate for Cs-137; a typical soluble contamination for spent fuel handling facilities.
  - Bi_2O_3 can be used as a non-soluble surrogate for Pu or U oxides. It's non-soluble in water but can be processed with strong acid.

- Needs to be uniformly and quantifiably deposited onto substrate
  - A standardized method for contaminating a sample is essential to make meaningful comparisons across fixative products.
  - A reproducible standard method would have wider reaching impact across the industry and would feed into the creation of newer, better ASTM standards.







Stressor:

A modular chamber is used to apply various stressors

- Impact:
  - A pneumatic piston can deliver a controllable amount of force, that is measured using a high capacity load cell.
- Thermal:
  - Ceramic heaters are compact and can reach high temperatures typically up to 1800°F.
- Water:
  - A recirculating system and nozzle can be used to gently mist or forcefully jet a sample while collecting release in the fluid.

This approach would allow for direct A-B type comparisons to be made between fixatives and reinforce the development of standards and operational practices.

Experimental Design Continued

Collection:

- Need to collect suspended airborne particles
  - A gentle airflow passes through a HEPA filter stack
- Need to collect resettled particles
  - Wipes can be used to collect matter that settled inside the chamber
- Need to collect particles remaining on substrate and fixative
  - Both elements can be separated and directly chemically processed

Processing and Analysis:

- Needs to quantify contaminant from several sources
  - Cesium nitrate and bismuth oxide are soluble in strong acid
  - Digesting filters, wipes, fixative/substrate in acid will move all contaminant into liquid phase
- Needs to be element specific
  - Mass spectroscopy can detect single elements such as Cs and Bi while ignoring any other elements that make up the sample matrix
  - Processing in this way allows total release quantification, determination of airborne fraction, determination of resettled fraction, and determination of decontamination factor of fixative