Measuring Fire Resiliency through Mass Loss

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Basis for Interim Operations (BIO) for SRS 235-F

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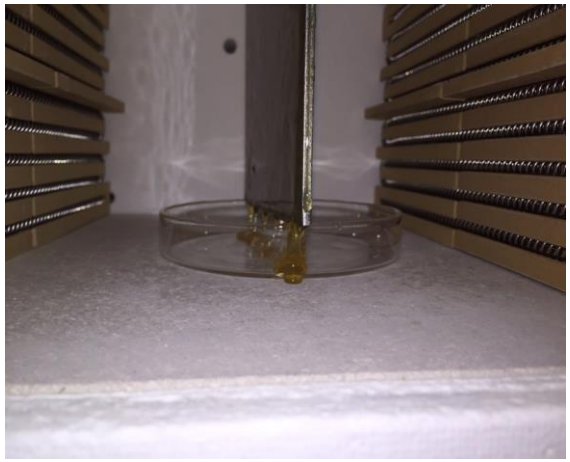
- Potential consequences of a seismically-induced full-facility fire are greater than 10 rem offsite and 27,000 rem to the collocated worker at 100 meters
- Fires could start inside the building if energized electrical equipment or wiring failed or was damaged during a seismic or other natural hazard event
- Very proactive fire preventive controls ISO D&D activities
  - Eliminating potential ignition sources
  - Controlling the amount of combustibles
  - Removal of residual contaminants
  - Identification and deployment of tools, fire resilient fixatives, etc.

Baseline of Fixatives ISO D&D

- Conducted extensive baseline of 5 industry fixatives and decon gels on various substrates (stainless steel, wood, glass, sheetrock)
- Primary focus was on determining fire resiliency
  - Exposure to open flame
  - Incremental temperature increases in muffle furnace
- Collected date on combustibility, mass loss, impact on adhesion, contaminant transport, chemical breakdown



Baseline of Fixatives ISO D&D Executive Highlights

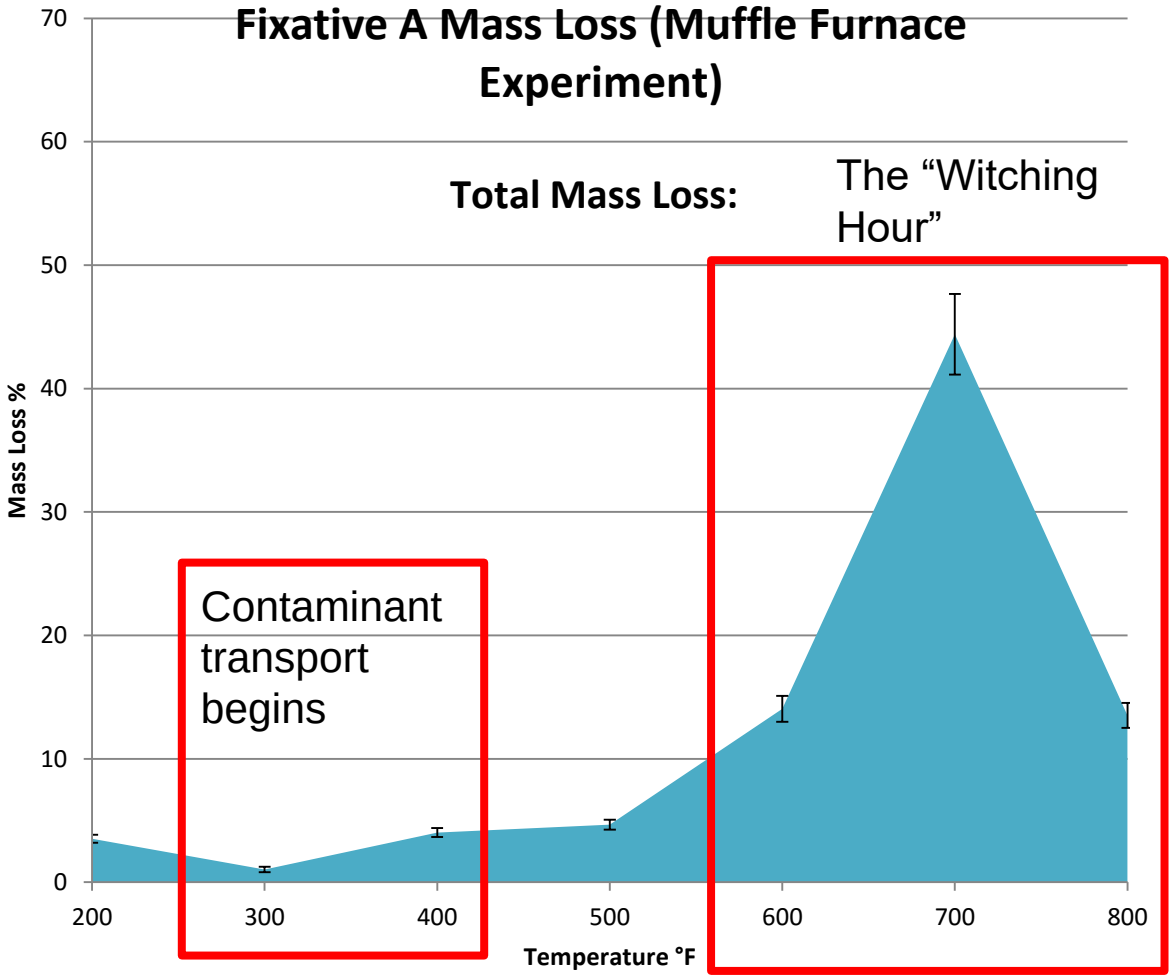
Melting / expansion / transport of fixative and contaminant began, on average, at 300^{o}-400^{o} F within minutes of exposure

All 5 fixatives began to exhibit minor mass loss starting at temperatures as low as 200^{o} F, but most significant degradation in terms of mass loss, desiccation, chemical breakdown / change, etc. occurred between 600^{o}-800^{o} F (ref matrix and charts)

All fixatives lost anywhere from 70% to upwards of 90% mass when exposed to incremental temperature increases (200^{o}-800^{o} F). Again, greatest mass loss percentage occurred between 600^{o}-800^{o} F.

All 5 fixatives “ignited” / became flammable almost immediately when exposed to the propane torch / open flame and burned completely between 1-5 minutes.

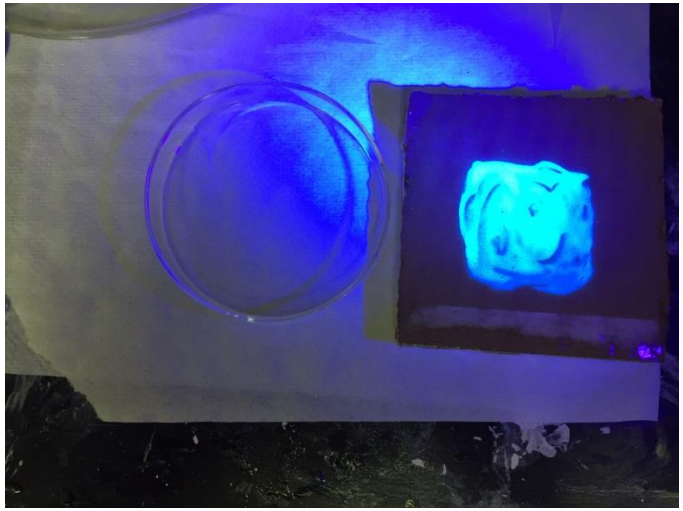
Basic Fixative Profile

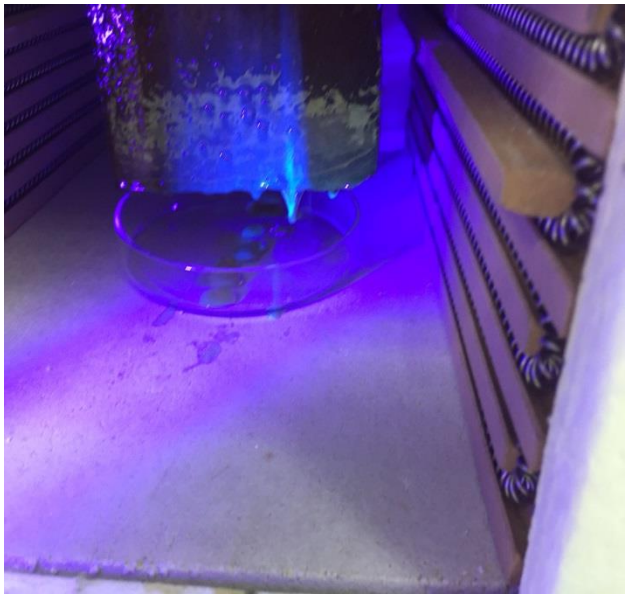


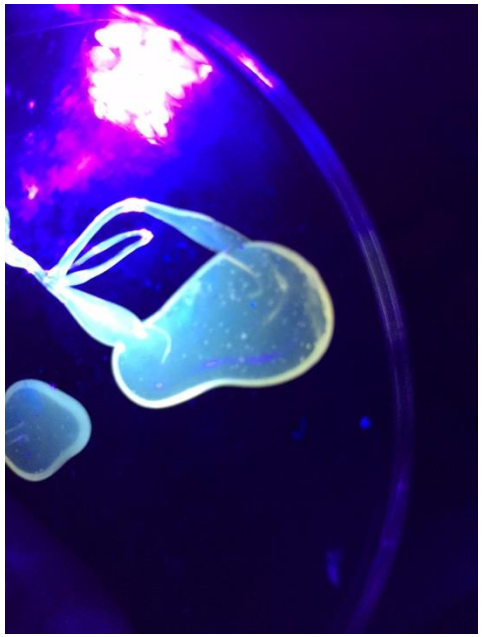
Contaminant Transport

All 5 x fixatives baselined demonstrated contaminant flow beginning at temperature ranges between 250-300 degrees in less than 5 minutes of exposure. At 500 degrees and above GloGerm particles could no longer be tracked due to extensive damage to fixative.

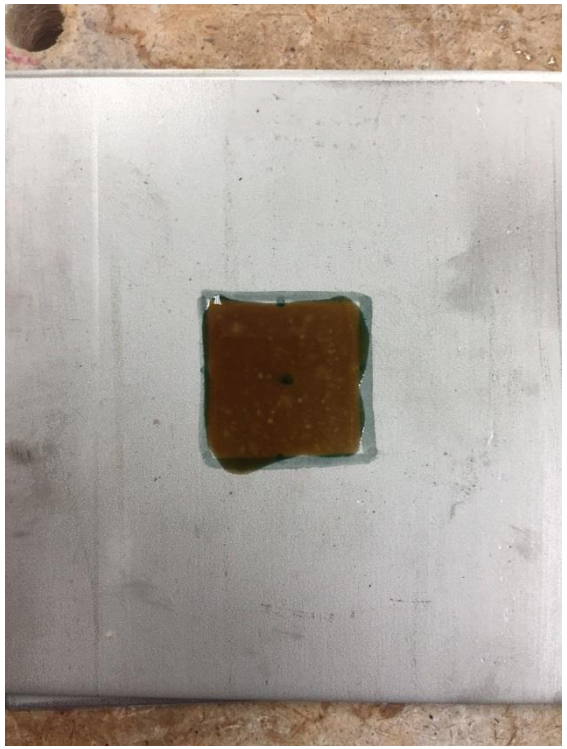
A product called GloGerm was used to simulate the contaminant and track particle flow during degradation. When exposed to a black light the GloGerm particles glow (note photos – Fixative A with GloGerm at 300 degrees).







Observed Impacts to Fixative "A" at Incremental Temperatures



Discoloration, expansion, and minor mass loss (400° F)

Discoloration, bubbling, continued expansion, "off gassing", desiccation and mass loss (600° F)

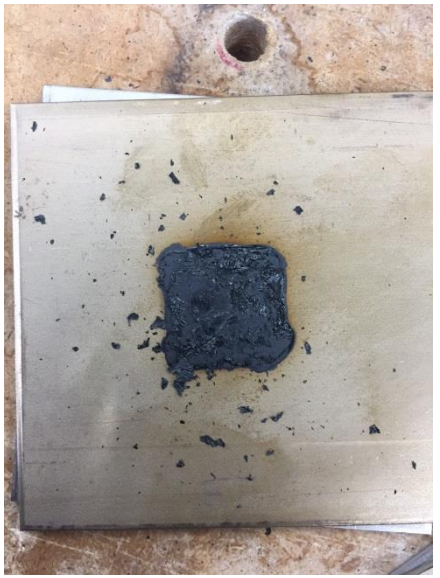
Significant mass loss, discoloration, desiccation, cracking, and flaking. Slightest abrasion with fixative resulted in total flaking. (800° F)

Observed Impacts to Fixative "B" at Incremental Temperatures

Discoloration, expansion, and minor mass loss (200° F)

Discoloration, bubbling, continued expansion, "off gassing", and mass loss (400° F)

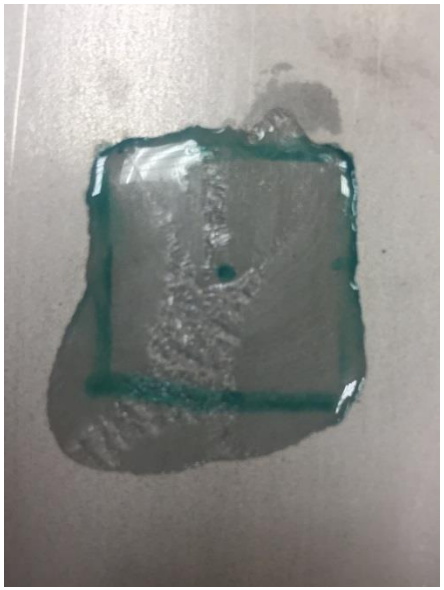
Significant discoloration, continued expansion, "off gassing", mass loss, desiccation, cracking, and brittle composition (500° F)



Significant mass loss, discoloration, desiccation, cracking, and flaking. Slightest abrasion with fixative resulted in total flaking. (800° F)

Observed Impacts to Fixative "C" at Incremental Temperatures

Starting Point

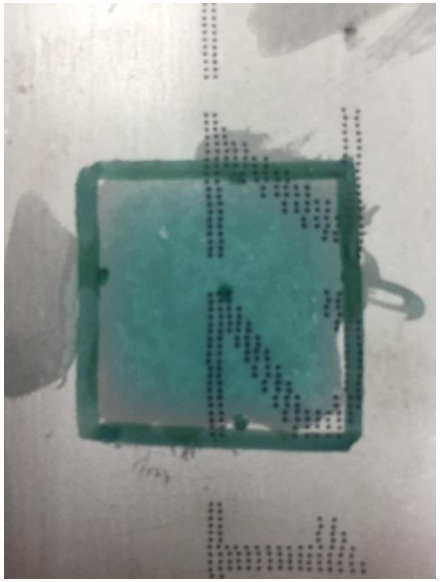


Discoloration, bubbling, continued expansion, "off gassing", and mass loss noted (200° F)

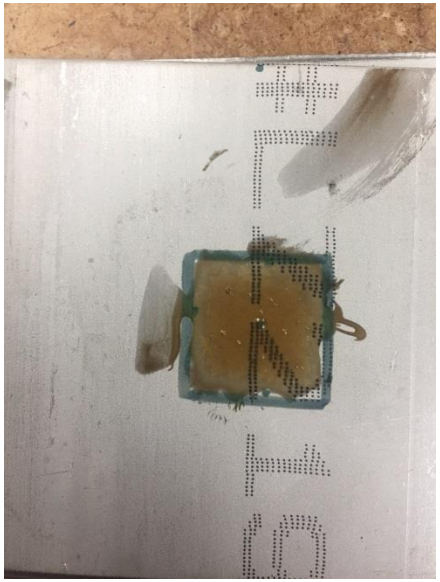
Significant discoloration, continued expansion and "off gassing", mass loss, desiccation, cracking, and brittle composition (500° F)

Significant mass loss, discoloration, desiccation, cracking, and flaking. Slightest abrasion with fixative resulted in total flaking. (800° F)

Observed Impacts to Fixative "D" at Incremental Temperatures



Starting Point



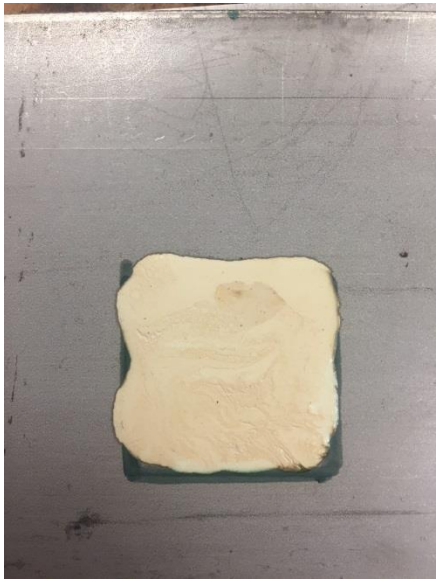
Discoloration, bubbling, continued expansion, "off gassing", and mass loss noted (500° F)

Significant discoloration, continued expansion and "off gassing", mass loss, desiccation, cracking, and brittle composition (700° F)

Significant mass loss, discoloration, desiccation, cracking, and flaking. Slightest abrasion with fixative resulted in total flaking. (800° F)

Observed Impacts to Fixative "E" at Incremental Temperatures

Starting Point



Discoloration, "off gassing", and mass loss
(500° F)

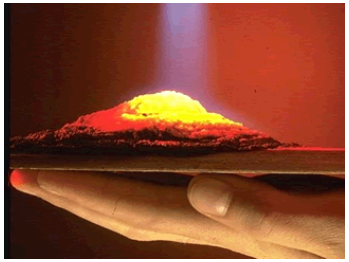
Significant discoloration, continued expansion and "off gassing", mass loss, desiccation, cracking, and brittle composition
(700° F)

Significant mass loss, discoloration, desiccation, cracking, and flaking. Slightest abrasion with fixative resulted in total flaking.
(800° F)

Baseline of Fixatives ISO D&D Video Documentation

Adapting Technological Advancements in other Industries and Applying to D&D Activities (Intumescent Coatings)

- **Goal:** Improve operational performance of fixatives used in D&D activities by enhancing their fire resiliency
- **Potential Solutions:** 1) Layer an intumescent coating (IC) with existing fixatives; or 2) adapt / formulate IC as a standalone fixative
- **Explanation:** Since 9/11, there have been significant improvements in fire retardant / fire resistant technologies, with intumescent coatings being at the forefront of this development. U.S. Military, NASA, oil and gas industry and others use this proven technology extensively to fire harden / protect facilities.



Proof of Concept Executive Highlights Intumescent Coatings

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- All 5 fixatives, when layered with the intumescent coating, conclusively displayed enhanced fire resiliency during the propane torch / open flame on all substrates
  - Excellent Thermal Insulation Protection
    - Fixative and substrate remained relatively intact
  - Minimum Flame Spread
  - Long-term thermal protection
    - Exposed coupon to propane torch for 35+ minutes with minimal damage to fixative
  - No smoke
  - Easy application via brush or sprayer
- During muffle furnace tests, reduced off-gassing and mass loss

Flame Spread Comparison

Flame Spread Test #2

- 4”x4” steel coupon was coated with intumescent coating except for a 1 cm portion in the center which was coated with Fixative A only
- 2 propane torches were ignited and pointed towards outer edges (upper and lower, respectively) at a distance of ~1 ¾” from the exposed fixative (middle)
- Charring at both edges commenced immediately, and prevented flame spread and heat transfer to exposed fixative

Thermal Insulation / Heat Transfer Comparison

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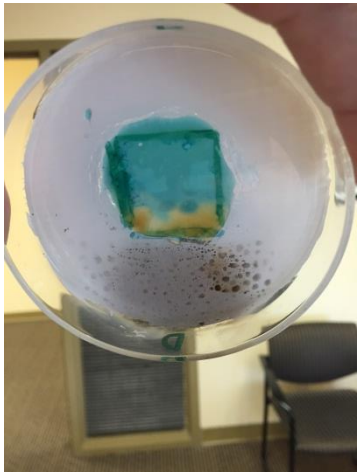
Thermal Insulation Reaction

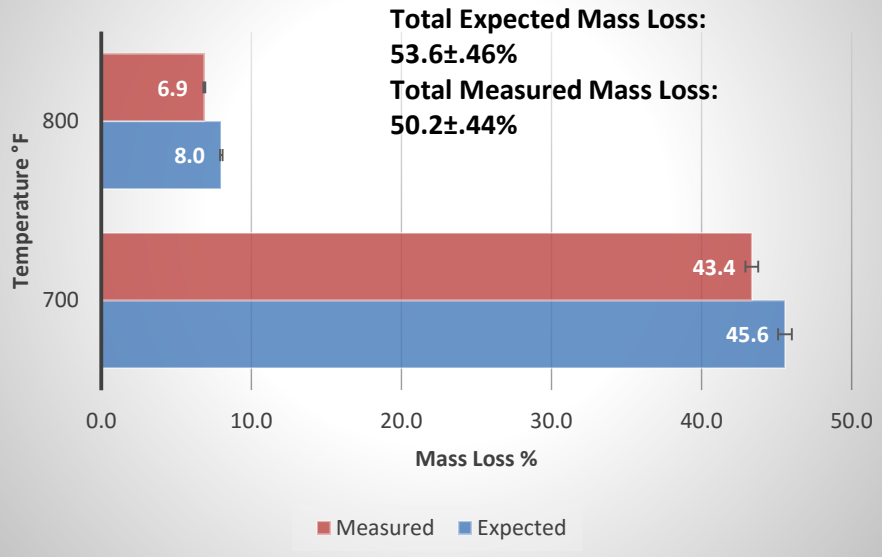
- Each substrate (stainless steel, wood, glass, sheetrock) was layered to IC manufacturer's recommended thickness
- Charring commenced immediately when exposed to propane torch; it occurred at ~700° F in muffle furnace
- Dense charring ranged from 1"-2.5" depending on time, substrate, fixative, etc.
- Provided excellent thermal insulation to both substrate and fixative

Thermal Insulation Test #2

- Used glass substrates to observe impact to fixative when covered with intumescent coating
- Charring commenced immediately when exposed to propane torch; it occurred at ~700° F in muffle furnace
- As long as charring is immediate, thermal insulation begins and provides protection to fixative

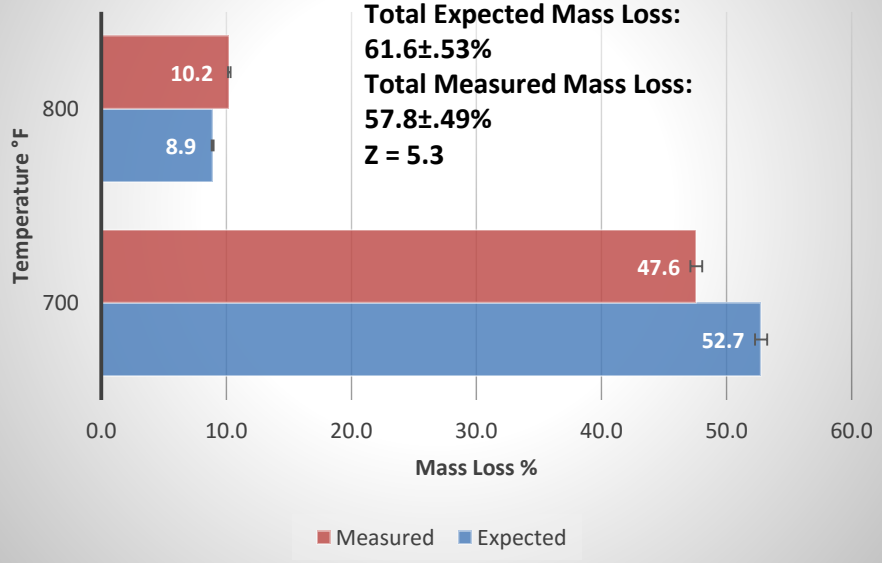


Mass Loss IC+E:G700-1 vs. "Projected" Loss

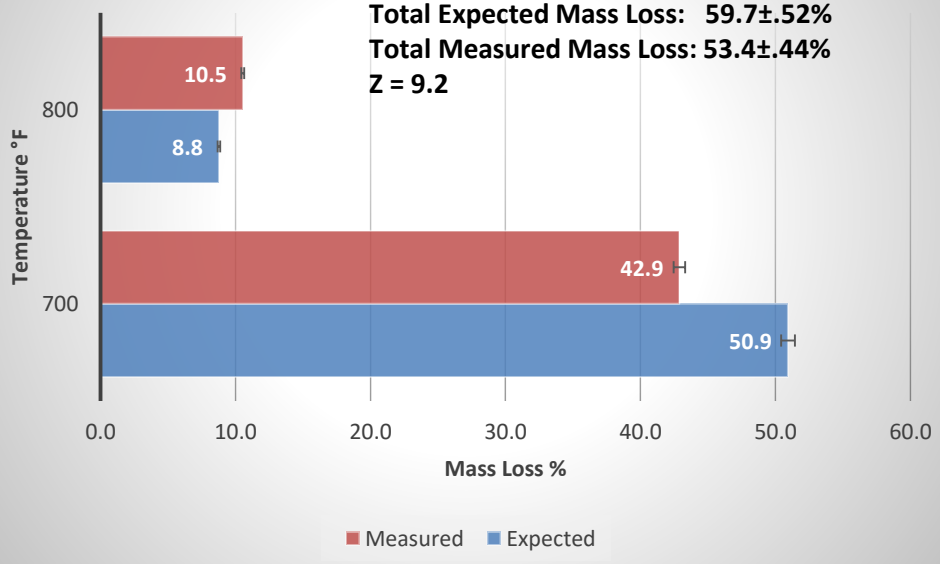


Mass Loss IC+E:G700-2 vs. "Projected" Loss

Mass Loss IC+A:G700-1 vs. "Projected" Loss



Mass Loss IC+A:G700-2 vs. "Projected" Loss



Way Ahead for R&D

- Based on initial results from Proof of Concept experiments, SRS 235-F site personnel requested expedited adaptation of intumescent coating to address requirements with hot cells
  - Rad hardened to withstand heat generation of Pu-238
  - Able to fix Pu-238 particle sizes between 10-300 um
  - Capable of being applied via existing devices

- Preference is to pursue adaptation of intumescent coating as a standalone fixative, but need to continue R&D in optimizing the layering process as well
  - Baseline other top rated industry ICs and identify one that matches most closely with requirements – modify from there
  - Enhance intumescent coatings thermal reaction at lower temperatures
  - Improve adhesion and bonding characteristics

- Conduct full scale demo