

Determining Airborne Release Fraction (ARF) from DOT 7A Drums Exposed to Thermal Insult



PRESENTED BY

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Background

Motivation

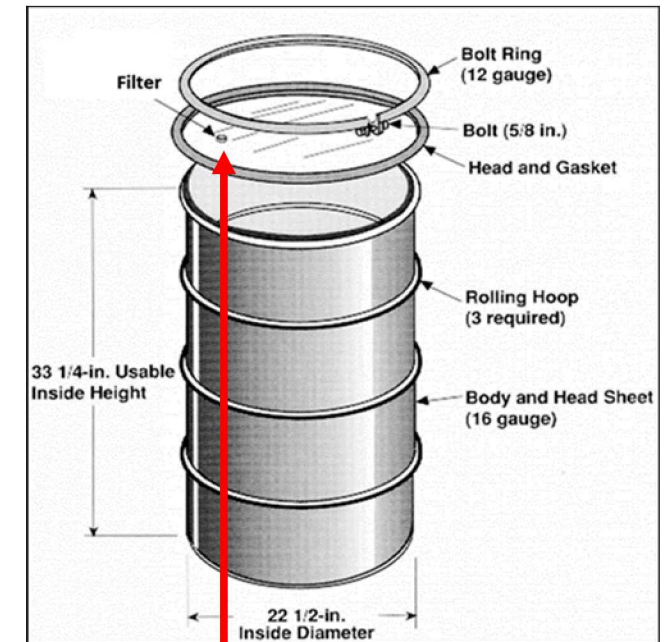
Test Sequence Overview

Test Results

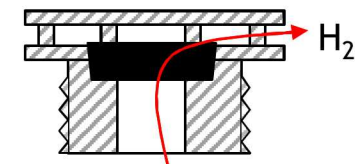
Summary

What is a Department of Transportation (DOT) 7A drum?

- Shielded container designed to confine small quantities of Class 7 radioactive material
- Total payload composition and volume ranges from drum to drum
 - Radioactive material mass is kept relatively constant
- Typically equipped with a NUCFIL-019DS lid filter for hydrogen release
- Currently used at various storage sites across the U.S



NUCFIL-019DS



Current assumptions by *DOE-STD-5506-2007* for a liquid pool fire at a site (drums are equipped with a NUCFIL-019DS)

- 25% of drums are assumed to lose lid and undergo an unconfined burn \Rightarrow ARF ($m_{rad_release}/m_{rad_initial}$) of $\sim 1E-2$

Pool fire tests in 2017 with UT-9424S filter replacing the NUCFIL-019DS filter

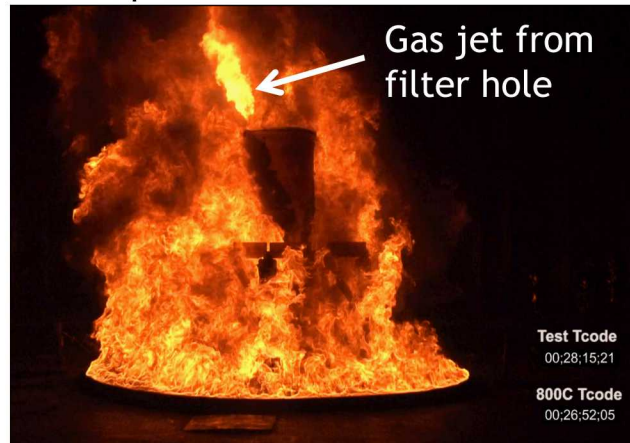
- Plastic sleeve on UT-9424S filter softens/melts, filter pops off, internal pressure is relieved and lid remains in place (with filter orifice exposing internal contents)
- Confined burn \Rightarrow *DOE-STD-5506-2007* suggests that ARF could be $\sim 5E-4$

If ARF can be shown to be less than assumed by *DOE-STD-5506-2007* by replacing filters with a UT-9424S:

- Funding to maintain fire suppression systems could be deemed unnecessary and thus result in cost savings to DOE complex (on the order of millions of dollars)

Since 2017 tests were preliminary and non-bounding, objective of this test series is to test bounding configurations of 7A drums in a pool fire while equipped with a UT-9424S filter with the goal of precisely measuring ARF in these scenarios

2017 pool fire test on 7A drum



7A drum post test



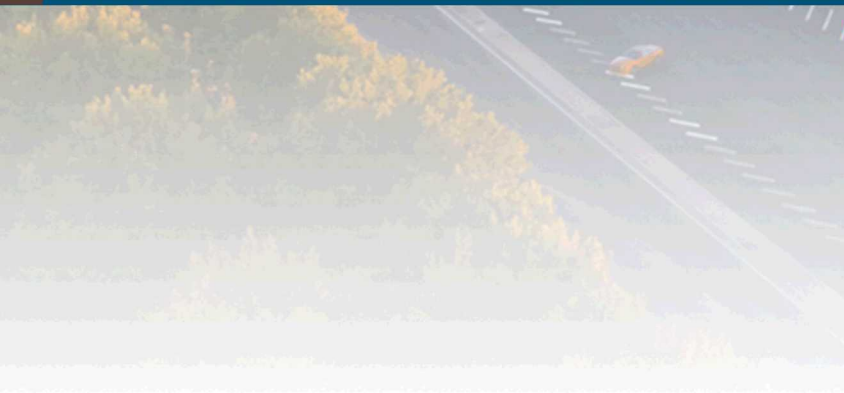
UT-9424S filter before [left] and after [right] pool fire



1. Thermogravimetric Analyses (TGA)
 - To identify the more volatile payload materials
2. Pool fire tests with temperature and pressure instrumentation
 - To measure fire environment for most conservative scenario
3. Developing and calibrating a radiant heat setup
 - To reproduce fire environment in a way that allows ARF measurement
 - Calibration for these tests based on pool fire results



TGA Study



Thermogravimetric Analysis (TGA) Test Matrix

Test Matrix

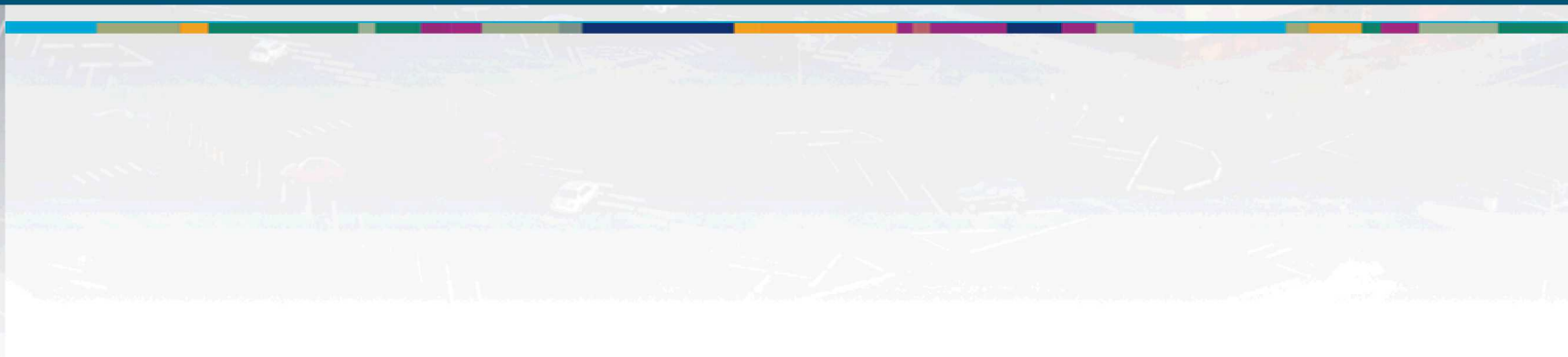
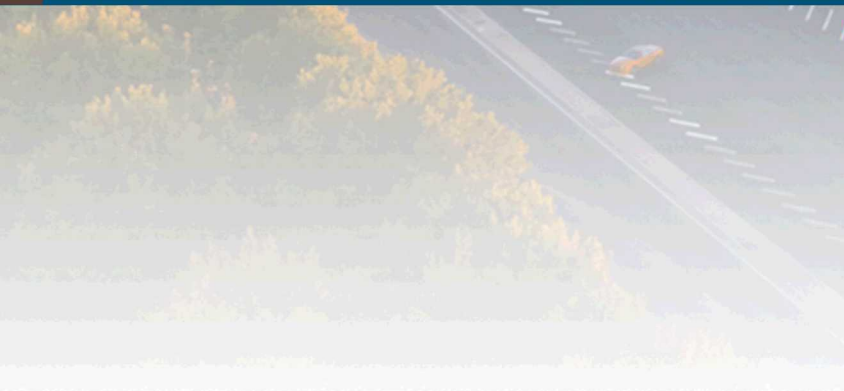
Test #	Constituent	Conditions of constituent	Ramp Rate [°C/min]
1	Cheesecloth	Pure	30
2	Plastic bag	Pure	30
3	PMMA	Pure	30
4	CeO ₂	Pure	30
5	Cheesecloth	w/ added CeO ₂ , ~1% by wt.	50
6	Plastic bag	w/ added CeO ₂ , ~1% by wt.	50
7	PMMA	w/ added CeO ₂ , ~1% by wt.	50
8	Cheesecloth	w/ added CeO ₂ , ~10% by wt.	50
9	Plastic bag	w/ added CeO ₂ , ~10% by wt.	50
10	PMMA	w/ added CeO ₂ , ~10% by wt.	50

Test Results

Test #	Constituent	Initial amount of CeO ₂ (as a % of total initial mass)	Total residual mass at end of TGA (as a % of total initial mass)
1	Cheesecloth	0 %	~0 %
2	Plastic bag	0 %	~0 %
3	PMMA	0 %	~0 %
4	CeO ₂	100 %	~100 %
5	Cheesecloth	1.57 %	2.28 %
6	Plastic bag	2.11 %	2.48 %
7	PMMA	0.82 %	0.6 %
8	Cheesecloth	15.57 %	15.57 %
9	Plastic bag	12.62 %	13.36 %
10	PMMA	10.16 %	12.22 %



Pool Fire Tests



9 Pool Fire Test Matrix

Conservative payloads chosen for Test #1

- Four different locations to identify most conservative location/scenario

Location of Test #2 based on results of Test #1 (most conservative location)

Differences in Test #1 and Test #2 would determine if free volume or payload constituents would induce higher pressurization

Test #	Drum	Test Location	% Fill	Composition
1	1	150 kW/m ² (Center of pool fire)	20% of Volume	85% rubber, 15% cellulose, and plastic bag
	2	55 kW/m ²	20% of Volume	85% rubber, 15% cellulose, and plastic bag
	3	45 kW/m ²	20% of Volume	85% rubber, 15% cellulose, and plastic bag
	4	35 kW/m ²	20% of Volume	85% rubber, 15% cellulose, and plastic bag
2	1	150 kW/m ² (Center of pool fire)	60% of Volume	50% cellulose, 40% plastic, 10% rubber, plastic bag, and rigid liner

Pool Fire Test Results Summary

Center of pool fire was most conservative location

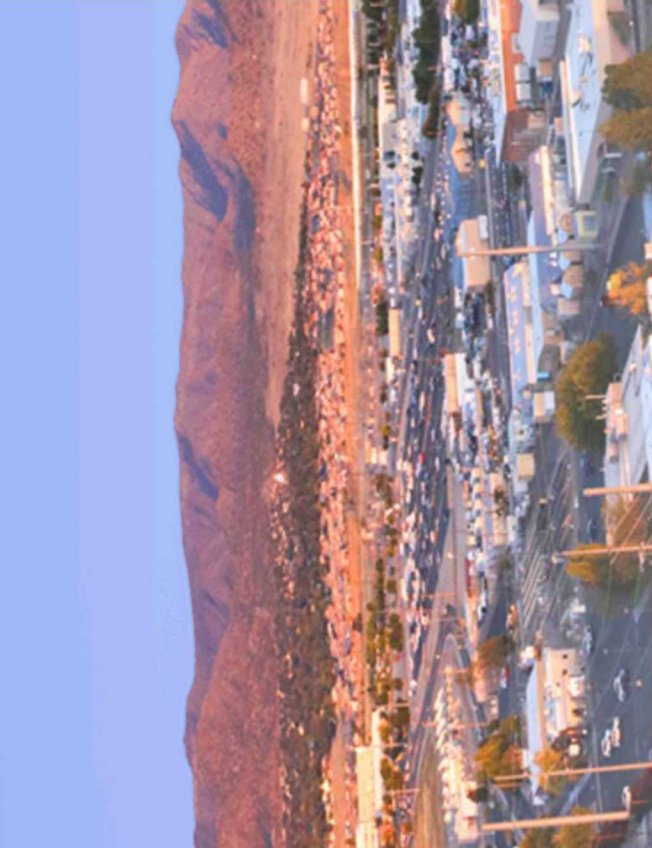
- Highest mass loss and pressurization

Free volume (air) is main contributor to pressurization

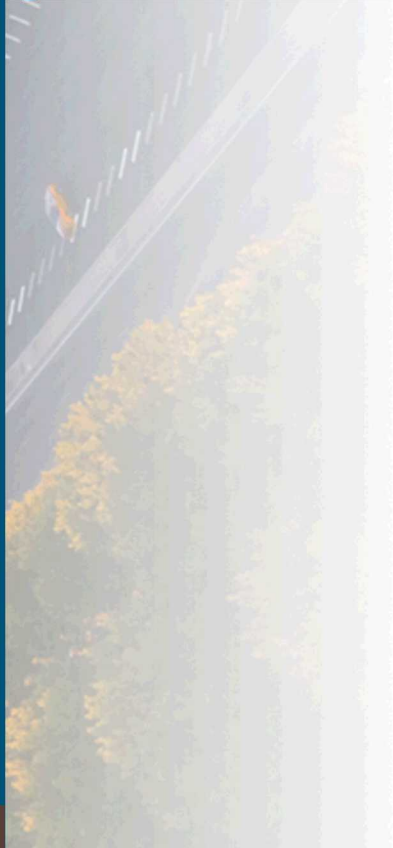
- Test #1 (80% air) pressurized significantly more than Test #2 (40% air)

Fire environment was measured and used to calibrate radiant heat tests (next section)

Test #	Drum	Drum Location	% Mass Loss	Peak Pressure Differential
1	1	150 kW/m ² (Center of pool fire)	87.14%	~16 psi
	2	55 kW/m ²	16.67%	N/A
	3	45 kW/m ²	3.8%	N/A
	4	35 kW/m ²	0.56%	N/A
2	1	150 kW/m ² (Center of pool fire)	71.11%	~2 psi



Radiant Heat Tests



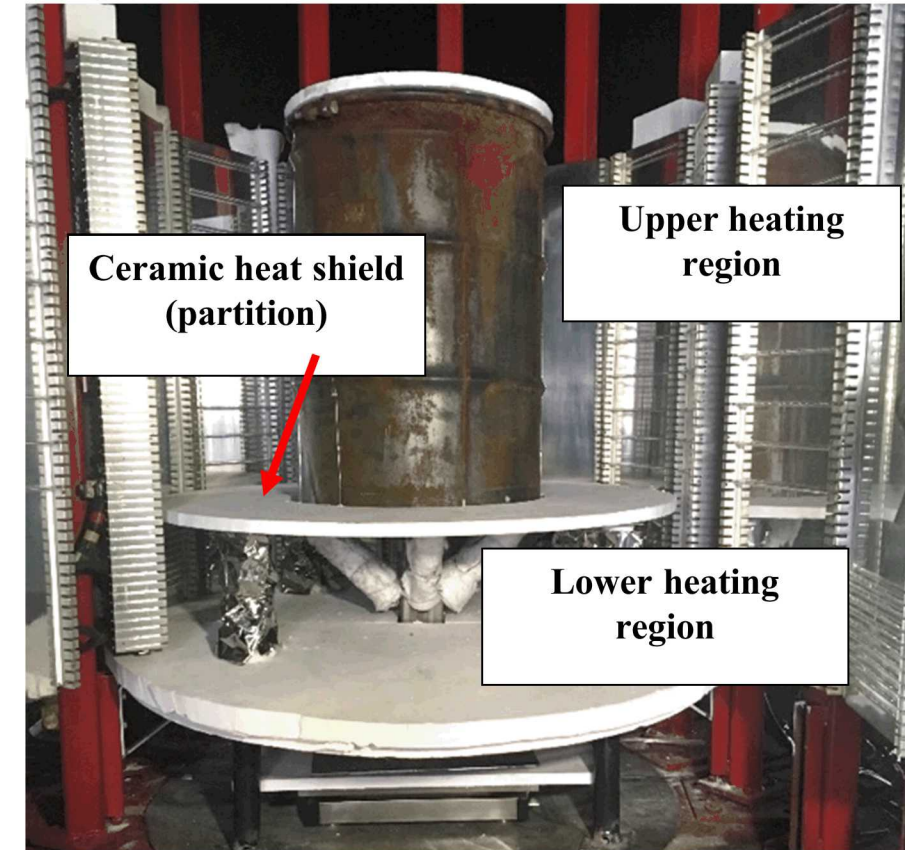
Goal was to replicate fire environment at center of pool fire

- Two tests: Payload composition of center drums from pool fire tests was matched for these tests

Calibration of radiant heat environment based on pool fire measurements

- Two heating regions separated by a partition and guided by TCs on the drum
 - Total of 12 heating panels
 - 10 high voltage heating lamps per panel
- Pressure transducers used to monitor internal pressure

Test #	Drum	Test Location	% Fill	Composition
1	1	Center of radiant heat setup	20% of volume	85% rubber, 15% cellulose, and plastic bag
2	1	Center of radiant heat setup	60% of volume	50% cellulose, 40% plastic, 10% rubber, plastic bag, and rigid liner



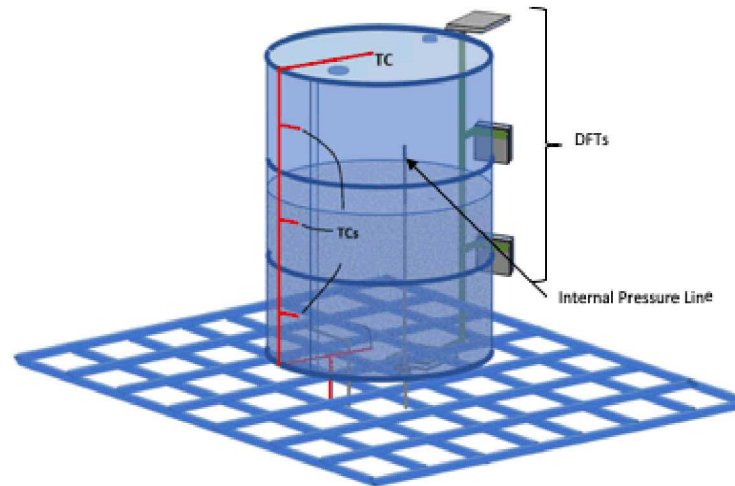
Comparison of Radiant Heat Thermal Response with Pool Fire Response

Thermal response comparisons shown in plot

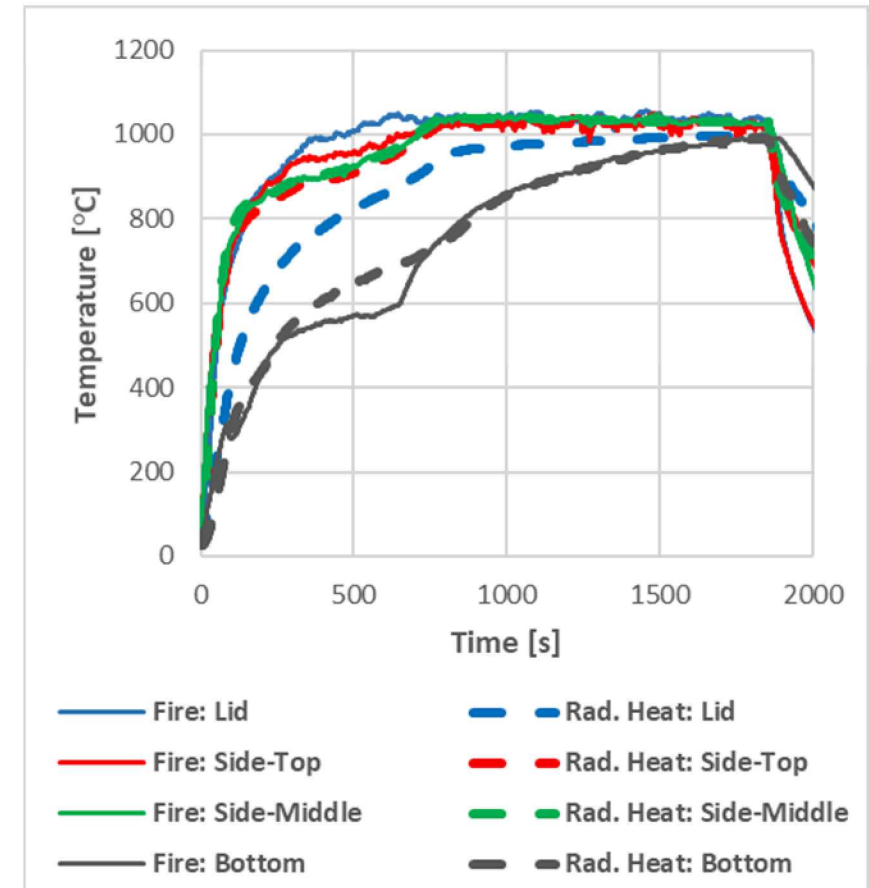
- Pool fire => Solid lines
- Radiant heat => Dashed lines

Temperature response closely matched on sides and bottom of drum

Slight deviation on lid region, but similar profile maintained



Thermocouple (TC) locations



Comparison of Radiant Heat Pressure Response with Pool Fire Response

Drums for radiant heat setup were tested without a lid filter

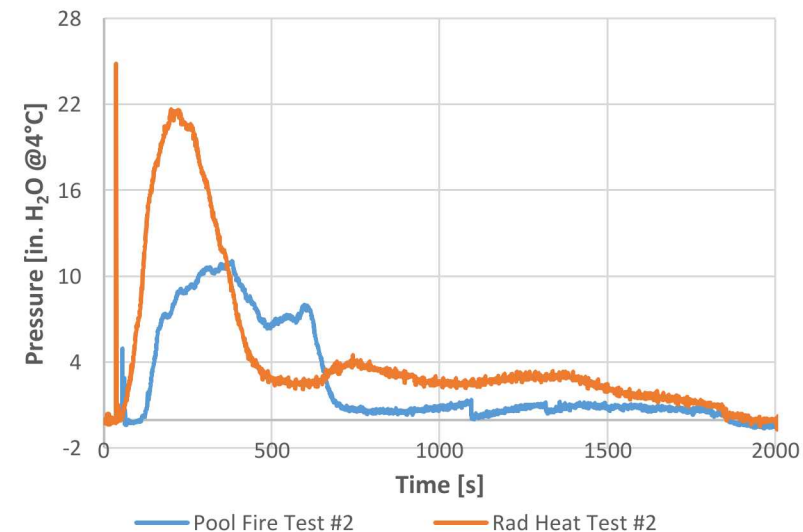
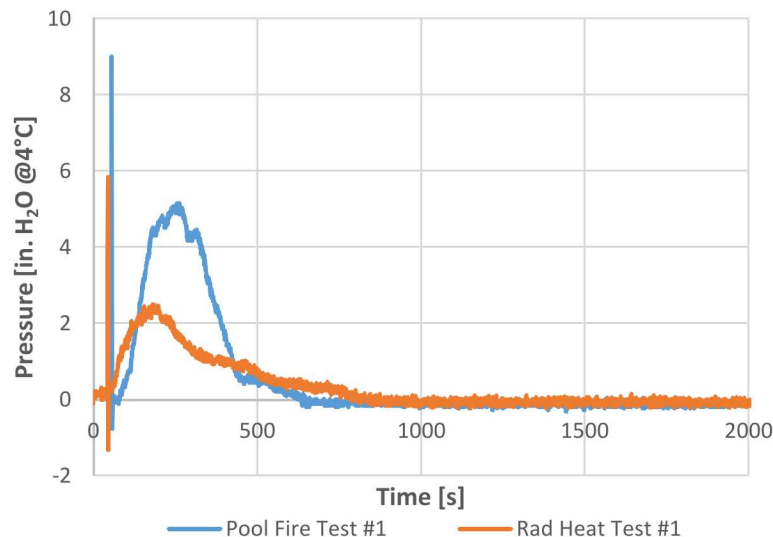
- Pressurization comparisons to pool fire were post filter ejection
- Source of plotted pressurization => Combustion of payload
 - Observed earlier in radiant heat tests due to missing filter

Comparing Tests #1 with Test #2

- Drums in Tests #1 saw lower peak pressures, speculated to be due to smaller payload

Overall, pressure response is comparable between two setups for each test

- Variations in peak pressures (for each test) between two setups attributed to mass variations



1. Conservative scenarios were defined for DOT 7A drums exposed to a pool fire
 - Lid response of pool fire tests for drums with conservative loads showed potential for 7As equipped with UT-9424S filter to result in ARF lower than currently assumed by safety basis documents
2. Radiant heat setup that could allow ARF measurements was designed
 - Thermal and pressure response of radiant heat tests shown to be comparable to pool fire tests

Success of radiant heat setup is encouraging to consider as a novel option that can mimic a fire environment while simultaneously allowing [ARF] diagnostics of the drum exhaust gases

Future work

- SNL is currently exploring different options to measure ARF now that calibration of radiant heat setup was successful

Thank You!