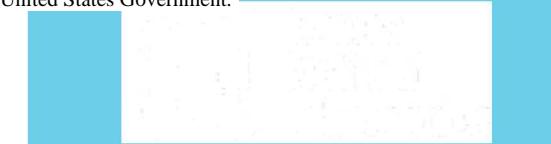


# Determining Airborne Release Fraction (ARF) from DOT 7A Drums Exposed to Thermal Insult



## PRESENTED BY

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## Outline

Background

Motivation

Test Sequence Overview

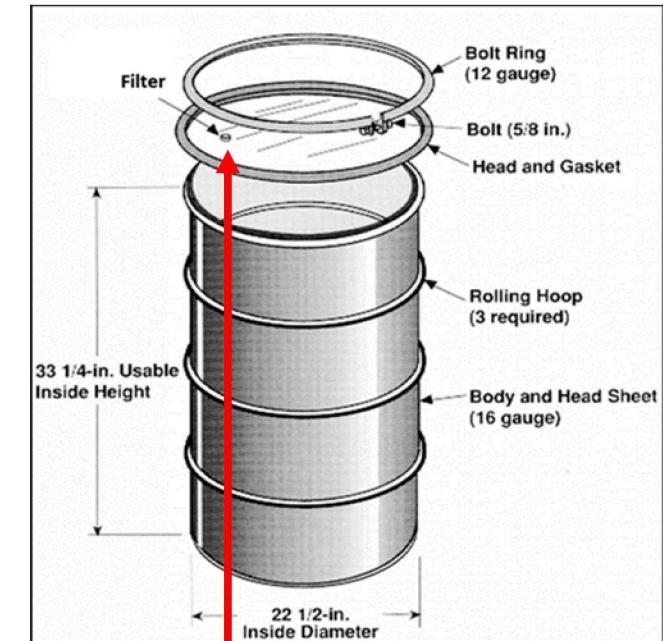
Test Results

Summary

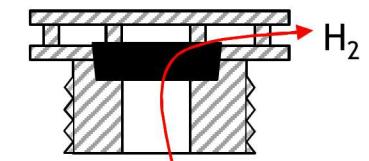
## Background

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 US



NUCFIL-019DS



## Motivation

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 => 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

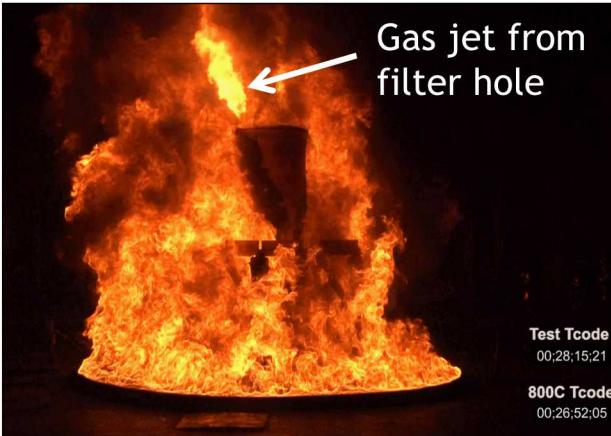
- Plastic sleeve on UT-9424S filter softens/melts, filter pops off, internal pressure is relieved and lid remains in place (with filter orifice exposing internal contents)
- Confined burn=> *DOE-STD-5506-2007* suggests that ARF could be  $\sim 5E-4$

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

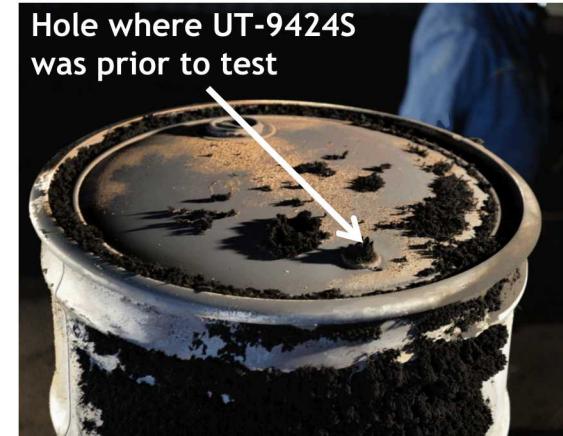
- Funding to maintain fire suppression systems could be deemed unnecessary and thus result in cost savings to DOE complex (on the order of millions of dollars)

**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



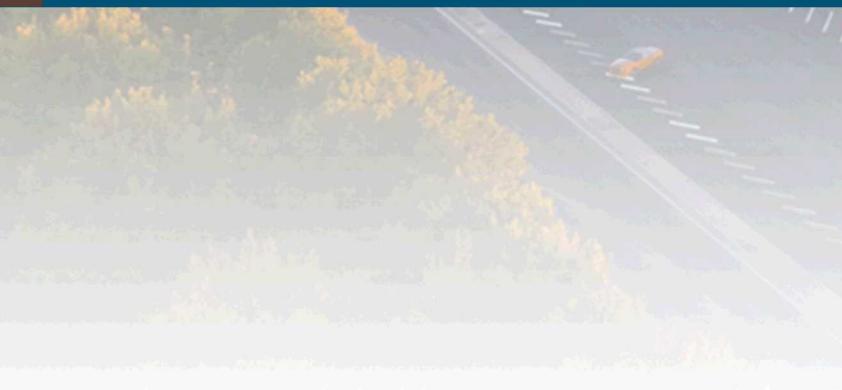
UT-9424S filter before [left] and after [right] pool fire



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



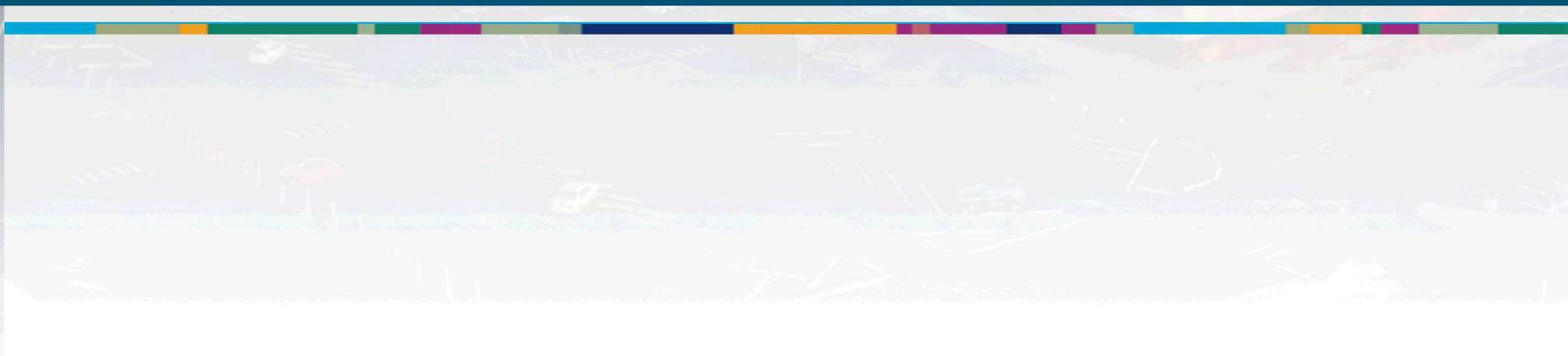
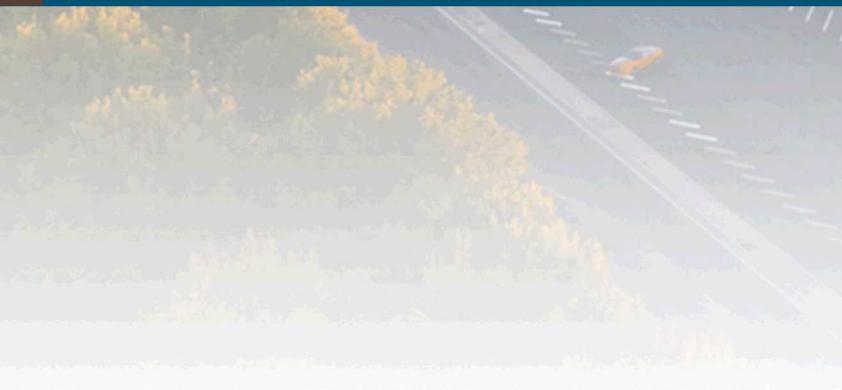
# Thermogravimetric Analysis (TGA) Test Matrix

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 <sub>2</sub>	Pure	30
5	Cheesecloth	w/ added CeO <sub>2</sub> , ~1% by wt.	50
6	Plastic bag	w/ added CeO <sub>2</sub> , ~1% by wt.	50
7	PMMA	w/ added CeO <sub>2</sub> , ~1% by wt.	50
8	Cheesecloth	w/ added CeO <sub>2</sub> , ~10% by wt.	50
9	Plastic bag	w/ added CeO <sub>2</sub> , ~10% by wt.	50
10	PMMA	w/ added CeO <sub>2</sub> , ~10% by wt.	50

Test Results			
Test #	Constituent	Initial amount of CeO <sub>2</sub> (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 <sub>2</sub>	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 <sup>2</sup> (Center of pool fire)	20% of Volume	85% rubber, 15% cellulose, and plastic bag
	2	55 kW/m <sup>2</sup>	20% of Volume	85% rubber, 15% cellulose, and plastic bag
	3	45 kW/m <sup>2</sup>	20% of Volume	85% rubber, 15% cellulose, and plastic bag
	4	35 kW/m <sup>2</sup>	20% of Volume	85% rubber, 15% cellulose, and plastic bag
2	1	150 kW/m <sup>2</sup> (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 <sup>2</sup> (Center of pool fire)	87.14%	~16 psi
	2	55 kW/m <sup>2</sup>	16.67%	N/A
	3	45 kW/m <sup>2</sup>	3.8%	N/A
	4	35 kW/m <sup>2</sup>	0.56%	N/A
2	1	150 kW/m <sup>2</sup> (Center of pool fire)	71.11%	~2 psi

# Radiant Heat Tests



## 12 Radiant Heat Test Matrix

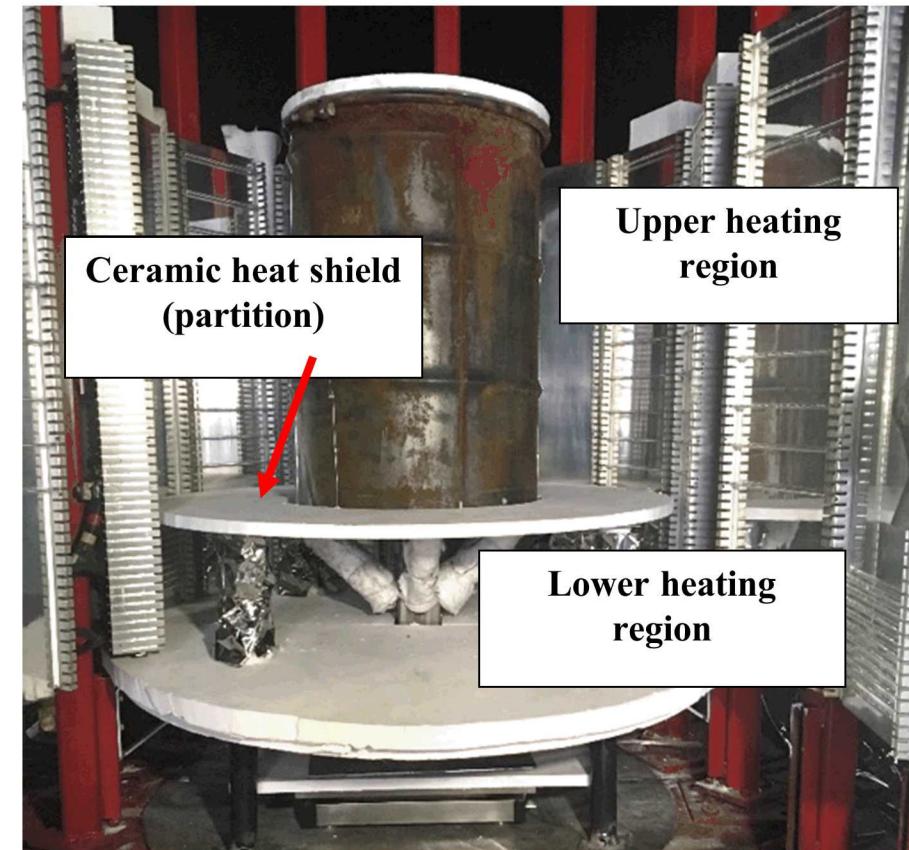
Goal was to replicate fire environment at center of pool fire

- 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



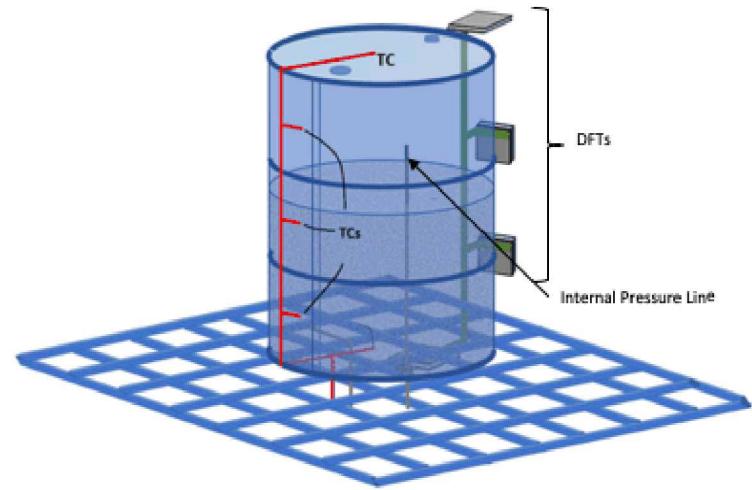
# Comparison of Radiant Heat Thermal Response with Pool Fire Response

Thermal response comparisons shown in plot

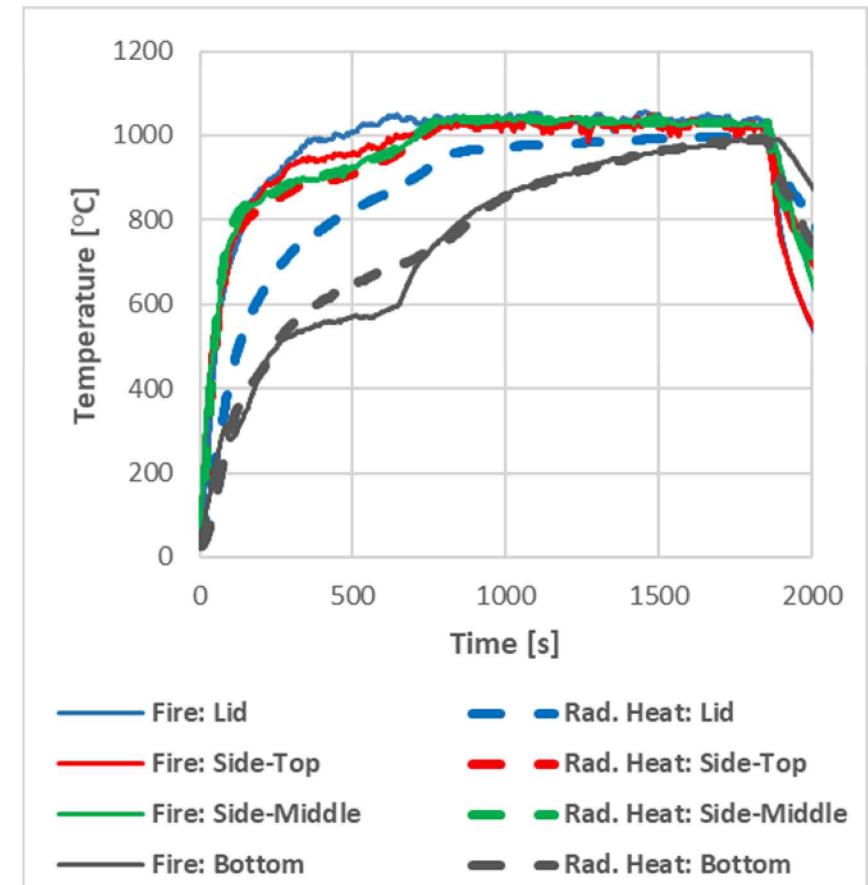
- Pool fire => Solid lines
- Radiant heat => Dashed lines

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

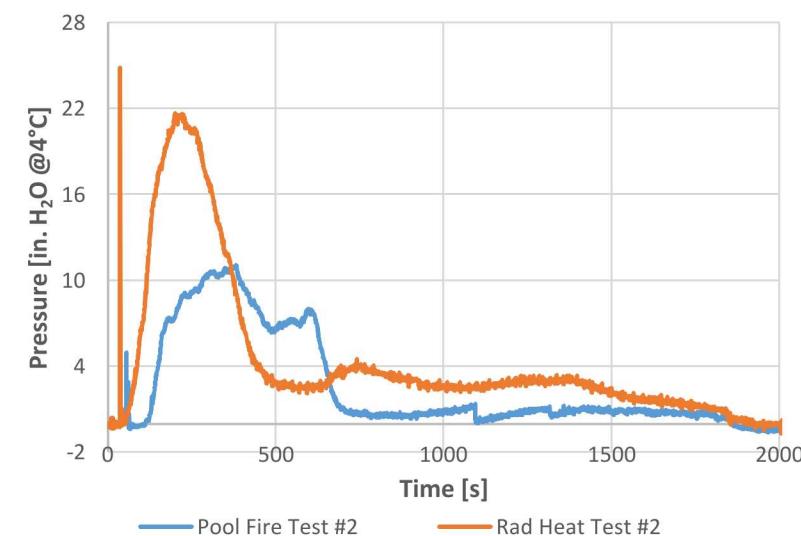
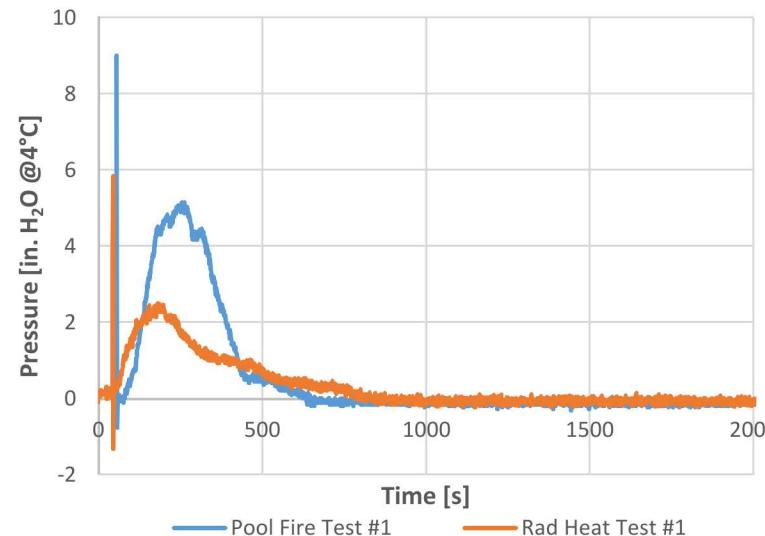
- Pressurization comparisons to pool fire were post filter ejection
- Source of plotted pressurization => Combustion of payload
  - Observed earlier in radiant heat tests due to missing filter

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!