Thermal Testing to Determine ARF on 7A Drums Equipped With UT 9424S Filter

PRESENTED BY

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SNL

SAND2019-4266

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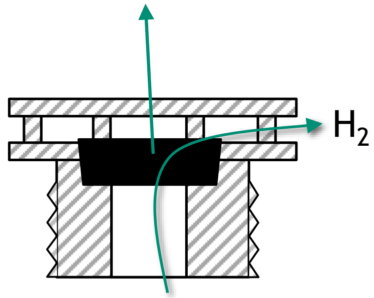
History of POC/7A Testing at Sandia Prior to 2017



Conducted several test from 2015-2016 to address POC concerns

- POCs filled with combustibles
- Concern that the POC lid would not stay on during a fire
- When drum is fully-engulfed, POC drum lid is ejected less than 3 minutes in a 30-minute fire test
  - Expansion of small volume of gas inside the POC is enough to cause ejection of the lid (i.e., no significant combustions of material is necessary)
- Outside the fire, POC the drum lid stays on

During 2015-2016 test campaign, 7A drums were added to the periphery of the fire

- NFT filter
- Demonstrated that drum lid stays on even when the drum is fully loaded and right on the edge of the fire

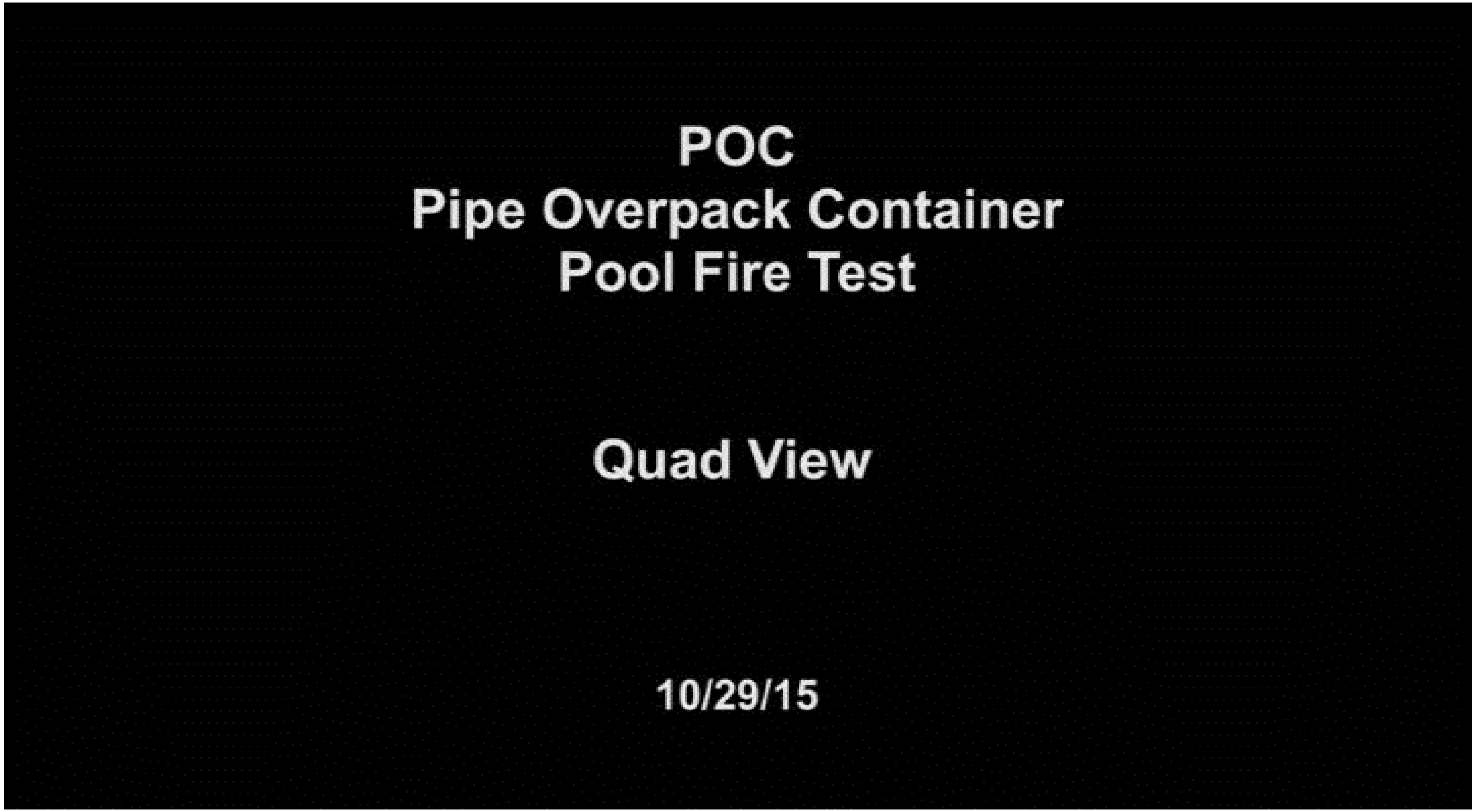
What about 7A drums inside the fire

- Results from POC drums inside the fire demonstrated that 7A drum lids would be ejected inside the fire
- DOE-STD-5506-2007 assumes, based on previous tests, 1/3 of contents are ejected
  (Aerosol Release Fraction (ARF) ~ 1e-3)

2015-2016 Test of POC/7As: Typical Test Setup

- POC drum inside fire loaded with typical combustibles on top level of stack at center of pool fire
- One or more POC or 7A drums loaded with typical combustibles set at some distance from edge of the fuel pool

POC inside the Fire and POC/7A Outside Fire



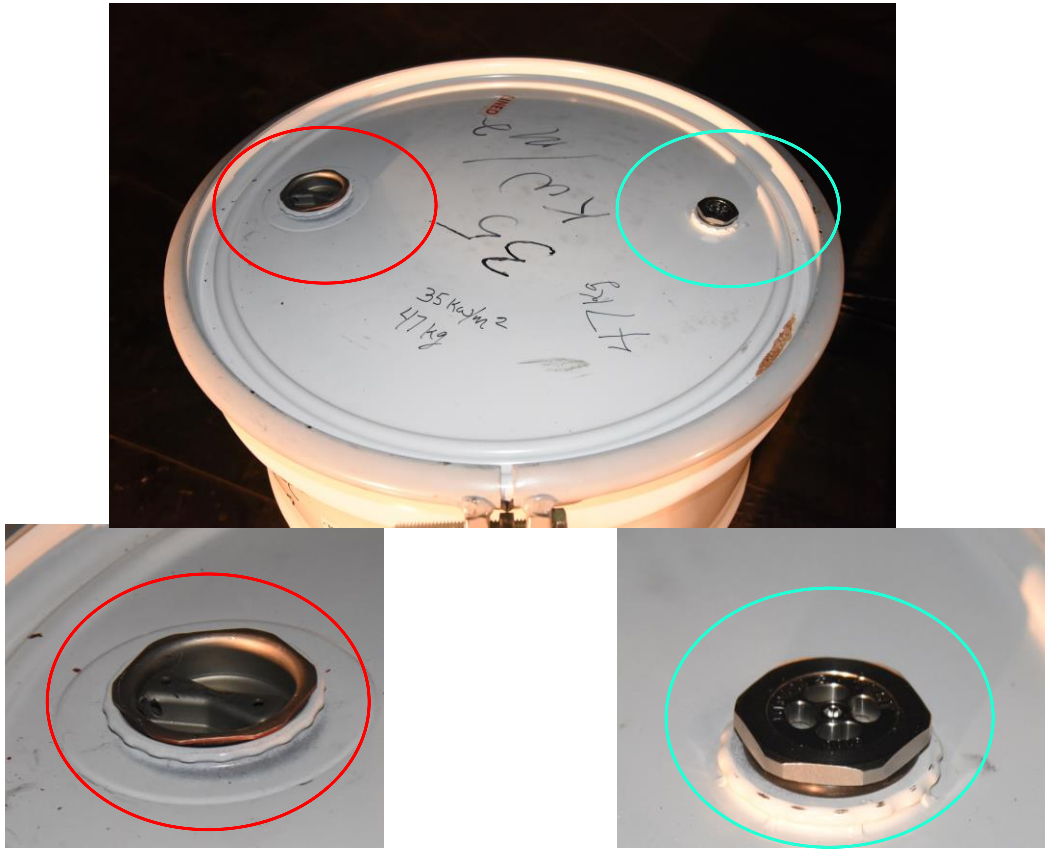
History of 7A Testing at Sandia <u>after 2017</u>

- Fitted POCs with Ultra Tech (UT) 9424S
- Post-2017 fire test campaign [SAND2018-6570] demonstrated that this new filter can be used as a passive design feature to yield a Damage Ratio = 0 for POC loaded with combustibles
  - 30 minute fully engulfing fire
- 7A drums using UT 9424S filters, and loaded with typical combustible materials, will not eject their lids during a 30-minute pool fire
  - Even when the 7A drum is fully engulfed for 30 minutes
  - However, the combustible materials burned inside the 7A drums – similar to a confined burn.
  - 1/3 of the contents was burned when 7A drum volume ¾ full

- With new filter, hypothesized ARF for a <u>7A **confined burn** could be orders of magnitude smaller than an **unconfined burn**.</u>
  - Area of release is much smaller when the lid stays on

2017 Test of 7As: Loading and Assembly

- 7As were loaded with typical combustibles: ~50% plastic and ~50% cellulose, by volume.
- UT 9424S filter was used along with a bung on drum lid



7A Inside the Fire

Summary of 2017 Pool Fire Studies on POCs/7As

- Test series documented in [SAND2018-6570].
- For drums (POCs or 7As) **equipped with a UT 9424S filter** and exposed to a 30-minute fully engulfing pool fire, the following sequence of events occurs:
  1. The plastic filter sleeve melts/softens;
  2. the filter pops off, opening up a ¾-inch diameter hole;
  3. the internal drum pressure is relieved through the ¾-inch diameter hole, and drum lid remains in place.

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

7A drum after 30-minute fully engulfing pool fire.

Summary Pool Fire Studies of 7As

- No lids ejected from loaded 7A drums placed at 35 kW/m^2, 45 kW/m^2 (part of another test in same test series), or center of pool fire.
- Combustibles burned inside 7A but were not ejected.
- 7A drum at 35 kW/m^2 saw negligible mass loss (image (a) below)
- 7A drum at 45 kW/m^2 saw a 2% mass loss
- 7A drum at center of pool fire lost approximately 27% of its initial mass (image (b) below)
    - **>2/3 of the material remained in drum (image (b))**

- **With new filter, 7A drum lid can be assumed to stay on**
    - **What is the ARF for a confined burn?**
    - **Current hypothesis is that ARF is lower than stated in DOE-STD-5506-2007**

(a)

(b)

Proposed 7A Test Series

Current Objective and Potential Impact

Technical Objective:

- Demonstrate that 7A drums with an Ultra Tech (UT) 9424S filter installed on the lid will **release less material** than currently assumed by DOE-STD-5506-2007 when the drum is loaded with typical combustible materials and exposed to pool fire thermal conditions.

- How? Use a aerosol collection system to capture all material release from a 7A drum
  - Main assumption: all aerosol material release from the drum filter hole is assumed respirable
  - Worse case drum load
  - Surrogate material is CeO_2 particles less than 1-micron in size (mean size ~0.6 microns)

Potential Impact and Benefits:

- With lower ARF values, current and future facilities would be able to eliminate the need to credit Safety Class and or Safety Significant SSCs / SACs, such as Fire Suppression System (FSS).
- Supports hierarchy of controls as defined in DOE-STD-3009
- Supports philosophy established in DOE-O-420.1C Facility Safety, DOE-STD-1189, Integration of Safety into the Design Process
- Can be used as “initial” condition for mitigated analysis
- ***Immediate and long term cost savings of millions of dollars to the complex***.

Approach to define ARF for a confined burn inside a 7A drum

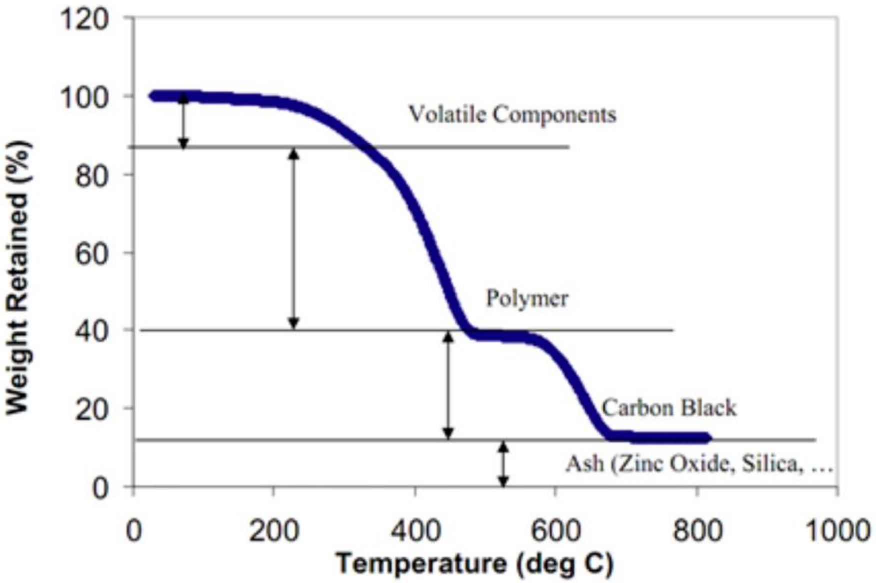
Four task over approximately three years

- Task 1: Determine what is the worse case load? – End of FY2019
  - Thermogravimetric Analysis (TGA)
- Task 2: Determine what are the conditions inside and outside the drum during the fire – End FY2019
  - Required to design the aerosol collection system
- Task 3: Design/Fabricate Aerosol Collection System and Radiant Heat Environment – F2019-2022
  - Small Scale Filter Testing – FY2019
  - Large Scale Radiant Heat Environment Benchmark Test – End of 2019
  - Aerosol Collection System Design phase – End of FY2020
  - Aerosol Collection System Benchmark Test - FY2020-2021
- Task 4: Final Matrix Tests to determine ARF – End of FY2021, possibly

Tasks broken down into two phases

- Understand the environment (Phase I)
- Design/Benchmark of Heat Environment/Aerosol Collection System and Execution of ARF Test (Phase II)

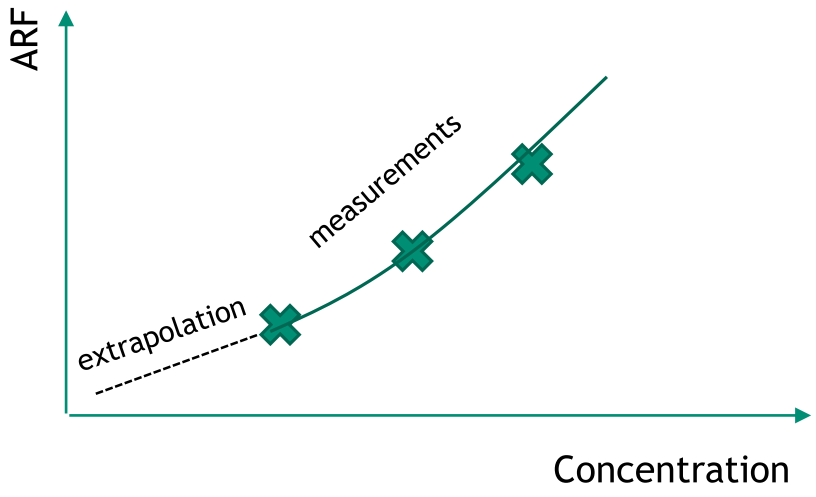
Thermogravimetric Analyzer



Phase I, Task I: Thermogravimetric Analysis (TGA)

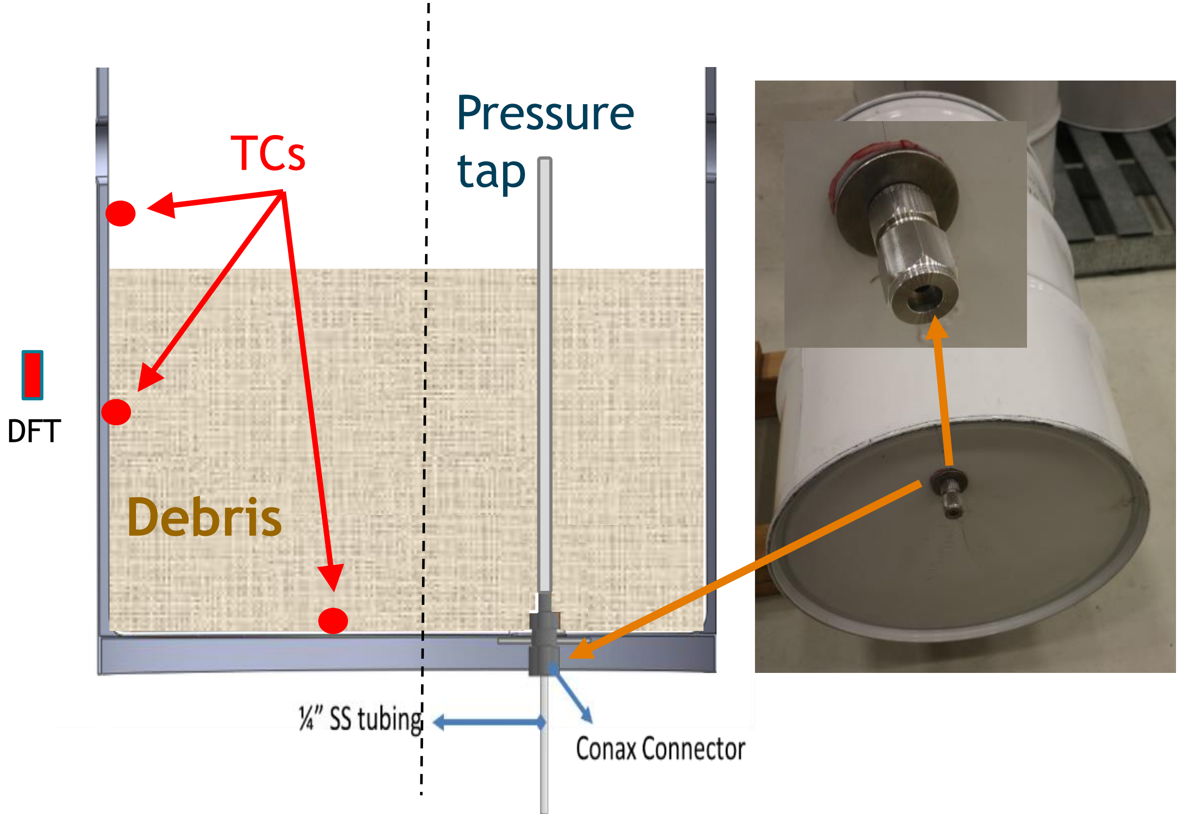
- TGA can help understand the importance of the drum configuration
  - Will using a powder substrate produce different results (for worst case scenario) than using a solid, layered substrate?
  - Different substrate forms of cellulose and plastic samples will be prepared for TGA
- A range of controlled heating rates can be applied to the substrates in a TGA
  - Heating rates can strongly influence the decomposition, so this would study any uncertainty experienced by materials as they are heated from the perimeter towards the center of the drum
- Gas environment can be controlled (Air vs inert gas)
- A limited range of controlled flow rates and static pressures can be used for the prescribed environment
- A range of CeO_2 concentrations can be studied in a TGA setup
  - TGA and/or post-TGA chemical analysis sensitivity is an issue

Proposed TGA test samples
Pure cellulose sample
Pure plastic sample
Powder cellulose with CeO_2
Powdered plastic with CeO_2
Solid, layered cellulose with CeO_2
Solid, layered plastic with CeO_2
Mixed cellulose/plastic with CeO_2



Phase 1, Task 2: Full-scale Pool Fire Tests on 7A drums

- 7As will be equipped with:
  1. **Pressure tap** above debris to determine pressure evolution during fire exposure and post test.
     - Prior tests on POCs have shown success with this method (see image on lower right hand side)
  2. **Directional Flame Thermometers (DFTs) and Thermocouples (TCs)** to determine heating rate of debris
     a) On the walls of the 7A (with insulation backing to measure heat flux)
  3. Pre- and post-test **mass balance**
- Combined results of Task 1 and Task 2 will inform Phase II.
- Data collected in Phase I can inform potential modeling efforts
  - Recorded pressure differential seen between the inside and outside the drum can help derive a velocity for gases exiting the filter orifice
  - Thermocouples can help identify the heating rates experienced by the debris inside the drum



Phase 2, Task 3: Design Heat Environment & Filter System

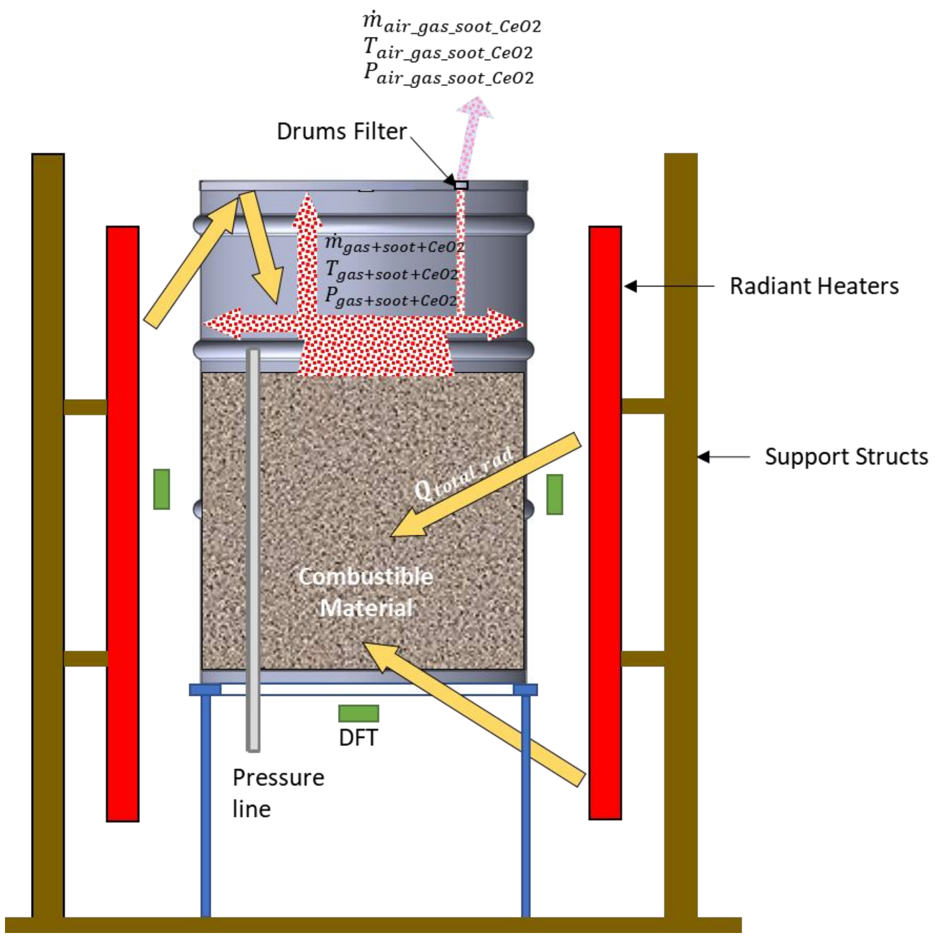
Need benchmark testing to determine performance of the aerosol collection system and heating environment

Small scale tests to understand filter performance, Task 3

- Understand filter loading under small scale conditions
  - Which material or which combination of materials load the filter more?
  - Do more iterations – Cost effective
- Understand chemical uncertainties associated with chemical analysis of material to extract ARF
  - Digestion of filter
  - Sampling method

Large scale test to examine the performance of the Radiant Heat System, Task 3

- Mimic fire environment
  - Measure heat flux, pressure, mass consumption and compare these against results obtained from fire test
  - Regulate the heat flux to sides and bottom of the drum to get same results
- High temperature can damage the collection filters
  - Measure maximum possible temperature filter can be subjected to



Phase 2, Task 3 and 4: Design Aerosol Collection System & Final ARF Tests

Small scale benchmark tests may not produce same results as larger scale test

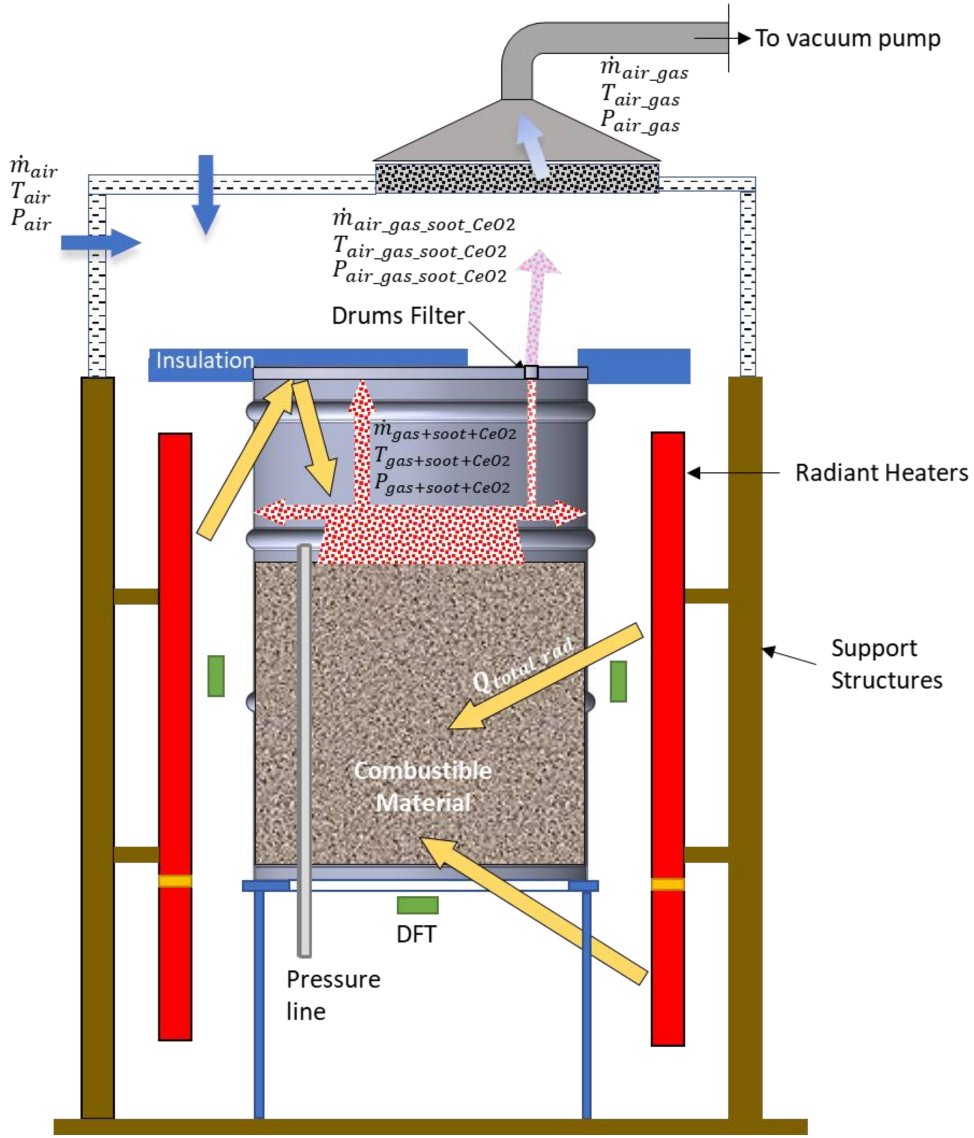
- Effect of large scale heating environment are not easily scaled down
- Expect more surface area, more deposition on drum inner walls

Large scale benchmark test are more costly than the small scale tests, Task 3

- Fewer tests (2)
- Needed to test conditions to make sure pressure differential and mass loss is close to the same as in the fire test with the collection system over the drum
  - Adjust air inflow to maintain pressure during loading
  - Adjust air temperature to protect the filter
- Understand filter digestion/sampling at larger scale
  - What does the chemical digestion of a large filter entail?
  - Perhaps do final adjustments to digestion/sampling procedure

Full-scale test matrix in Phase II, Task 4

- Based on TGA results, small- and large-scale benchmark test information



Questions?

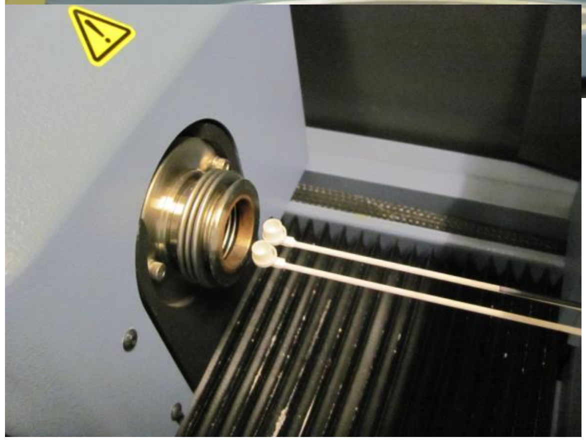
Backup Slides

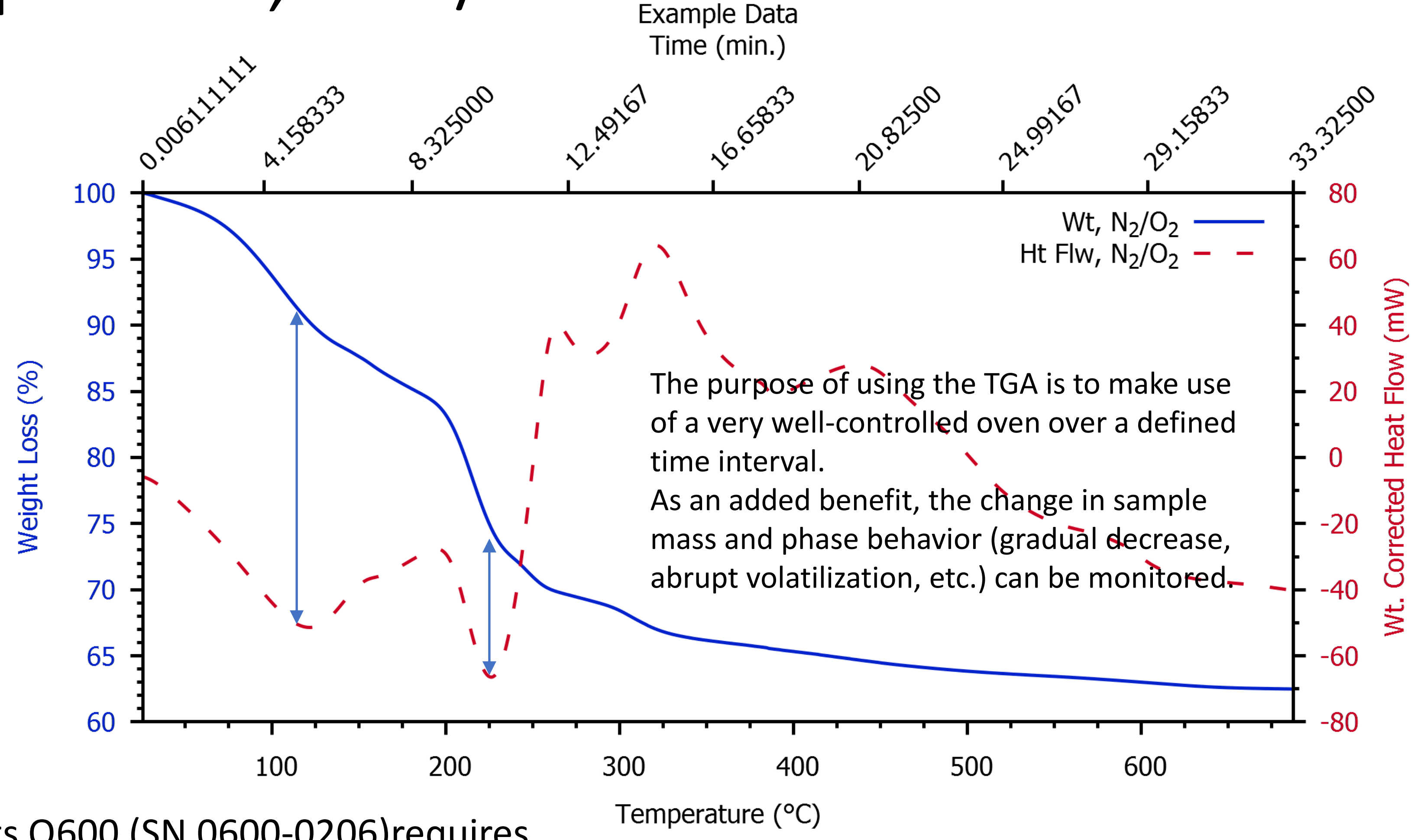
Risks

Medium Risk
High Risk

Phase FY	Initial Task	Purpose/Notes
Phase 1 2019	**TASK 1:** Perform TGA analysis of both cheesecloth and plastic bag-out bag	Determine factors that affect ARF Conditions represent extremes of free burning with full exothermic release and confined thermal decomposition with full endothermic release.
	Task 2: Full-scale pool fire tests on 7A drums	Determine parameters for designing aerosol collection system Three test
Phase 2 2019-2022	**Task 3:** Small and Large tests to assess performance of aerosol collection system	Test collection system that will provide quantitative release fraction Assembly of test setup Conduct 2-3 tests to understand system performance under bounding conditions
	Task 4: Full scale test to determine ARF	Determine the ARF under established conditions
	Task 5: **Documentation and Final Report**	Document final results to NSRD-NA

Thermogravimetric Analysis provides controlled ramp rates, exo/endothermic data

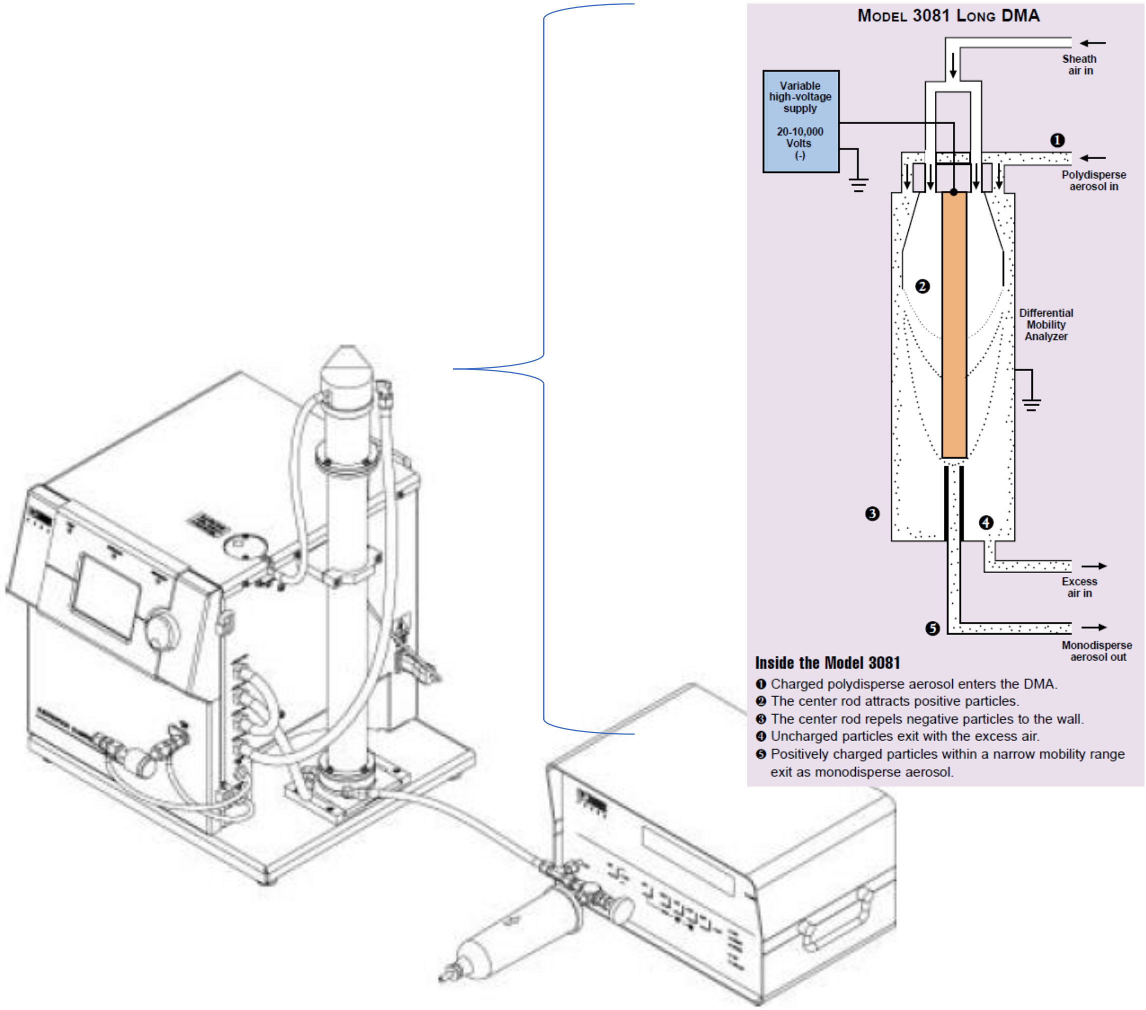




The purpose of using the TGA is to make use of a very well-controlled oven over a defined time interval.
As an added benefit, the change in sample mass and phase behavior (gradual decrease, abrupt volatilization, etc.) can be monitored.

TA Instruments Q600 (SN 0600-0206)requires 5-20 mg of material to monitor the change in mass while heating the sample.

The Scanning Mobility Particle Sizer (SMPS) can determine the size distribution of aerosol particulates



TSI, Inc. Scanning Mobility Particle Sizer (SMPS)

- The 3080 Long Differential Mobility Analyzer (DMA, SN 8152) separates particulates by charge over a biased column.
- Only particulates with the desired size range are able to pass through the exit aperture, where they are counted by the 3022A Condensation Particle Counter (SN 548).
- This configuration has a range from 10 to 1000 nm, with a maximum concentration of 10^8 pt/cm^3.