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LLNL-PROC-752234

Examination of Alternative Nuclear Filtration Materials using the Mini High Temperature Test Unit (mHTTU)

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June 1, 2018

International Nuclear Air Cleaning Conference (by ISNATT)
Charleston, SC, United States
June 3, 2018 through June 5, 2018

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ISNATT Nuclear Air Cleaning Conference

June 2018

LLNL Team: Dr. Lauren Finkenauer, Erik Brown, Dr. Jeff Haslam, Dr. James Kelly, Mark Mitchell
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Cal Poly Faculty: Dr. Hans Mayer, Dr. Peter Schuster, Dr. Scott Patton, Dr. Peter Schuster, Dr. James Widman, Dr. Eileen Rossman, Dr. Sarah Harding, Dr. Tom Mase, Dr. Joe Mellow, Dr. Andrew Davol

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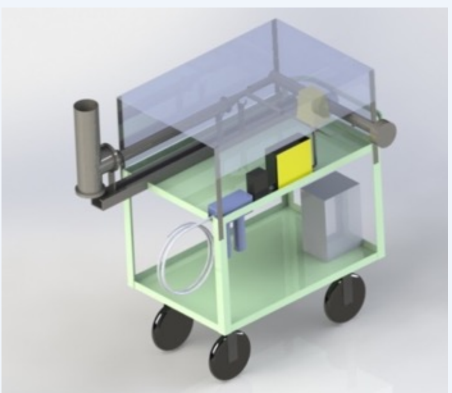
Lawrence Livermore National Laboratory

Presentation Outline

Introduction

Past Projects

mHTTU Design Evolution and Improvements



Present Efforts

Onsite Testing and Equipment Acquisition

Future Plans

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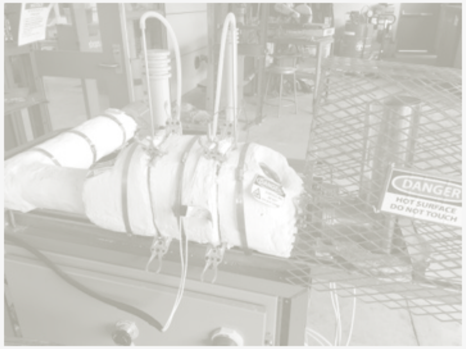

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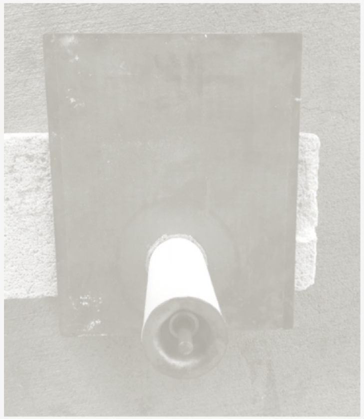

Acknowledgements

Mini High Temperature Testing Unit (mHTTU)
Capability Now Established at LLNL

- Presenting **culmination of effort** by several student projects on the mHTTU at the California Polytechnic State University at San Luis Obispo (Cal Poly)
- Test materials for HEPA filter components at temperature and airflow conditions including simulated catastrophic failure
- mHTTU test results will be used to down select the most promising materials for HEPA filter components (e.g. *filter media, sealants, gaskets*)
- Improvements and redesigns to mHTTU will be highlighted.
  - Greatly reduces flow leakage
  - Better heat retention in sample chamber (most notably at higher flow rates)
  - Operation through universal, straightforward GUI that is not operating system dependent

Equipment Evolution – Multi Year Story

High temperature testing and operations:

- Team Phoenix (Cal Poly)
- Team MicroFire (Cal Poly)
- Team Daedalus (Cal Poly)
- Independent student report (Cal Poly)
- K. Liu, H. Mayer (Cal Poly), L. Finkenauer (LLNL)
- L. Finkenauer, S. Lee (LLNL) – forthcoming testing of new materials

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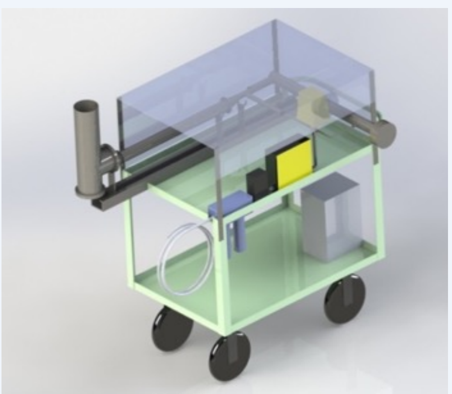

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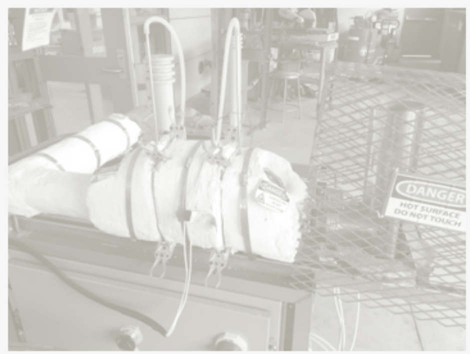

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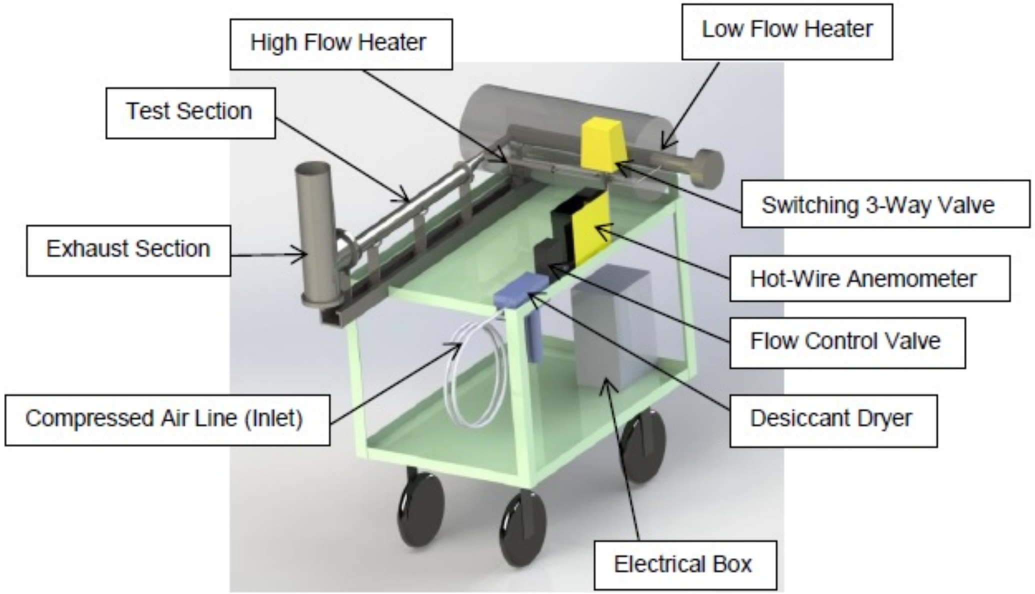
Project Background
Original High Temperature Testing Unit (HTTU)

- Full scale HTTU built at Cal Poly
  - 1000°F at 250ACFM
  - High power demand (480V, ~37.5kW)
  - Full scale filter testing capability
- Limitations
  - Operable locations
  - Infrastructure requirements
  - Time + $$$

mHTTU Team 1

Team Phoenix (Fall 2013 – Spring 2014)

- Needed: faster testing
  - Rapid testing of multiple materials for down select (sealants, gaskets, filter media)
- Solution: smaller HTTU
  - Rapid sample change out
  - Easier access for testing
    - Designed around lower flow rates
    - Increased operating temperature
    - Reduced power requirements
    - Increased portability
  - Faster warm up
  - Intuitive control scheme



Design Specifications and Considerations

Primary Specifications

Primary Specifications	Target
Operating Temperature (°C)	538
Time to Operating Temperature (min)	15
Test Section Flow Rate (ACFM)	1.25 – 12
Maintain Flow With Test Section Pressure Drop (Pa)	120 – 3000

Mini-HTTU developed around low flow, enabling it to **utilize standard compressed air and 240 V**

- Design operating temperature higher than CFAST modeling of typical conditions (LLNL-CONF-698278, *Temperature-Time Curves for Real Compartment-Fire Conditions,* Kazem Mohammad)
- Good insulation, overpowered heaters and minimal metal → fast warm-up times and rapid, efficient tests
- Low-flow inline heater created by using element designed for stagnant fluids in a tube
- Dual heater design originally selected to achieve range of flow rates

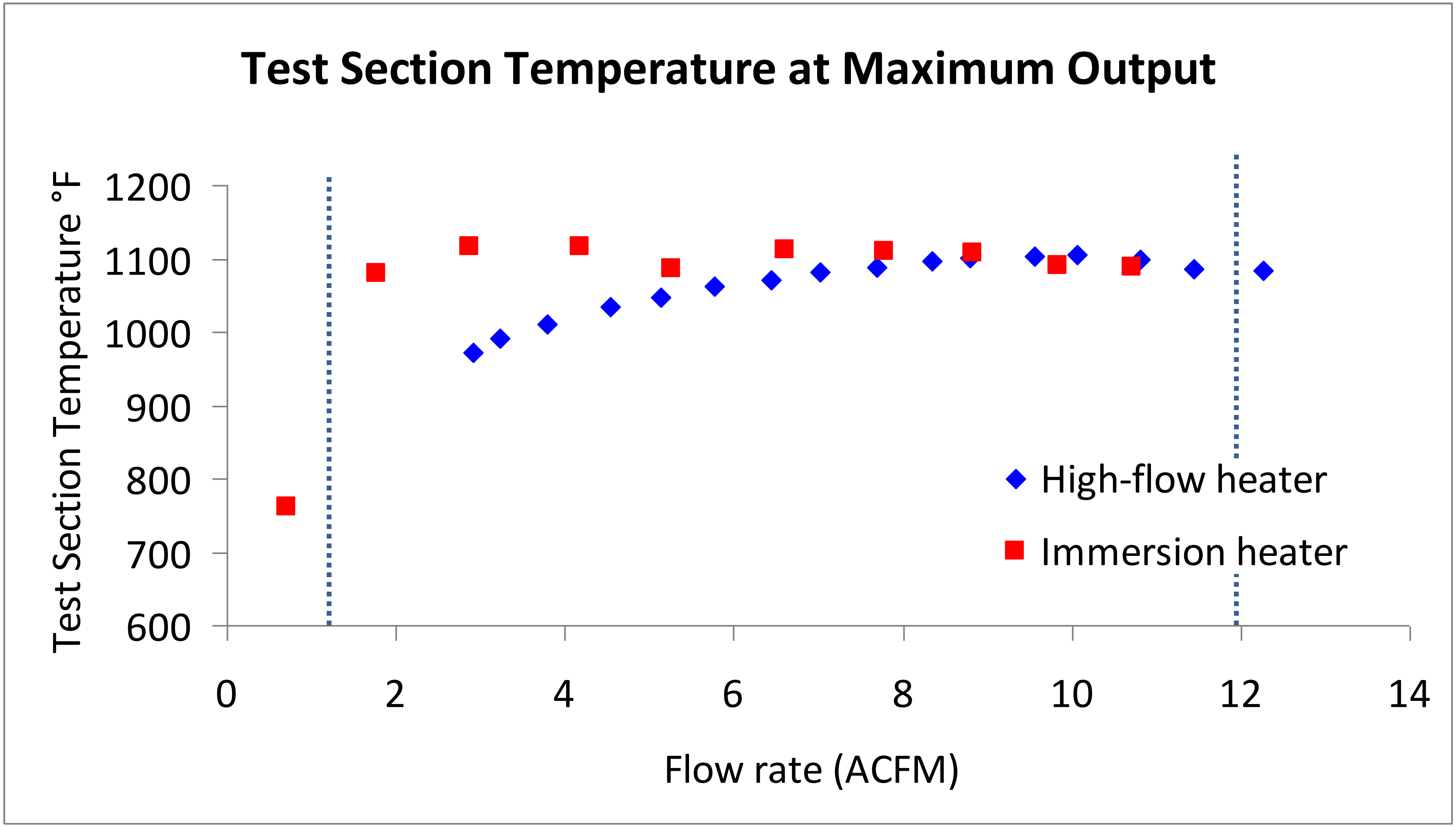
Design Specifications and Considerations

Additional Considerations

Mount to movable cart	√
Flow, temperature, and pressure readouts for operator feedback	√
Adherence to safety codes (ASME, OSHA, IEEE)	√
Digital capability for integration to control system	√
Debris catch in case of filter failure	√
Integration with a universal test section	√
Safe surface temperature	√

Team Phoenix Results

Final Design Testing



Team Phoenix Results

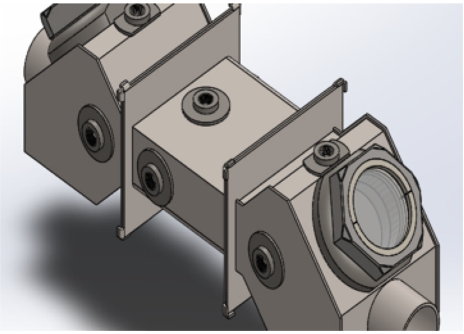
Conclusions, Recommendations

- mHTTU max temperature exceeded R&D testing requirements
  - Max achieved 602°C (1116°F), exceeding max temperatures of two independent fire modeling studies by 100°
- Time to temperature just 12 minutes
  - Dramatic improvement from HTTU
- Able to maintain temperature across flow range of 6E-4 ACMS (1.25 ACFM) to 6E-3 ACMS (12 ACFM)

mHTTU Team 2

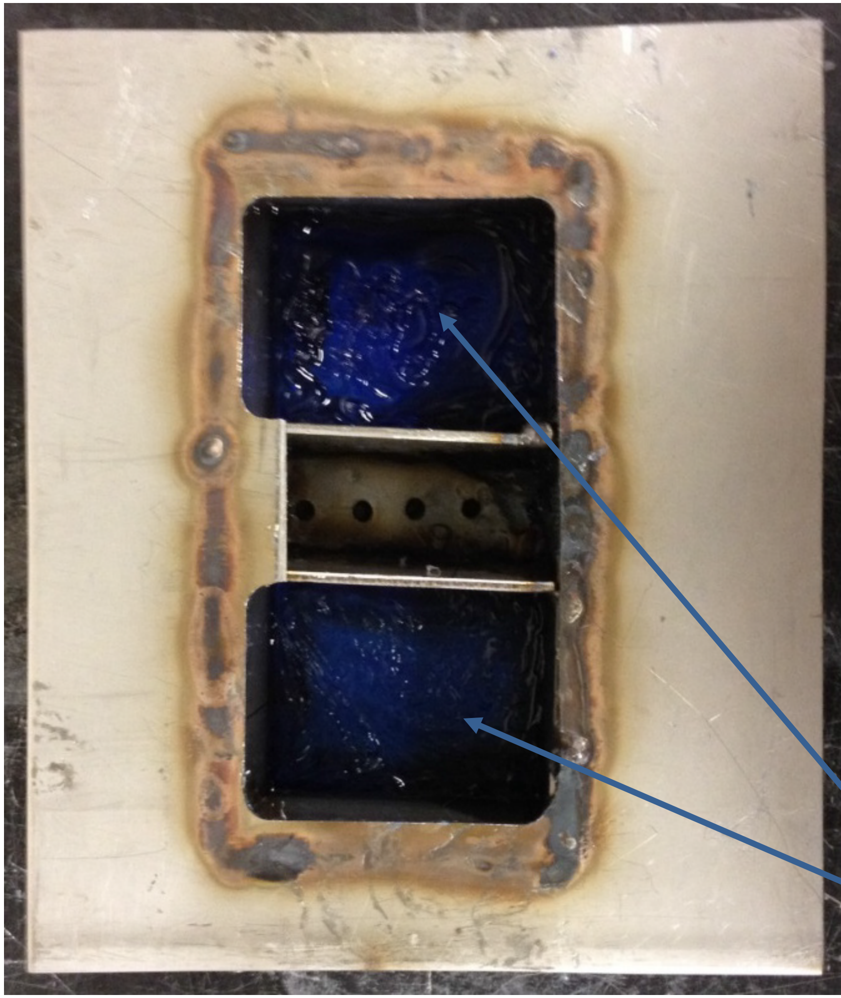
Team MicroFire (January 2014)

- Began work to design and incorporate test section into mHTTU and perform measurements on sealants and gaskets
- Accomplishments
  - Built and integrated the test section
  - Quick-release clamps and modularity achieved rapid change out capability
  - Initial static high temperature tests on sample materials
- Consequently reduced operating temperature from 602°C to 400°C

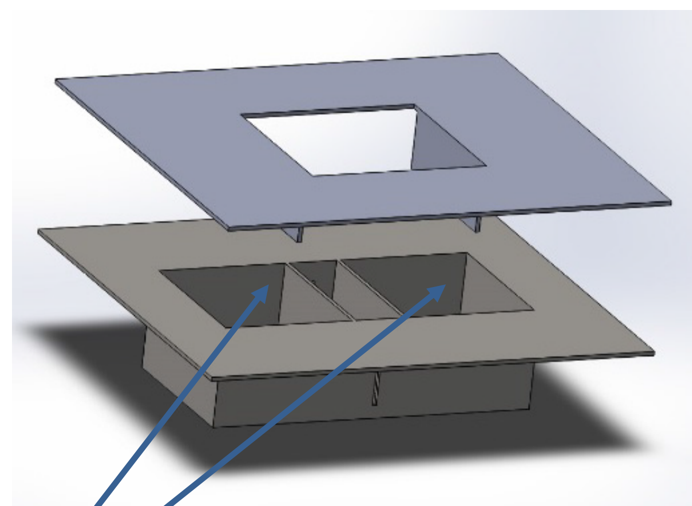


Team MicroFire

External Sealant Test Fixture



- Open chamber design allowed for range of insertable test fixtures
  - Example: plate for testing clean release of "external sealants"

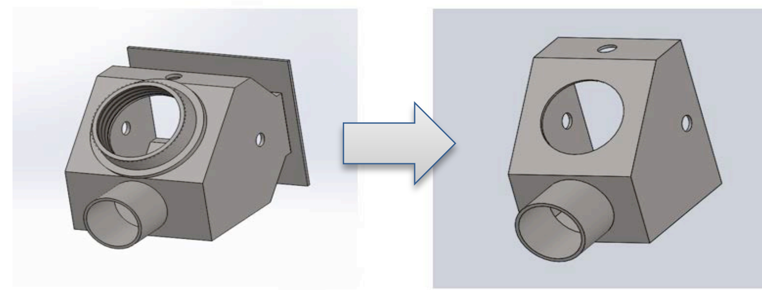


Sealant

mHTTU Team 3

Team Daedalus (Spring 2017)

- Redesigned sample test chamber to reach target temperature of 1000°F
  - Minimized thermal mass of test chamber
  - Increased external insulation
  - Updated test fixtures of the mHTTU
- Developed robust control system
  - Capability to change parameters of testing routine dynamically
  - Open source software: University of Basel based Python
    - Instrumentation and control system using Intrumentino, Controlino
- Electrical system professionally rebuilt



Current Mass: 7.25 lb

New Mass: 3.47 lb

Team Daedalus

Conclusions and Recommendations

- Test fixtures needed refining
- Heat loss greater than estimated
  - Unused heater acted as pin-fin heat sink when off
  - Immersion heater performance exceeded expectations
  - High-flow heater not needed, could be removed
    - Shorten flow path to reduce heat losses
  - Refractory insulation inadequate
  - Rudimentary control system

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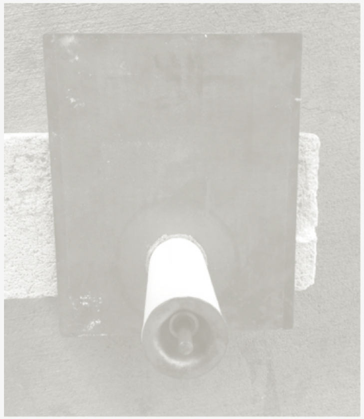


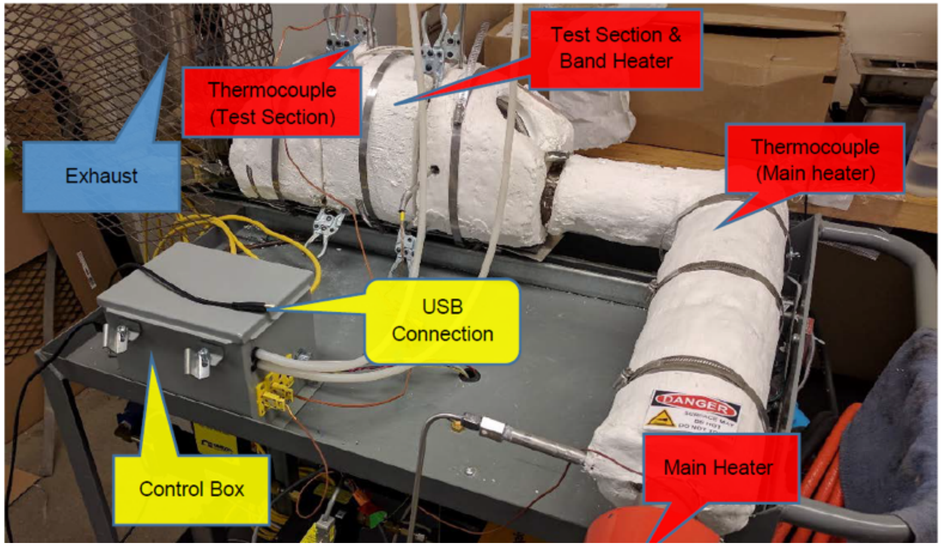
Acknowledgements

mHTTU Final Version – K. Liu, Dr. H. Mayer (Cal Poly)

- Achieved repeated, stable operations at > 900°F (up to 500°C)
  - Revamped internal insulation
  - Redesign of control GUI
- Detailed mHTTU User Manual
- Initial proof-of-concept testing on high temperature materials

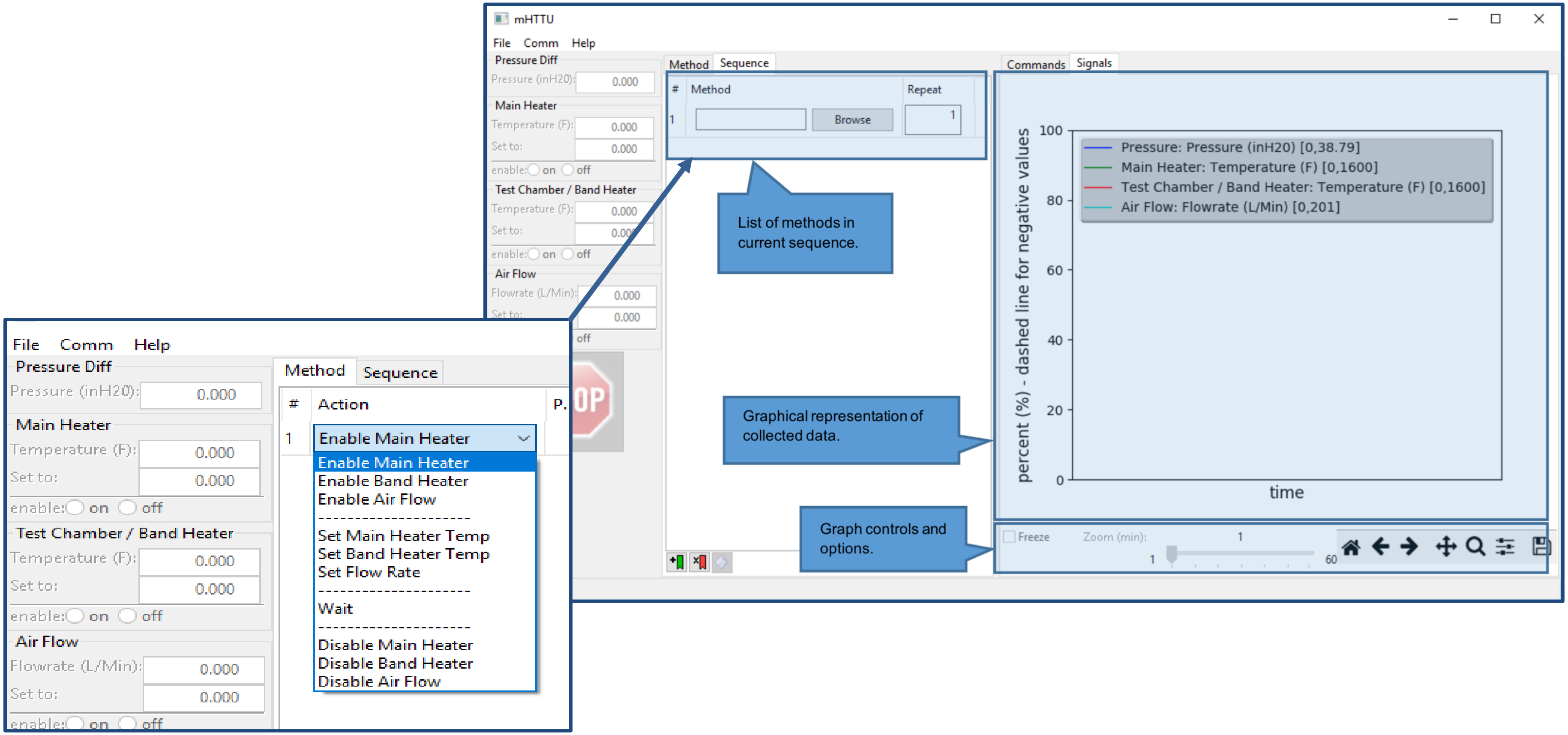
Text Box Key

Color/Shape	Type
Yellow	Electrical Components
Red	Heating/High Temp Components
Blue	Gas Delivery Components
Rounded Box	For User Use (Adjustments/ Connections)
Square Box	For Descriptive Purposes



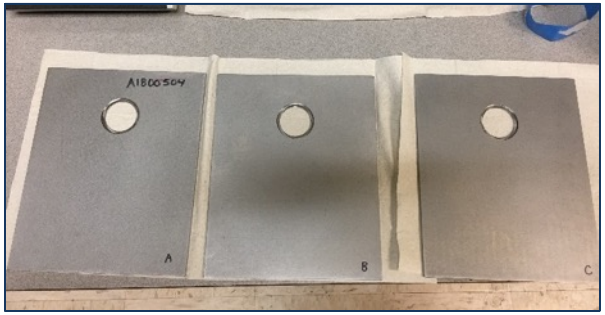
mHTTU Final Version – K. Liu, Dr. H. Mayer (Cal Poly)

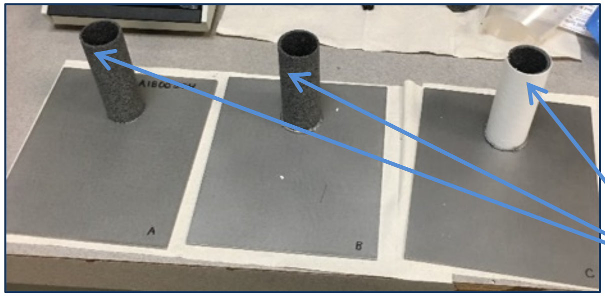
- Example of GUI Interface

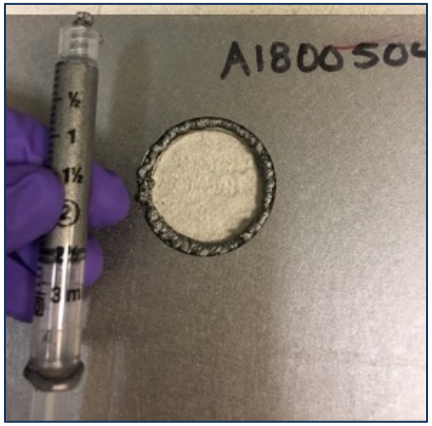


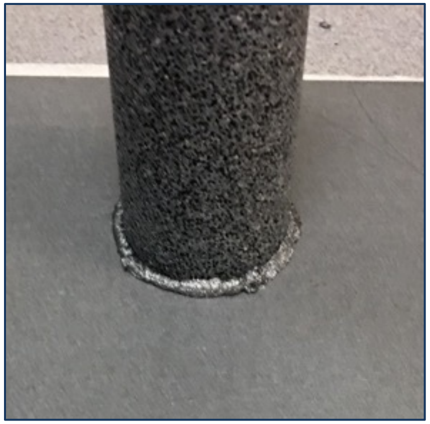
Proof-of-Concept Testing: Ceramic Filter Tubes

- High temperature sealant applied directly to stainless steel plates mounting fixtures
  - Ceramic “prefilter” tubes (left 2 samples)
  - Tube wrapped with filter media (right sample)





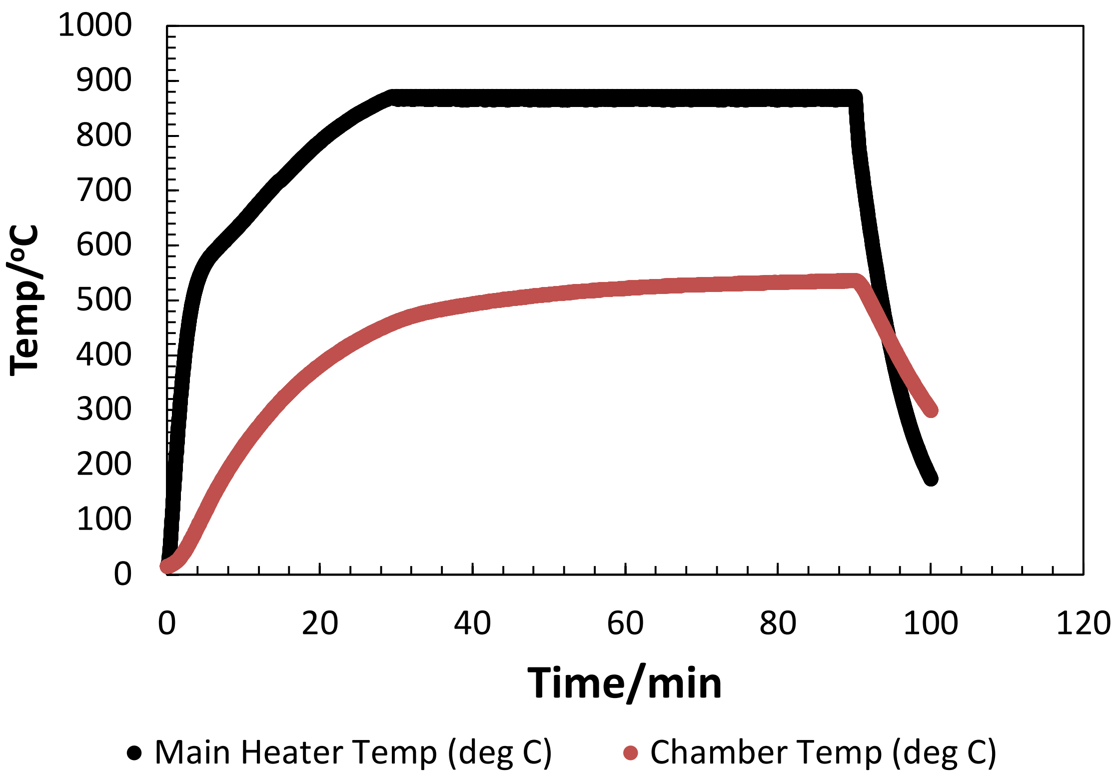




Endcaps (not shown) were also bonded

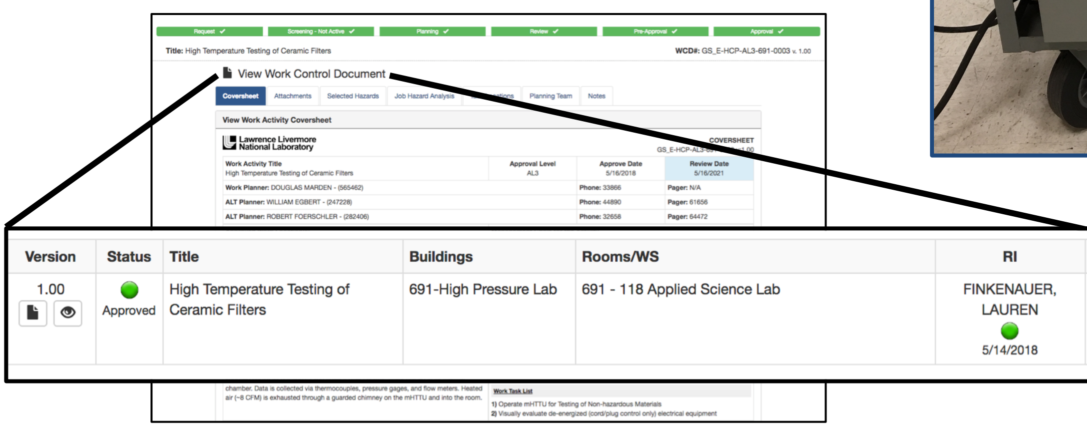
Example mHTTU Test (Single Ceramic Tube)

- Promising performance of mHTTU
  - Chamber temperature (thus sample temperature) reaches 500°C target



mHTTU Capability Now Established at LLNL

- Retrieved equipment from Cal Poly after student projects concluded
- Successfully passed LLNL inspection, operational onsite (May 2018)


Title: High Temperature Testing of Ceramic Filters

WCD#: GS_E-HCP-AL3-691-0003 v. 1.00

View Work Control Document

Version	Status	Title	Buildings	Rooms/WS	RI
1.00	Approved	High Temperature Testing of Ceramic Filters	691-High Pressure Lab	691 - 118 Applied Science Lab	FINKENAUER, LAUREN 5/14/2018

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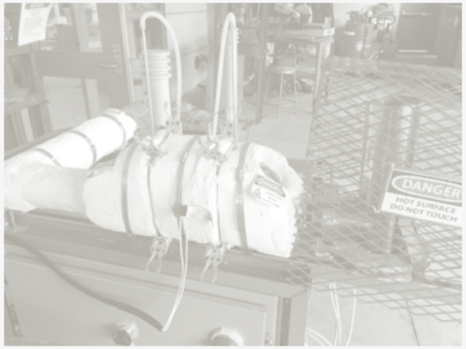

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Big Picture: Alternative Nuclear Filter Materials

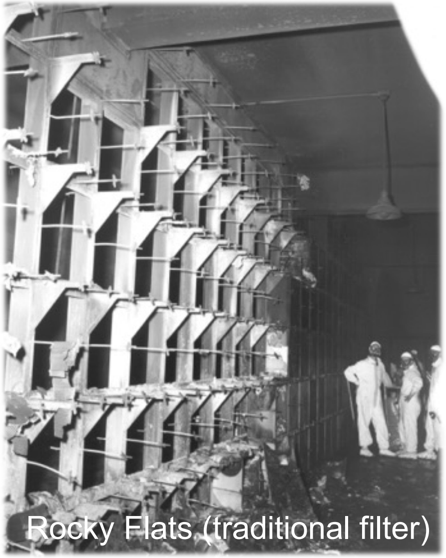
Technical Objective

- Develop and deploy advances in HEPA filter technology to benefit DOE nuclear facilities by providing lower life-cycle costs and safety basis costs
  - Ceramic HEPA filters will have better resistance to damaging factors such as heat, flame, moisture, corrosion, and loading
- Must evaluate every aspect of ceramic filter construction to identify and improve potential weak points in barrier between radiological material and public
- Temperature Goal: 500^{o}C (932^{o}F)
  - Based on CFAST modeling of nuclear facility fire conditions
  - LLNL-CONF-698278, *Temperature-Time Curves for Real Compartment-Fire Conditions*

Improving Nuclear Facility Safety During Fires

- Need capability to evaluate at high temperatures how:
  - Filter seals with ventilation system via external sealants and gaskets
  - Filter internal components (e.g., media, ceramic substrate) seals with steel housing of filter via internal sealants
    - Sealant bonding ceramic to stainless steel
    - Impact of filter media on sealant bond to stainless steel
    - Improved design for sealant application
  - Filter internal components survive

Rocky Flats (high temp filter)



Rocky Flats (traditional filter)

Conclusions

- Culmination of student efforts has produced a temperature test unit that can rapidly, efficiently, and inexpensively evaluate a large number of new and innovative materials for HEPA filter components
- mHTTU capability now at LLNL and operational
- Research will continue towards improvement of DOE nuclear facility safety and reduction of filtration life-cycle costs

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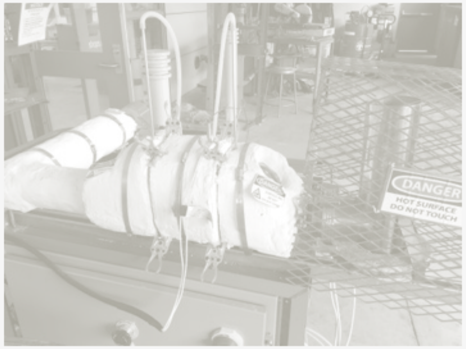

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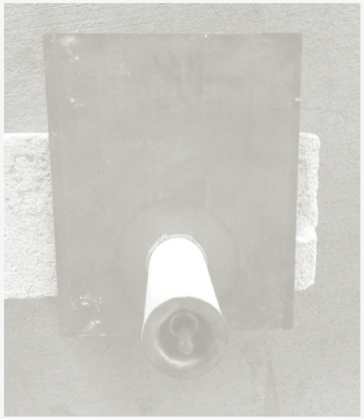

Acknowledgements

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