An Application of the Fire Propagation Apparatus to the Measurement of Fire Toxicity

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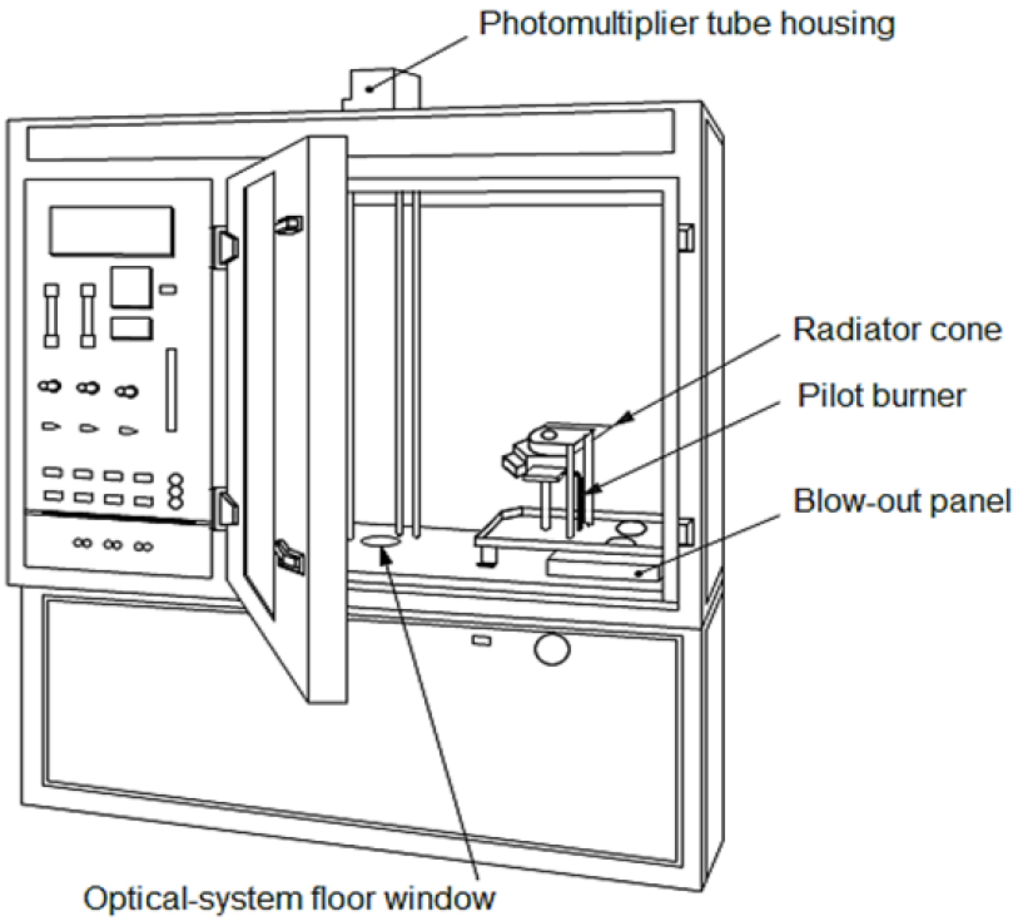
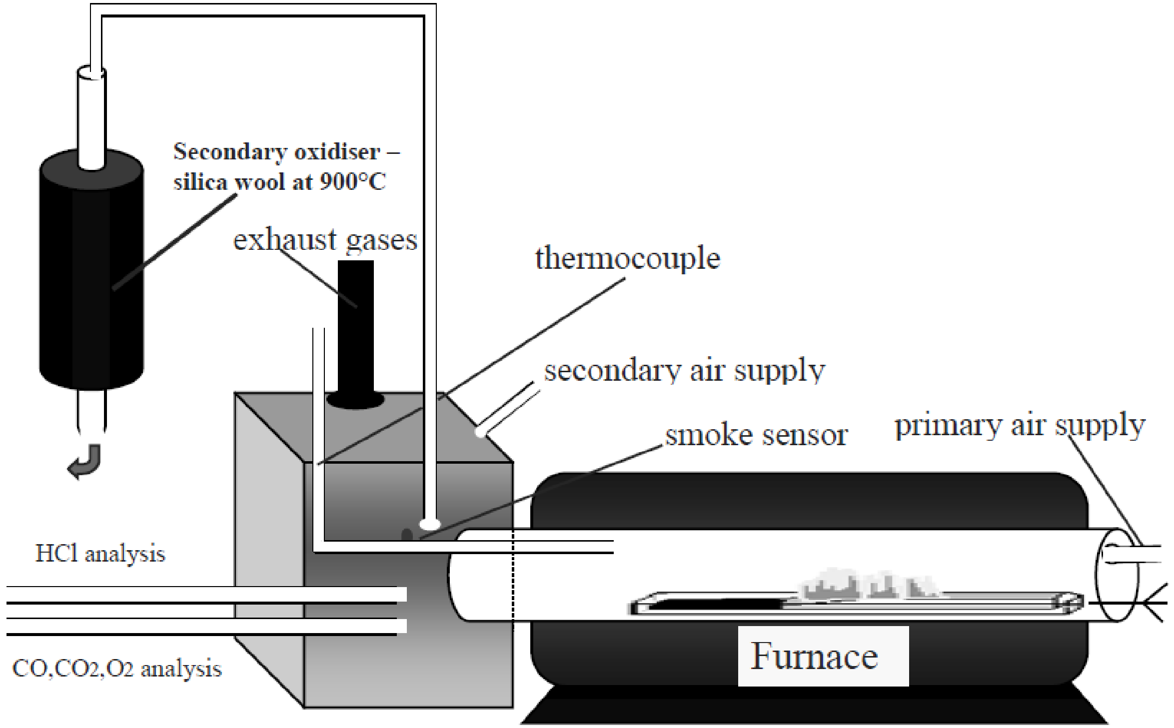
Traditional Approaches To Characterization of Fire Effluent at Bench Scale

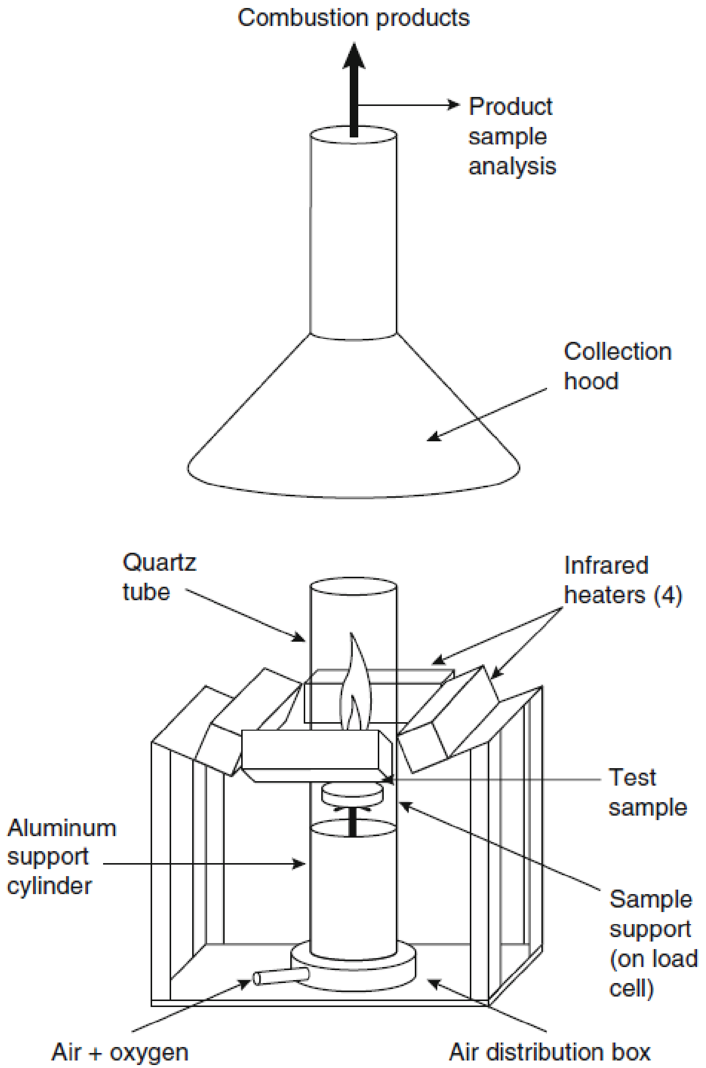
NBS Smoke Density Chamber



Purser Furnace



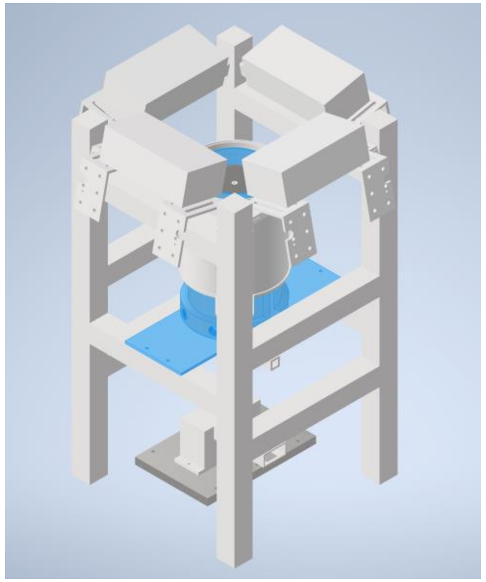
Fire Propagation Apparatus (FPA)

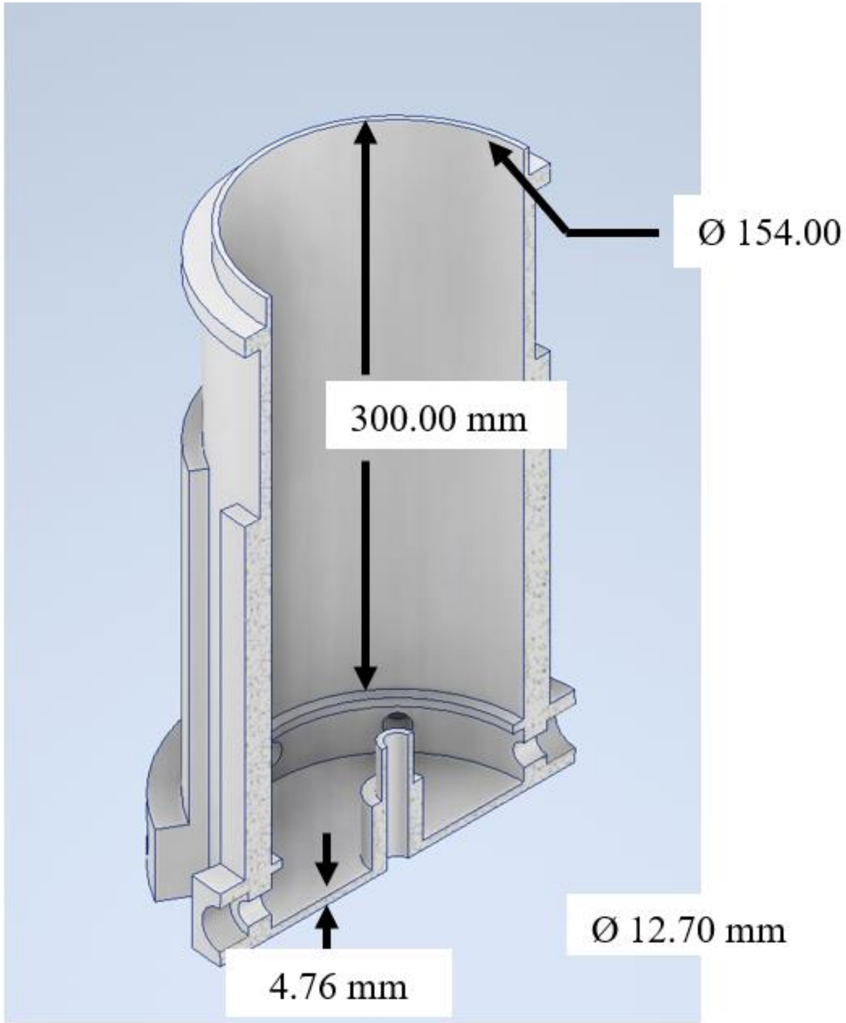


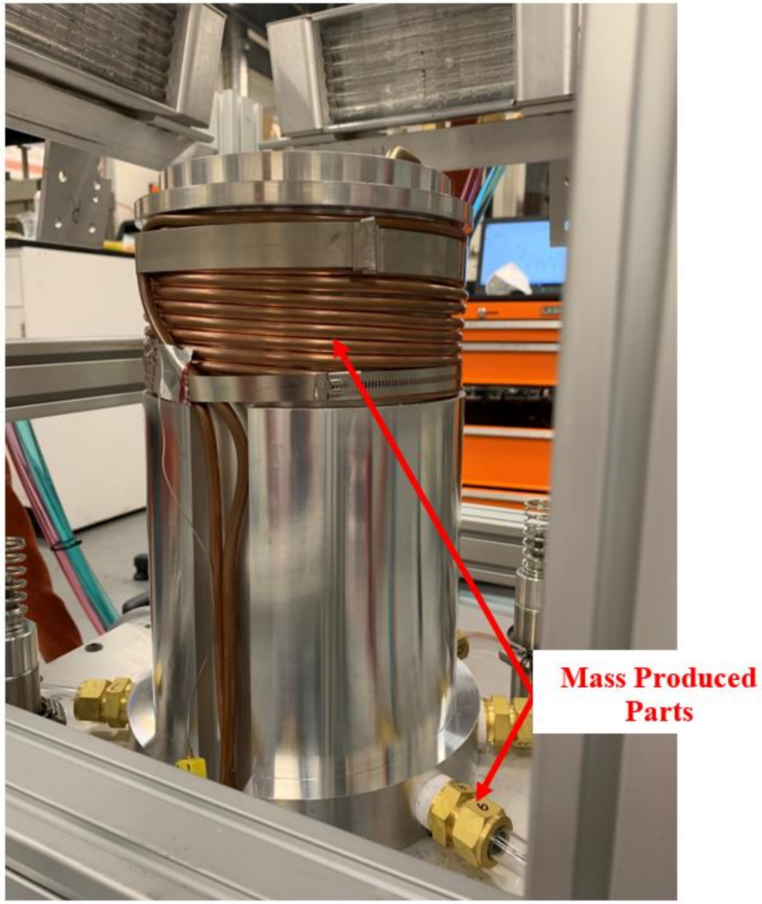
- Large flames can be studied in controlled oxidizer flow with no/minimal recirculation
- Optical access
- Fire effluent is highly diluted with cold air to "freeze" composition and facilitate gas analysis
- Control of the equivalence ratio, φ, is achievable

$$\varphi = \frac{\dot{m}_F}{(Y_{O_2,in}\dot{m}_{in})} \Big/ \left(\frac{m_F}{m_{O_2}}\right)_{stoic}$$

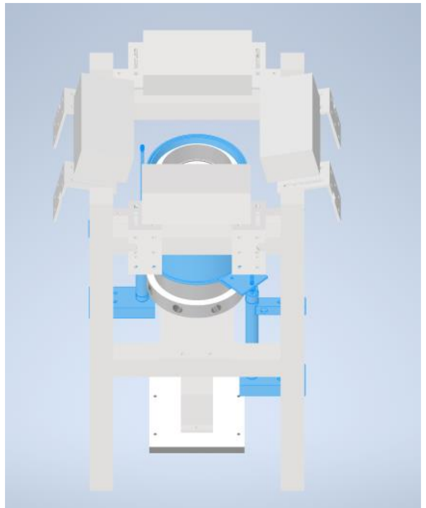
FPA Air Distribution Chamber

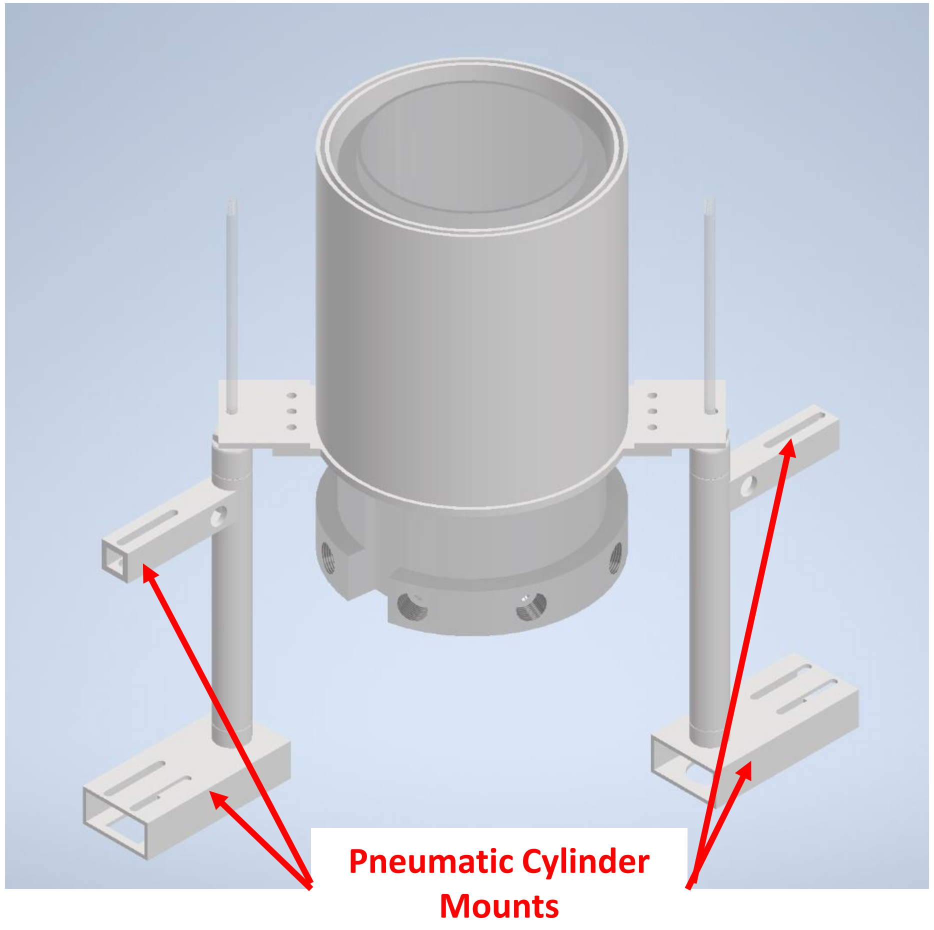


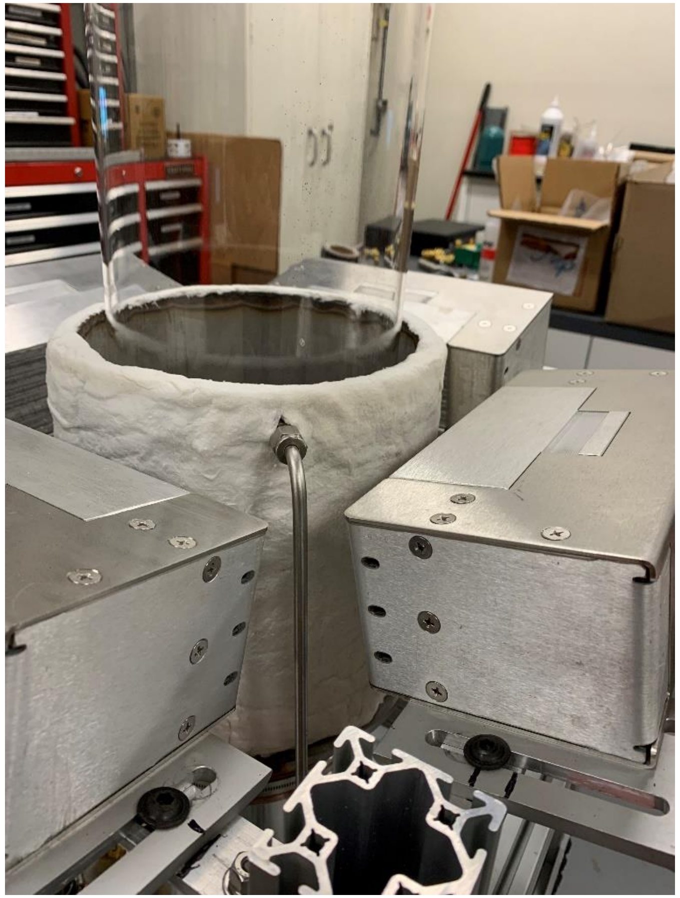




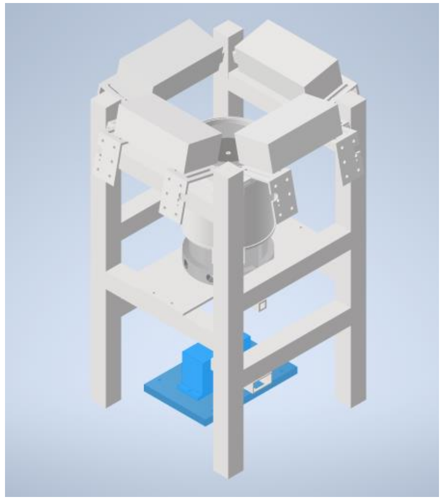
FPA Water-cooled Shield

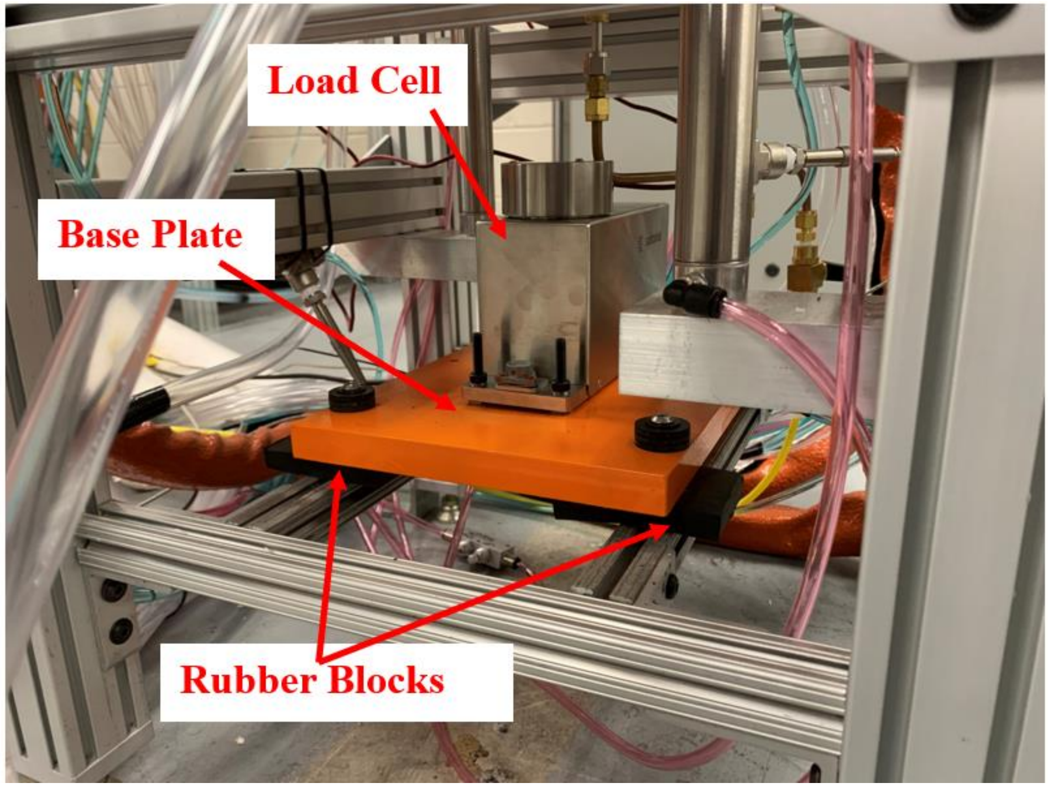






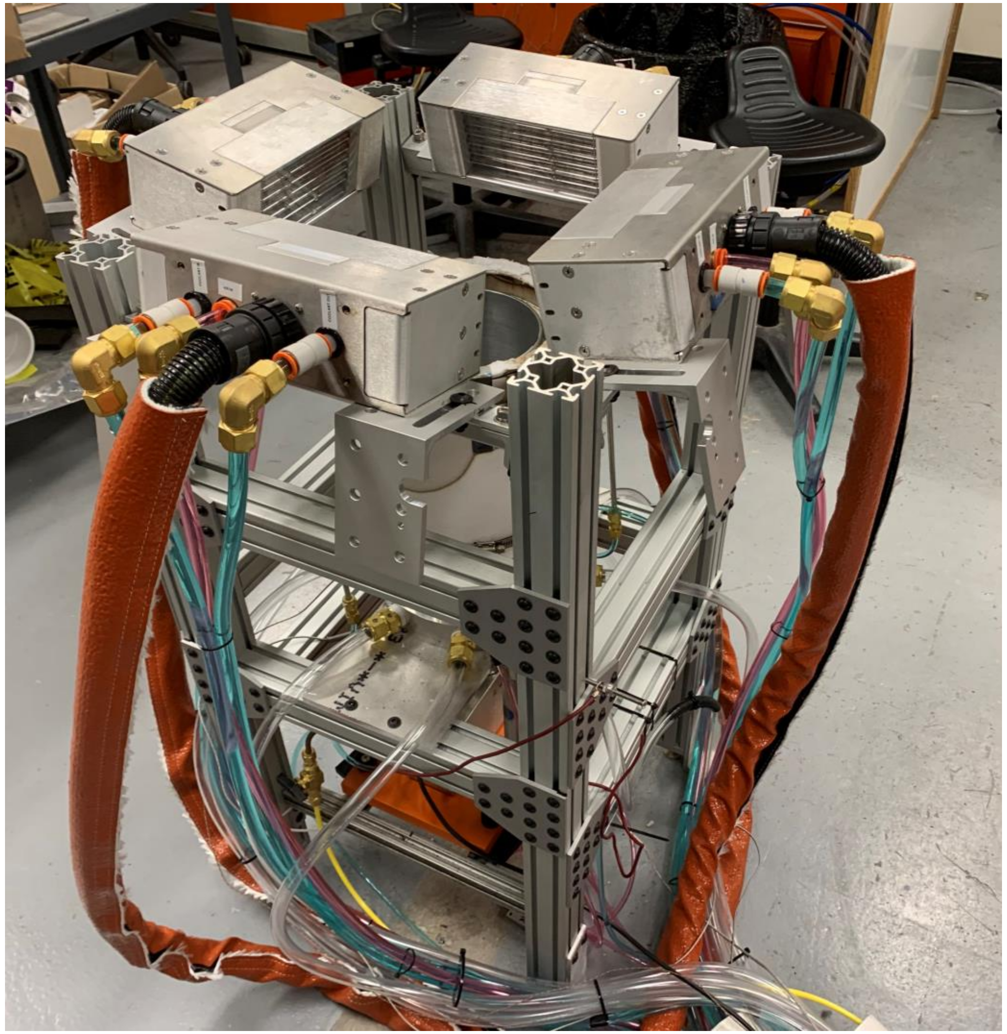
FPA Load Cell



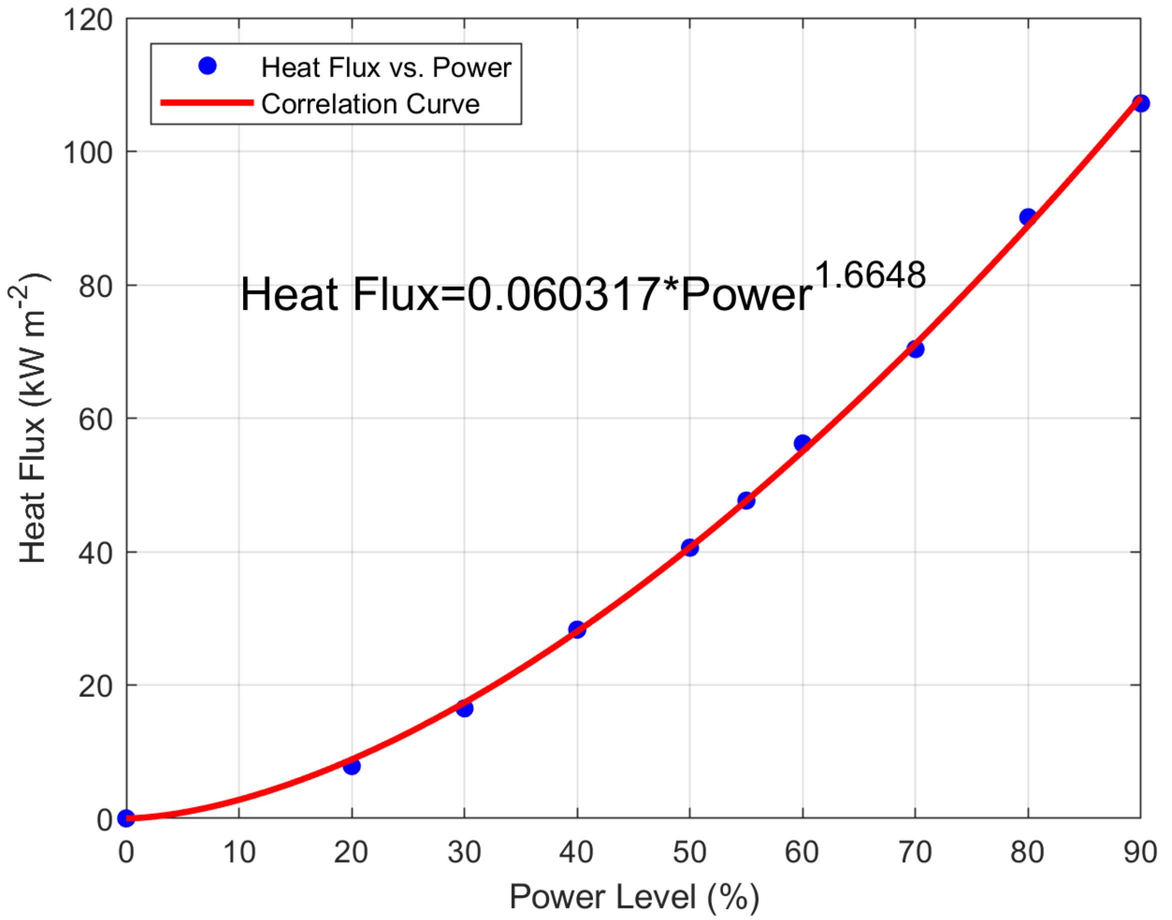


- Sartorius WZA8202-N
  - 0.01 g resolution
  - 8200 g capacity
  - 5 Hz sampling rate
- Mounting plate
  - Material: Steel
  - Mass: 9.21 kg
  - Dimensions:
    - 19.05 mm thick
    - 203.20 mm x 304.80 mm
  - Four 50.80 mm x 50.80 mm x 13.00 mm rubber block isolate the load cell from the frame

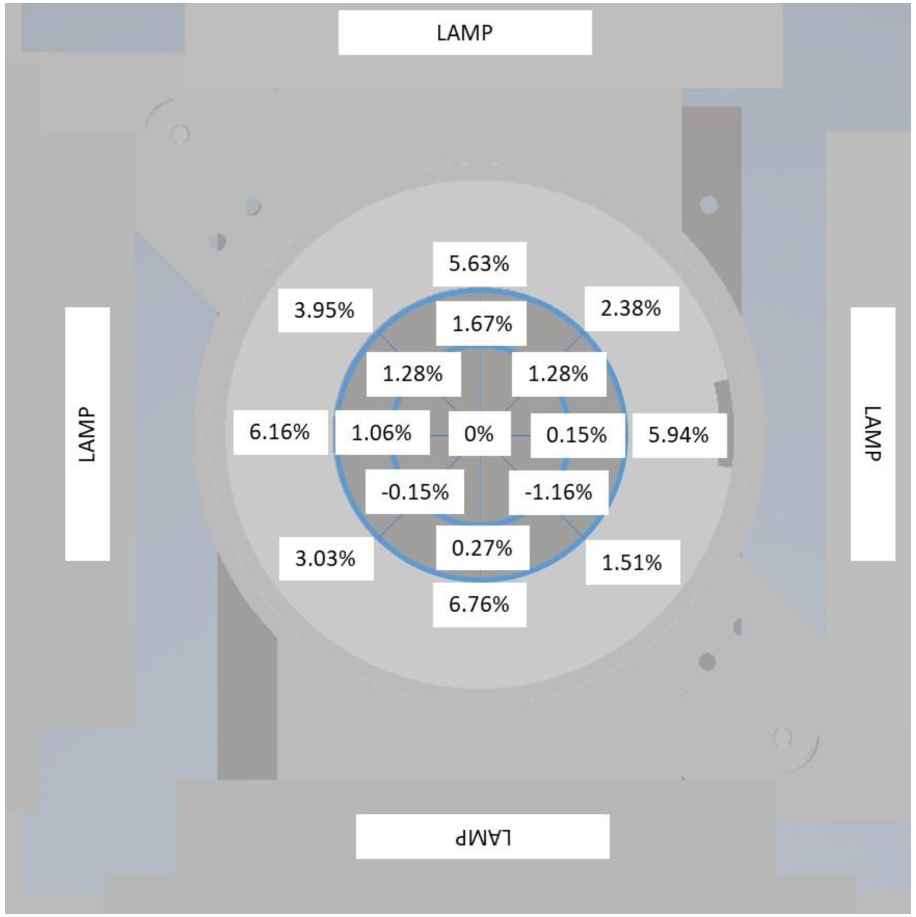
FPA Base Characterization and Performance Comparison

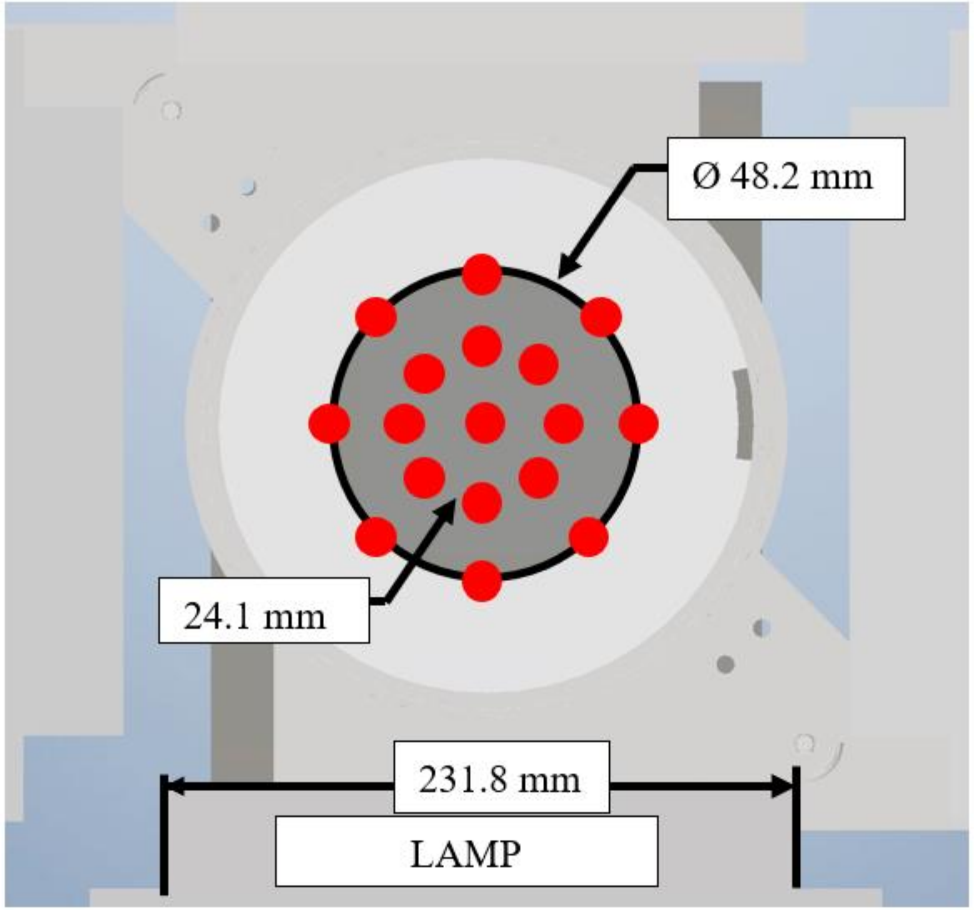


FPA Heat Flux Range



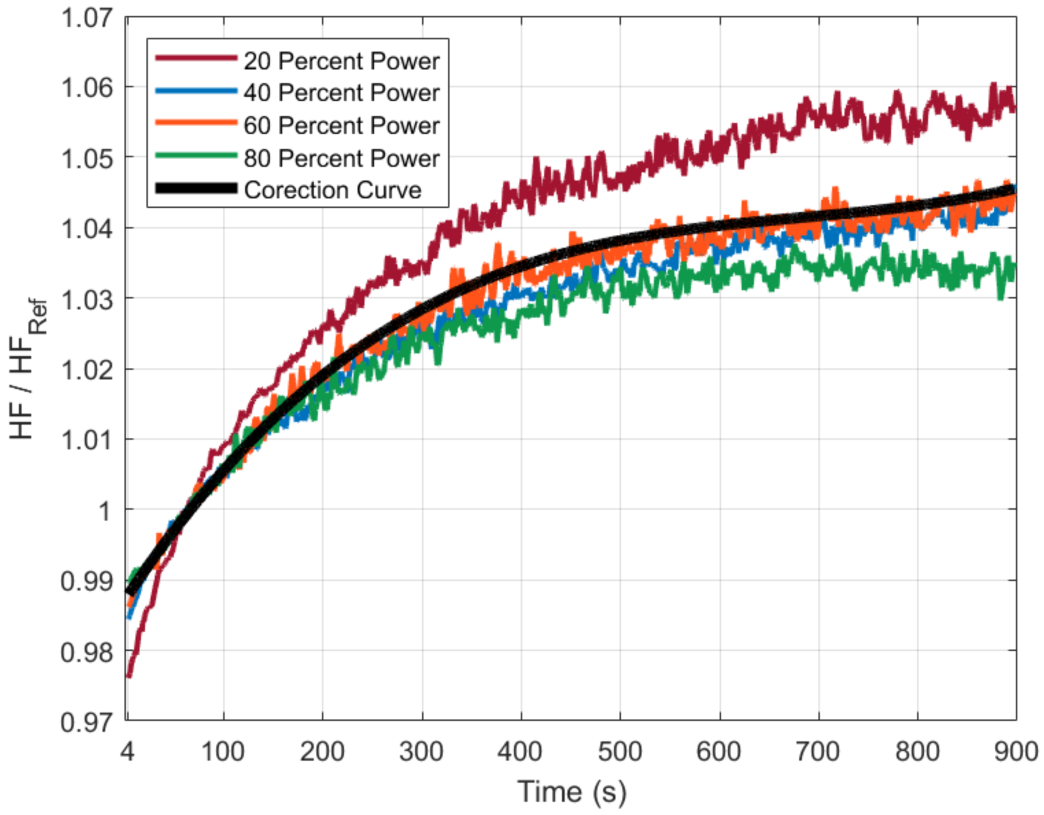
FPA Heat Flux Spatial Uniformity





Represents gauge location

FPA Heat Flux Time Drift



- Heat flux drift is characterized by

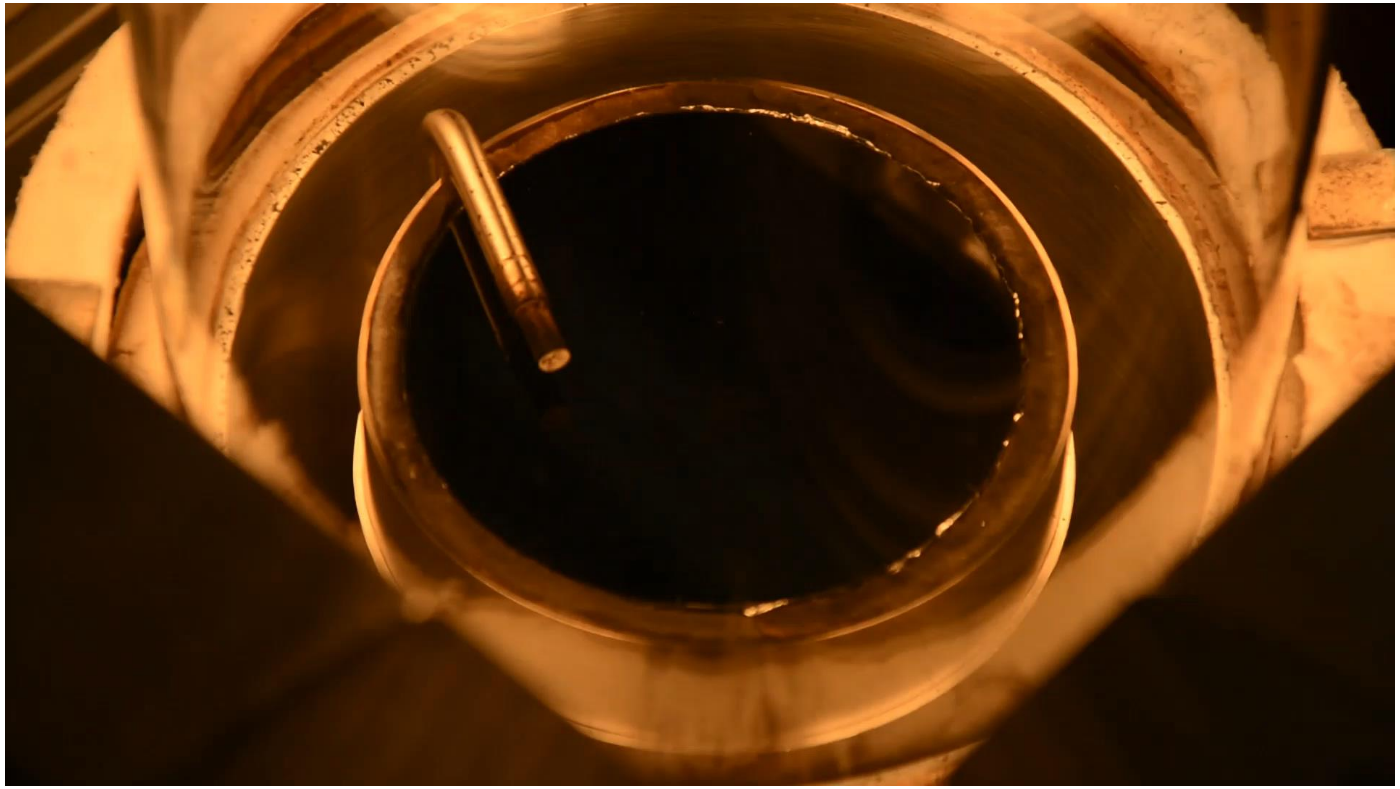
$$HF = HF_{Ref} * \left(1.415 \times 10^{-10} * t^3 - 2.893 \times 10^{-7} * t^2 + 2.099 \times 10^{-4} * t + 0.9879 \right)$$

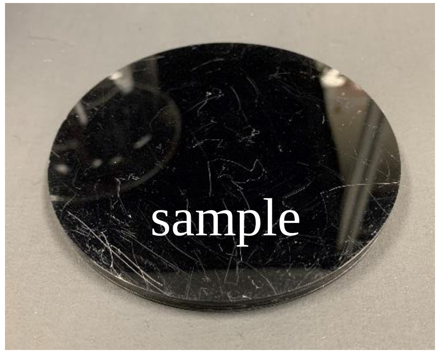
HF_{Ref} is the average heat flux from 45 to 75 seconds

t is the time in seconds since the water-cooled outer shield was dropped

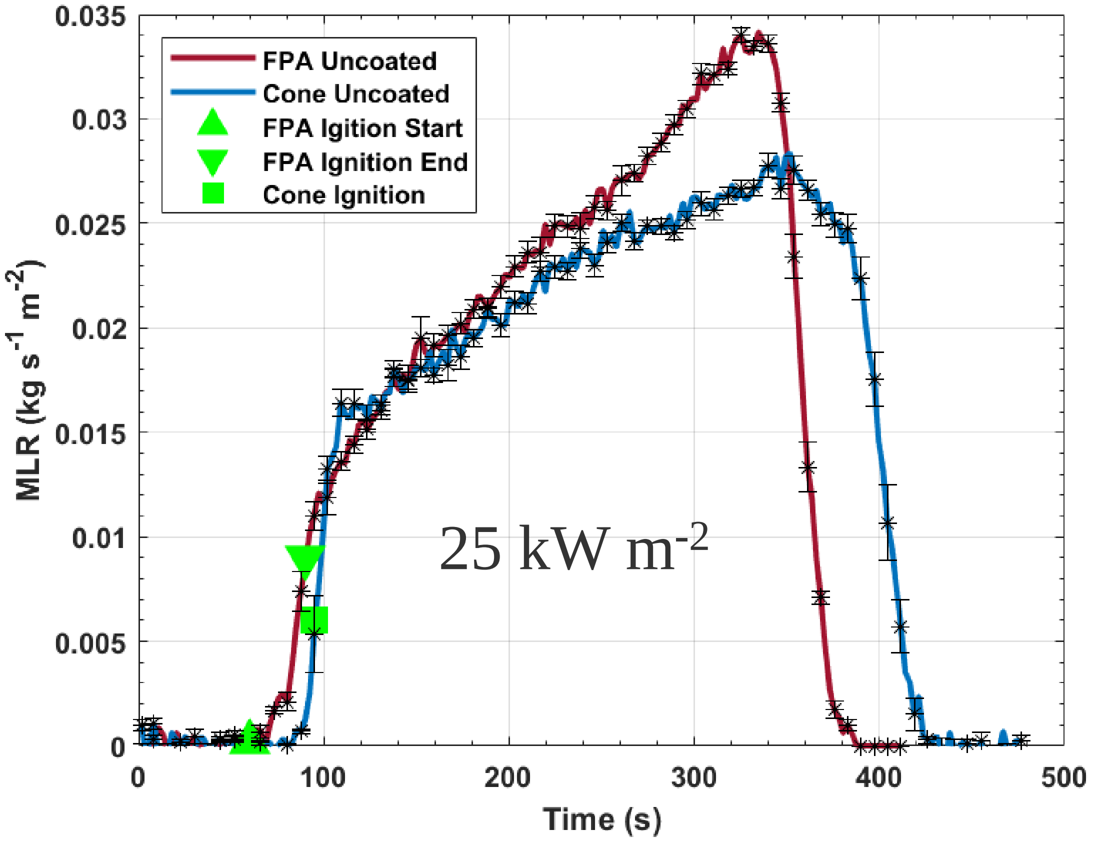
- Possible cause of drift:
  - Radiation from heated quartz tube
  - Convection from radiatively heated gauge mount and/or glass beads
  - Further investigation is needed better understand the drift

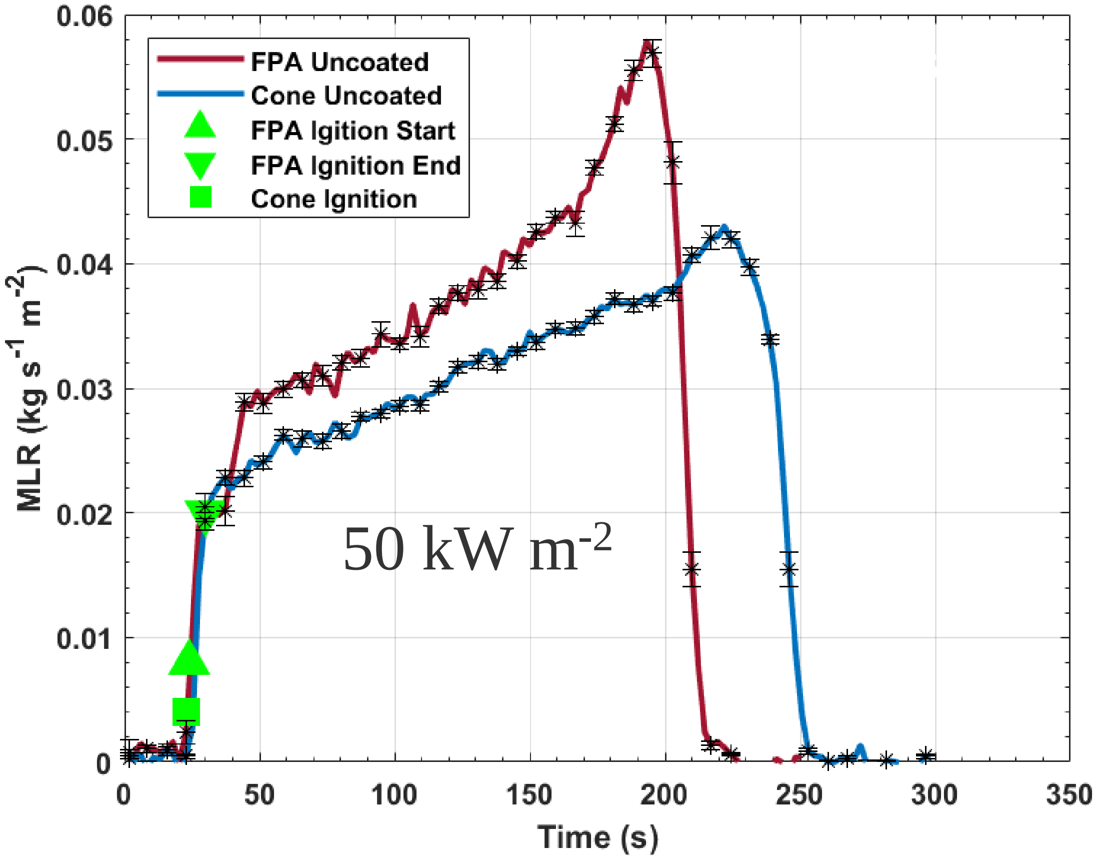
Black PMMA Test in FPA at 25 kW m^{-2} of Imposed Radiant Heat Flux





Comparison between Cone and FPA Data Obtained for Black PMMA

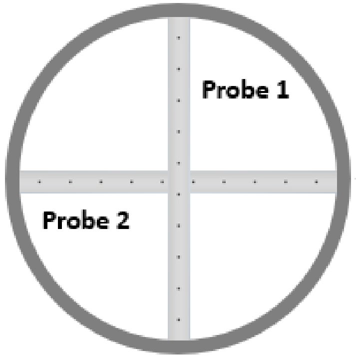




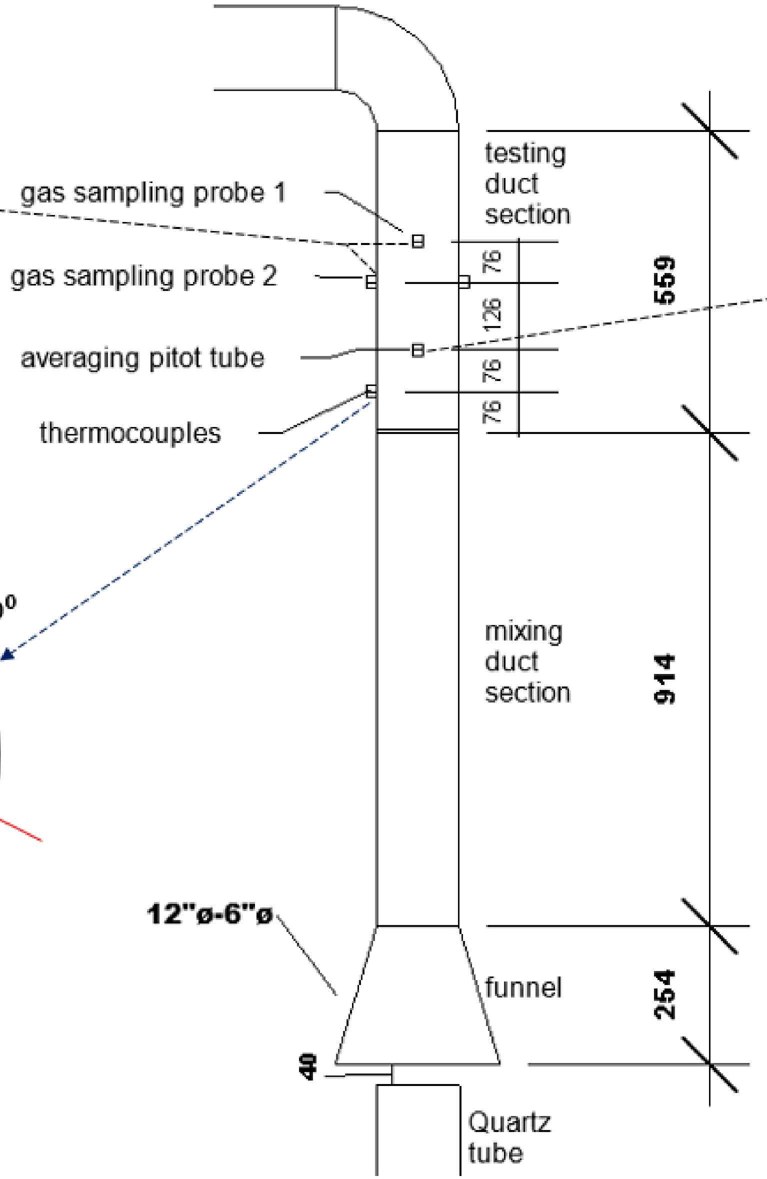
FPA Gas Analysis System Development

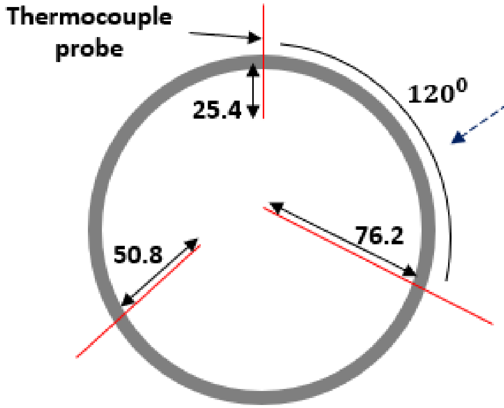
FPA Exhaust System

Probe Information:
- Stainless Steel
- 6.35 mm ID
- 10 holes (1.18 mm ID) on one face
- Probe 1 goes to sampling line 1
- Probe 2 goes to sampling line 2



Sampling Probe Planar View

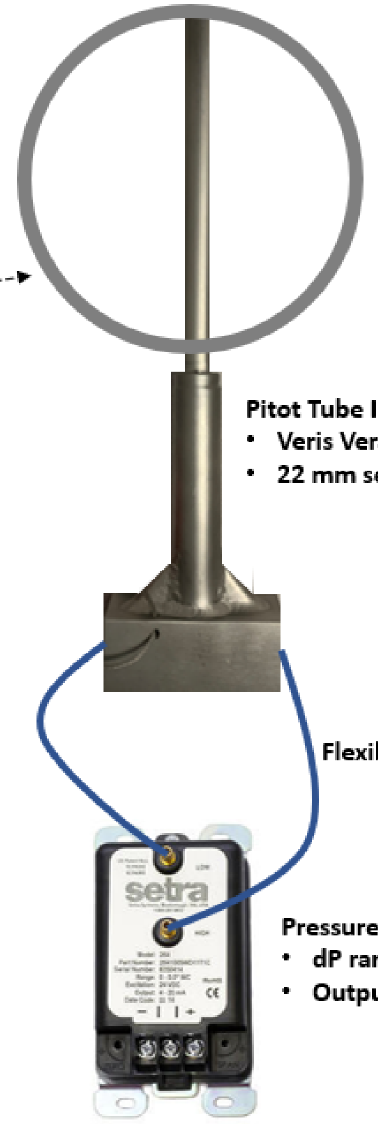




Thermocouple Planar View

Thermocouple information:
- Sheathed stainless steel
- K type
- 0.254 mm diameter
- 152 mm length
- Grounded

Pitot Tube Planar View



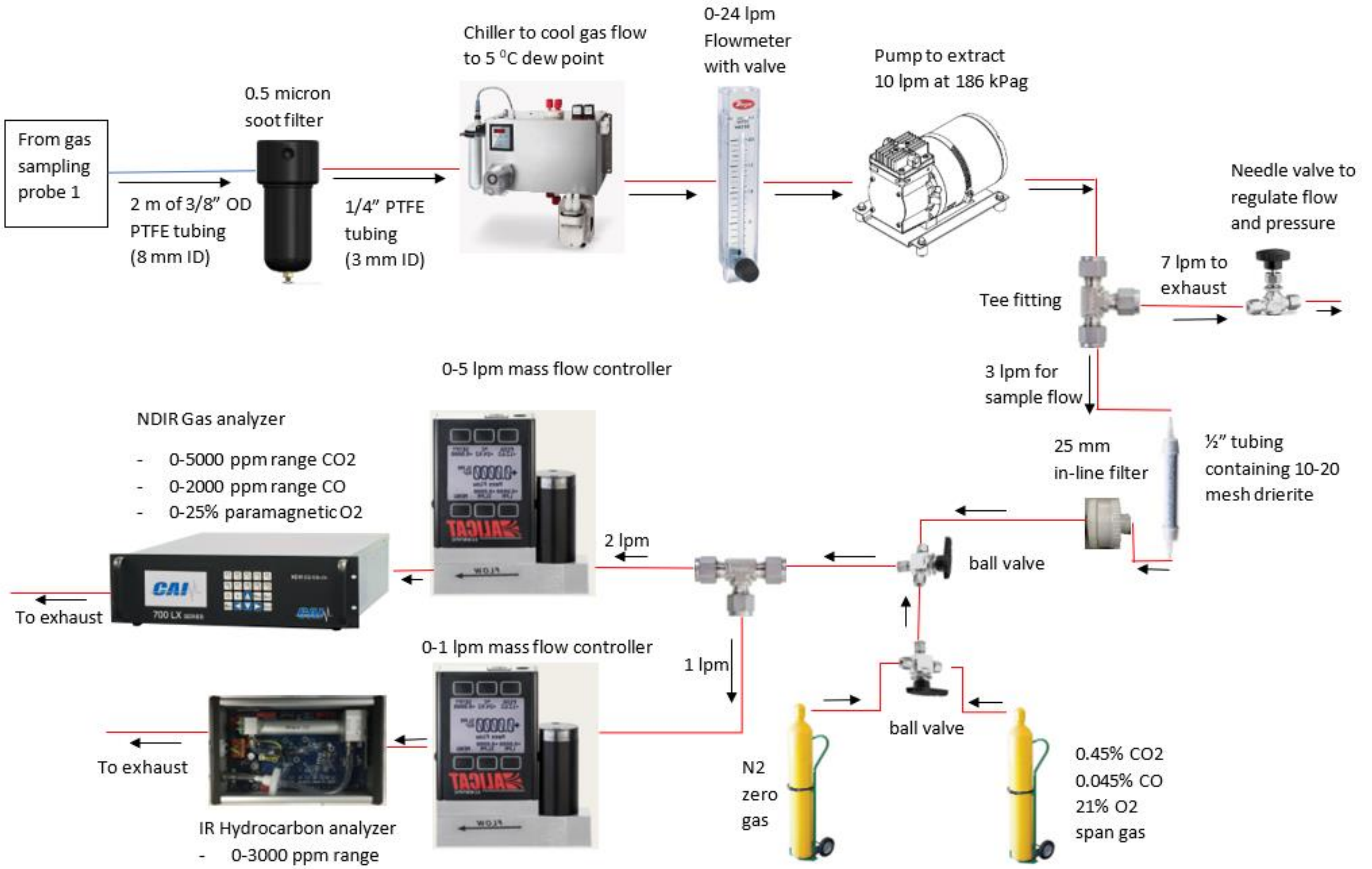
Pitot Tube Information:
- Veris Verabar V100
- 22 mm sensor diameter

Flexible tygon tubing

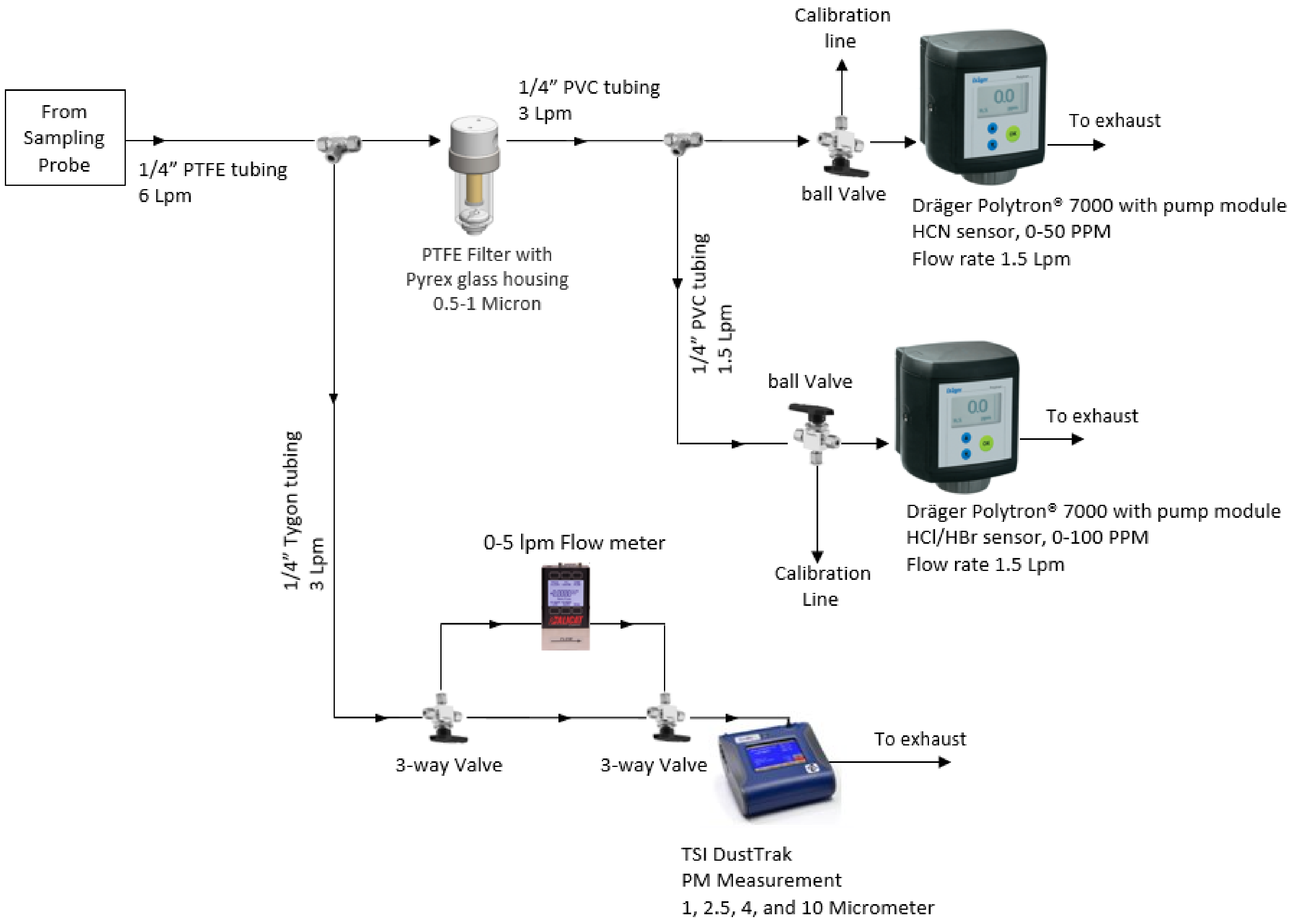
Pressure transducer:
- dP range: 0 – 373 Pa
- Output: 0.5 – 5 VDC

Notes:
- All measurements are in mm unless specified otherwise
- For planar views, exhaust flow direction is coming out of the page

FPA Gas Sampling System 1



FPA Gas Sampling System 2



Conclusions

- A Fire Propagation Apparatus (FPA) was designed and built.
- Several elements of the apparatus were redesigned to simplify manufacturing and maintenance while keeping all performance parameters consistent with the ASTM E2058 standard.
- The apparatus was equipped with a high accuracy sample mass loss system, high accuracy exhaust flow measurement system, and a fast response gas analysis system.
- The apparatus was equipped with a light scattering particle measurement system that provides time resolved mass concentrations of PM2.5 and PM15 (total).
- The apparatus was also equipped with a set of gas analyzers that enable time resolved measurement of total hydrocarbons, hydrogen cyanide, hydrogen chloride, and hydrogen bromide.

Acknowledgments

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