The National Fire Research Laboratory and Recent Results Supporting Smokestack Emissions Measurements

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Workshop on Improving Measurement for Smokestack Emissions

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Preview

- Objective: To demonstrate ±1.0% measurement uncertainty for CO_2 emissions and generate best practice documents as guides for the industry to follow.

- NFRL and power plants have similar measurement capabilities and therefore similar measurement challenges.

- NFRL improvements
  - Improved flow measurements
  - Implemented independent confirmation measurements
    - Exhaust Flow – Averaging Pitot Tube (Annubar) vs TGDM
    - CO_2 emissions – Burner (Fuel Calculation) vs Exhaust
  - Increased sustained fire capacity from 2 MW to 20 MW

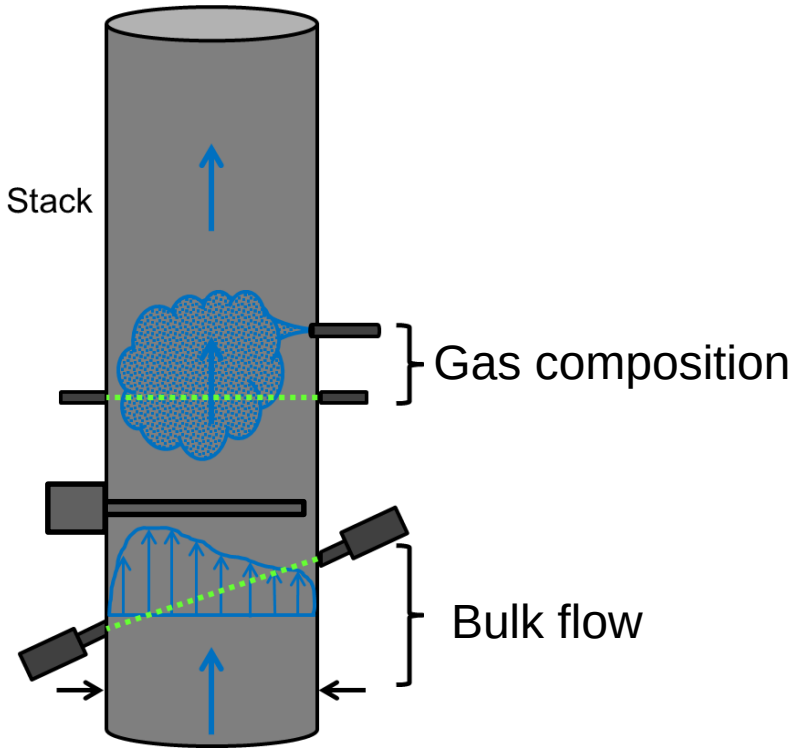
- Demo confirmation measurements, Burner vs Exhaust
  - Heat release
  - CO_2 emissions

Heat released by a fire is the primary measurement capability of the NFRL. Heat release is measured by oxygen consumption calorimetry.

- Heat release
- Flame and fire spread
- Smoke movement and toxicity
- Early detection and abatement

- Support fire model validation studies
- Enable fire investigations
- Support post disaster and failure studies
- Enable advances in fire measurements, standards, and codes

Power plants and the NFRL have a shared problem: accurate characterization of flow and concentration for an industrial scale flue gas.



$$\dot{m}_i = \dot{m}_{exh} \Delta X_i \, MW_i / MWexh$$

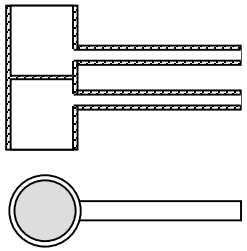
$$HRR = (\dot{m}_{exh} \Delta X_{O2} \, MW_{O2} / MWex_h) \Delta H_C$$

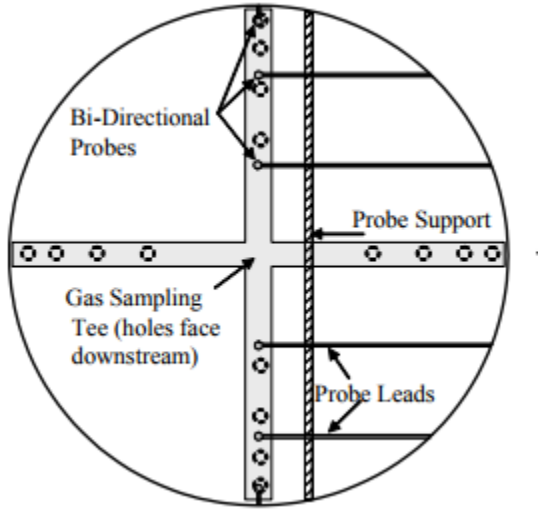
Uncertainty due to flow measurement is a major contributor to the overall uncertainty of heat release and emissions measurement.

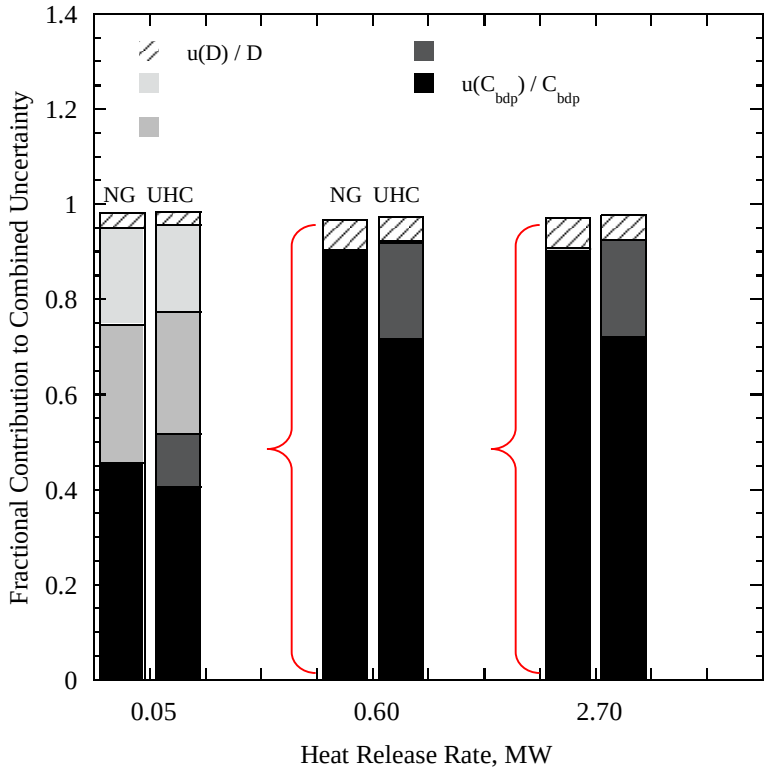
Around 2003, a detailed audit of measurement uncertainty for heat release was conducted.

Flow: std unc = ±5%; contribution ≤ 90%

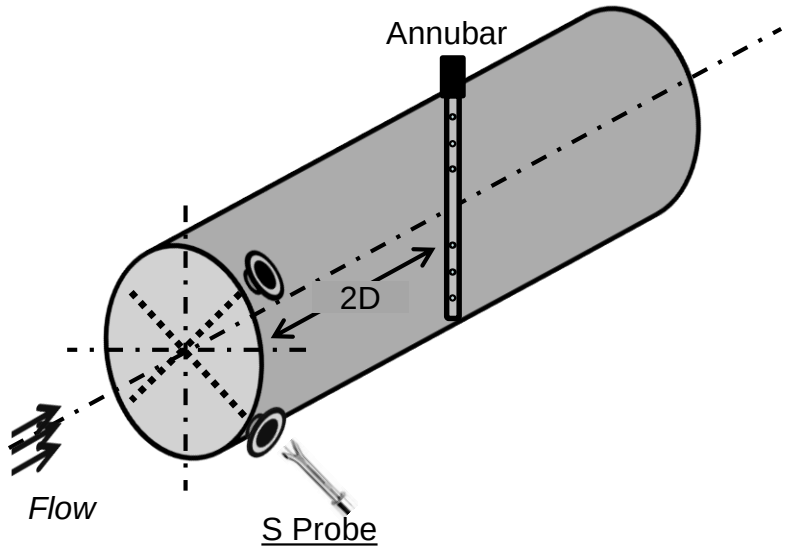
Bi-Directional Probe



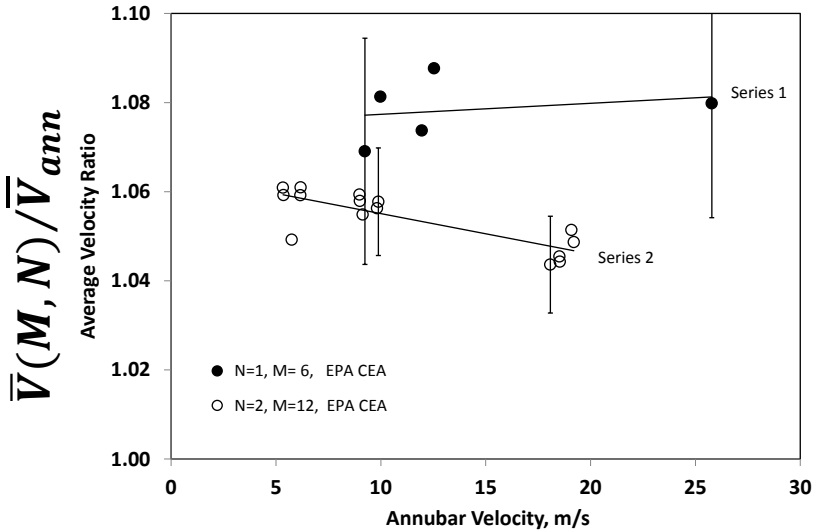




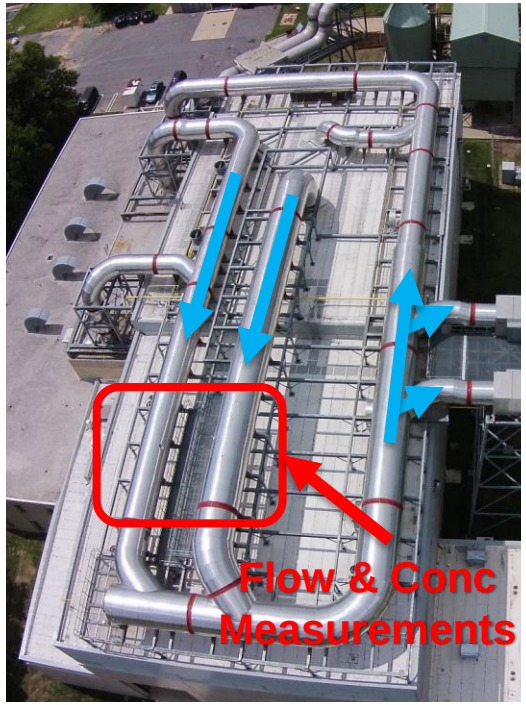
Major modifications to the facility's exhaust flow measurement between 2003 and 2010 resulted in reduced measurement uncertainty.



- Modified the flow path to create longer sections of straight run for flow development.
- Replaced the bi-directional probes with an averaging pitot tube (Annubar).
- Performed detailed flow characterization with flow RATAs; ±0.7% ≤ std unc ≤ ±1.3%

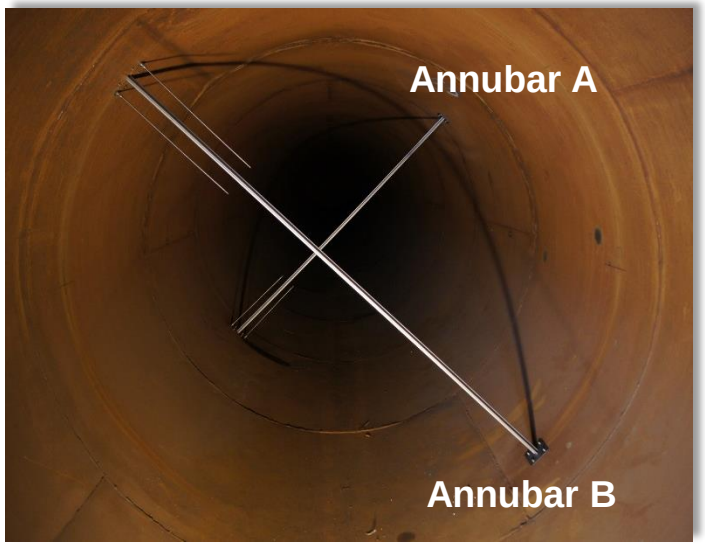


Lessons learned from past results have been applied to further the improvements of NFRL's exhaust flow measurements.

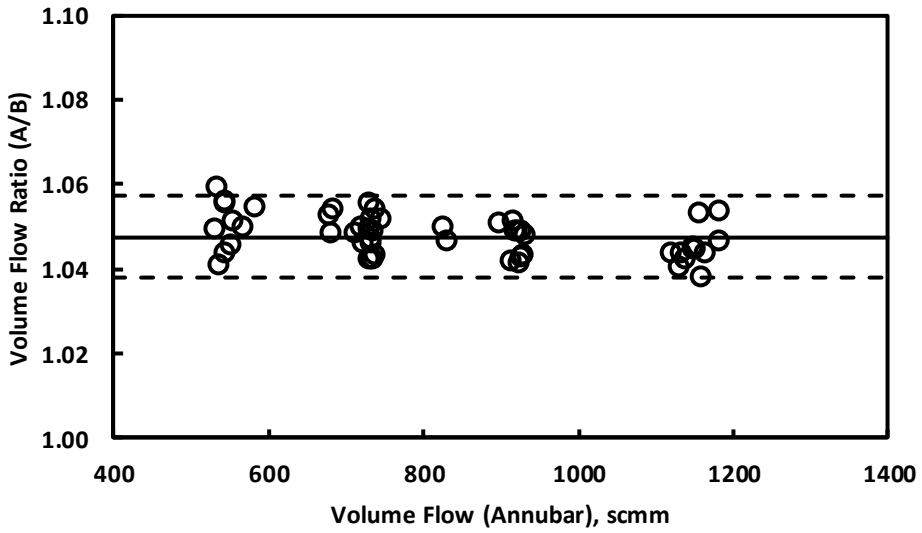


Installed two Annubars in each exhaust duct, offset by 90°.

Additional measurement provides redundancy and reduces measurement uncertainty.

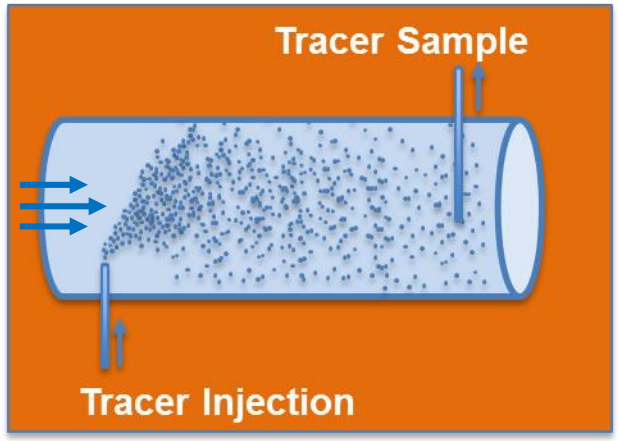


For the flow path considered here, the average difference between the two Annubar measurements is 4.8%.

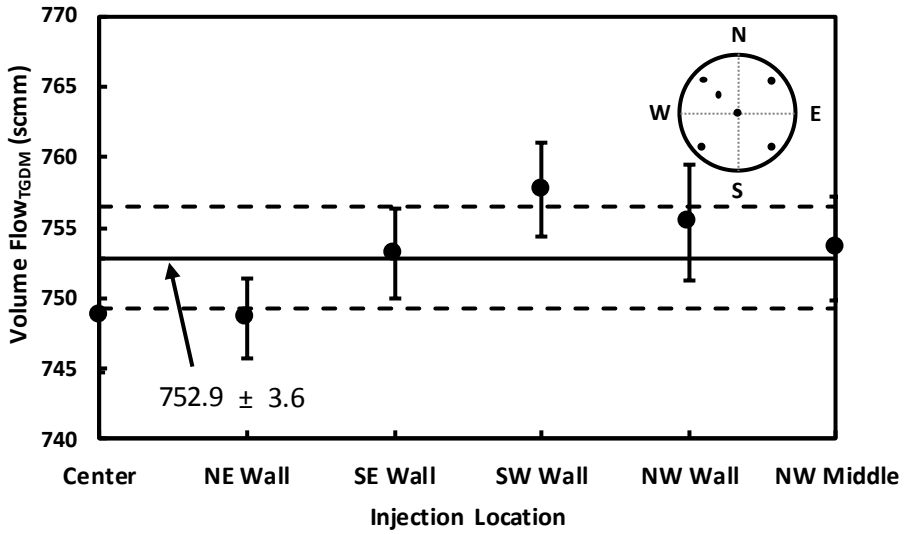


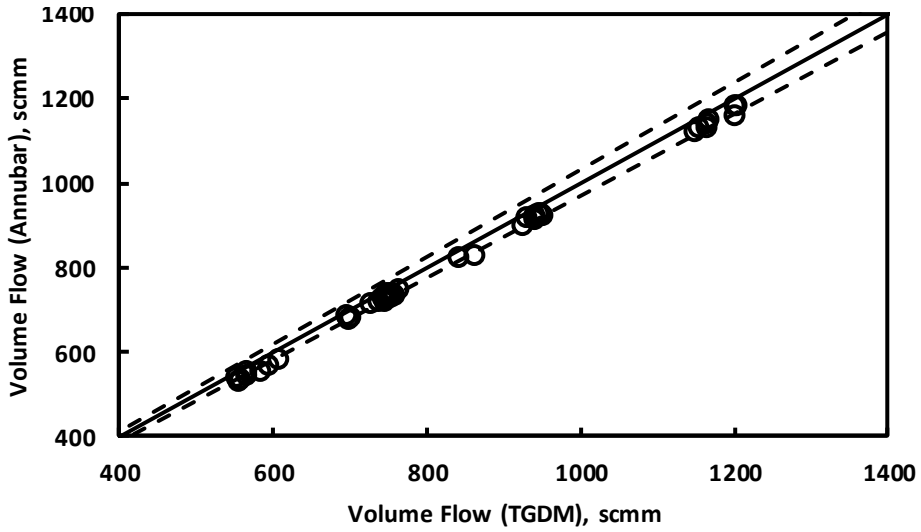
Lessons learned from past results continue to be applied to further the improvements of NFRL's exhaust flow measurements.

Completed a series of experiments to compare the routine flow measurement (Annubar) to flow measured using the Tracer Gas Dilution Method



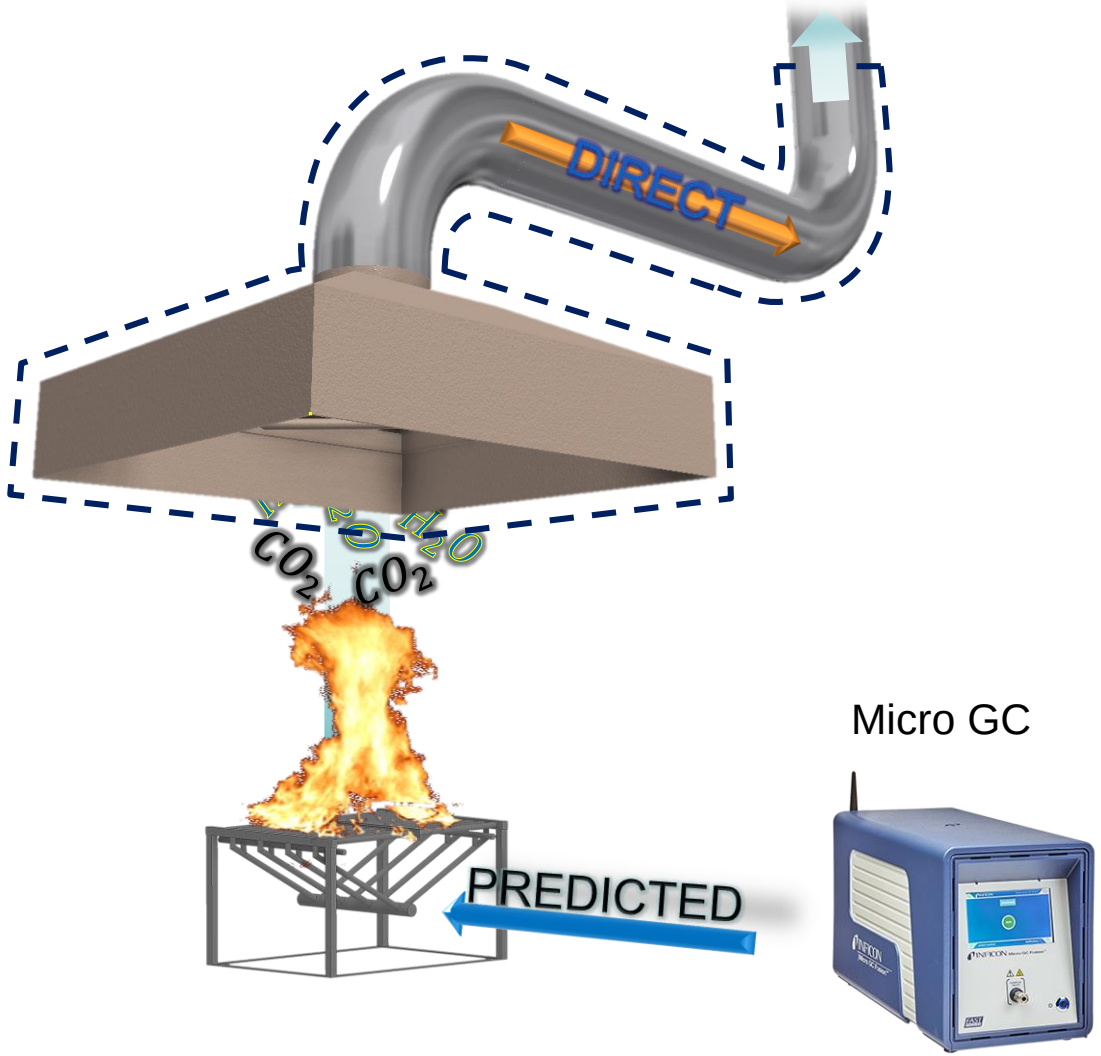
- Verified uniform mixing of the tracer
- Demonstrated ±(1.0% - 3.0%) repeatability for TGDM
- Methods agree to within preliminary uncertainty estimates, ±(3.0% - 4.0%)



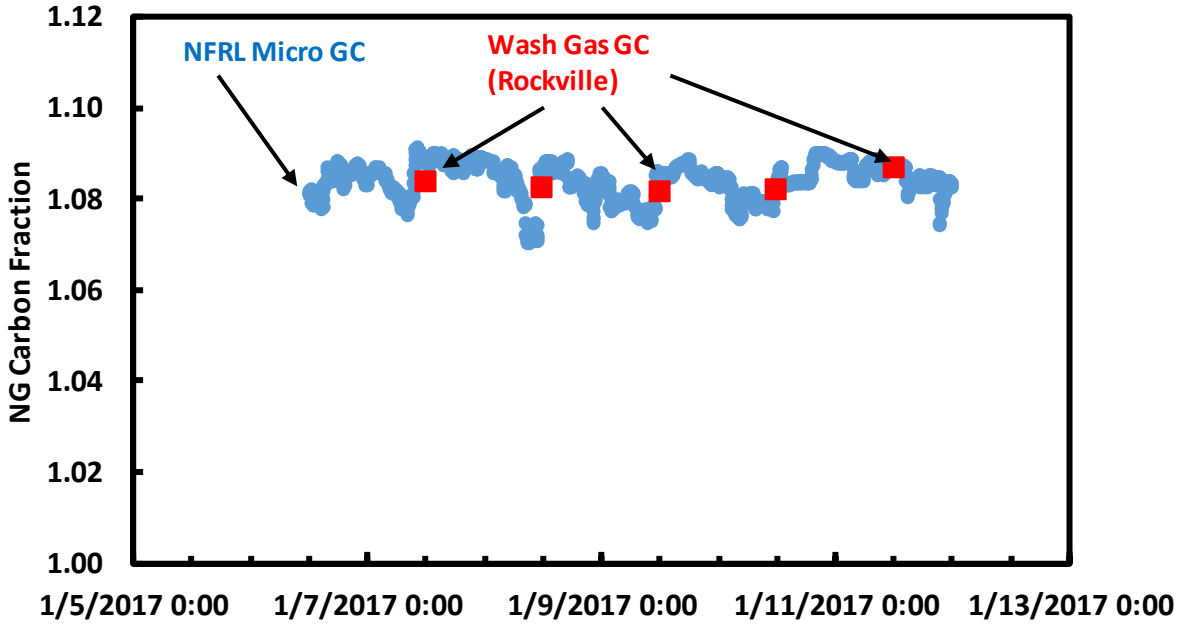


NFRL has the capability to confirm CO_2 emissions with mass balance experiments.

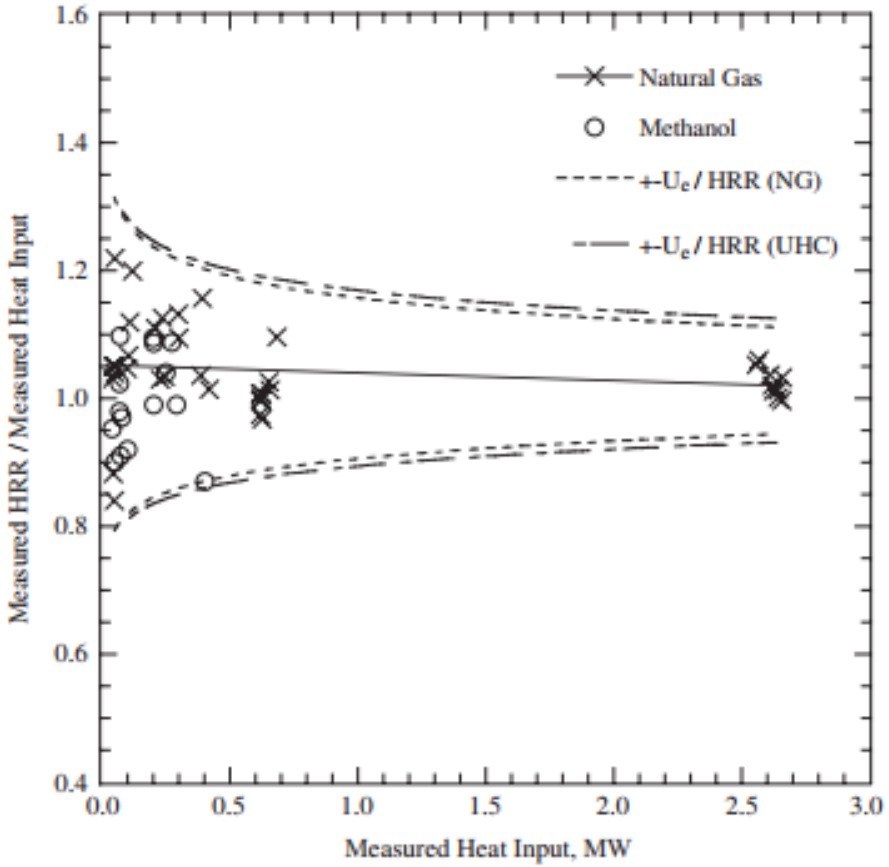
$$CO_2\ Mass\ In\ (PREDICTED) = CO_2\ Mass\ \ IRECT)$$



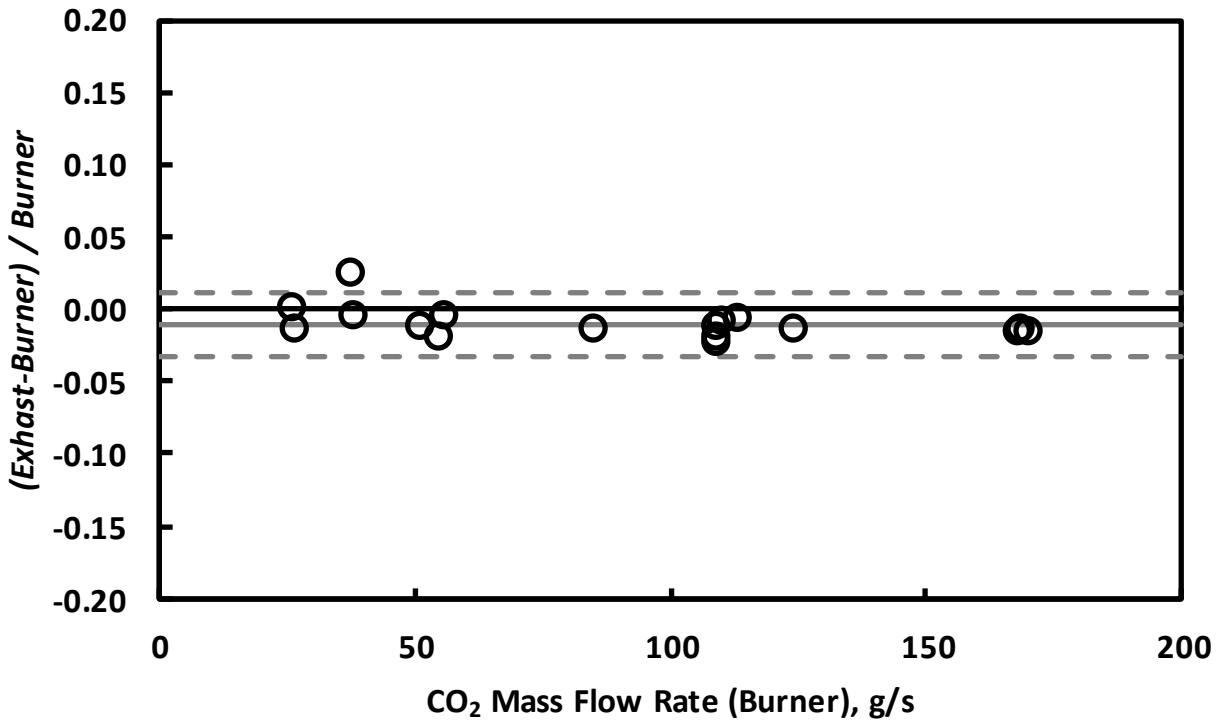
- Micro gas chromatograph for natural gas analysis provides real-time fuel composition measurements
- Demonstrated good agreement with NG carbon fraction, X_c, from local gas supplier
- Real-time measurements improve accuracy; 2.0% shift in X_c, observed in 24 hr period



Improved flow measurements have resulted in better agreement between the natural gas burner and the exhaust measurements of heat release and CO_2 mass flow.



2003: ±10% ≤ Std Dev ≤ ±20%



2010: Std Dev ≤ ±7%

Summary

- NFRL and power plants have similar measurement challenges: accurate characterization of gas flow and gas concentration.
- Improvements in NFRL's flow measurement have resulted in better agreement for energy (heat release) and mass (CO_2 mass flow) balance experiments – demonstrating the benefits of improved flow measurements.
- NFRL's energy and mass balance examples demonstrate the use of independent measurement confirmation for quality control.

Questions?