

Emissions Characteristics of Residential Gas, Oil and Wood Pellet Fueled Heating Systems

Work Conducted Under NYSERDA Agreement No. 8909 by Brookhaven National Laboratory, Roger J. McDonald, Principal Investigator

Abstract

The goal of the Emissions Characteristics of Heating Systems project is to develop an up-to-date evaluation of emissions from typical residential, gas-fired, oil-fired, and wood-fired heating equipment. The project seeks to accurately analyze heating equipment performance with natural gas, heating oil of different sulfur contents, varied blends of biofuels, and wood pellets, by measuring emissions of carbon monoxide, sulfur oxides, nitrogen oxides, and fine particulate matter (PM 2.5.) Phase I of the project measured emissions from a representative sample of typical gas-fired, oil-fired, and wood pellet-fired, residential heating systems that are found in homes and small businesses in New York State. Oil-fired heating systems were tested with conventional, 0.2% sulfur heating oil, low sulfur (500 ppm S) diesel fuel, and ultra-low sulfur (15 ppm S) diesel fuel. Wood pellet-fired heating systems were tested with premium (low ash content) residential quality wood pellet fuel. Phase II of the project will measure emissions from advanced heating technologies including: low NOX burners, condensing boilers and furnaces. Phase II will also include the testing of both conventional and advanced, oil-fired, heating technologies with B20 and B100 biofuels.

Reducing Fine Particulate Emissions in Heating Systems

Scope

- fine particulates can have significant health impacts
- EPA has revised National Ambient Air Quality Standards to include PM_{2.5}
- states are developing implementation strategies to control emissions from different stationary sources including utilities, industry and buildings

Project Objectives

- establish new PM data so that regulators, policy makers can make informed decisions regarding oil, gas & wood pellet-fired heating appliances
- develop cost-effective solutions that would provide for reduced emissions and improved efficiency of heating systems

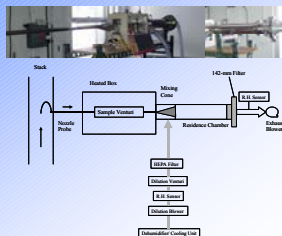
Heating oil issues

- small emission sources from individual homes, but in certain states like NY oil serves many consumers ~ 2.5 million in NY
- potential to achieve large reductions in fine particulate emissions with lower sulfur heating oil and potentially with advanced technologies

Emission Measurement – Particulate Matter 2.5 μ Energy Resources Division - Oilheat Research

- MACTEC worked for over four years with EPA's Emission Measurement Center to develop a reasonably sized stack testing system to measure primary and estimate secondary PM 2.5 emissions

- BNL acquired one of the first prototype dilution tunnel measurement systems from Environmental Supply Co. Inc. which was based on Conditional Test Method 39 late in 2004



PM 2.5 Dilution Tunnel Sampling System

NYSERDA Project Phase I (+ WP)

Measure PM 2.5 for Gas and Oil-fired systems and standard emissions (SO_x, NO_x, CO)

Oil-fired to include:

- conventional furnace (warm air) with flame retention head burner
- commercial cast iron boiler (hydronic) with flame retention head burner
- both systems tested with No. 2 heating oil, No. 2 Diesel (500ppm Sulfur) and Ultra Low Sulfur Diesel No. 1 (< 15ppm Sulfur)

Gas-fired systems include:

- conventional gas furnace (warm air) with draft inducer using utility gas
- conventional gas cast iron boiler using utility gas

Wood Pellet-fired Stoves

- over feed combustion type wood pellet stove
- under feed combustion type wood pellet stove

Gas Furnace Under Test



Utility Gas Fired Warm Air Furnace 81% AFUE
NO_x: 75ppm, SO₂: ND, CO: 10ppm @ 3% O₂ Equiv.

Emission Measurement – Particulate Matter 2.5 μ



Condensing Warm Air Oil
Fired Furnace 90-95% AFUE

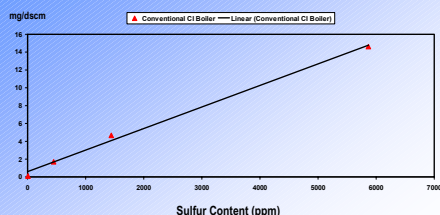
Conventional Hydronic Boiler 83-85% AFUE
NO_x: 130ppm, SO₂: 89ppm, CO: 2 ppm @ 3% O₂ Equiv.

Wood Pellet Stove Test Stand Emission Measurement – Particulate Matter 2.5 μ

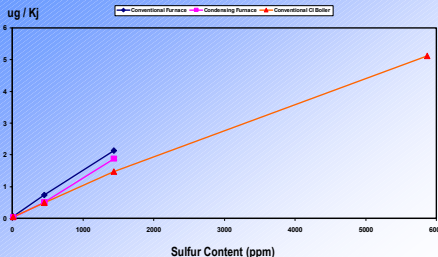


61-71% Steady State Efficiency
NO_x: 96-115ppm, CO: 180-780ppm,
SO₂: ND-15 ppm @ 3% O₂ Equiv.

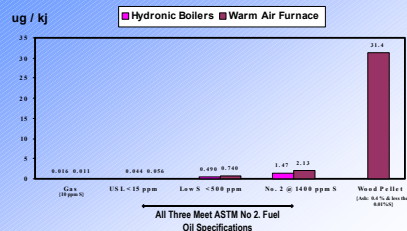
Particulate Mass Concentration @ 3% Oxygen (mg/dscm) Vs. Sulfur Content (ppm)



Particulate Mass (ug) per Heating Unit (kj) as a Function of Sulfur (ppm) in Heating Oil



Fine Particulate Emissions - Utility Gas, Heating Oil & Wood Pellet Preliminary Results Measured Under NYSERDA Project



U. S. EPA Project at BNL to Determine the Physical & Chemical Characterization of the Emissions from a Residential Oil-fired Boiler Fired with ASTM No. 2 Fuel

- EPA visited BNL to collaborate on a project to conduct detailed speciation study
- Provide BNL an opportunity to make side by side gravimetric measurements
- Results - EPA: 48.6 +/- 5.3 mg/kg of fuel and BNL: 47.2 mg/kg (S=1440 ppm)
- Other preliminary EPA results:
 - Sulfur predominant chemical - sulfate aerosols significant, 95% of inorganics
 - 4-8% Carbonaceous, with ~ 2/3 elemental and ~ 1/3 organic related
 - EC-OC ~ two orders of magnitude less than prior larger stationary system studies
 - VOCs 17.4 +/- 11.9 mg/kg not related to fuel but formed during combustion
 - Again confirmed size dist. less than 1 micron



Note: US EPA paper submitted, peer reviewed, edited awaiting final edit and publication



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NYSERDA Project Manager

NYSERDA

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Preliminary Conclusions Concerning PM 2.5 μ

- data on 3 different oil-fired heating units using 3 different sulfur contents all exhibited a significant linear relationship between PM 2.5 and sulfur content
- published literature & US EPA/BNL study all conclude oil-fired residential heating systems particulates are less than 1 micron in size
- for normal heating fuel (1440 ppm S) - largest portion of fine particulate mass for oil-fired residential combustion units consist of sulfates & associated water
- gravimetric PM 2.5 emission levels for utility gas verified to be very small
- heating fuel with a sulfur level of < 15 ppm results in a PM 2.5 gravimetric emission rate that is virtually the same as that measured with utility gas
- PM 2.5 emissions from wood pellet stoves using premium pellets (low ash), although far better compared to the published literature for other wood combustion choices, are still ~ 15 times higher than oil fired systems using current S level fuels (1440 ppm) & ~ 200 times higher than utility gas heating systems