

Heating Oil and Turbines

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SIXTY YEARS
OF DISCOVERY
1947-2007

BROOKHAVEN
NATIONAL LABORATORY



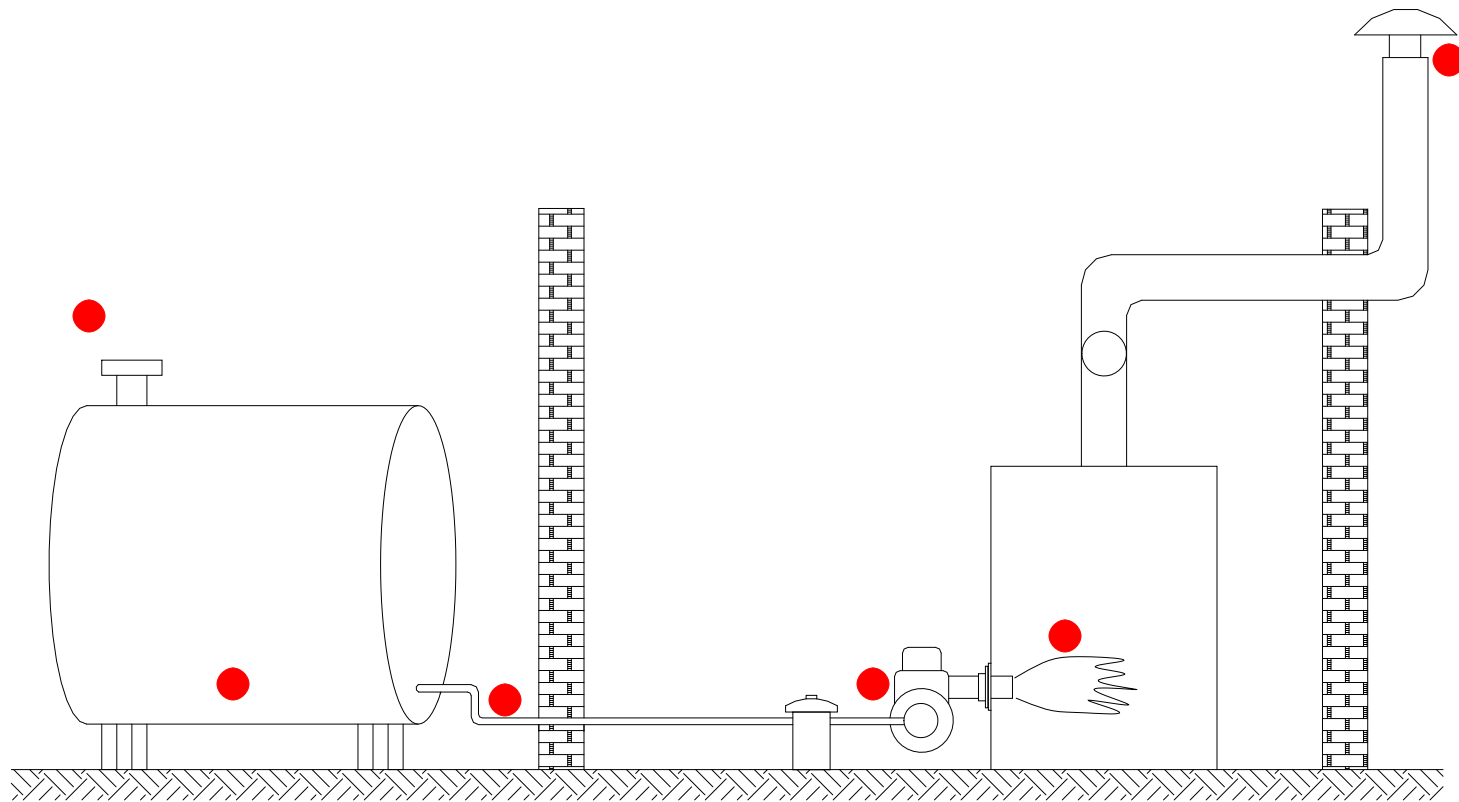
Stationary Market

- No2. Heating oil, kerosene, residual oil
- Residential, commercial, industrial sectors
 - 9 million homes
 - 10.3 billion gallons 2 oil/year all 3 sectors
 - 2.0 billion gallons residual
 - 0.8 billion gallons kerosene
 - @ \$3.00/gallon - \$39 billion

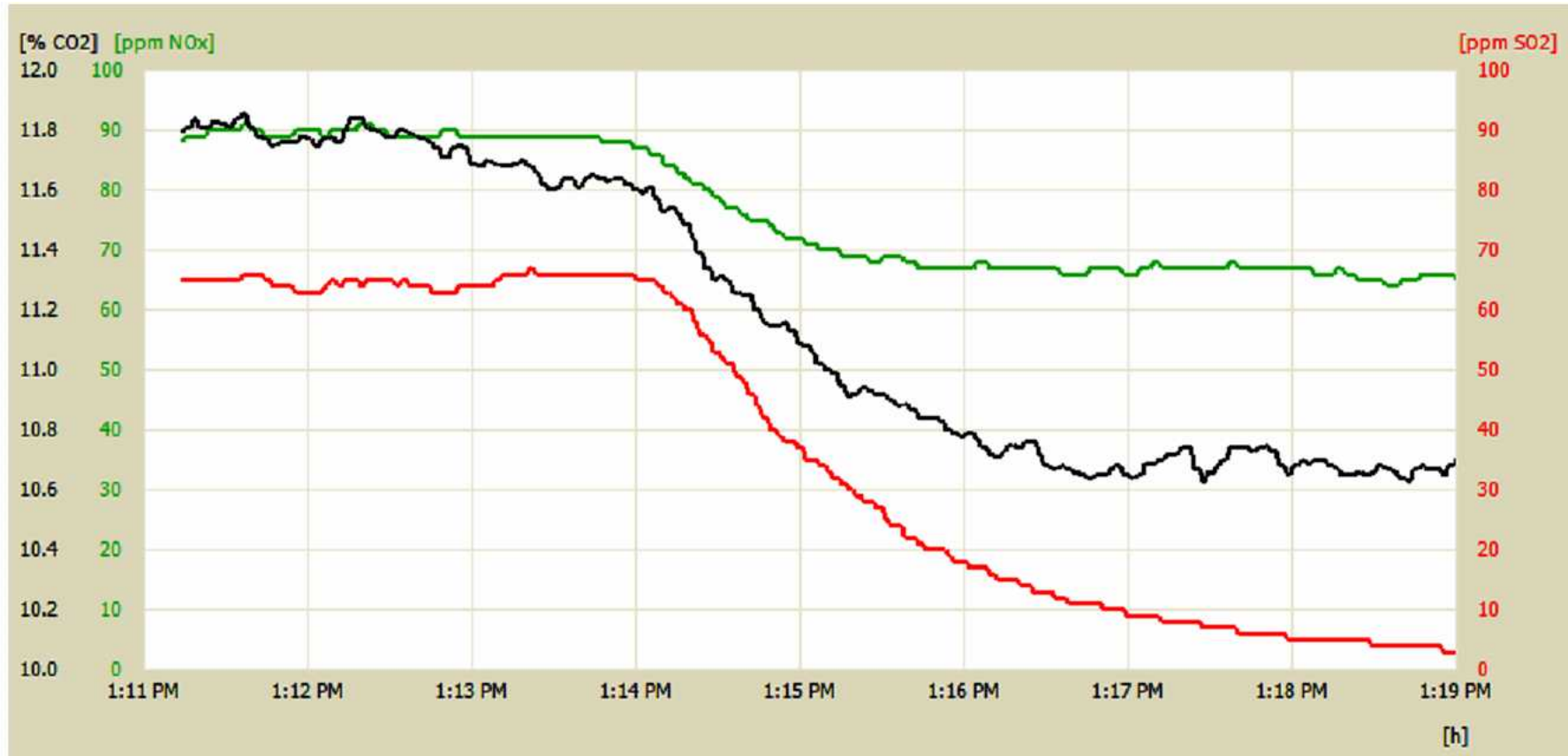
Applications



Aspects affected by the fuel



Transition - #2 to B100



Key conclusions – lab tests in boilers and furnaces with No. 2 oil

- Combustion stability is good to B-100
- NOx emissions are somewhat lower
- Particulate emissions are lower, in proportion to fuel sulfur content
- Flame luminosity somewhat lower at higher blend ratios, particularly during startup transients

Low sulfur is an attribute that can reduce boiler corrosion and enable low cost, high efficiency, condensing operation



Field Studies – Warwick

1) Warwick Public School Department



Control



10% - B-10 Blend



15% - B-15 Blend



20% - B-20 Blend



Field Studies – Warwick

- 2001-2002 in two phases
- 32,285 gallons blend burned
- NOx emissions reduced by 19%
- No combustion performance impacts
- Fuel storage temperatures to 50 F

Field Studies – Abbott and Mills

- In cooperation with Brookhaven, NYSERDA sponsored
- 2001-2005, Upstate New York
- B-20, 100 homes
- Furnaces, boilers, water heaters
- Indoor, outdoor, buried tanks
- Winter design temperature 0 F
- No increase in service resulting from biodiesel use

Field Studies – Sagamore Hill

- In cooperation with Brookhaven, National Park Service, NYSERDA sponsored
- Theodore Roosevelt home and museum
- B-20, 2 years
- No problems in appliances or storage
- B-100 test now in progress, pump seals changed to viton

Utility Boilers

- Charles Poletti Power Project – NYPA – Queens NY
- 5,10,15,20% tested
- 100,000 gallons B-100
- 900,000 gallons No. 6 oil
- Two day test
- SO₂ reduced
- NO_x and particulates no significant change



Suppliers of Bioheat

- 143 retail fuel suppliers listed on NBB web page
- Worley and Obetz, PA, B-5, 10,000 sites
- Wilson Fuel Co., Halifax, B-2 to B-100
- Columbia Fuels, Pacific Northwest, B-20, 14000 sites
- Fred M. Schildwachter and Sons, Inc, Bronx, NY, B-20, 7800 sites*

* Recently reduced due to changes in NY tax laws.



B-5 Fact Finding Study Objective

To develop data on:

- **Material compatibility of B5 Biodiesel with materials employed in residential oil-fired heating appliances (including metals, refractory / combustion chamber liners, thermosets, thermoplastics and elastomers)**
- **B5 Biodiesel combustion characteristics**
- **General performance comparisons between B5 Biodiesel and No.2 fuel oil**

Participants

Sponsors:

**National Biodiesel Board – Paul Nazarro, Steve Howell,
National Oilheat Research Alliance – John Huber**

Main Performer:

Underwriters Laboratories Inc. – Travis Hardin, Thomas Blewitt, Thomas Thompson

Supporting Organizations:

R.W. Beckett Corp. – Vic Turk

Carlin Combustion Technologies – Thomas Tubman, Chuck Feldman

Riello Burners – Alan Simpson

Brookhaven National Laboratory – Tom Butcher, C.R. Krishna, Yusuf Celebi, George Wei

Approach

- Evaluate the performance of 5% ASTM D6751 Biodiesel / D396 No. 2 fuel oil blend in residential heating systems that are representative of the existing stock of equipment
- Tests based on the standard for safety for oil burners, ANSI/UL 296
- For certain tests (material compatibility), acid numbers in B5 Biodiesel test fuel were elevated to provide “worst-case” with respect to corrosion.
- All burner testing conducted at manufacturer facilities, and witnessed by UL engineering staff.
- Material compatibility tests conducted at UL-Northbrook
- Combustion chamber testing conducted at BNL

Appliance/burner combinations

- **12 combinations tested**
 - **2 warm air furnaces**
 - **1 water heater**
 - **9 boilers**
- **Both new and used**
- **Test samples selected based on collaboration of UL Fact Finding Investigation participants**
- **Test samples considered representative of the past (Approximately 1 to 20 years) and present residential oil heating appliance market**

Observations from Combustion Test of ANSI/UL 296 w/ B5 Biodiesel Blend

- **Observed acceptable combustion performance**
- **Flame did not flash outside of appliance**
- **Observed smoke less than 1**
- **No tar or soot buildup on burner or heat exchanger**
- **No fuel leakage observed**
- **Seals and gasket materials did not appear to be degraded**
- **Data unaffected by the presence of a nozzle line heater**
- **Additional Build-up of “red” deposits from the joints between sections of cast iron boilers.**
- **At one test site an issue was noted with blockage of fuel filters**
 - **Appliance safely shutdown**
 - **Cause of filter blockage was not further investigated.**

Materials Compatibility

Elastomers

Results of the tests deemed acceptable since the tensile strength and elongation retained more than 60% of the unconditioned value and volume change was within the required -1 to plus 25%.

Combustion Chamber Materials

Combustion chamber refractory tests passed.

Detailed side-by-side tests to evaluate impacts on cast iron boiler section sealants showed no impact.



Sediment and biodiesel

- Most tanks have water and sediment on bottom
- Product of years of biological and oxidative degradation
- What is solvency impact of biodiesel blends

Tests

Sediment dispersion and refiltering

Settling rate comparison

Particle size distribution of dispersed sediment

FTIR analysis of biodiesel in which sediment has been dispersed

No. 2 oil



B-100

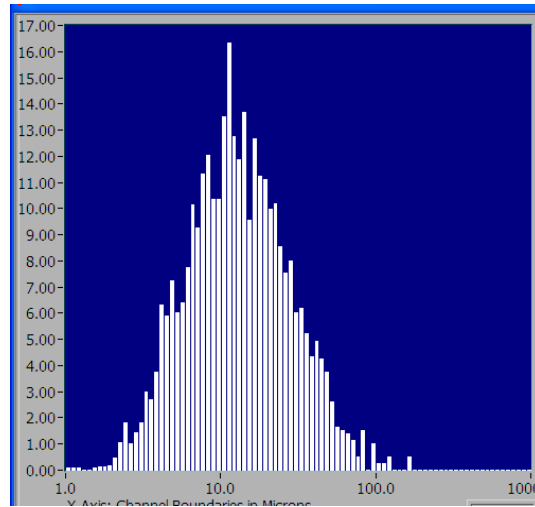


Just
before
mixing
mixing
Just after
mixing

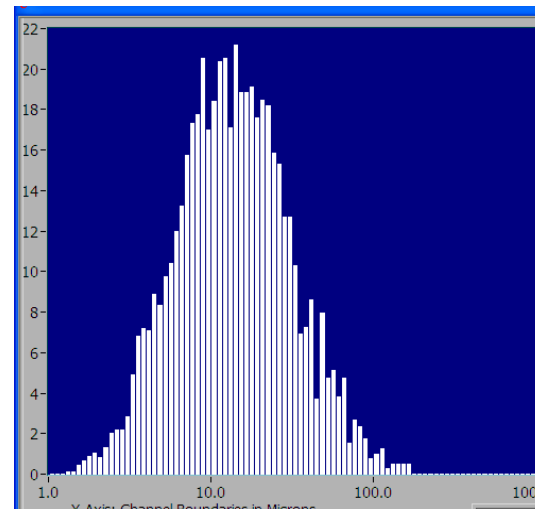
3 hrs after
mixing

16 hrs
after
mixing

No. 2 oil



B100

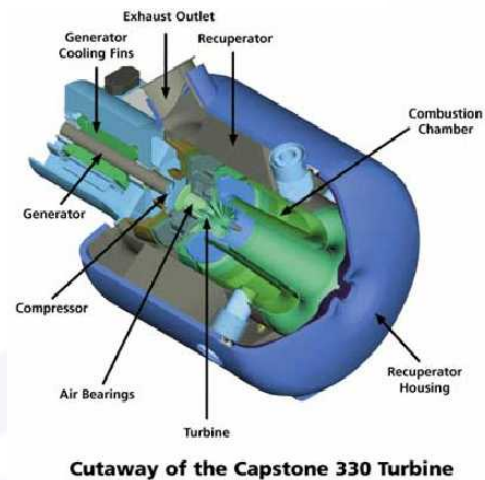
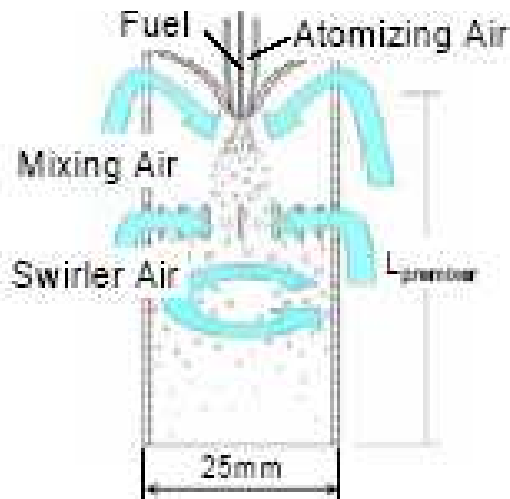
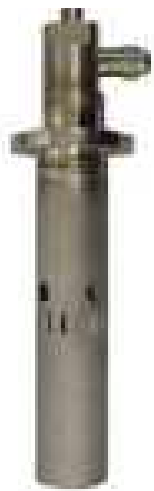


Conclusions from sediment tests

- No significant change in size distribution of dispersed particles.
- No quantitative impact of solubility of sludge
- No measureable change in biodiesel following mixing with sludge based on FTIR
- Slower settling rate which may be due to viscosity and density differences.

Testing of Biodiesel Blends in Capstone C 30

- **Project to study use of biodiesel in a microturbine**
 - **Funded by Department of Energy with support from Capstone Turbine Corporation**
 - **Blends of biodiesel to ASTM 6751 in ASTM # 2 oil were tested**
 - **Capstone C 30 Microturbine was used**
 - **Atomization and combustion testing**



Key conclusions from turbine work

- **Atomization performance similar for all fuels, popular correlations relating fuel properties and air fuel ratio to mean drop size evaluated.**
- **Microturbine can be operated on blends up to B100**
- **'Cold' Starts are possible on all blends**
- **Lower sulfur dioxide emissions when blended with heating oil, ASTM #2**
- **Biodiesel blending leads to similar NOx emissions at high powers, but lower at low power conditions**
- **Turbine-Generator efficiency seems unaffected by biodiesel blending**

Future Areas of Interest

- Storage – tests to date have showed no “solveny effect” for heating tank bottom sludge
- Impact of “old” copper
- Benefits of biodiesel used in residual oil blends for commercial and industrial boilers
- Fuel alternatives

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