Combustion and Atomization Performance Testing

UCI Combustion Laboratory

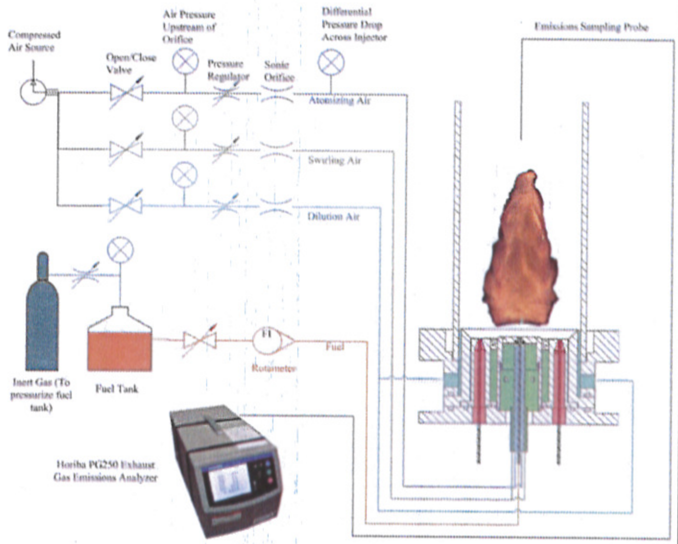
11 Oct 14

Content

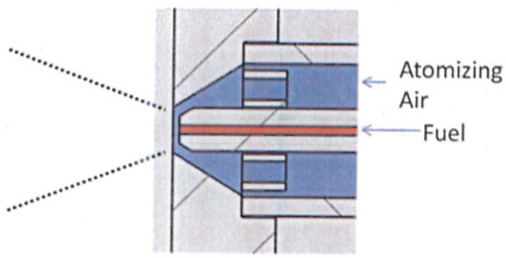
- Experimental Apparatus
- Test Results
  - Diesel Fuel Combustion Performance
  - Diesel Fuel Atomization Performance
  - Diesel Fuel Physical Properties

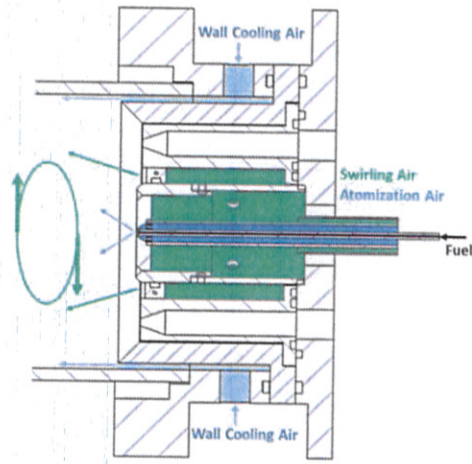
Combustion Test Apparatus

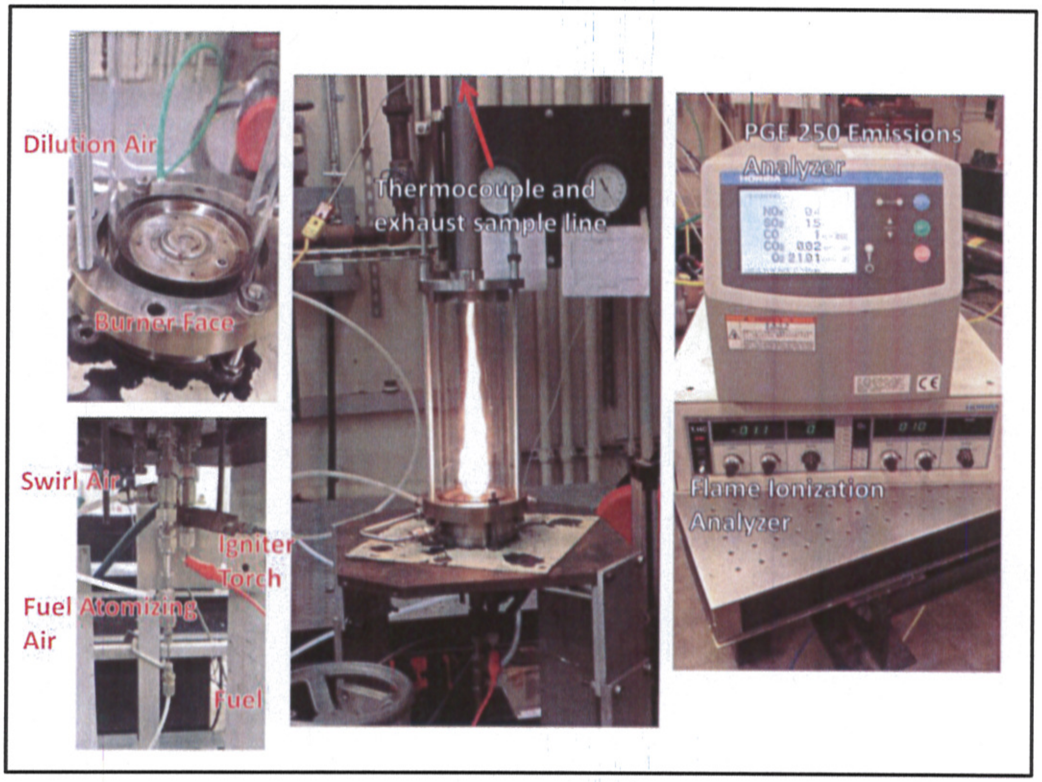
- PGE250 Exhaust Analyzer
  - NO_x
  - CO
  - CO_2
  - O_2
- Flame Ionization Analyzer
  - UHC
- Nikon J1 Camera
  - 1200 fps high speed color video
- Andor ICCD Camera
  - Capture OH Chemiluminescence images



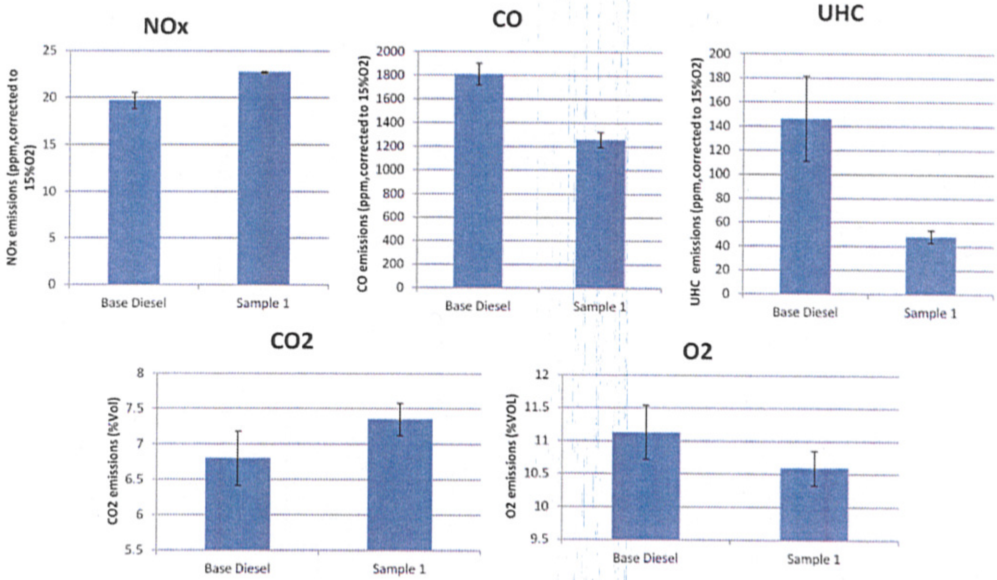
- Low Velocity Burner Rig
  - Plain-jet airblast atomization
  - 3 Combustion Air Circuits
    - Atomization Air
    - Swirling Air
    - Dilution/Wall Cooling Air





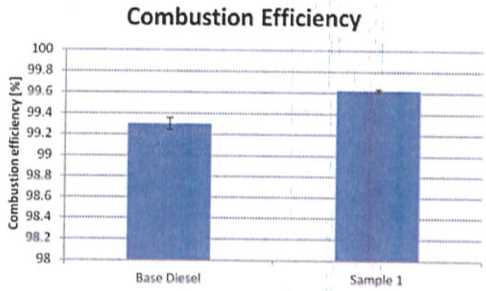

Dilution Air
Burner Face
Swirl Air
Igniter Torch
Fuel Atomizing Air
Fuel
Thermocouple and exhaust sample line
PGE 250 Emissions Analyzer
Flame Ionization Analyzer

Viscon Testing
Diesel Emissions



- Basic Emissions Performance

Diesel Emissions

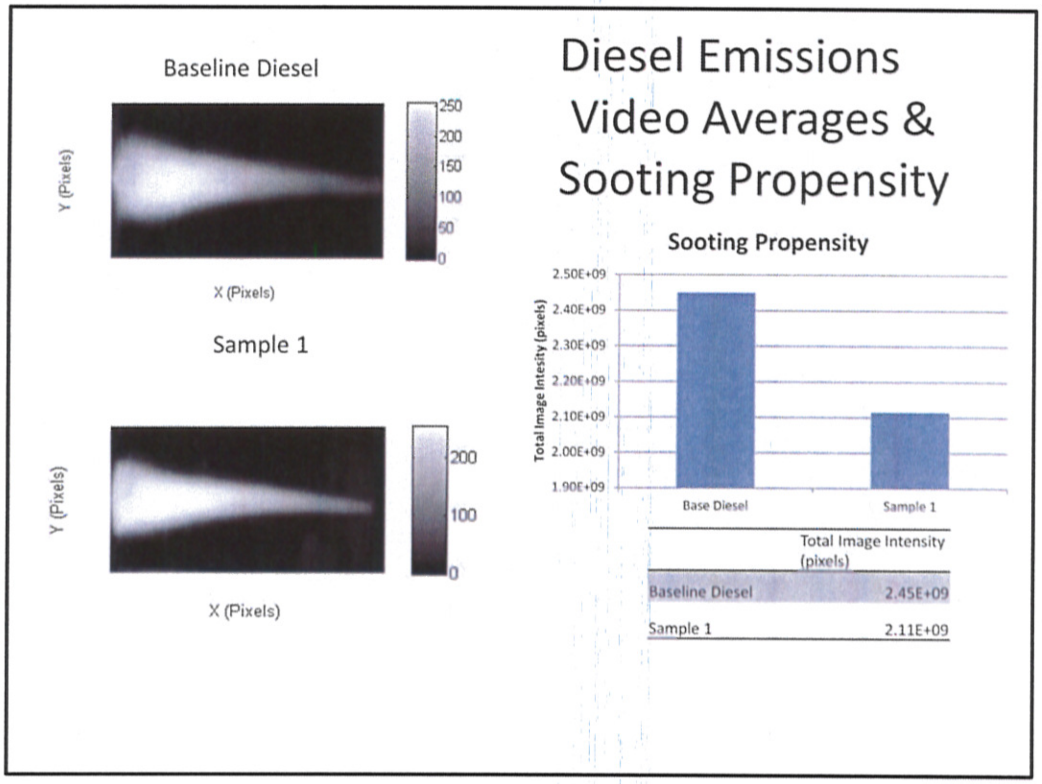


- All No_x, CO, & UHC emissions listed are corrected to 15% O_2

	Equivalence Ratio	Exhaust Temperature (C)	Error Bar (± %)	NOx (ppm)	Error Bar (± %)	CO (ppm)	Error Bar (± %)	UHC (ppm)	Error Bar (± %)
Baseline Diesel	0.486	671.1	1.92	19.6	4.29	1810.6	4.96	146.0	24.26
Sample 1	0.485	689.1	0.32	22.7	0.24	1260.0	5.01	48.0	10.97

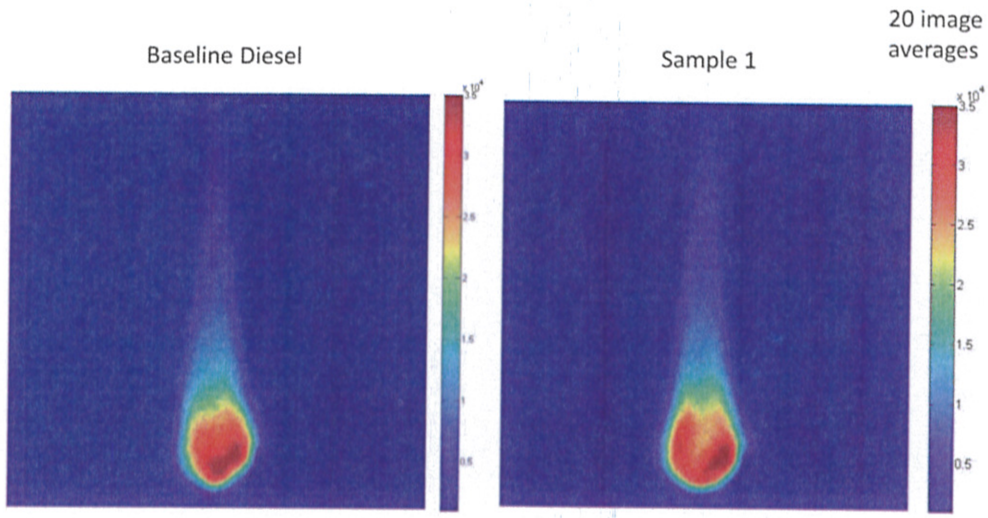
	CO2 (% vol)	Error Bar (± %)	O2 (% vol)	Error Bar (± %)	Combustion Efficiency (%)	Error Bar (± %)
Baseline Diesel	6.7	5.65	11.1	3.64	99.3	0.05
Sample 1	7.3	3.06	10.5	2.46	99.6	0.012

- Sample 1 exhibits superior combustion efficiency than baseline.
- The combustion efficiency trends match the measured exhaust temperatures trend—higher efficiency leads to higher temperature because more of the fuel energy is converted to heat.
- Lower combustion efficiency means less potential fuel energy is converted to heat.



- This is qualitative imaging based on color video.
- Average image based on 400 individual frames.
- The overall flame shape and appearance varies somewhat.
- The "sooting propensity" is determined by adding up the pixel intensities on the images to left. This is qualitative but suggests somewhat lower sooting for Sample 1.

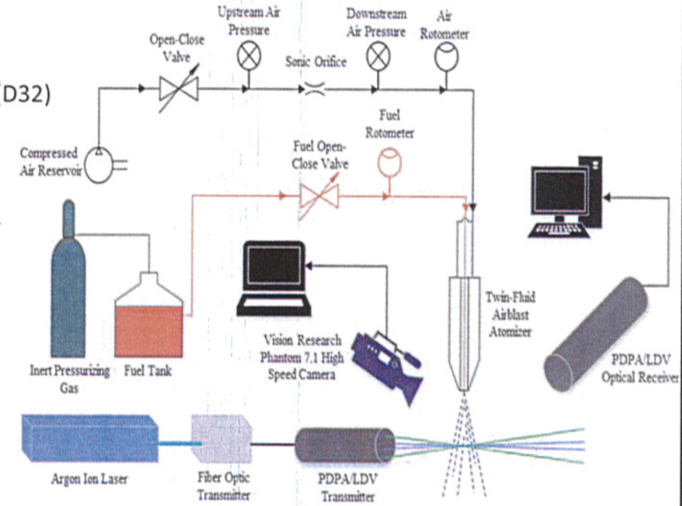
OH Chemiluminescence

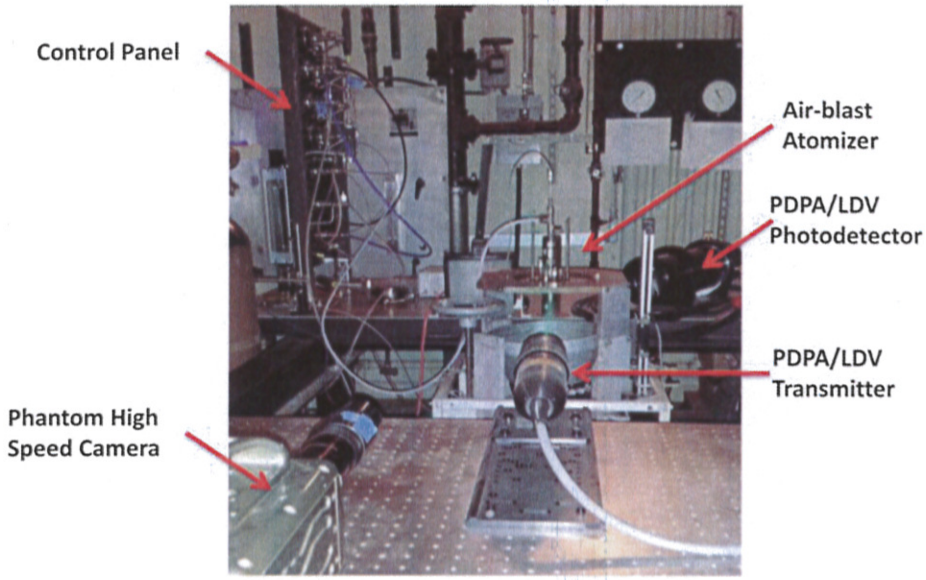


- Qualitative based on OH* imaging
- Not really any discernible differences??

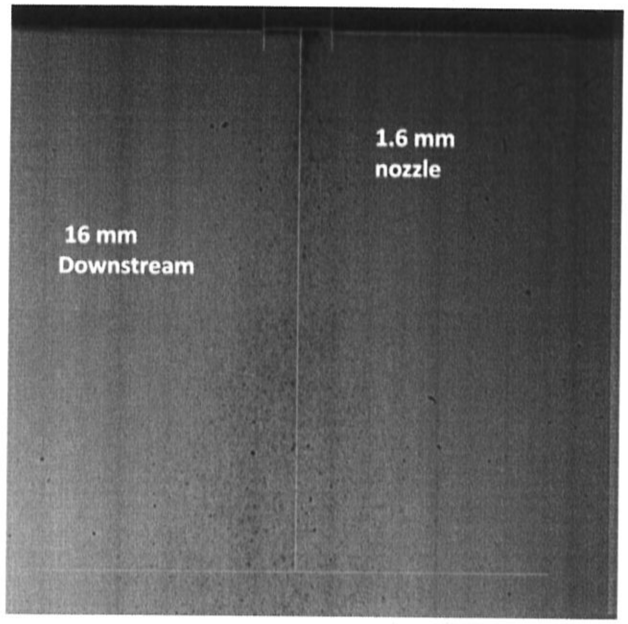
Atomization Test Apparatus

- TSI FSA-4000 Phase Doppler Particle Analyzer
  - Sauter Mead Diameter (D32)
  - Mean Diameter (D10)
  - Volume Flux
- Vision Research Phantom 7.1 High Speed Camera
  - -516 x 516 Resolution
  - -8200 fps
  - -2 μs Exposure



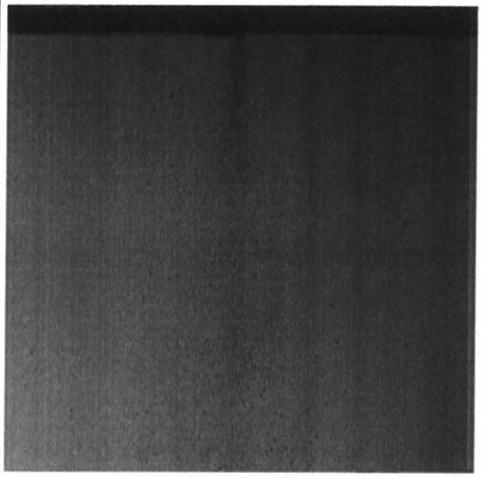

Control Panel
Air-blast Atomizer
PDPA/LDV Photodetector
PDPA/LDV Transmitter
Phantom High Speed Camera

Diesel Atomization Results

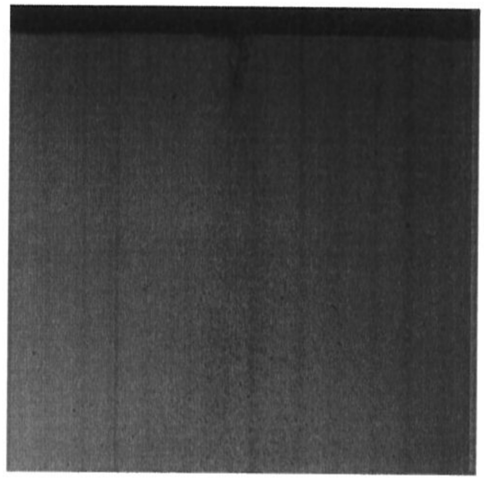


- Single frame from high speed video
- All diesels displayed similar atomization behavior. Follows consistently with previous diesels sprayed during other testing.
- Fuels ejected from nozzle at similar angles to left hand side of image, no noticeable differences

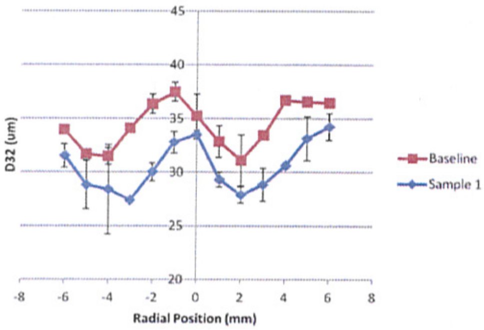
Baseline

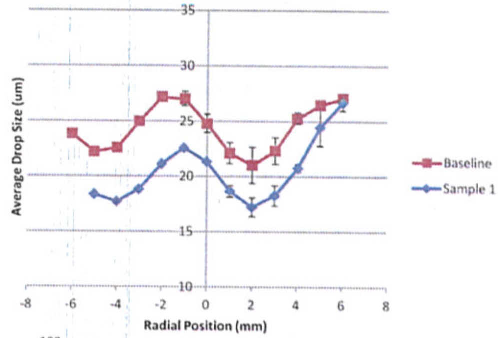


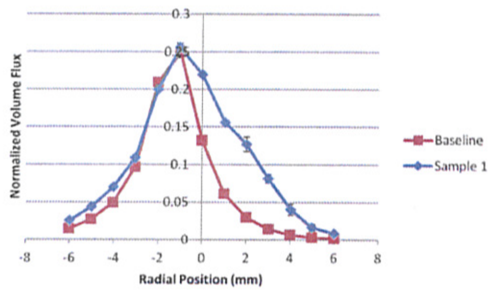
Sample 1

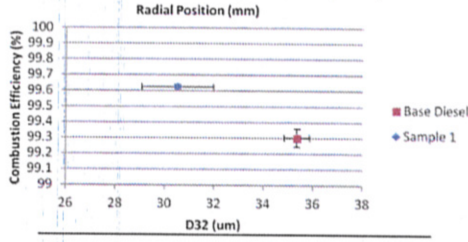


Diesel Atomization Results









	Weighted D32 (μm)	Error Bar (± %)
Sample 1	30.5	4.73
Baseline	35.3	1.45

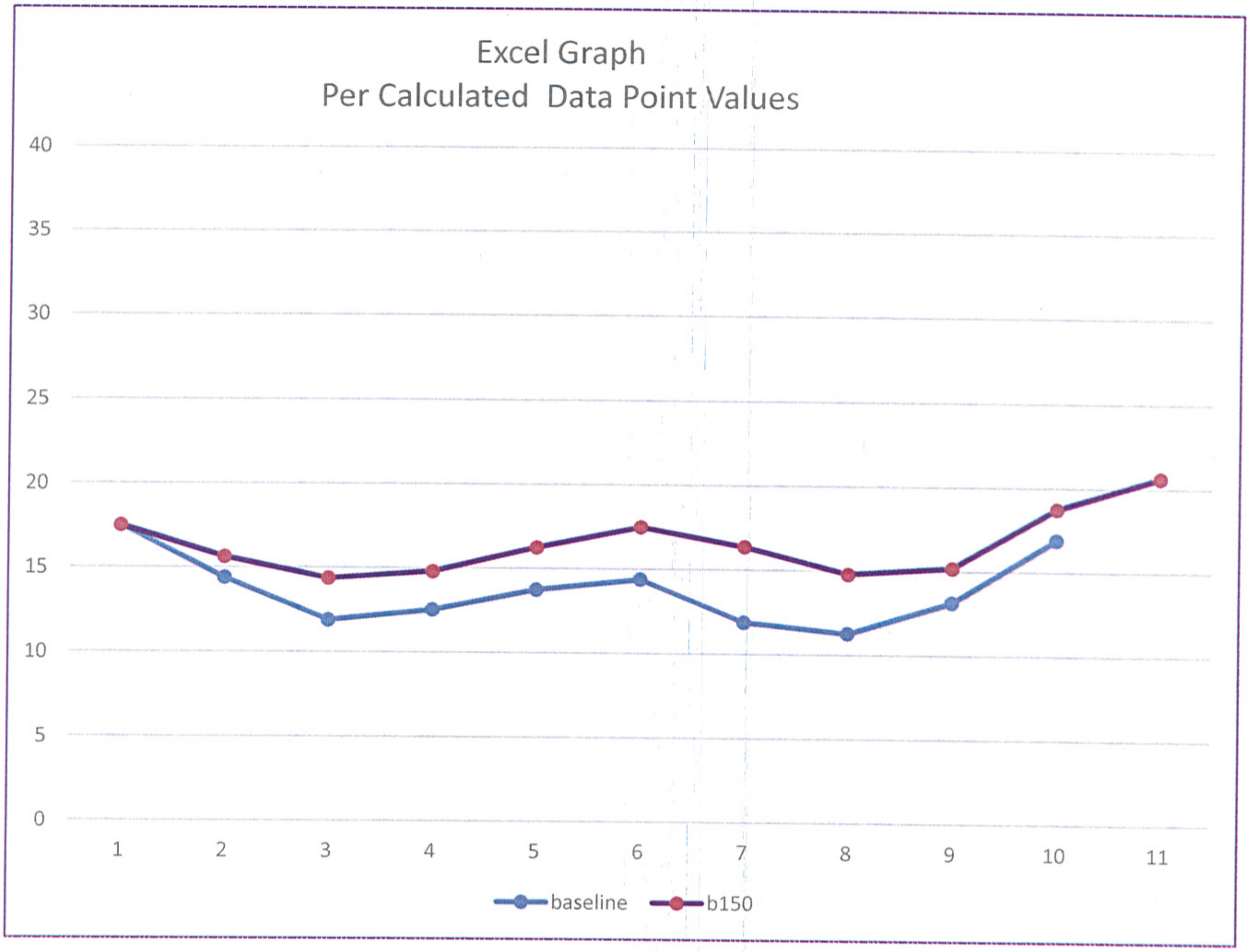
- Sample 1 has superior atomization performance (i.e. finer drops).
- The Average Drop size indicates this.
- The weighted D32 represents an overall drop size for each fuel.
- Note that the combustion efficiency trends match the inverse of the size. Smaller drop sizes for Sample 1 lead to better combustion efficiency..
- The spray plume spread of Sample 1 also appears to be greater than that of the baseline.

Diesel Physical Properties

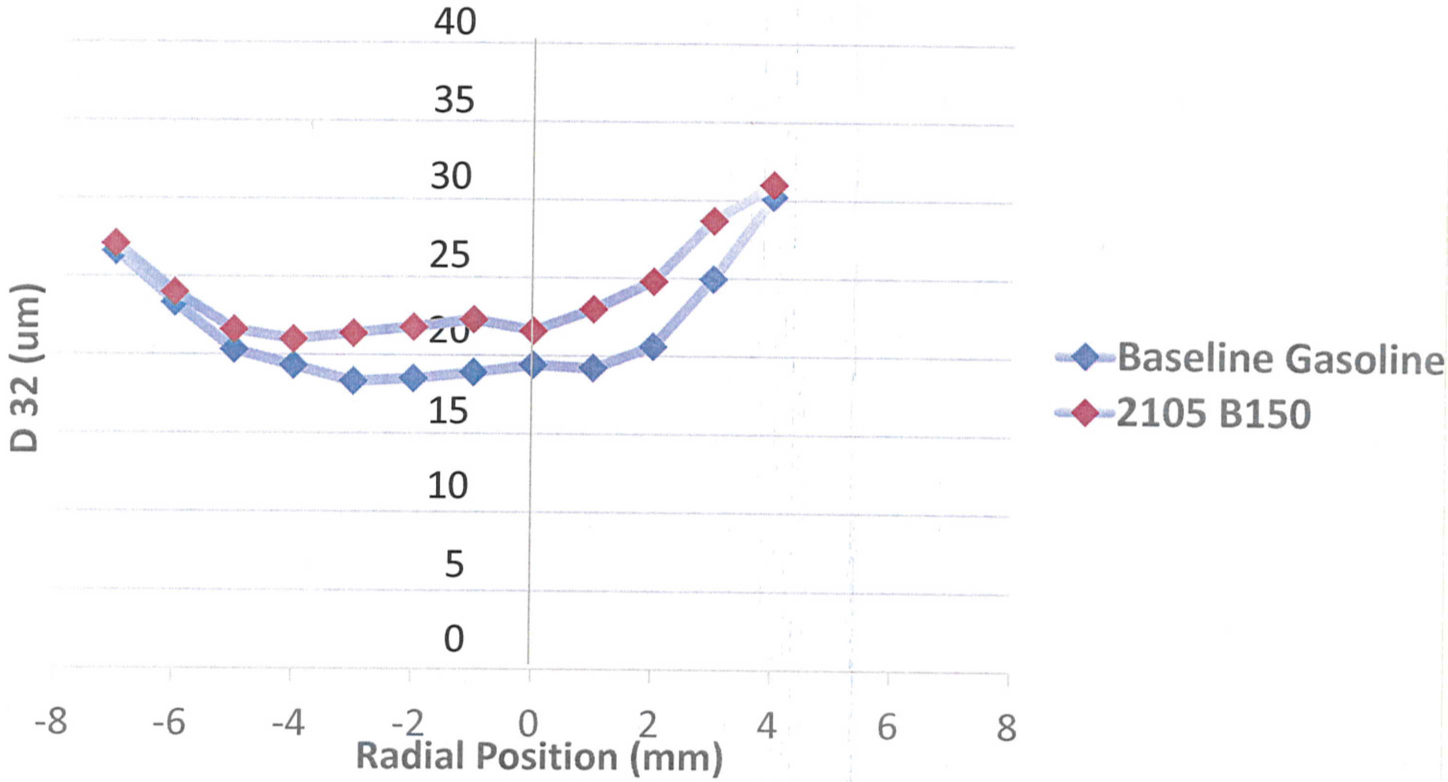
- Viscosity (falling ball method) ~70 F
  - Essentially the same within experimental uncertainty
    - Baseline: 2.81 centipoise +/- 0.09
    - Sample 1: 2.94 centipoise +/- 0.11
- Surface Tension (Stalagmometer) ~70 F
  - Slightly lower surface tension for Sample 1:
    - Baseline: 27.98 dynes/cm +/- 0.001
    - Sample 1: 27.56 dynes/cm +/- 0.001

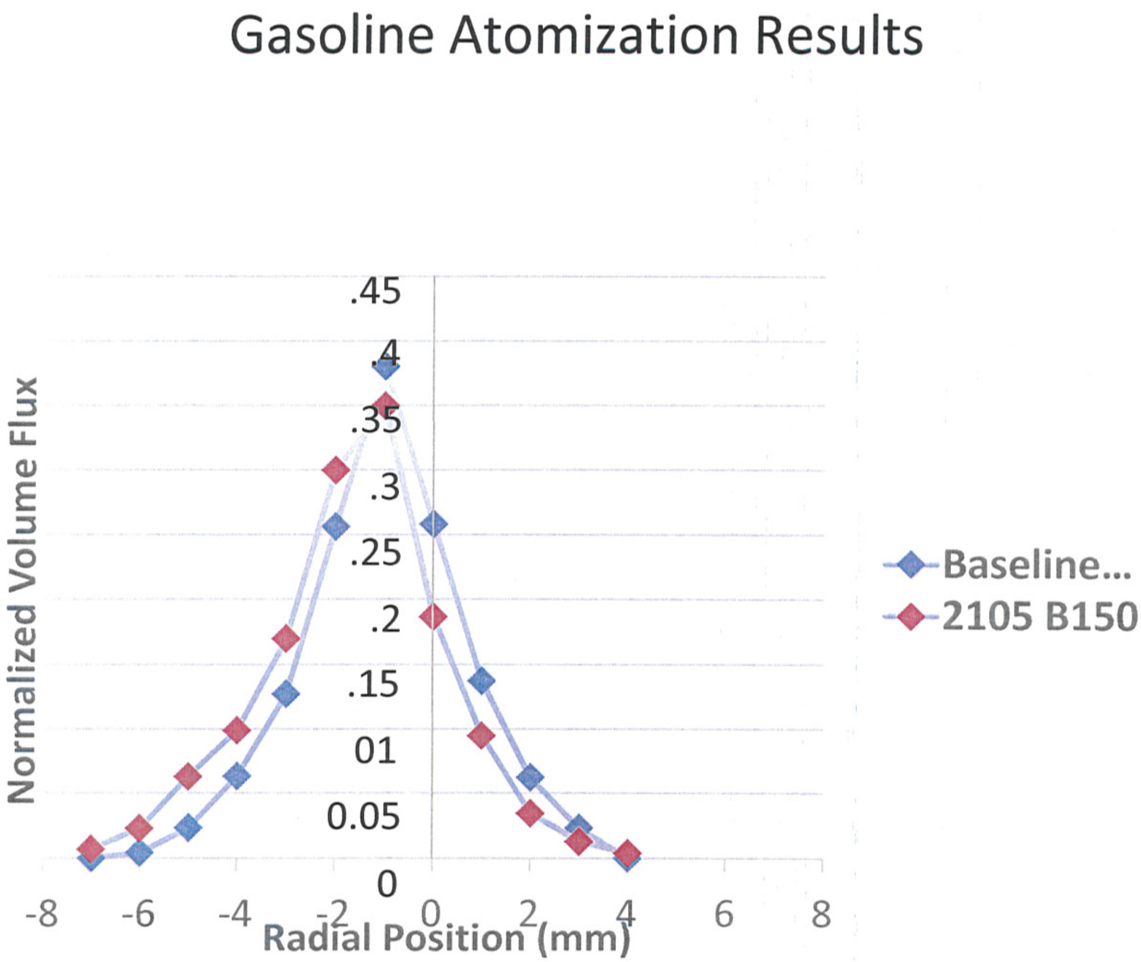
- Falling Ball method cannot capture any non-newtonian behavior—need to test again with a different method that can resolve any shear thinning/thickening behavior

Gasoline Atomization Results



Gasoline Atomization Results




Gasoline Atomization Results
Normalized Volume Flux
.45
.4
.35
.3
.25
.2
.15
01
0.05
0
-8
-6
-4
-2
0
2
4
6
8
Radial Position (mm)
Baseline...
2105 B150

Gasoline Atomization Results