EFFECTS OF DIESEL FUEL QUANTITY ON THE EMISSIONS CHARACTERISTICS OF A DUAL FUEL ENGINE

BETTER AIR QUALITY 2018

SARAWAK

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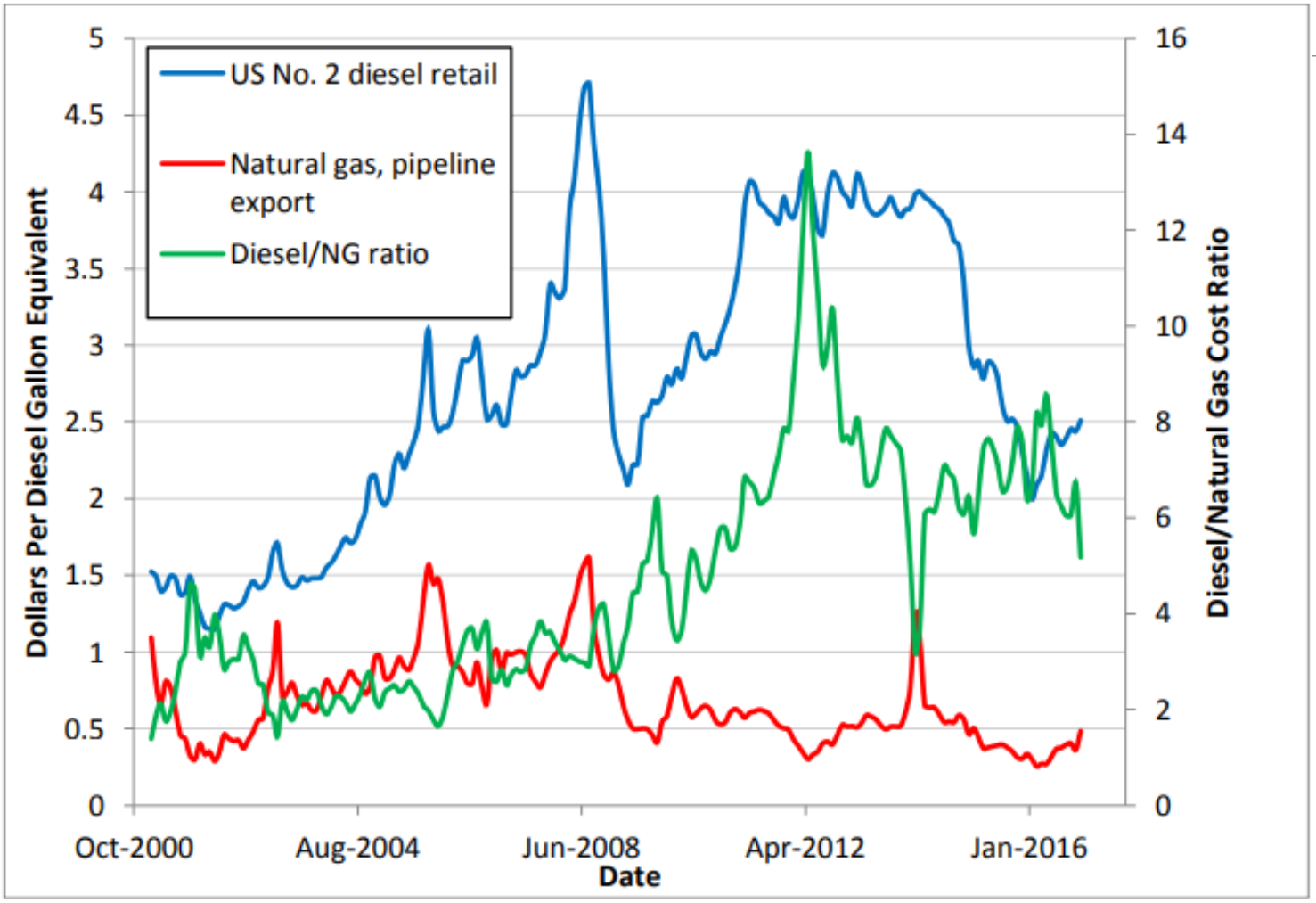
Motivation for Natural Gas Usage Diesel vs Natural Gas Prices



Motivations for Natural Gas Usage Emission Regulations for Non-road CI Engines

U.S. EPA Non-Road and Stationary Emissions Regulations

Summary Chart Optimized for MQ Power Generators 2004-2017

Select Generator Model - Go - - Help -

kWm	(HP)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0 ≤ P < 8	(0 - 11)	Tier 1	(7.5) / 8.0 / 0.80			(7.5) / 6.6 / 0.40									
8 ≤ P < 19	(11 - 25)	Tier 1	(7.5) / 6.6 / 0.80												
19 ≤ P < 37	(25 - 50)	(7.5) / 5.5 / 0.60				(7.5) / 5.0 / 0.30					(4.7) / 5.0 / 0.03				
37 ≤ P < 56	(50 - 75)	(7.5) / 5.0 / 0.40				(4.7) / 5.0 / 0.30 [EPA Option 1]					(4.7) / 5.0 / 0.03				
56 ≤ P < 75	(75 - 100)					(4.7) / 5.0 / 0.40				3.3 / 0.19 / 5.0 / 0.02			0.40 / 0.19 / 5.0 / 0.02		
75 ≤ P < 130	(100 - 174)	(6.6) / 5.0 / 0.30				(4.0) / 5.0 / 0.30									
130 ≤ P < 225	(174 - 302)	(6.6) / 3.5 / 0.20				(4.0) / 3.5 / 0.20				2.0 / 0.19 / 3.5 / 0.02			0.40 / 0.19 / 3.5 / 0.02		
225 ≤ P < 450	(302 - 603)	Tier 2	(4.0) / 3.5 / 0.20												
450 ≤ P < 560	(603 - 750)	Tier 2	(4.0) / 3.5 / 0.20												
560 ≤ P < 900	(750 - 1206)	9.2 / 1.3 / 11.4 / 0.54				(6.4) / 3.5 / 0.20				3.5 / 0.40 / 3.5 / 0.10			0.67 / 0.19 / 3.5 / 0.03		
> 900	(>1206)	9.2 / 1.3 / 11.4 / 0.54				(6.4) / 3.5 / 0.20				0.67 / 0.40 / 3.5 / 0.10			3.5 / 0.19 / 3.5 / 0.04 (Non Generator)		

TIER 1 | TIER 2 | TIER 3 | TIER 4 (Interim) | TIER 4 (Final)

NO_x / HC / CO / PM (g/kW-hr)

(NO_x + HC) / CO / PM (g/kW-hr)

[Conversion: (g/kW-hr X 0.7457 = g/bhp-hr)]
Separate NO_x and HC standards separated by a forward slash.

Combined NO_x and HC standards enclosed by parentheses. "( )"

Definitions of Natural Gas Engine

Dedicated

- Run on one fuel

Bi-Fuel

- An engine that has two independent fuel systems (one of them natural gas) can run alternatively on either fuel, but only one at a time.

Dual Fuel

- An engine that has two independent fuel systems (one of them for natural gas) and can run on both fuels simultaneously. It also may run on one fuel alone.

Micropilot

- Dual fuel with special injector-1-4% of diesel amount is injected

Flexible Fuel

- Run on a mixture of fuels eg. gasoline & ethanol

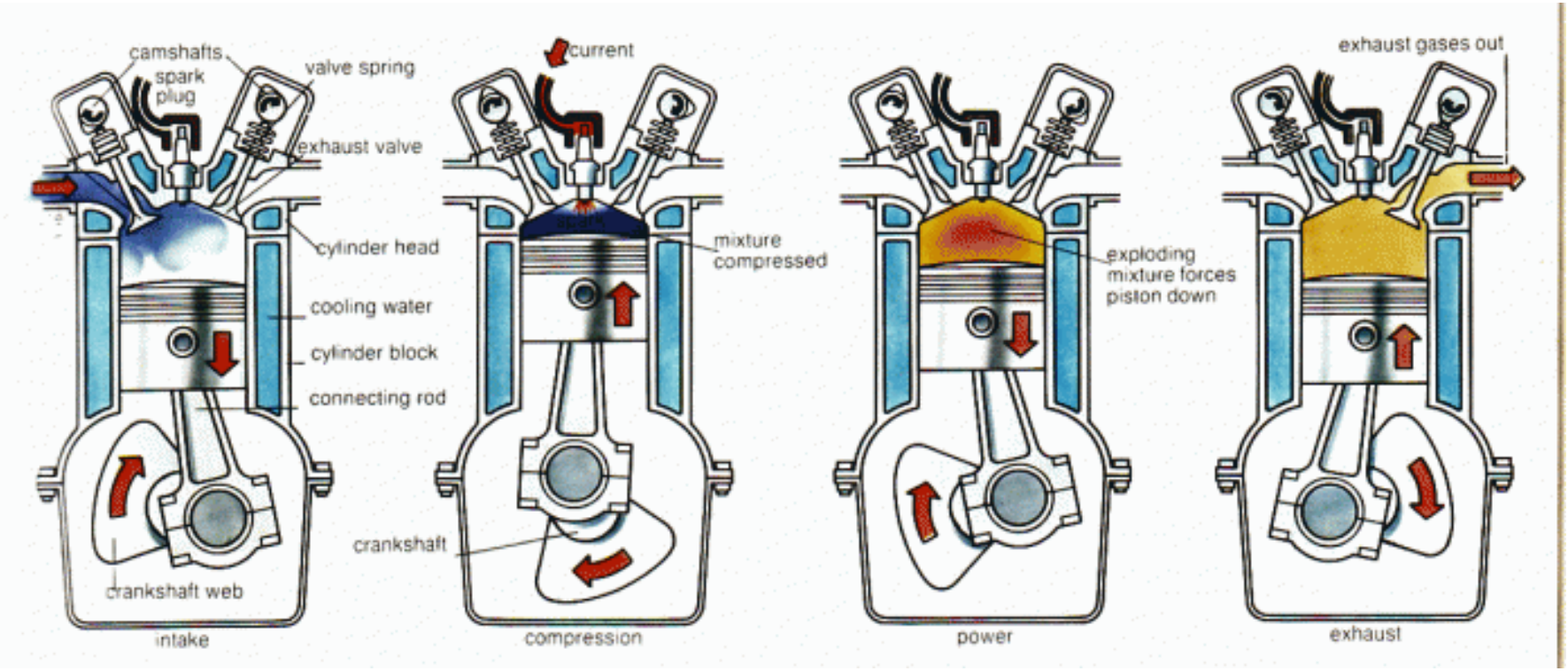
Why Dual Fuel?

- Existing engines, does not require replacement
  - Dual fuel kit
- Low cost of entry & maintenance
  - Reduce de-carbonize & overhaul of engines
- Seamless transition to 100% diesel fuel
- Non-invasive to OEM diesel engine
- Maintain power or torque

Fuel Gas Options

Fuel	Cost	Environment	Con.
Biogas	Low	HC & CO	Power derating
Producer Gas	Moderate	CO	Power derating & efficiency
LPG	Moderate	HC & CO	Combustion noise
NG	Moderate	HC & CO	Part load performance
Diesel	High	PM & NOx	Cost & emission

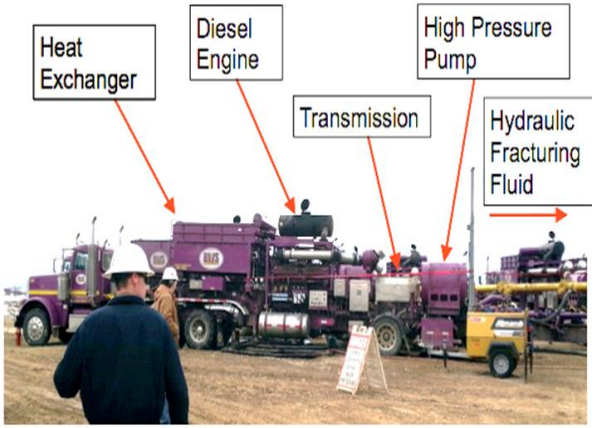
Dual Fuel Engine Basic Operation



Intake Compression Power Exhaust

Applications

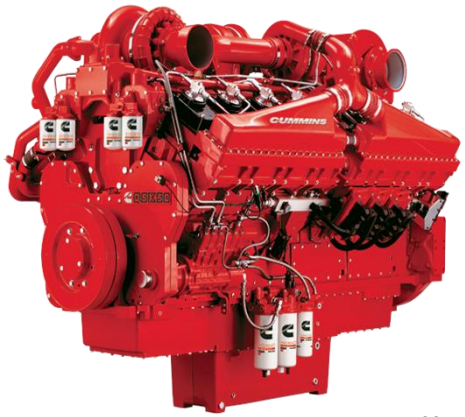
- The Oil and Gas industry is prime for utilization of natural gas as a fuel.
- Dual fuel engine in land-based oil, well-drilling and fracking applications
- Dual fuel in hydraulic fracturing truck → high pressure pump and diesel engine
- Transportation



Dual Fuel Conversion Technologies

For Industrial Engines

- Altronic GTI Bi-Fuel
- Hythane Opti-Blend
- GFS Corp
- ComAp Bi-Fuel
- Woodward Dual-fuel
- Continental Controls
- Caterpillar DGB (OEM)
- Cummins (OEM)



Cummins QSK50 Tier 2 well servicing applications

Objectives

To study the effect of diesel fuel quantity in dual fuel engines that will reduce THC and CO emissions.

- Performance

- Emissions

Experimental Setup & Test Plan

Experimental apparatus

Engine specifications

Dual fuel components

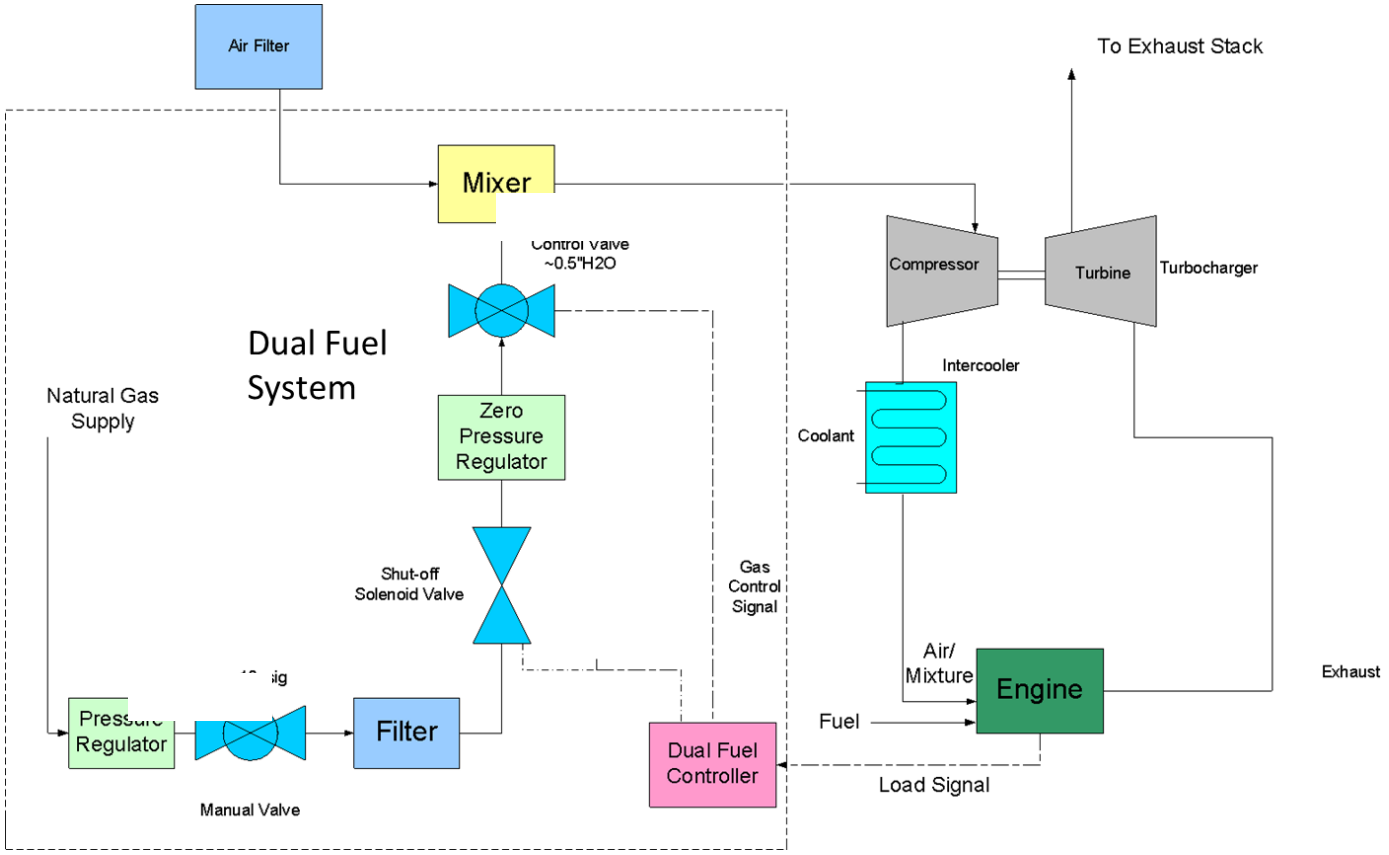
Flow meters

Emission concentration measurement

Test plan

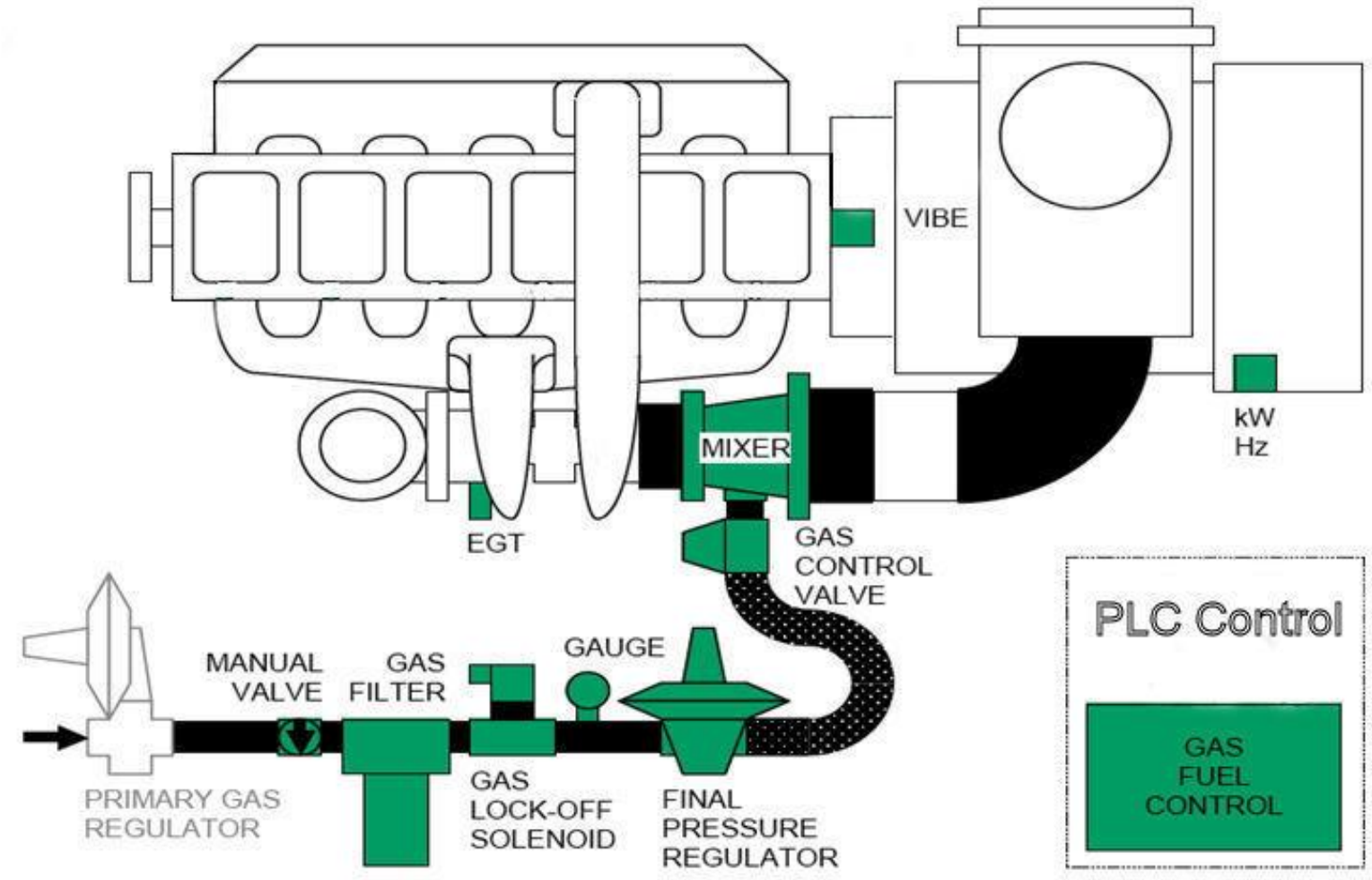
Optimization testing

Experimental Apparatus



Experimental Apparatus

Dual Fuel System Overview



Engine Specifications

Engine Model	6068HF475
Number of Cylinders	6
Bore and Stroke	106 x 127 mm
Connecting Rod	203 mm
Compression Ratio	17:1
Engine Type	In-line, 4-cycle
Aspiration	Turbocharged and Aftercooled
Displacement	6.8 liters
Rated Power	205 kW (275 hp)
Rated Speed	2400 rpm
Normal operation speed	1800 rpm
Number of Injector Nozzle Holes	6
Injector Nozzle Hole Diameter	1.75E-04 cm
Nominal Start of Injection Timing	6.5 bTDC

Emission Concentration Measurement

The 5-gas analyzer measures CO, CO2, O2, NOX, and THC concentrations

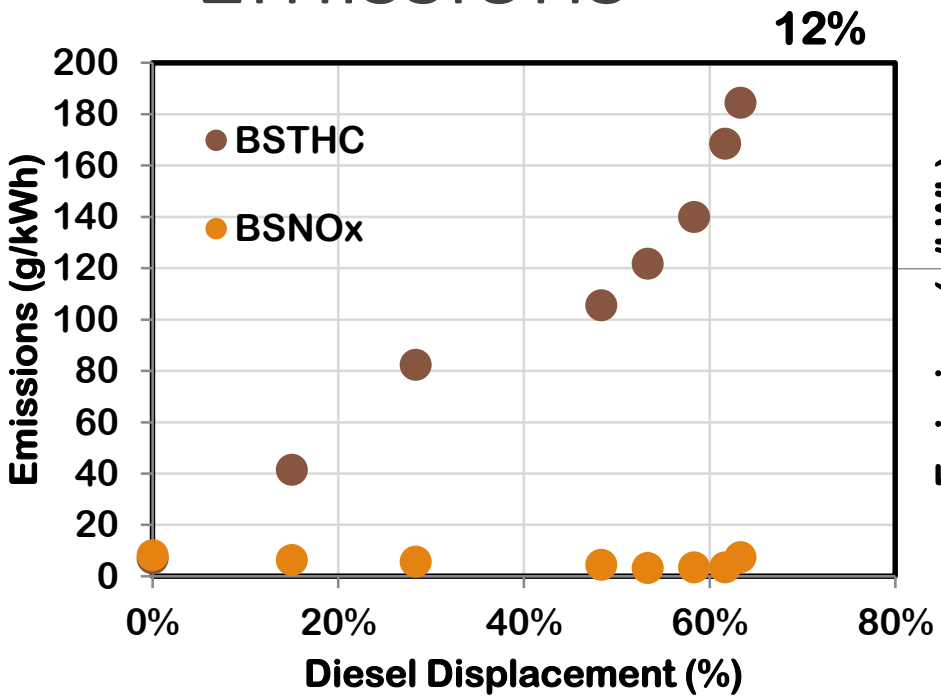
The FTIR is used to formaldehyde, acrolein, and acetaldehyde.

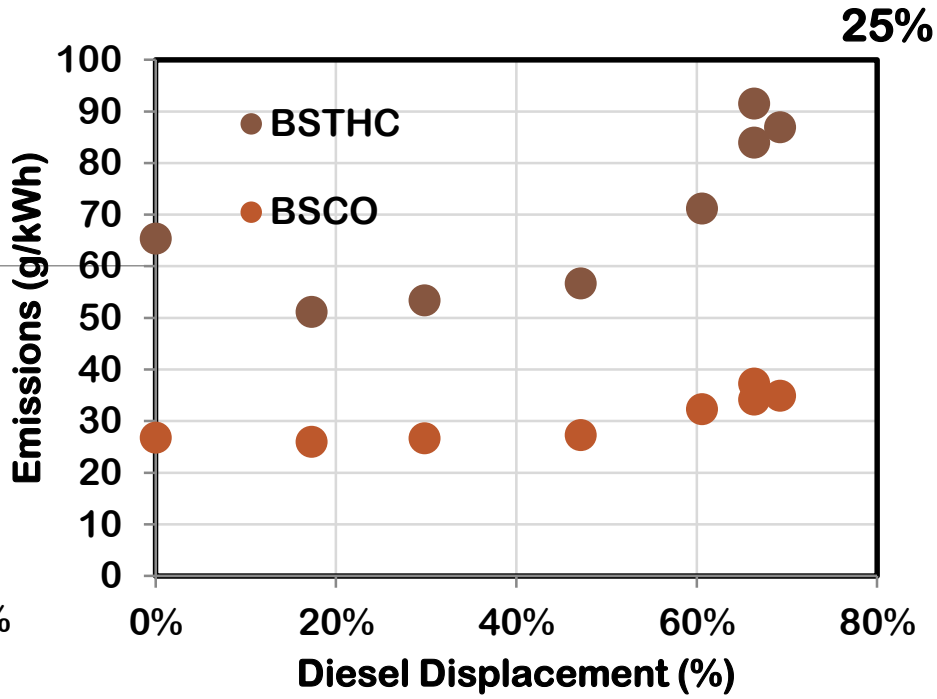
The dilution tunnel is used to measure PM

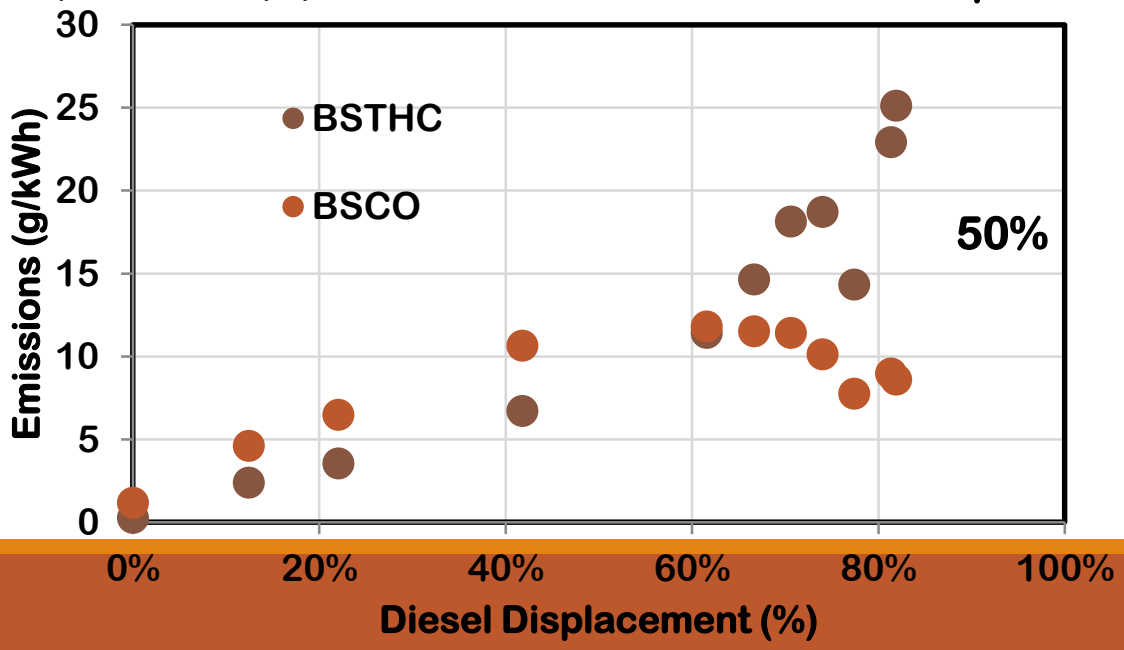
Dual Fuel Baseline Map Displacement

Load	12%	25%	50%	75%	100%
Diesel displacement (%)	35.0	59.6	70.0	69.4	58.7
Equivalence ratio	0.15	0.23	0.22	0.27	0.24

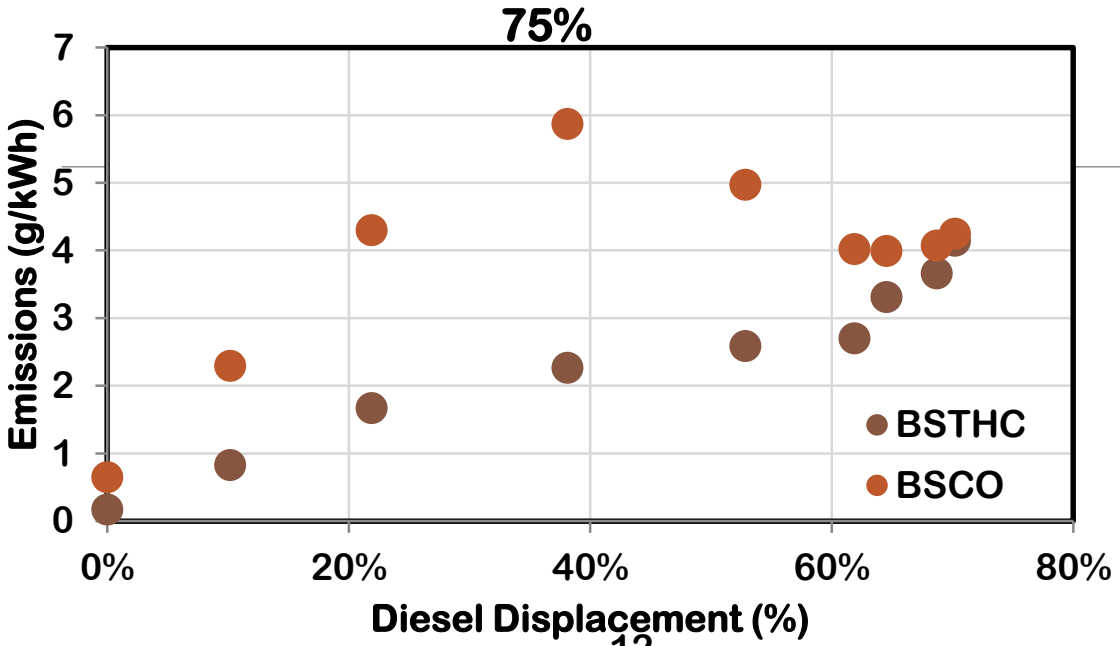
Emissions

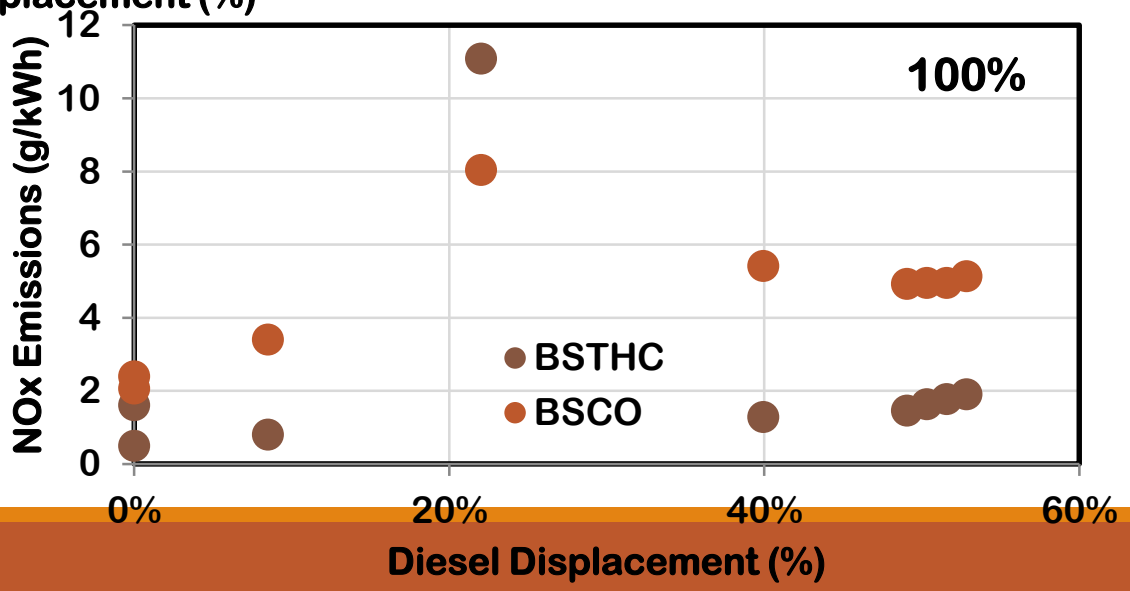

12%
BSTHC
BSNOx
Emissions (g/kWh)
200
180
160
140
120
100
80
60
40
20
0
0%
20%
40%
60%
80%
Diesel Displacement (%)


25%
BSTHC
BSCO
Emissions (g/kWh)
100
90
80
70
60
50
40
30
20
10
0
0%
20%
40%
60%
80%
Diesel Displacement (%)

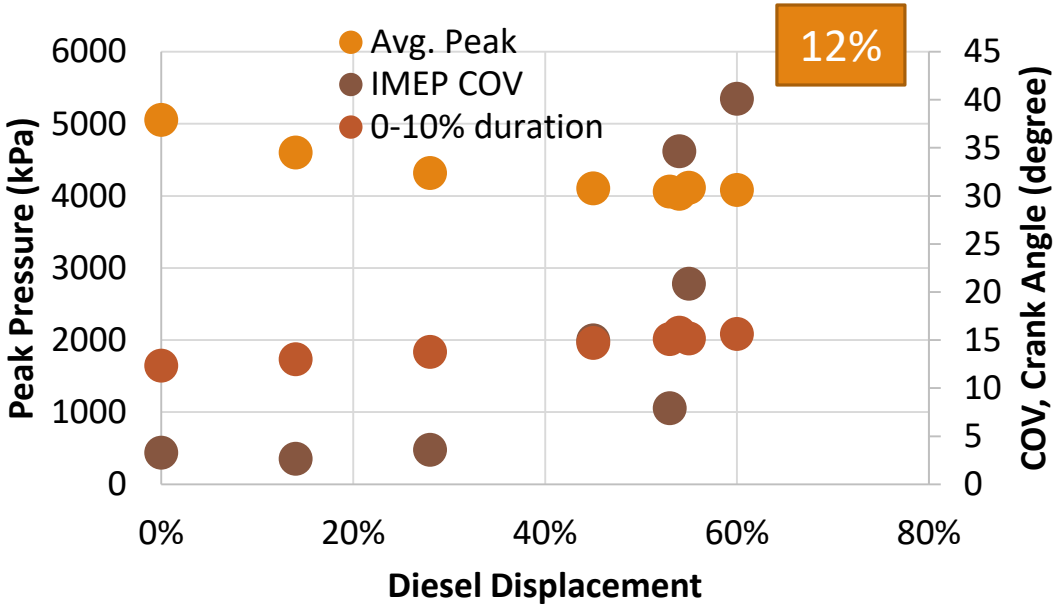

50%
BSTHC
BSCO
Emissions (g/kWh)
30
25
20
15
10
5
0
0%
20%
40%
60%
80%
100%
Diesel Displacement (%)

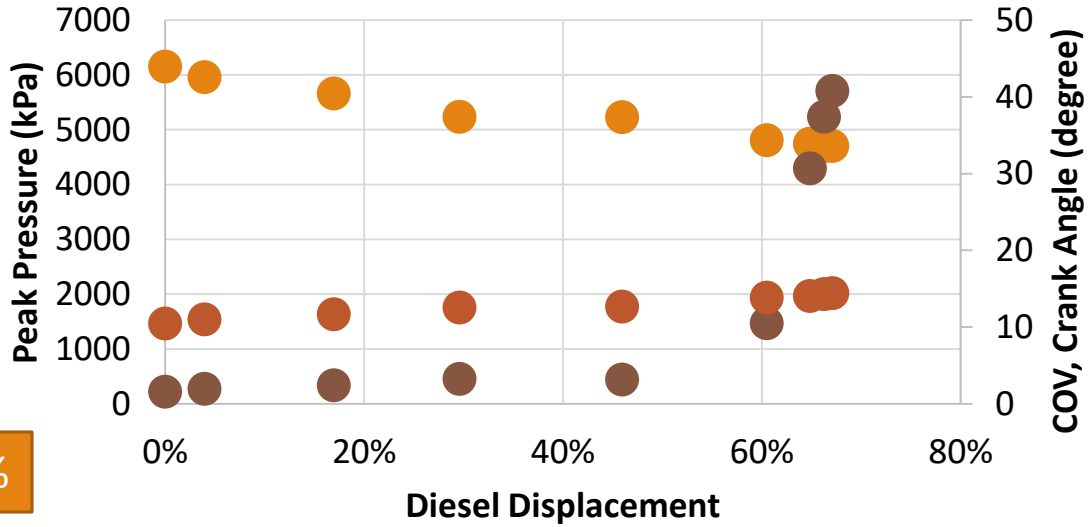
Emissions


75%
Emissions (g/kWh)
0
1
2
3
4
5
6
7
0%
20%
40%
60%
80%
Diesel Displacement (%)
BSTHC
BSCO

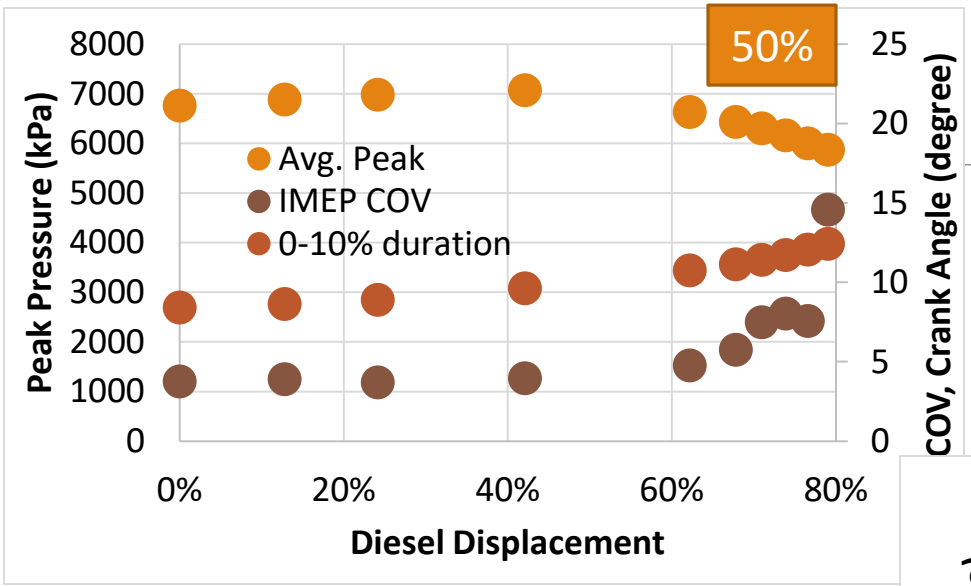

100%
NOx Emissions (g/kWh)
0
2
4
6
8
10
12
0%
20%
40%
60%
Diesel Displacement (%)
BSTHC
BSCO

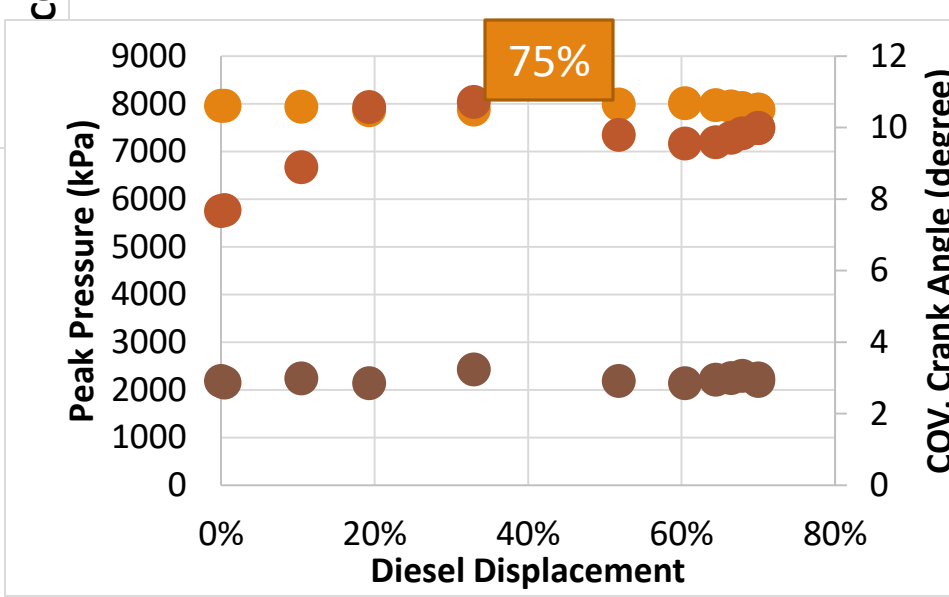
Combustion Performance

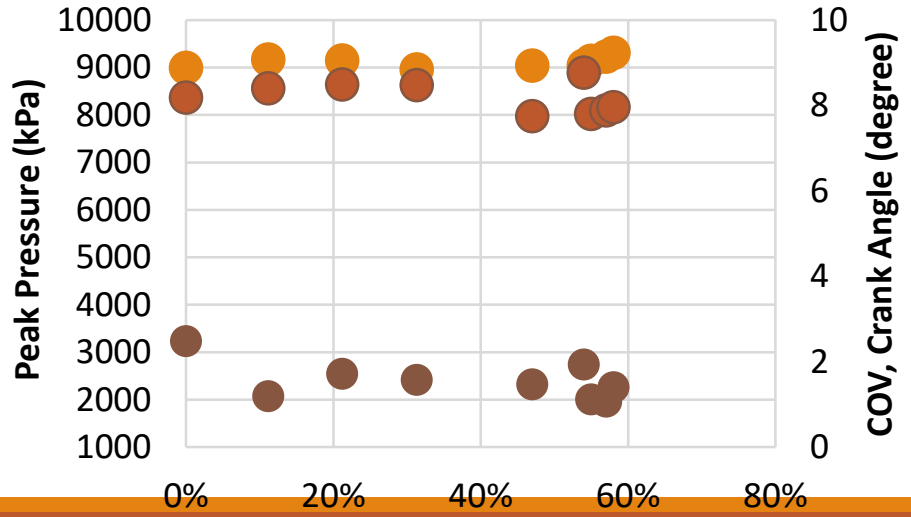




Combustion Performance







100%

Conclusions & Recommendation

Load	Baseline Displacement	Maximum Displacement Achieved	Effects on Combustion	Effects on Emissions
12%	35%	63%	High COV of IMEP, Peak pressure reduced	THC increased, no significant changes in CO
25%	60%	70%		
50%	70%	82%	Ignition delay and COV IMEP increased, PP reduced	THC increased, slight reduction in CO
75%	70%	70%	No significant changes	Slight increase in CO, THC reduced
100%	60%	53%		Reduction trend in CO and THC

Thanks