Evaluation of Biodiesel Source Type on Cad Cell Resistance

August 2017

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NORA Report 17-2

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Report

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Introduction

This test was done to provide additional data on the impact of biodiesel on the resistance of an oil burner cad cell. Tests were run using a cast iron boiler manufactured by Utica Boilers, model SFH-3100WT. The burner used for these tests is a conventional retention head burner, Model AFG manufactured by the R.W. Beckett Corporation. The burner control is a Beckett Genesis Primary Control Model 7505B-1500. For these tests the control flame sensor ("Cad Cell") input was disconnected from the control input terminals. The presence of the flame was provided manually into the control terminals with a simply electrical closure. This allowed direct measurement of the cad cell resistance using an external digital multimeter. For this specific control, the recommended burner cad cell resistance is under 1600 ohms.

For determination of excess air level and overall combustion quality, flue gas composition including CO_2 and CO were measured using an infrared (NDIR) fixed gas analyzer (CAI – Model ZRE). The flue gas sample was transported from the exhaust to the sample conditioning system using a heated sample line. A mechanical refrigeration drier (MAK10-1 / Clean Air Engineering) was used to remove flue gas moisture after filtering. Calibration gases are used for daily calibration of the gas analyzer. Flue gas smoke number was measured using a standard industry smoke number test.

Test fuels included No. 2 fuel oil as available in the NORA lab. An analysis showed the biodiesel content of this fuel to be under 1% by volume. Two different biodiesel fuels were used to prepare blends. This included one biodiesel produced from soy oil and a second from tallow. Both of these fuels were provided by Renewable Energy Group, Inc (REG) and a full certificate of analysis for these fuels is provided in Attachments I and II to this report.

Fuel blends studied include B-0 (the plain No. 2 oil without biodiesel addition), B-20 (a 20% by volume blend of biodiesel in No. 2 oil), and B-100 (just the feed biodiesel).

In a typical test series, the burner fuel suction was arranged to draw in the test fuel and the system operated to steady state to ensure the test fuel had fully flushed through the system. Following this excess air was varied with the burner inlet air damper. Flue gas analysis and cad cell resistance was measured. In determining the cad cell resistance and average value was taken. Also noted was the typical range of variation of cad cell resistance over the test period and the peak reading observed. Each fuel was tested twice over the whole excess air range.

Test Results

Figure 1 shows the smoke number and CO vs measured CO_2 for B-0. Figure 2 shows the results for the average cad cell resistance and Figure 3 shows the results for the maximum reading and approximate range of cad cell readings for this fuel.

Figure 4 through Figure 6 show the same results for B20 blends with soy biodiesel. Figure 7 through Figure 9 show the same results for B20 blends with the tallow biodiesel. Figure 10 through Figure 12 show the same results for B100 with the soy biodiesel and Figure 13 through Figure 15 show the same results for B100 with the tallow biodiesel.

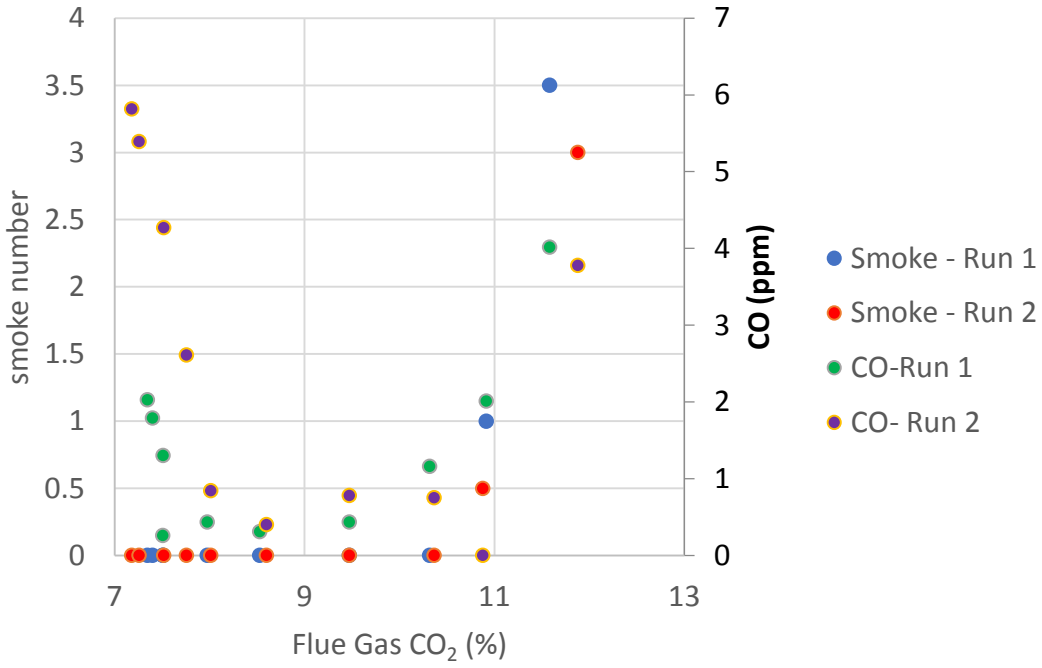

Figure 1 B0 Flue gas smoke number and CO

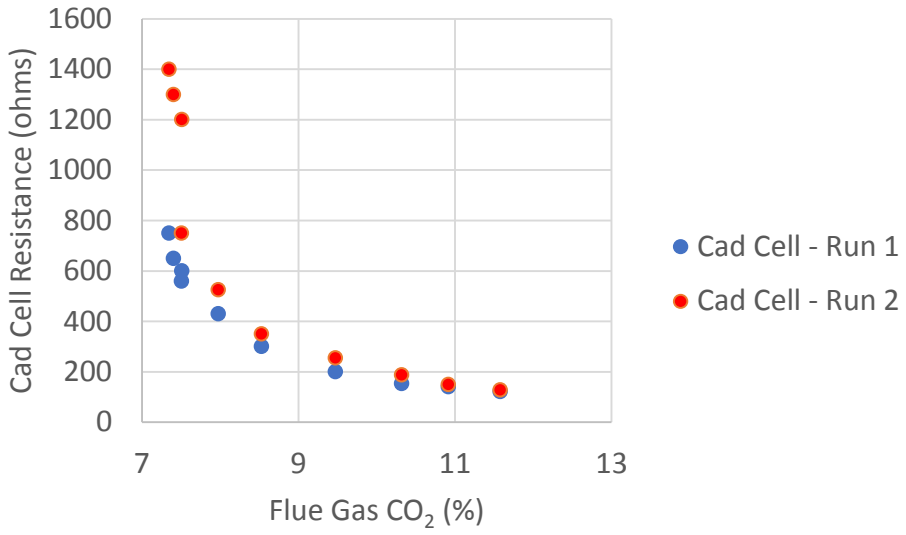

Figure 2 B0 Average cad cell resistance

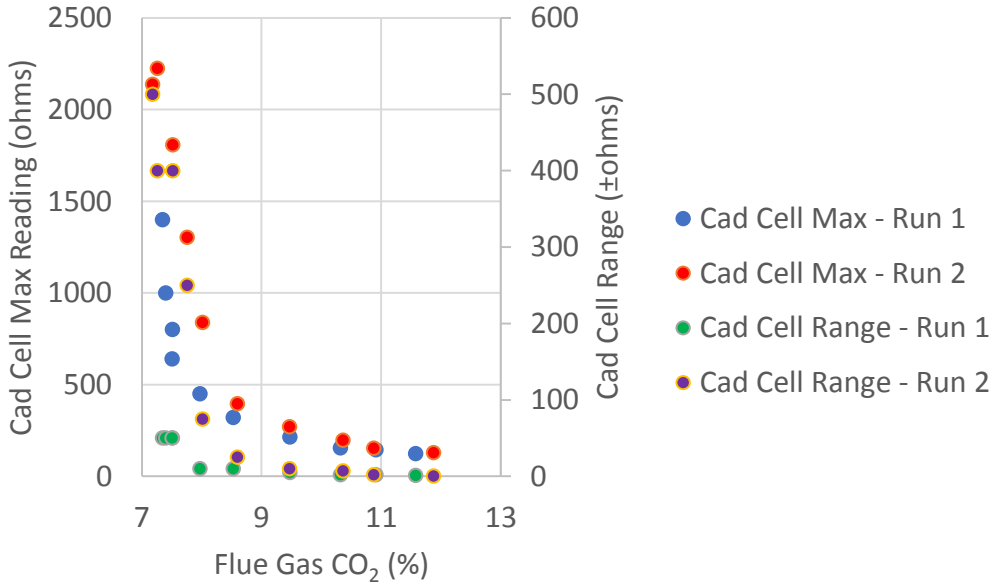

Figure 3 B0 Cad cell max reading and range

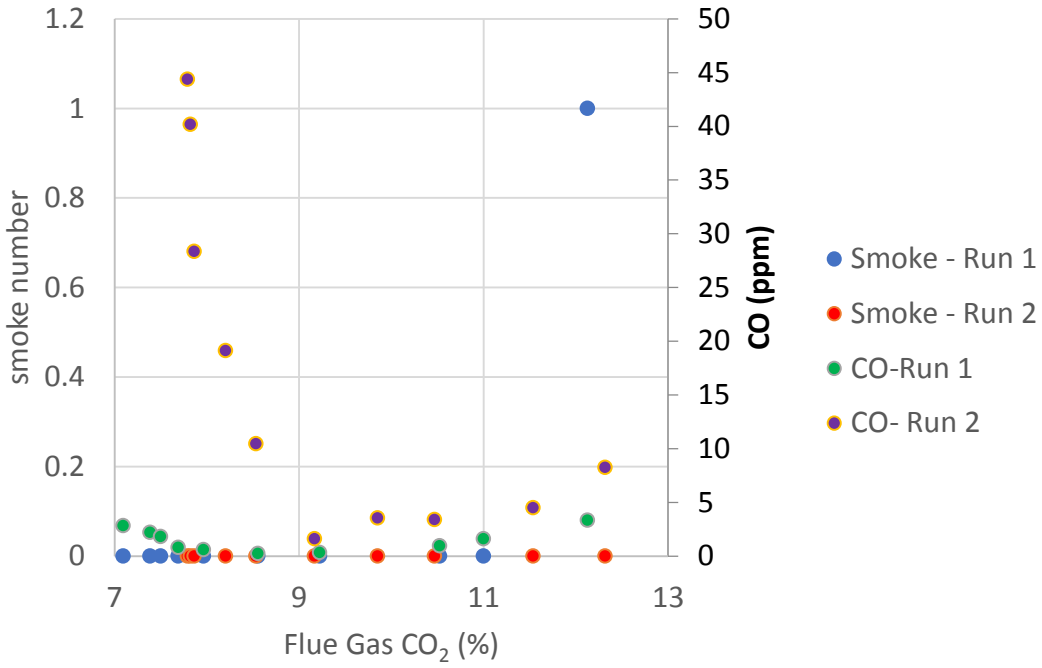

Figure 4 B20 Soy Flue gas smoke number and CO

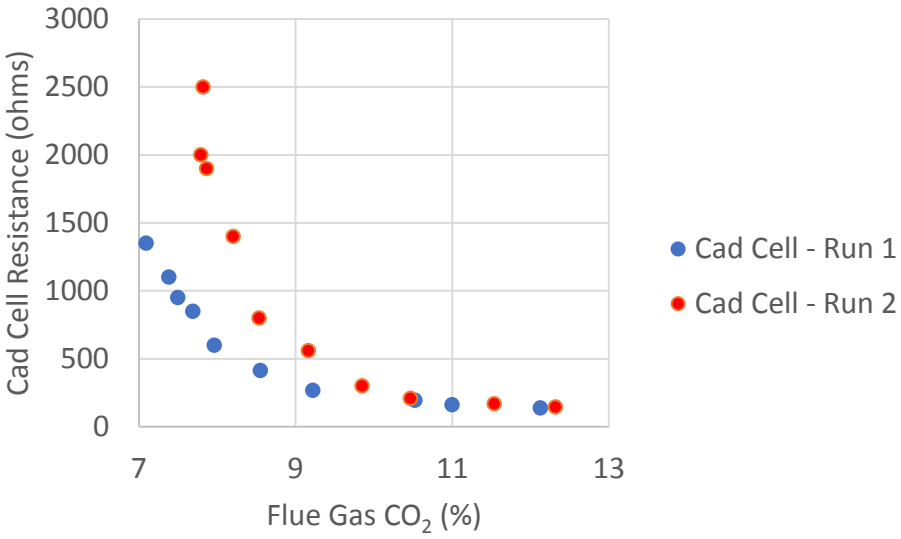

Figure 5 B20 Soy Average cad cell resistance

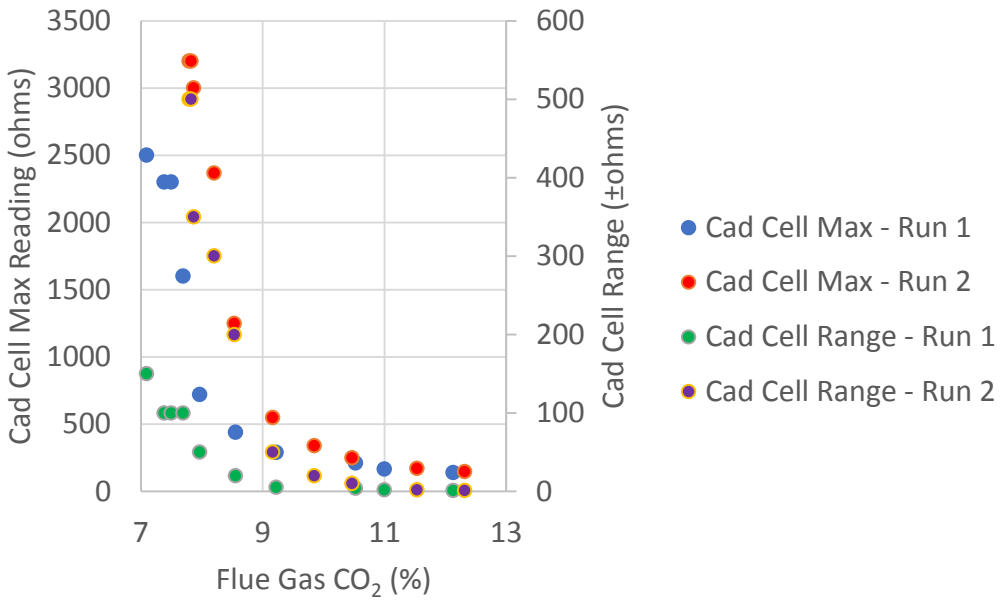

Figure 6 B20 Soy Cad cell max reading and range

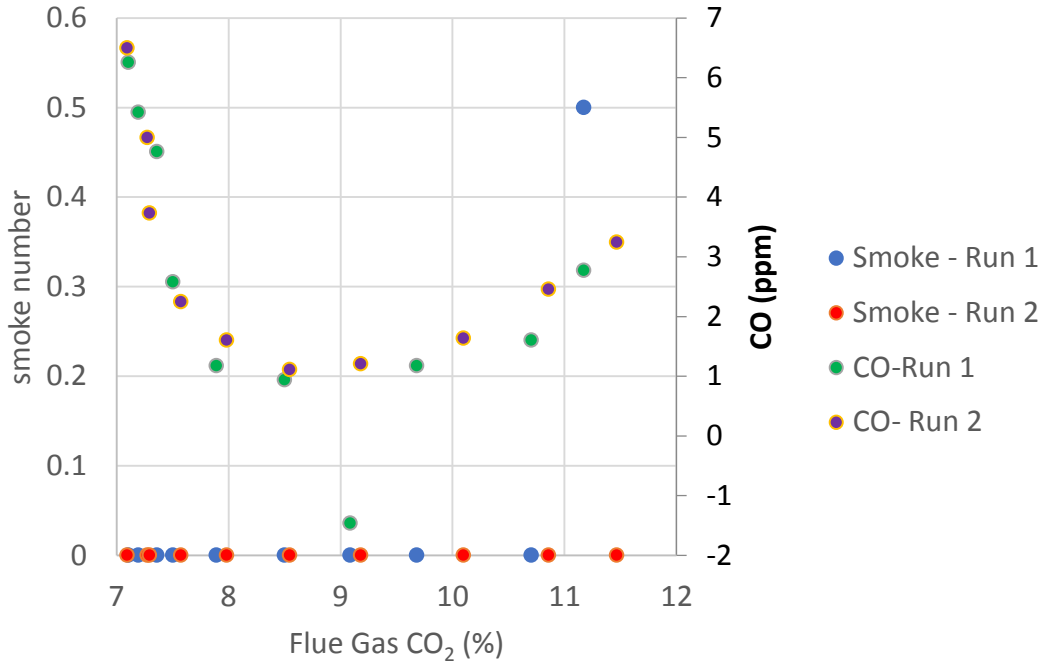

Figure 7 B20 Tallow Flue gas smoke number and CO

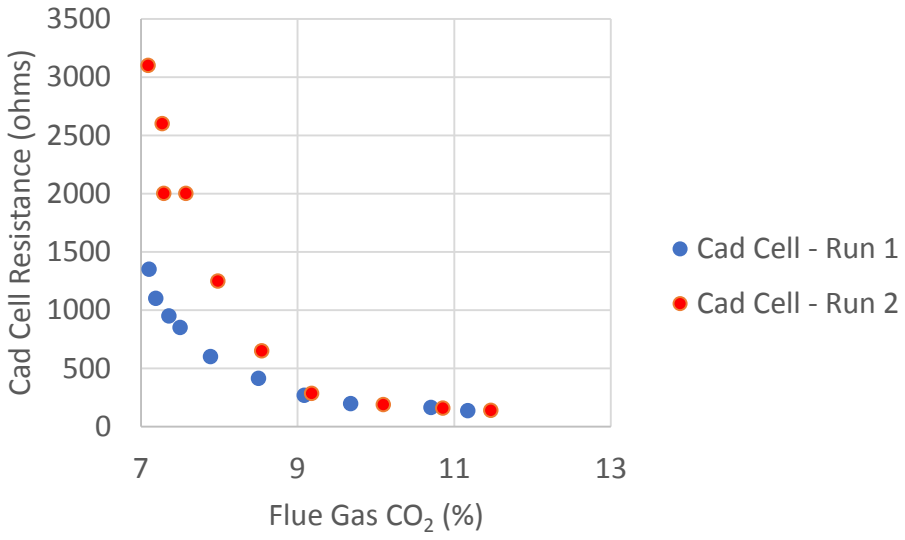

Figure 8 B20 Tallow Average cad cell resistance

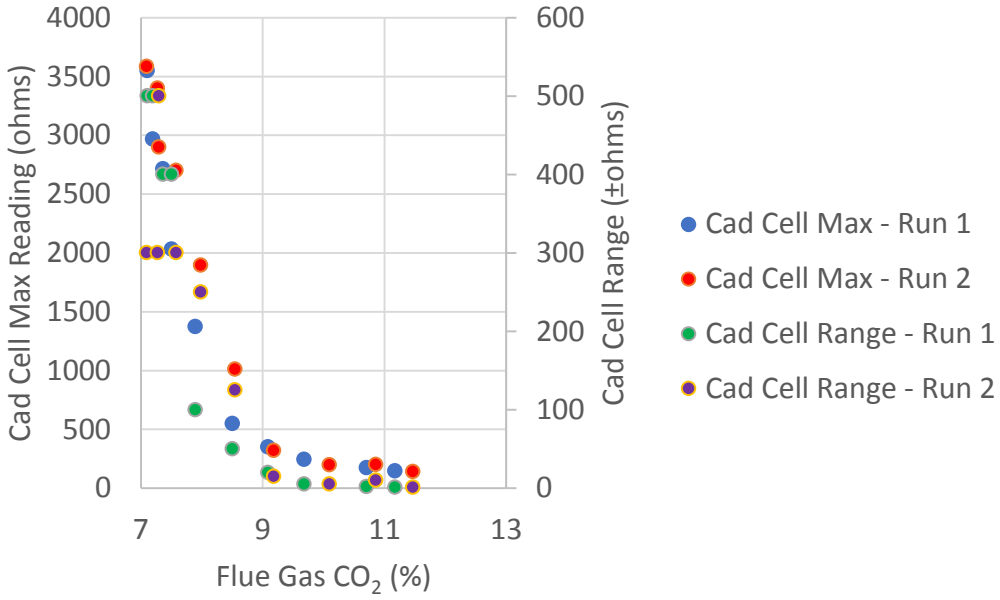

Figure 9 B20 Tallow Cad cell max reading and range

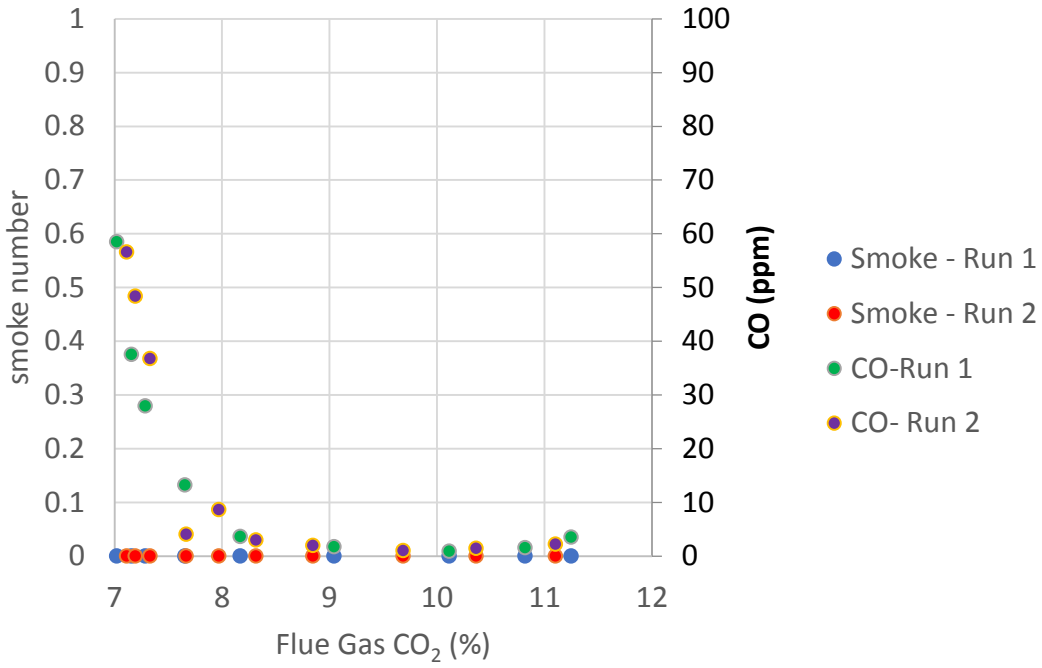

Figure 10 B100 Soy Flue gas smoke number and CO

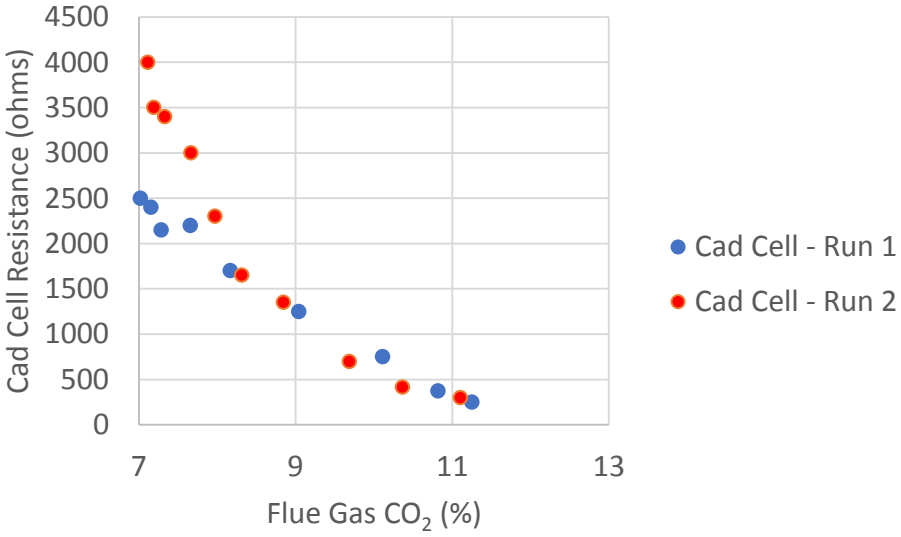

Figure 11 B100 Soy Average cad cell resistance

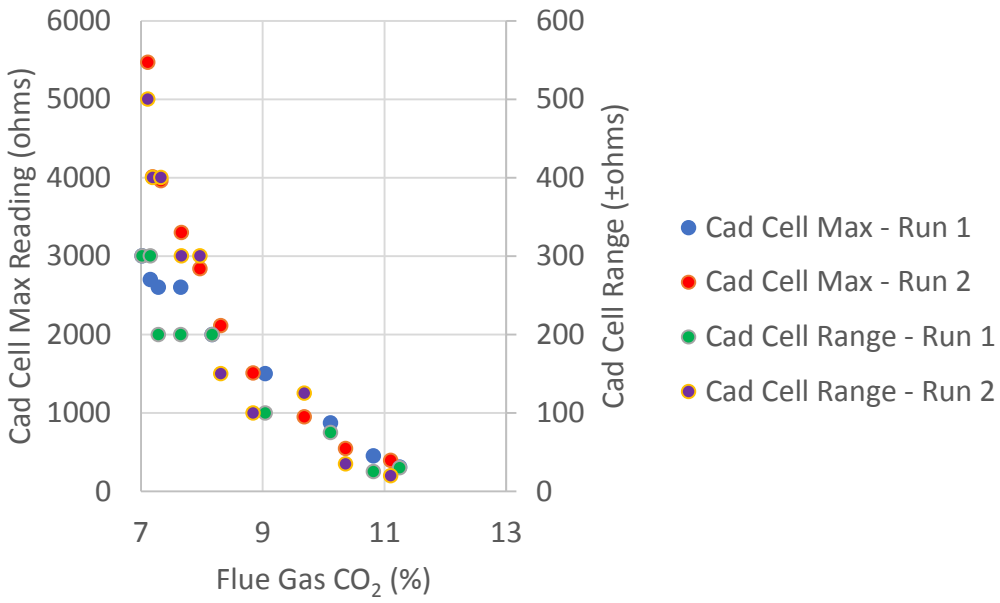

Figure 12 B100 Soy Cad cell max reading and range

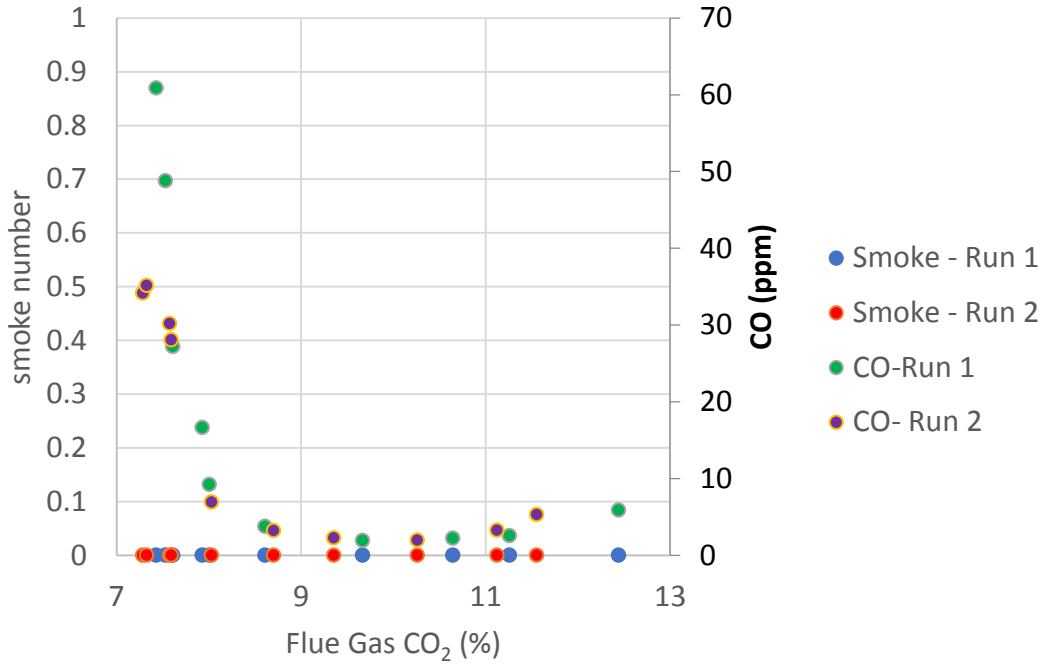

Figure 13 B100 Tallow Flue gas smoke number and CO

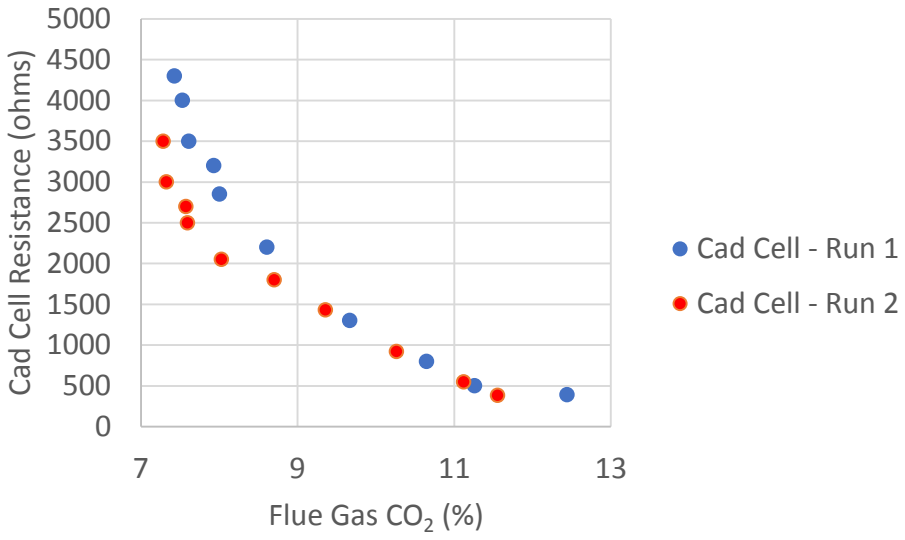

Figure 14 B100 Tallow Average cad cell resistance

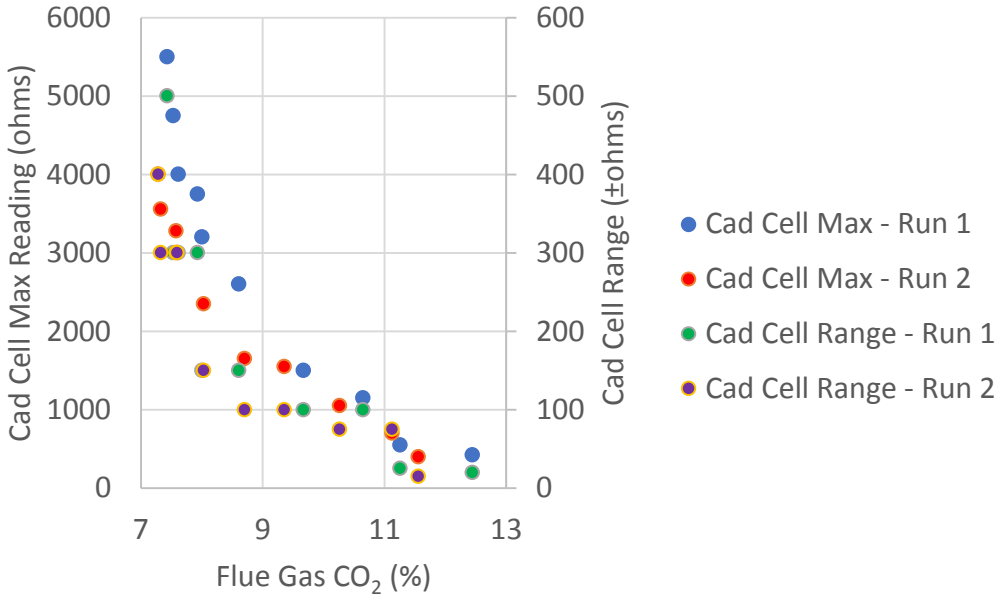

Figure 15 B100 Tallow Cad cell max reading and range

In considering all of these results some general observations can be made. First the trends for all fuels tested can be considered broadly similar. It is notable that the No. 2 oil had higher smoke number relative to the B100 fuels in particular. With the B100 fuels the achieved maximum CO_2 was slightly lower simply because of the oxygen in the fuel. At the maximum achieved CO_2, the burner air dampers were closed.

For all fuels, cad cell resistance increases sharply as flue gas CO_2 is reduced below 9% (high excess air range). In addition, the cad cell range, which can be considered an indicator of the stability of the flame also increased with all fuels. Table 1, below, summarizes the average CO_2 at which the average cad cell resistance hit the recommended limit of 1600 ohms for this control.

Table 1. Average Flue Gas CO_2 at Which a Cad Cell Resistance of 1600 Ohms Was Observed (Both Runs Averaged)

Fuel	Average CO_2 at 1600 ohms (%)
No. 2 oil	Target ohms not obtained
B20 Soy	8.2
B20 Tallow	7.5
B100 Soy	8.3
B100 Tallow	9.0

In all cases the flue gas CO_2 is significantly lower (excess air is higher) than the normal operating range.

Table 2 summarizes the results in a bit different way – it presents the average value of the cad cell resistance at 11% CO_2, interpolated from all test results and averaged for each of the two runs. This shows increased cad cell resistance at higher biodiesel level and, at B100 higher resistance for tallow-based biodiesel than for soy-based biodiesel. In all cases the cad cell resistance is under the 1600 ohms recommended for this control.

Table 2. Average Cad Cell Resistance for All Fuels at 11% CO_2

Fuel	Average cad cell resistance at 11% CO_2
B0	145
B20 Soy	167
B20 Tallow	163
B100 Soy	391
B100 Tallow	843

All of the results above have been correlated to the flue gas CO_2. This is commonly used as an indicator of excess air for No. 2 oil and this relationship is based on the composition of the fuel. Since biodiesel is an oxygenated fuel it is useful to reexamine this relationship for the different chemistry of this fuel.

Table 3, below, lists the carbon, hydrogen, and oxygen contents, on a mass basis, for B0, B20, and B100 based on typical compositions of No. 2 oil and biodiesel.

Table 3. Composition of B0, B20, and B100.

	B0	B20	B100
% C	86.8	84.61	75.83
% H	13.2	13.08	12.58
% O	0.0	2.32	11.60

From these compositions, relations between excess air and flue gas CO_2 were calculated and results are shown in Figure 16, below.

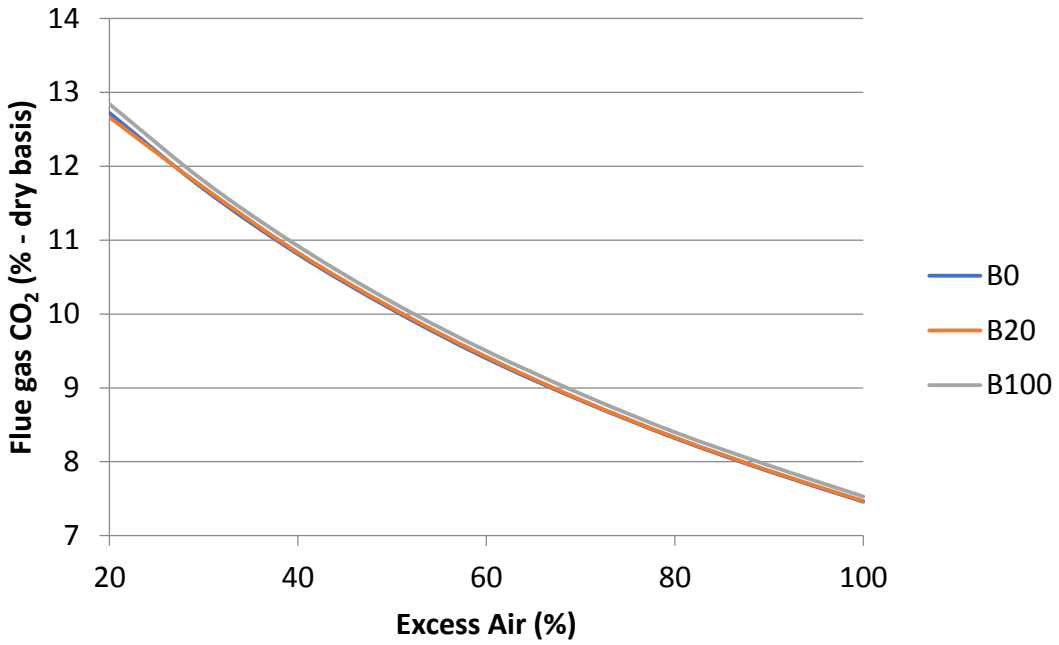

Figure 16 Relationship between flue gas CO2 and excess air for different fuels.

This curve shows very little difference between the fuels and so a comparison based on measured flue gas CO_2 is considered a fair basis for comparison.

Conclusions

Cad cell response to biodiesel from two different sources, soy and tallow, has been tested at the B20 and B100 levels over a wide excess air range. All of the fuels show a similar response trend. At very high excess air levels cad cell resistance becomes high and the level of fluctuation of cad cell resistance increases consistent with reducing quality of flame retention on the head. For all fuels, at 11% CO_2, the average cad cell resistance is lower than the 1600 ohms recommended for the specific burner primary control used in these tests.

Acknowledgements

The authors would like to acknowledge the strong technical assistance from John Levey, Mike McCutcheon and Brian Gainey. We would also like to thank REG for the supply of the B100 fuels with analysis.

Attachment I. Properties of Soy-Based Biodiesel Tested

Biodiesel Certificate of Analysis

FM.LAB.001a Biodiesel Certificate of Analysis-REG 20151130

BQ-9000 Producer

Lot Number:	701-90001-161103-T107	**Product Type:**	REG-9000/1
Inlet Seal Number:	000000257	**OS:**	C

ASTM D6751 Analysis of REG-9000® Biodiesel

Property		Value	ASTM D6751 Limit	REG-9000® Limit	Units	Test Method (current revision)
Cloud point:		-2.4 *(28)*	Report	Report	°C *(°F)*	D7397
Free Glycerin:		0.008	0.020, max	0.014	**% mass**	D6584
Total Glycerin:		0.113	0.240, max	0.16	**% mass**	D6584
Monoglycerides[1]:		0.381	N/A	0.40, max	**% mass**	D6584
Diglycerides[1]:		0.042	N/A	0.20, max	**% mass**	D6584
Triglycerides[1]:		0.004	N/A	0.20, max	**% mass**	D6584
Water & Sediment:		0.000	0.050, max	0.01	**% volume**	D2709
Acid Number:		0.33	0.50, max	0.40	**mg KOH/g**	D664
Visual Inspection[1]:		1 @ 88.0°F	N/A	1	**Haze rating**	D4176, Procedure 2
Relative Density at 60°F[1]:		0.8845	N/A	0.87 – 0.89	**N/A**	D1298
Oxidation Stability (110 °C):		8.3	3, min	6.0	**hrs**	*EN 15751*
Flash point (closed cup):		120.5	93, min	93	**°C**	D93
Alcohol Control	**Option 1: Methanol**	0.098	0.2, max	0.2	**% mass**	*EN 14110*
	Option 2: Flashpoint	N/A	130, min	130	**°C**	D93
Moisture[1]:		0.018	N/A	0.040, max	**% mass**	E203
Cold Soak Filtration:		105	360	200	**seconds**	D7501
Sulfur:		0.9	15	15	**ppm (mg/kg)**	D5453
Sodium & Potassium Combined:		0.0	5, max	1.5	**ppm (mg/kg)**	*EN 14538*
Calcium & Magnesium Combined:		0.3	5, max	1.5	**ppm (mg/kg)**	*EN 14538*
Total Contamination[1]:		0.6 *	N/A	15,max	**mg/L**	D7321
Ester Content[1]:		99.1 *	N/A	97, min	**% mass**	*EN 14103*
Phosphorus:		0.0000 *	0.001, max	0.001	**% mass**	D4951
Carbon Residue:		0.000 *	0.050, max	0.050	**% mass**	D4530
Sulfated Ash:		0.005 *	0.020, max	0.020	**% mass**	D874
Kinematic Viscosity at 40 °C:		4.016 *	1.9-6.0	3.8 – 5.0	**mm^2/sec.**	D445
Copper Corrosion (3 hrs at 50 °C):		1a *	No. 3, max	No. 1a	**N/A**	D130
Distillation at 90% Recovered:		351 *	360, max	360	**°C**	D1160
Cetane Number:		47.3 *	47, min	47	**N/A**	D613

[1] These tests are not ASTM D6751 specification requirements.

* This value is the most recently acquired result for this product from this plant. This test is performed periodically.

Prepared by: Randy Strough Lab\Quality Coordinator REG Ralston, LLC 11/4/2016

Name Title Location Date

Attachment II. Properties of Tallow-Based Biodiesel Tested

REG
Marketing & Logistics Group, LLC

Terminal Tank Report

FM.ML.003 Terminal Tank Report 20150710

Reference Number: B707-161107-T25B-15	**Report Date:** 11/07/2016
Product Type: Biodiesel	**Terminal Location: Houston Terminal**

ASTM D6751 Biodiesel Report

Test Parameter		Result[1]	ASTM Limit	Units	Test Method (current revision)
Cloud point:		**14.1 *****	Report	**°C**	D7397
Free Glycerin:		0.007	0.020, max	**% mass**	D6584
Total Glycerin:		0.091	0.240, max	**% mass**	D6584
Monoglycerides:		0.303	N/A	**% mass**	D6584
Diglycerides:		0.048	N/A	**% mass**	D6584
Triglycerides:		0.000	N/A	**% mass**	D6584
Water & Sediment:		0.000	0.050, max	**% volume**	D2709
Acid Number:		0.35	0.50, max	**mg KOH/g**	D664
Relative Density @ 60°F:		0.8751	N/A	**N/A**	D1298
Visual Inspection:		1 @ 70°F **	N/A	**Haze rating**	D4176, Procedure 2
Oxidation Stability (110 °C):		**19.6 *****	3, min	**hrs**	*EN 15751*
Flash point (closed cup):		139.5	93, min	**°C**	D93
Alcohol Control	Methanol Content	n/a	0.2, max	**% volume**	*EN 14110*
	Flashpoint	139.5	130, min	**°C**	D93
Moisture:		0.025	N/A	**% mass**	E203
Cold Soak Filtration:		**132 *****	360	**seconds**	D7501
Sulfur:		6.0	15	**ppm**	D5453
Sodium & Potassium Combined:		0.0	5, max	**ppm (µg/g)**	*EN 14538*
Calcium & Magnesium Combined:		0.0	5, max	**ppm (µg/g)**	*EN 14538*
Phosphorus:		0.000	0.001, max	**% mass**	D4951
Carbon Residue:		0.000	0.050, max	**% mass**	D4530
Sulfated Ash:		0.003	0.020, max	**% mass**	D874
Kinematic Viscosity at 40 °C:		4.398	1.9-6.0	**mm^2/sec.**	D445
Copper Corrosion (3 hrs at 50 °C):		1a	No. 3, max	**N/A**	D130
Distillation at 90% Recovered:		350	360, max	**°C**	D1160
Cetane Number:		60.4	47, min	**N/A**	D613

[1] Unless otherwise specified, each value is a weighted average of the values reported for the fuel in the tank

** This value is an actual test result from a representative sample from this tank

*** This value is the least favorable result from the commingled blend

Prepared by:	Debbie Tremont	Houston Terminal	11/07/2016
	Name	Location	Date