

# Environmental Technology Verification Report

## Mobile Source Retrofit Air Pollution Control Devices

Clean Clear Fuel Technologies, Inc.'s, Universal Fuel Cell

Prepared by

Southwest Research Institute



RTI International



Under a Cooperative Agreement with  
U.S. Environmental Protection Agency



**ET** ✓ **ET** ✓ **ET** ✓

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EPA Cooperative Agreement No. CR829434-01-1

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## Notice

This document was prepared by RTI International (RTI)\* and its subcontractor Southwest Research Institute (SwRI), with partial funding from Cooperative Agreement No. CR829434-01-1 with the U.S. Environmental Protection Agency (EPA). The document has been submitted to RTI/EPA's peer and administrative reviews and has been approved for publication. Mention of corporation names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products.

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\* RTI International is a trade name of Research Triangle Institute.

## Foreword

The Environmental Technology Verification (ETV) Program, established by the U.S. Environmental Protection Agency (EPA), is designed to accelerate the development and commercialization of new or improved technologies through third-party verification and reporting of performance. The goal of the ETV Program is to verify the performance of commercially ready environmental technologies through the evaluation of objective and quality-assured data so that potential purchasers and permittees are provided with an independent and credible assessment of the technology that they are buying or permitting.

The Air Pollution Control Technology (APCT) Center is part of EPA's ETV Program and is operated as a partnership between RTI International (RTI) and EPA. The Center verifies the performance of commercially ready air pollution control technologies. Verification tests use approved protocols, and verified performance is reported in verification statements signed by EPA. RTI contracts with Southwest Research Institute (SwRI) to perform verification tests on engine emission control technologies.

Retrofit air pollution control devices used to control emissions from mobile diesel engines are among the technologies evaluated by the APCT Center. The Center developed (and EPA approved) the *Generic Verification Protocol for Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines* to provide guidance on the verification testing of specific products that are designed to control emissions from diesel engines.

The following report reviews the performance of Clean Clear Fuel Technologies, Inc.'s, Universal Fuel Cell, Model CCFT21061. ETV testing of this technology was conducted during November 2003 at SwRI. All testing was performed in accordance with an approved test/quality assurance plan that implements the requirements of the generic verification protocol at the test laboratory.

## Availability of Report

Copies of this verification report are available from:

- RTI International  
Engineering and Technology Unit  
P.O. Box 12194  
Research Triangle Park, NC 27709-2194
- U.S. Environmental Protection Agency  
Air Pollution Prevention and Control Division (E343-02)  
109 T. W. Alexander Drive  
Research Triangle Park, NC 27711

Web sites: <http://www.epa.gov/etv/verifications/verification-index.html> (electronic copy)  
<http://www.epa.gov/ncepihom/>

## Table of Contents

Notice .....	ii
Foreword.....	iii
Availability of Report .....	iv
List of Figures .....	vi
List of Tables .....	vi
Acronyms/Abbreviations .....	vii
Acknowledgments.....	viii
Section 1.0 Introduction.....	1
Section 2.0 Description of Products.....	2
Section 3.0 Test Documentation .....	4
3.1 Engine Description.....	4
3.2 Engine Fuel Description .....	4
3.3 Summary of Emissions Measurement Procedures.....	5
3.4 Deviations from the Test/QA Plan.....	6
3.5 Documented Test Conditions.....	7
Section 4.0 Summary and Discussion of Emission Results.....	9
4.1 Emissions Test Data.....	9
4.2 Quality Assurance.....	11
Section 5.0 References.....	12
Appendix A Vendor Comments.....	A-1

## List of Figures

<b>Figure</b>	<b>Page</b>
1. Mounting location of aged Universal Fuel Cell, Model 21061, Serial Number 0642, in Test Cell 8.....	3
2. Constant volume sampler setup for emissions measurement. ....	6

## List of Tables

<b>Table</b>	<b>Page</b>
1. Engine Identification Information .....	4
2. Selected Fuel Properties and Specifications .....	5
3. Engine Performance Data .....	7
4. Magnetic Flux Density Measurements .....	8
5. Brake Specific Fuel Consumption .....	8
6. Emissions Test Data.....	9
7. Composite Weighted Emissions Values (English units) .....	10
8. Composite Weighted Emissions Values (metric units) .....	10
9. Summary of Verification Test Emission Values.....	11
10. Summary of Verification Test Emission Reductions.....	11

## Acronyms/Abbreviations

°F	degrees Fahrenheit
°C	degrees Celsius
APCT	Air Pollution Control Technology
ASTM	American Society for Testing and Materials
bhp	brake horsepower
bhp-h	brake horsepower hour
BSFC	brake specific fuel consumption
CCFT	Clean Clear Fuel Technologies, Inc.
CFR	Code of Federal Regulations
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
DDC	Detroit Diesel Corporation
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
FTP	Federal Test Procedure
ft	foot (feet)
g	gram(s)
HC	hydrocarbon(s)
HD	heavy duty
Hg	mercury
kW	kilowatt(s)
kWh	kilowatt hour(s)
kPa	kilopascal(s)
lb	pound(s)
lbf/ft	pound force foot (feet)
LSD	low-sulfur diesel
mm	millimeter(s)
N	newton(s)
N•m	newton-meter
NO <sub>x</sub>	nitrogen oxide(s)
OTAQ	Office of Transportation and Air Quality
Pa	pascal(s)
PDP	Positive Displacement Pump
PM	particulate matter
ppm	parts per million by volume
QA	quality assurance
QC	quality control
rpm	revolutions per minute
RTI	RTI International
SwRI	Southwest Research Institute



## Acknowledgments

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## **Section 1.0 Introduction**

This report reviews the performance of the Clean Clear Fuel Technologies, Inc.'s (CCFT's) Universal Fuel Cell, Model CCFT21061. Environmental Technology Verification (ETV) Program testing of this technology was conducted during a series of tests in November 2003 by Southwest Research Institute (SwRI) under contract with RTI International's (RTI's) Air Pollution Control Technology (APCT) Center. The objective of the APCT Center and the ETV Program is to verify, with high data quality, the performance of air pollution control technologies. Control of air emissions from diesel engines is within the scope of the APCT Center. An APCT Center program area was designed by RTI and a technical panel of experts to evaluate the performance of diesel exhaust catalysts, particulate filters, and engine modification control technologies for mobile diesel engines. Based on the activities of this technical panel, the *Generic Verification Protocol for Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines*<sup>1</sup> was developed. The specific test/quality assurance (QA) plan addendum for the ETV test of the technology submitted by CCFT was developed and approved on August 27, 2003.<sup>2</sup> The goal of the test was to measure the emissions control performance of the technology system and its emissions reduction relative to an uncontrolled engine.

A description of the Universal Fuel Cell is presented in Section 2. Section 3 documents the procedures and methods used for the verification test and the conditions under which the test was conducted. The results of the test are summarized and discussed in Section 4, and references are presented in Section 5.

This report contains only summary information and data as well as the verification statement. Vendor comments are included in Appendix A. Complete documentation of the test results is provided in a separate test report<sup>3</sup> and audit of data quality (ADQ) report.<sup>4</sup> These reports include the raw test data from product testing and supplemental testing, equipment calibration results, and QA and quality control (QC) activities and results. Complete documentation of QA/QC activities and results, raw test data, and equipment calibration results are retained in SwRI's files for 7 years.

## **Section 2.0**

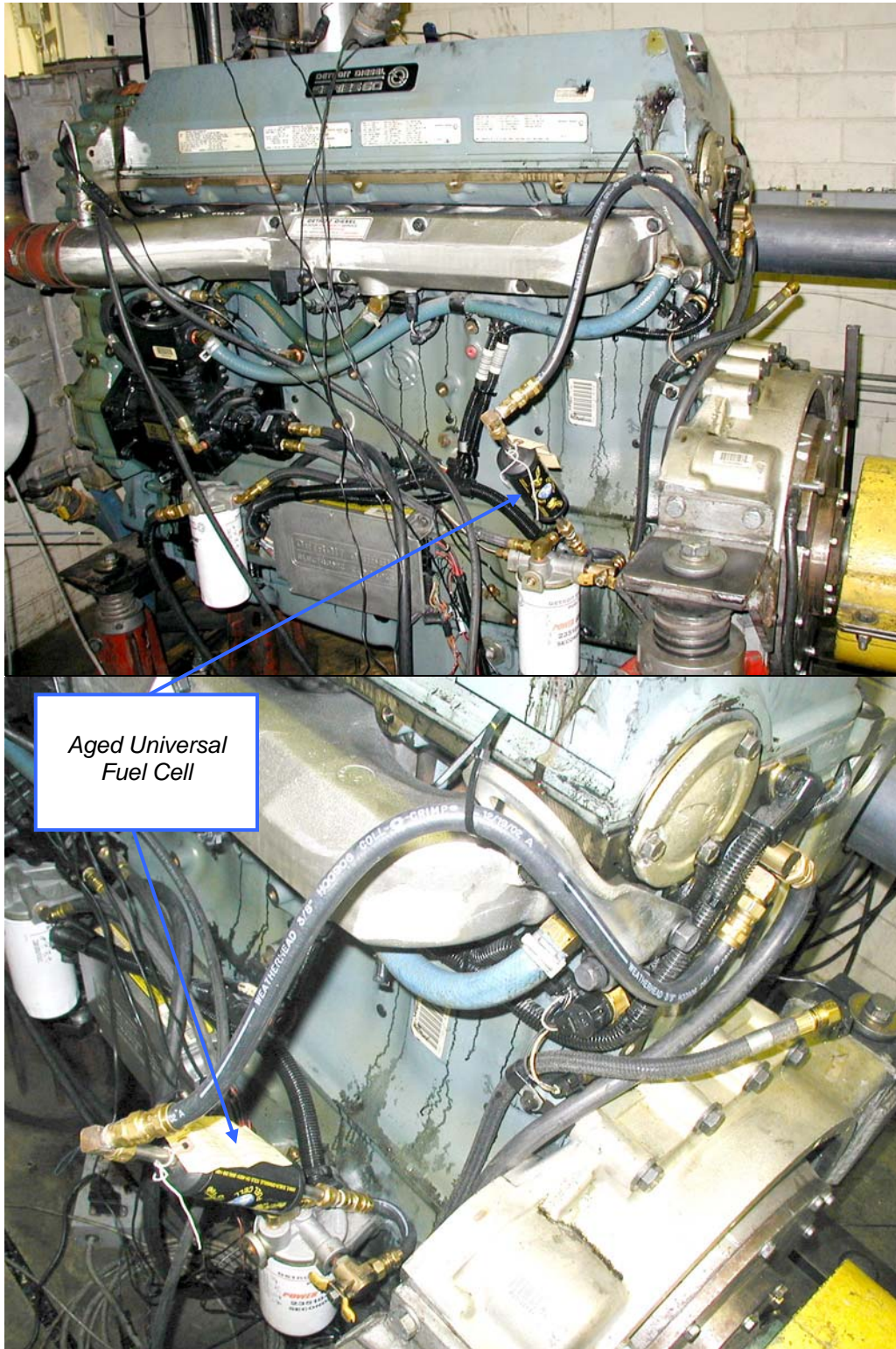
### **Description of Products**

The APCT Center conducted verification testing for CCFT's system described below (descriptions provided by CCFT). The system consisted of CCFT's Universal Fuel Cell, Model CCFT21061. The technology was provided directly to the APCT Center's test organization, SwRI, as:

- one degreened Universal Fuel Cell, Model CCFT21061 (Serial Number 0963), and
- one aged Universal Fuel Cell, Model CCFT21061 (Serial Number 0642).

The degreened unit was labeled to have run 139 hours, and the aged unit was labeled to have run 3,187 hours.

The Universal Fuel Cell is a high-density magnet with a field strength of at least 1000 gauss. The strength of the tested device ranged from 1,300 to 1,600 gauss (see Section 3.5). Fuel lines were fabricated by SwRI and approved by CCFT to mount the fuel cells along the fuel line after the engine's secondary fuel filter and before the fuel injector gallery. Figure 1 shows the aged Universal Fuel Cell mounted in the fuel system of the Detroit Diesel Corporation (DDC) engine in Test Cell 8.



**Figure 1. Mounting location of aged Universal Fuel Cell, Model 21061, Serial Number 0642, in Test Cell 8.**

## Section 3.0 Test Documentation

The ETV testing took place at SwRI under contract to the APCT Center. Testing was performed in accordance with:

- *Generic Verification Protocol for Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines;*<sup>1</sup>
- *Test/QA Plan for the Verification Testing of Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines;*<sup>5</sup> and
- *Test-Specific Addendum to ETV Mobile Source Test/QA Plan for Clean Clear Fuel Technology Universal Fuel Cell;*<sup>2</sup> and

The generic verification protocol and the test/QA plan were available to the applicant prior to testing.

### 3.1 Engine Description

The ETV testing was performed using an inline, 6-cylinder, 12.7-liter, 1998 model year Detroit DDC, heavy-duty (HD), on-highway diesel engine. It was turbocharged and used a laboratory water-to-air heat exchanger for a charge air intercooler. The engine was owned by SwRI and has been used on various research programs. Table 1 provides the engine’s identification details.

**Table 1. Engine Identification Information**

Engine serial number	06R0422316
Date of manufacture	April 1998
Make	Detroit Diesel Corporation
Model year	1998
Model	Series 60
Engine displacement and configuration	12.7-L, in-line 6-cylinder
Service class	On-highway, heavy-duty (HD) diesel engine
EPA engine family identification	WDDXH12.7EGD
Rated power	298 kW (400 bhp) at 1,800 rpm
Rated torque	2130 N•m (1550 lbf/ft) at 1,200 rpm
Certified emission control system	Electronic control
Aspiration	Turbocharged, air-to-air intercooled
Fuel system	Direct injection, electronically controlled unit injectors

### 3.2 Engine Fuel Description

The diesel fuel used during all test runs for this verification test was a conventional No. 2 low-sulfur diesel (LSD) fuel, with a sulfur level of 386 ppm. The LSD fuel meets EPA current diesel

fuel specifications given in 40 CFR 86.1313-98, Table N98-2<sup>6</sup>. Selected fuel properties from suppliers' analyses are summarized in Table 2.

**Table 2. Selected Fuel Properties and Specifications**

Item	Code of Federal Regulations (CFR) Specification <sup>a</sup>		Test Fuel
	ASTM	Type-2D	Low-Sulfur Diesel EM-4991-F
Cetane number	D613	40–50	47.3
Cetane index	D976	40–50	46.7
Distillation range:			
Initial boiling point, °C (°F)	D86	171–204 (340–400)	177 (350)
10% Point, °C (°F)	D86	204–238 (400–460)	207 (404)
50% Point, °C (°F)	D86	243–282 (470–540)	258 (496)
90% Point, °C (°F)	D86	293–332 (560–630)	302 (575)
End point, °C (°F)	D86	321–366 (610–690)	328 (642)
Gravity (American Petroleum Institute)	D287	32–37	35.9
Specific gravity		–	0.8453
Total sulfur, ppm	D2622	(300–500) <sup>b</sup>	386
Hydrocarbon composition:			
Aromatics (minimum), %	D1319	27	30.6
Paraffins, naphthenes, and olefins, %	D1319	<sup>c</sup>	69.4
Flash point (minimum), °C (°F)	D93	54 (130)	67 (153)
Viscosity, centistokes @ 40 °C	D445	2.0–3.2	2.3

Note: ASTM = American Society for Testing and Materials.

<sup>a</sup> Diesel fuel specification as in 40 CFR 86.1313-98(b)(2)<sup>6</sup> for the year 1998 and beyond for heavy-duty diesel engines.

<sup>b</sup> 1998 sulfur range specification.

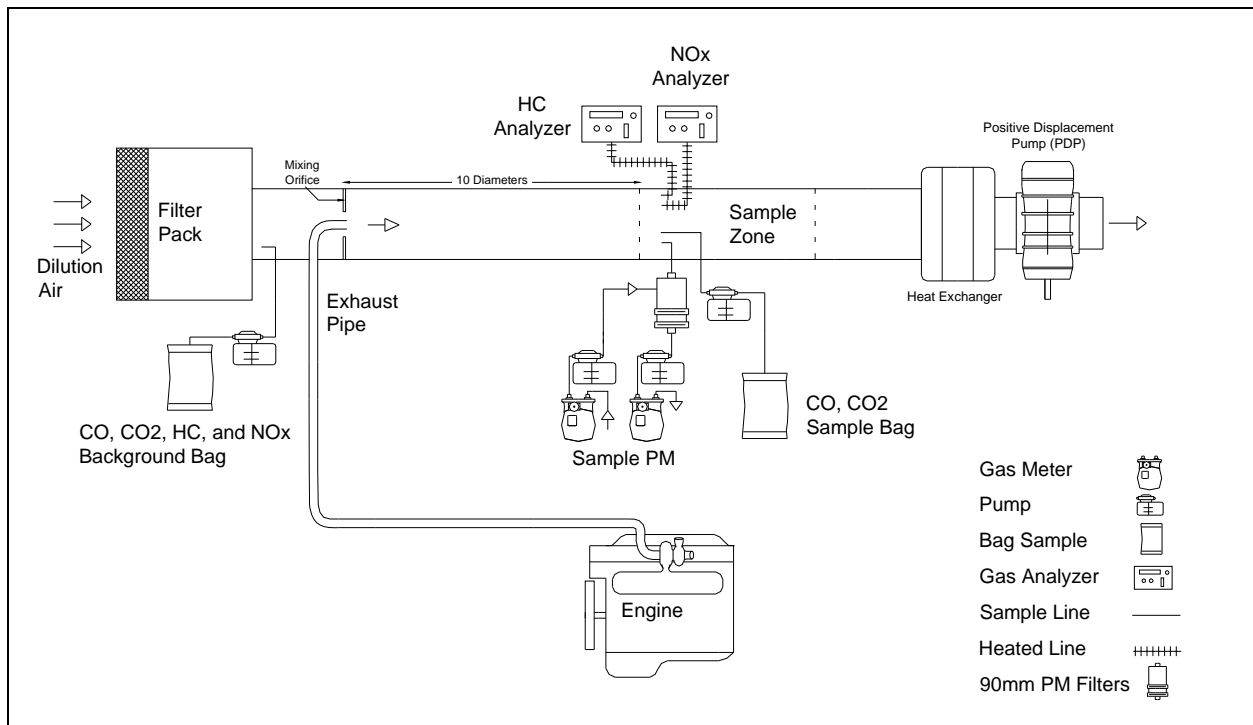
<sup>c</sup> Remainder of the hydrocarbons.

### 3.3 Summary of Emissions Measurement Procedures

The ETV tests consisted of baseline uncontrolled tests and tests with the control system installed. The baseline engine and the installed Universal Fuel Cell were tested on conventional LSD fuel. The standard HD Transient Federal Test Procedure<sup>7</sup> (FTP) for exhaust emissions testing was performed. The engine and control system were conditioned before the official tests with three hot-start transient cycles conducted in accordance with the test/QA plan.<sup>5</sup> Individual exhaust gas and particulate matter (PM) samples were taken during the official tests for each cycle.

## Emissions Test Procedures

Exhaust emissions were measured using HD Transient FTP<sup>7</sup> and the experimental setup shown in Figure 2. Dilute exhaust emissions measured during tests over the transient FTP operating conditions included total hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and exhaust PM. The CO and CO<sub>2</sub> levels were determined using nondispersive infrared instruments. Total HC were measured using continuous sampling techniques employing a heated flame ionization detector. The NO<sub>x</sub> was measured continuously using a chemiluminescent analyzer.



**Figure 2. Constant volume sampler setup for emissions measurement.**

The exhaust PM level for each test was determined using dilute sampling techniques that collected PM on a pair of 90-mm diameter Pallflex T60A20 filter media used in series. The particulate filter pair unit was weighed together both before and after each test to establish exhaust PM emissions for the test.

### 3.4 Deviations from the Test/QA Plan

The original test plan incorporated the use of a 1998 rebuilt Cummins ISM 370 ESP (Serial Number 34936044), HD diesel engine supplied by CCFT. Baseline emission tests with this engine resulted in a PM weighted composite average of 0.142 g/hph. This level exceeded the applicable certification standard (0.10 g/hph) by more than the allowable 10%. Upon further investigation, a water leak was found in the engine's head and five pistons were noted to have the incorrect part number for the engine's CPL.

After reviewing the situation, SwRI was instructed by CCFT to remove the Cummins engine and install a 1998 DDC Series 60 HD engine supplied by SwRI. During initial cold-start runs of the Series 60, cold-start HC levels were excessive. New rebuilt fuel injectors were installed, and baseline tests of the DDC engine showed that the engine did not exceed the applicable emission standards by more than 10%.

On November 21, 2003, a new battery charger was installed in Test Cell 8 to replace an older unit. Battery chargers are periodically replaced with new models to maintain equipment reliability. The charger maintains the charge on a 12-V battery, which powers the engine control module. The DDC Series 60 engine control module is very sensitive to low battery voltage. During hot-start tests 112103-H2 and 112103-H3, the DDC engine misfired, coinciding with HC concentration spikes that peaked out of the measurable range of 0–100 ppm. The HC spikes caused the tests to be voided as specified in the Code of Federal Regulations (CFR), Title 40, Part 86, Subpart N. Low battery voltage was determined to be the cause of the erratic engine behavior. The malfunctioning battery charger was replaced with a functional unit, a preparatory hot-start cycle was run, and two additional hot-start tests were conducted to complete the data set. No erratic behavior of the engine or HC concentration spikes were noted after the charger was replaced.

### 3.5 Documented Test Conditions

#### *Engine Performance*

Table 3 gives the observed engine performance while power validating the DDC engine for the baseline and the controlled configurations. The performance was similar for all configurations. Performance curves were generated by operating the engine at full load while increasing its speed by 8 rpm per second for both the baseline and controlled configurations.

**Table 3. Engine Performance Data**

<b>Fuel</b>	<b>Test Date</b>	<b>Test Type</b>	<b>Rated Power<sup>a</sup> bhp (kW)</b>	<b>Peak Torque<sup>b</sup> lbf/ft (N•m)</b>
LSD	11/18/2003	Baseline	422 (315)	1633 (2214)
LSD	11/19/2003	Controlled	419 (312)	1630 (2210)
LSD	11/20/2003	Controlled	420 (312)	1658 (2248)

#### *Engine Exhaust Backpressure*

The engine backpressure was set to 2.4 in Hg (8.1 kPa) at rated speed and load in accordance with the engine manufacturer specifications.

#### *Universal Fuel Cell Magnetic Flux Density*

An AlphaLab, Inc., DC Magnetometer, Serial Number 1187, was supplied by CCFT to measure the magnetic flux density of each fuel cell both before and after the cells were emission tested. Triplicate readings were recorded for each measurement and are given in Table 4.



**Table 4. Magnetic Flux Density Measurements**

Unit	Test Stage	Test Date	Reading #1, gauss	Reading #2, gauss	Reading #3, gauss
Degreened Cell (SN 0963)	Pre-test	11/19/2003	1500	1600	1600
Degreened Cell (SN 0963)	Post-test	11/20/2003	1434	1585	1523
Aged Cell (SN 0642)	Pre-test	11/20/2003	1420	1540	1370
Aged Cell (SN 0642)	Post-test	11/26/2003	1413	1307	1495

***Fuel Consumption***

Table 5 presents the brake specific fuel consumption (BSFC) for all baseline and control configurations.

**Table 5. Brake Specific Fuel Consumption**

Test Number	Test Type	Test Date	BSFC, lb/bhp-h	BSFC, kg/kWh	Weighted BSFC, lb/bhp-h	Weighted BSFC, kg/kWh
<i>Engine Baseline</i>						
111903-C1	Cold-start	11/19/2003	0.424	0.257		
111903-H1	Hot-start	11/19/2003	0.401	0.243	0.404	0.245
111903-H2	Hot-start	11/19/2003	0.404	0.244	0.407	0.246
111903-H3	Hot-start	11/19/2003	0.401	0.243	0.404	0.245
<i>Engine with Degreened Fuel Cell</i>						
112003-C1	Cold-start	11/20/2003	0.42	0.254		
112003-H1	Hot-start	11/20/2003	0.405	0.245	0.407	0.246
112003-H2	Hot-start	11/20/2003	0.404	0.244	0.406	0.246
112003-H3	Hot-start	11/20/2003	0.402	0.243	0.405	0.245
<i>Engine with Aged Fuel Cell</i>						
112103-C1	Cold-start	11/21/2003	0.423	0.256		
112103-H1	Hot-start	11/21/2003	0.406	0.246	0.408	0.247
112103-H4	Hot-start	11/21/2003	0.399	0.241	0.402	0.243
112103-H5	Hot-start	11/21/2003	0.399	0.241	0.402	0.243

Note: BSFC = brake specific fuel consumption.

## Section 4.0 Summary and Discussion of Emission Results

### 4.1 Emissions Test Data

The baseline and controlled emissions data are summarized in Tables 6, 7, and 8. The emissions were measured at each test point for HC, CO, NO<sub>x</sub>, and PM. Table 6 also provides data on CO<sub>2</sub> emissions and work. For each pollutant/hot-start test combination, the transient composite-weighted emissions per work (bhp-h) were then calculated following the fractional calculation for highway engines as follows:

$$(E_{COMP})_m = \frac{\frac{1}{7} \bullet E_{COLD} + \frac{6}{7} \bullet (E_{HOT})_m}{\frac{1}{7} \bullet W_{COLD} + \frac{6}{7} \bullet (W_{HOT})_m} \quad (\text{Eq. 1})$$

where

- $E_{COMP}$  = composite emissions rate, g/bhp-h
- $m$  = one, two, or three hot-start tests
- $E_{COLD}$  = cold-start mass emissions level, g
- $E_{HOT}$  = hot-start mass emissions level, g
- $W_{COLD}$  = cold-start brake horsepower hour, bhp-h
- $W_{HOT}$  = hot-start brake horsepower hour, bhp-h.

These composite-weighted emissions rates are shown in Tables 7 and 8 and were used to calculate the mean and standard deviations for the baseline and controlled emissions rates. These data were in turn used to calculate mean emissions reductions and 95% confidence limits. These calculations are based on the generic verification protocol<sup>1</sup> and test/QA plan.<sup>5</sup>

**Table 6. Emissions Test Data**

Test Number	Test Type	Test Date	g					Work, KWh (bhp-h)
			Exhaust PM	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>	
<i>Engine Baseline</i>								
111903-C1	Cold-start	11/19/03	3.09	128	13.2	66.9	18.5	22.8 (30.5)
111903-H1	Hot-start	11/19/03	2.22	121	4.74	36.8	17.5	22.6 (30.3)
111903-H2	Hot-start	11/19/03	2.22	125	3.28	35.2	17.7	22.6 (30.3)
111903-H3	Hot-start	11/19/03	2.26	126	3.18	35.5	17.5	22.6 (30.3)
<i>Engine Controlled with Degreened Fuel Cell</i>								
112003-C1	Cold-start	11/20/03	4.02	130	18.5	68.2	18.3	22.8 (30.5)
112003-H1	Hot-start	11/20/03	2.26	124	3.96	37.3	17.7	22.6 (30.3)
112003-H2	Hot-start	11/20/03	2.21	123	3.14	37.1	17.6	22.6 (30.3)
112003-H3	Hot-start	11/20/03	2.21	129	2.45	36.3	17.5	22.6 (30.3)
<i>Engine Controlled with Aged Fuel Cell</i>								
112103-C1	Cold-start	11/21/03	4.91	128	23.1	70.5	18.4	22.7 (30.4)
112103-H1	Hot-start	11/21/03	2.47	124	4.44	40.4	17.7	22.6 (30.3)
112103-H4	Hot-start	11/21/03	2.31	123	3.94	37.4	17.4	22.7 (30.4)
112103-H5	Hot-start	11/21/03	2.37	124	5.22	38.6	17.5	22.7 (30.4)

**Table 7. Composite Weighted Emissions Values (English units)**

Test Number	Test Date	g/bhp-h				
		Exhaust PM	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>
<i>Engine Baseline</i>						
111903-H1	11/19/03	0.0772	4.00	0.196	1.35	581
111903-H2	11/19/03	0.0772	4.13	0.155	1.31	585
111903-H3	11/19/03	0.0784	4.17	0.152	1.32	581
<i>Engine Controlled with Degreened Fuel Cell</i>						
112003-H1	11/20/03	0.0828	4.12	0.199	1.38	585
112003-H2	11/20/03	0.0814	4.09	0.176	1.37	584
112003-H3	11/20/03	0.0814	4.26	0.156	1.35	581
<i>Engine Controlled with Aged Fuel Cell</i>						
112103-H1	11/21/03	0.0931	4.11	0.235	1.48	587
112103-H4	11/21/03	0.0883	4.09	0.220	1.39	579
112103-H5	11/21/03	0.0898	4.09	0.256	1.42	578

Note: PM = particulate matter; NO<sub>x</sub> = nitrogen oxide; HC = hydrocarbon(s); CO = carbon monoxide; CO<sub>2</sub> = carbon dioxide.

**Table 8. Composite Weighted Emissions Values (metric units)**

Test Number	Test Date	g/kWh				
		Exhaust PM	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>
<i>Engine Baseline</i>						
111903-H1	11/19/03	0.103	5.36	0.263	1.81	779
111903-H2	11/19/03	0.103	5.54	0.208	1.76	784
111903-H3	11/19/03	0.105	5.59	0.204	1.77	779
<i>Engine Controlled with Degreened Fuel Cell</i>						
112003-H1	11/20/03	0.111	5.52	0.267	1.85	784
112003-H2	11/20/03	0.109	5.48	0.236	1.84	783
112003-H3	11/20/03	0.109	5.71	0.209	1.81	779
<i>Engine Controlled with Aged Fuel Cell</i>						
112103-H1	11/21/03	0.125	5.51	0.315	1.98	787
112103-H4	11/21/03	0.118	5.48	0.295	1.86	776
112103-H5	11/21/03	0.120	5.48	0.343	1.90	775

Note: PM = particulate matter; NO<sub>x</sub> = nitrogen oxide; HC = hydrocarbon(s); CO = carbon monoxide; CO<sub>2</sub> = carbon dioxide.

Table 9 summarizes the mean composite weighted emission values and Table 10 the verified emissions reductions and their 95% confidence limits. The emissions reductions for CO and NO<sub>x</sub> could not be distinguished from zero with 95% confidence for either the degreened or aged device. HC emissions could not be distinguished from zero with 95% confidence for the degreened device, but showed a small increase during the test of the aged device compared to baseline emissions. The PM emissions for both devices showed a small increase during the controlled tests compared to baseline emissions. However, it was noted that if the 95% confidence limits are calculated using only the hot-start data, but the same statistical procedures, the controlled emissions could not be distinguished from zero for any pollutant or device type. This alternate view of the data should be considered when using the results of this verification.

**Table 9. Summary of Verification Test Emission Values**

Device type	Fuel	Mean Composite Weighted Emission Value, g/kWh (g/bhp-h)				
		PM	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>
Baseline	LSD	0.104 (0.0776)	5.50 (4.10)	0.225 (0.168)	1.78 (1.33)	782 (583)
Degreened	LSD	0.110 (0.0819)	5.58 (4.16)	0.237 (0.177)	1.82 (1.36)	783 (584)
Aged	LSD	0.121 (0.0904)	5.50 (4.10)	0.318 (0.237)	1.92 (1.43)	779 (581)

Note: LSD = low-sulfur diesel fuel; PM = particulate matter; NO<sub>x</sub> = nitrogen oxide; HC = hydrocarbon(s); CO = carbon monoxide; CO<sub>2</sub> = carbon dioxide.

**Table 10. Summary of Verification Test Emission Reductions**

Device type	Mean Emissions Reduction (%)				95% Confidence Limits on the Emissions Reduction (%)			
	PM	NO <sub>x</sub>	HC	CO	PM	NO <sub>x</sub>	HC	CO
Degreened	-5	-1	-6	-3	-3 to -8	<sup>a</sup>	<sup>a</sup>	<sup>a</sup>
Aged	-17	0	-41	-8	-26 to -7	<sup>a</sup>	-75 to -8	<sup>a</sup>

Note: PM = particulate matter; NO<sub>x</sub> = nitrogen oxide; HC = hydrocarbon(s); CO = carbon monoxide; CO<sub>2</sub> = carbon dioxide.

<sup>a</sup> The emissions reduction can not be distinguished from zero with 95% confidence.

## 4.2 Quality Assurance

The environmental technology verification of CCFT's Universal Fuel Cell, Model CCFT21061 for HD diesel engines was performed in accordance with the test/QA plan<sup>5</sup> (to be completed after EPA QA review).

## Section 5.0 References

1. RTI International (January 2002). *Generic Verification Protocol for Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines*. Research Triangle Park, NC: RTI International.
2. RTI International (August 2003). *Test-Specific Addendum to ETV Mobile Source Test/QA Plan for Clean Clear Fuel Technology Universal Fuel Cell*. Research Triangle Park, NC: RTI International.
3. Southwest Research Institute (December 2003). *Environmental Technology Verification of a Clean Clear Fuel Technology, Inc. Universal Fuel Cell for Heavy-Duty Diesel Engines*. San Antonio, TX: Southwest Research Institute.
4. Southwest Research Institute (December 2003). *Audit of Data Quality for Environmental Technology Verification of a Clean Clear Fuel Technology, Inc. Universal Fuel Cell for Heavy-Duty Diesel Engines*. San Antonio, TX: Southwest Research Institute.
5. RTI International (April 2002). *Test/QA Plan for the Verification Testing of Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines*. Research Triangle Park, NC: RTI International.
6. Fuel Specifications, 40 CFR 86.1313-98, Table N98-2 (updated July 2001).
7. 40 CFR 86, Subpart N, as of July 1, 1999, <http://www.epa.gov/epahome/cfr40.htm>.

## **Appendix A Vendor Comments**

Clean Clear Fuel Technology, Inc. has been offered the opportunity to comment on the findings of this report. Their comments are presented in Appendix A of the report and reflect their opinions. The Air Pollution Control Technology Center and EPA do not necessarily agree or disagree with the vendor's comments and opinions.

**CLEAN CLEAR FUEL TECHNOLOGY, INC.**  
**EXCLUSIVE DISTRIBUTOR OF THE UNIVERSAL FUEL CELL**

February 26, 2004

Andrew Trenholm  
Air Pollution Control Technology  
Verification Center  
Research Triangle Institute  
P.O. Box 12194  
Research Triangle Park, NC 27709-2194

**Re: Environmental Technology Verification of a Clean Clear Fuel Technology, Inc.  
Universal Fuel Cell**

Dear Mr. Trenholm:

Thank you for the opportunity to comment on the Environmental Technology Verification of a Clean Clear Fuel Technology, Inc. Universal Fuel Cell for Heavy-Duty Diesel Engines ("ETV Report") and the Chronology of ETV Testing of the CCFT Universal Fuel Cell ("Chronology Report"), both prepared by Southwest Research Institute ("SwRI"). For the reasons set forth below, Clean Clear Fuel Technology, Inc. ("CCFT") continues to believe that the 1998 DDC Series 60 Engine provided by SwRI for CCFT's use in testing the Universal Fuel Cell ("Fuel Cell") was defective and that the appropriate QA/QC procedures were not followed, thus invalidating the verification test.

**Background**

The ETV Report recognizes that CCFT intended to conduct the verification test on a 1998 Cummins ISM 370 engine. The preparatory testing, however, revealed that five of the six pistons in the Cummings engine were of the wrong make and model for the particular Cummins engine. CCFT was capable of providing a replacement engine, but accepted an offer from SwRI to use SwRI's engine in order to expedite the verification process and avoid incurring an additional \$60,000 in testing expenses. CCFT did not know, however, that SwRI's engine had been in storage for one-year or would exhibit continued malfunctions in the form of hydrocarbon spikes that remained during the verification testing.

**Engine Malfunction**

CCFT's December 8, 2003 letter (Exhibit A), explained in detail the malfunctioning of SwRI's engine and the failed attempts to fix it. During the preparatory tests, the engine misfired and produced significant hydrocarbon spikes. SwRI reported the misfiring in the Chronology Report and described SwRI's attempts to fix the misfiring. The Chronology Report explains that a bore scope found "small discoloration on the piston surface, but the findings were inconclusive." (ETV Report at p. 3). Previously, however, SwRI advised CCFT that the scope

revealed scoring on the #2 cylinder and white residue on one or more of the valves. A technical representative from Detroit Diesel confirmed that these observations are indicative of water, coolant, and/or aluminum residue, thus affecting the engine's combustion chambers. SwRI appeared to have understood the gravity of these findings by attempting to fix the engine by re-installing the intake manifold, changing the throttle potentiometer, changing the engine wiring harness and installing new engine sensors. The engine continued to malfunction, however, and SwRI decided to order an instrument to test cylinder compression.

SwRI advised CCFT on October 16, 2003 that a compression test had been ordered, although CCFT was not told that SwRI had also decided to replace the fuel injectors. Indeed, SwRI's October 22, 2003 electronic communication to CCFT advised only that it was still waiting for the compression gauge to arrive, without mentioning the planned fuel injector replacement. After waiting and not receiving the missing compression test part, SwRI installed rebuilt fuel injectors, without ever conducting a compression test to identify once and for all the root of the continued engine problems.

SwRI proceeded with the verification testing after installation of the rebuilt fuel injectors. However, it became evident that the engine was still not in good working order when the verification test results came back showing increasingly high HCs as the tests progressed, until two hydrocarbon spikes were observed during the "aged test" of sufficient magnitude that the two hot run tests were designated as "void." (See Exhibit B). It does not appear that the spikes and voided results were referenced in either of the ETV Report or the Chronology Report.

The slight increase in certain parameters as the verification testing proceeded on the Fuel Cell is further evidence of the defective nature of SwRI's engine. The Fuel Cell has had tremendous success in prior tests and has been proven to be one of the few, if not the only, technology that decreases air emissions and increases fuel mileage. CCFT conducted extensive laboratory and on-road testing of the Fuel Cell prior to registering the Fuel Cell for testing through RTI and, in all instances, had positive results. The first test was conducted on July 19, 2000 by Emission Testing Services in Costa Mesa, California, which is recognized by the California Air Resources Board as an approved testing facility. A test report is attached as Exhibit C and showed the following dramatic emission reductions:

	BASE 1	TEST 1	DIFFERENCE
Test	1	2	
Test Date	07/19/00	07/20/00	
Data File	13M1107	13M1107	
Weighted Avg. HP	119.22	127.32	+6.8%
Fuel Consumption, GM/BHPH	164.06	151.11	-7.9%
Hydrocarbons, GM/BHPH	0.27	0.26	-3.7%
Carbon Monoxide, GM/BHPH	0.77	0.64	-16.9%
Nitrogen Oxides, GM/BHPH	5.46	5.23	-4.2%



Particulates, GM/BHPH	0.155	0.066	-57%
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As result of this test, the Fuel Cell is recognized by the California Air Resources Board and was given a registration number of CARB EO # D514. CCFT had the Fuel Cell tested again on January 30-31, 2003 by Air Compliance Testing in Cleveland, Ohio. This test was conducted on an engine in the chassis, rather than in a substantially more controlled environment. This report and the test results are attached as Exhibit D and also showed the following dramatic results:

	Baseline HDDE Average	Condition Exhaust Stack	Universal Fuel Magnet Condition Exhaust Stack Average	Average Difference (%)
Average NOx Mass Emission Rate (gram/hr)	242.50		213.76	-11.85
Average CO Mass Emission Rate (gram/hr)	149.71		120.70	-19.38
Average Hydrocarbon Mass Emission Rate (gram/hr)	23.08		22.81	-1.19
Average Total Particulate Matter Mass Emission Rate (gram/hr)	3.12		2.05	-34.25

Further, on-road uses by CCFT's customers have seen significant decreases in fuel usage of up to 21%, (Exhibit E) and fuel savings of up to 14% (Exhibit F). A representative from FedEx is willing to speak directly with RTI and U.S. EPA regarding the success of the Fuel Cell used in the trucks in its fleet. In fact, the de-greened and aged Fuel Cells used in the verification tests came directly from trucks in the FedEx fleet. CCFT knows of no other emission control equipment that reduces emissions, while simultaneously increasing mileage (See Exhibit G). Less fuel usage logically results in decreased emissions. The fact that the Fuel Cell has demonstrated significant emission reductions in all tests other than verification test further demonstrates that the verification test is invalid.

#### Compliance with QA/QC Procedures

The Test/QA Plan for Verification Testing of Diesel Exhaust Catalysts, Particular Filters, and Engine Modification Control Technologies for Highway and Non-Road Diesel Engines, ("Test/QA Plan") prepared by RTI, sets forth the protocol to be used in testing certain emission control technologies. Section 2 of the Test/QA Plan requires a description of the engine to be tested to be documented as a test specific addendum to be submitted to U.S. EPA for review and approval prior to the start of testing. CCFT sent a significant amount of information to RTI regarding the Cummins engine and, in fact, went back and forth with RTI until CCFT submitted the entirety of the information requested by RTI on the engine. CCFT recently submitted additional information for a similar engine that CCFT proposes for use in a re-test. It does not appear that SwRI's engine was described in any detail to RTI and certainly not to CCFT, or that the engine had been approved for testing by RTI or U.S. EPA in accordance with the Test/QA procedures. Even if such information and approval was supplied, the failure to conduct a simple compression test after several engine misfires, carbon spikes, and observance of scoring and

white residue on the valves, did not comply with standard QA/QC procedures or good mechanical practices.

### **No Publication of the Verification Report or Verification Statement**

The Draft Generic Verification Protocol for Diesel Exhaust Catalyst, Particulate Filters, and Engine Modification Control Technologies for Highway and Non-Road Used Diesel Engines ("Generic Verification Protocol") states "tests that meet the ETV data quality requirements (a valid FTP test) are considered valid and suitable for publishing." The test performed by SwRI, however, was not valid or suitable for publishing. The scoring and white residue on the valves, continued hydrocarbon spikes during testing, the apparent lack of information provided with respect to SwRI's engine before testing and the test results themselves, all demonstrate a deviation from the Test/QA Plan and standard mechanical practices. Accordingly, the verification report and verification statement are not suitable for publishing and should not be published, and CCFT's Fuel Cell should be tested using an appropriate working and well-documented engine.

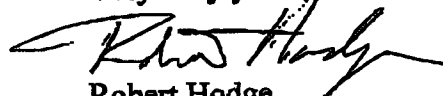
If RTI refuses to refrain from publishing the verification report and verification statement, then, of course, CCFT requests that RTI not issue the verification statement. Section 8 of the Generic Verification Protocol allows a party to request that the verification statement not be issued if the technology submitted for testing did not meet the applicant's expectation. Whether the SwRI engine is considered faulty or to have violated the QA/QC procedures, or the technology is considered not to have performed as expected, RTI should immediately provide for the re-testing of the Fuel Cell at SwRI on a qualified engine following all applicable QA/QC procedures. No "improvement" of the Fuel Cell is necessary or warranted as referenced in Section 8 of the Generic Verification Protocol since the Fuel Cell continues to be in perfect working order.

### **Conclusion**

The delays caused by the defective engine and testing procedures have resulted in significant lost sales to CCFT. In order that CCFT, its clients and the environment may enjoy the benefit of the Fuel Cell, CCFT requests that testing be allowed to proceed in March 2004, which is the time SwRI has "penciled in" for the purpose of re-testing the Fuel Cell. CCFT looks forward to working with RTI and SwRI to complete a successful verification test and demonstrate the Fuel Cell's ability to decrease air pollution and increase fuel efficiency.

If you have any questions with regard to the enclosed or require additional information, please contact me.

Very truly yours,



Robert Hodge  
Manager

Cc: Dennis Johnson, U.S. EPA