

US EPA ARCHIVE DOCUMENT

# Test and Quality Assurance Plan

EnviroFuels  
Diesel Fuel Catalyzer  
Fuel Additive

Prepared by:



Greenhouse Gas Technology Center  
Southern Research Institute



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

US EPA ARCHIVE DOCUMENT

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**Greenhouse Gas Technology Center**  
*A U.S. EPA Sponsored Environmental Technology Verification ( ETV ) Organization*

**Test and Quality Assurance Plan  
EnviroFuels  
Diesel Fuel Catalyzer  
Fuel Additive**

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indicates comments are integrated into Test Plan

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## List of Acronyms and Abbreviations

A	ampere
AC	alternating current
ADQ	audit of data quality
APPCD	Air Pollution Prevention and Control Division
CAR	corrective action request
CFR	Code of Federal Regulations
CH <sub>4</sub>	methane
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
COV	coefficient of variation
DC	direct current
DOE	Department of Energy
DOES2	dynamic off-road emissions sampling system
DQI	data quality indicator
DQO	data quality objective
DVM	digital voltmeter
EPA-ORD	Environmental Protection Agency Office of Research and Development
ETC	Environmental Technology Centre
ETV	Environmental Technology Verification
°F	degrees Fahrenheit
FS	full scale
FTP	Federal Test Procedure
g/bhp-h	grams per brake horsepower-hour
gph	gallons per hour
GHG	greenhouse gas
HFID	heated flame ionization detector
hp	horsepower
Hz	Hertz
ID	inner diameter
kVA	kilovolt-ampere (reactive power)
kW	kilowatt (real power)
lb/bhp-h	pounds per brake horsepower-hour
lpm	liters per minute
LPSS	locomotive particulate sampling system
mph	miles per hour
NDIR	non-dispersive infrared
NIST	National Institute of Standards and Technology
NMHC	non-methane hydrocarbons
NO <sub>2</sub>	nitrogen dioxide
NO <sub>x</sub>	blend of NO, NO <sub>2</sub> , and other oxides of nitrogen
PEA	performance evaluation audit
PLC	programmable logic controller
psia	pounds per square inch, absolute
QA	quality assurance
QA/QC	quality assurance / quality control
QMP	Quality Management Plan
rpm	revolutions per minute
scfm	standard cubic feet per minute
SOP	standard operating procedure
THC	total hydrocarbons (as carbon)
TPM	total particulate matter
V	volt

## 1.0 INTRODUCTION

### 1.1. BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) operates the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative technologies. The program's goal is to further environmental protection by accelerating the acceptance and use of these technologies. Primary ETV activities are independent performance verification and information dissemination. Congress funds ETV in response to the belief that many viable environmental technologies exist that are not being used for the lack of credible third-party performance data. With performance data developed under this program, technology buyers, financiers, and permittees will be better equipped to make informed decisions regarding new technology purchases and use.

The Greenhouse Gas Technology Center (GHG Center) is one of several ETV organizations. EPA's ETV partner, Southern Research Institute (Southern), manages the GHG Center. The GHG Center conducts independent verification of promising GHG mitigation and monitoring technologies. It develops verification Test and Quality Assurance Plans (test plans), conducts field tests, collects and interprets field and other data, obtains independent peer-review input, reports findings, and publicizes verifications through numerous outreach efforts. The GHG Center conducts verifications according to the externally reviewed test plans and recognized quality assurance / quality control (QA/QC) protocols.

Volunteer stakeholder groups guide the GHG Center's ETV activities. These stakeholders advise on appropriate technologies for testing, help disseminate results, and review test plans and reports. National and international environmental policy, technology, and regulatory experts participate in the GHG Center's Executive Stakeholder Group. The group includes industry trade organizations, environmental technology finance groups, governmental organizations, and other interested parties. Industry-specific stakeholders provide testing strategy guidance within their expertise and peer-review key documents prepared by the GHG Center.

GHG Center stakeholders are particularly interested in transportation technologies with the potential to increase fuel economy and reduce GHG and criteria pollutant emissions. The Department of Energy (DOE) reports that transportation CO<sub>2</sub> emissions were 32 percent of the total from all sectors during 2002 [1]. Railroad locomotives represent a significant fraction of the total. In 2002, railroads used approximately 8.7 percent of all petroleum distillate fuels in the transportation sector, or about 1.8 percent of all fuels consumed in the US. In 2000, railroad fuel consumption was about 3.071 x 10<sup>9</sup> gallons of diesel fuel [2]. Even incremental fuel efficiency or emission rate improvements would have a significant beneficial impact on nationwide air quality and railroad economics. Each 1 percent diesel fuel consumption reduction would reduce CO<sub>2</sub> emissions and fuel costs approximately 1 percent.

EnviroFuels, L.P. manufactures a diesel fuel additive and markets it to heavy-duty vehicle, off-road diesel engine, and railroad locomotive operators as the Diesel Fuel Catalyzer (catalyzer). The catalyzer is a suitable verification candidate considering its potential environmental benefits and ETV stakeholder interest. Based on in-house testing on heavy-duty diesel vehicles, EnviroFuels claims that proper use of the catalyzer can reduce:

- fuel consumption (and corresponding CO<sub>2</sub> emissions) by 5 percent
- NO<sub>x</sub> emissions by 12 to 18 percent
- unburned total hydrocarbon (THC) emissions up to 30 percent.

The GHG Center plans to verify the potential fuel consumption and pollutant emission improvements attributable to the catalyzer in a 3000 horsepower (hp) line-haul locomotive representative of much of the nationwide roster. This test plan specifies catalyzer verification performance parameters and the rationale for their selection. It contains the verification approach, data quality objectives (DQOs), and the relevant QA/QC procedures. The test plan will guide test implementation, document creation, data analysis, interpretation, and reporting.

The technology developer, testing subcontractor, expert peer reviewers, and the EPA-ORD QA team have reviewed this test plan. Once approved, as evidenced by the signature sheet at the front of this document, it will meet the GHG Center's Quality Management Plan (QMP) requirements. The GHG Center will post the final test plan on their internet site at [www.sri-rtp.com](http://www.sri-rtp.com) and the ETV program site at [www.epa.gov/etv](http://www.epa.gov/etv).

The GHG Center will prepare an Environmental Technology Verification Report and Verification Statement (report) upon field test completion. The same organizations listed above will review the report. When the reviews and responses are complete, the GHG Center Director and the EPA-ORD Laboratory Director will sign the Verification Statement, and the GHG Center will post the final documents as described above.

## **1.2. DIESEL FUEL CATALYZER DESCRIPTION**

EnviroFuels literature states that the key to the catalyzer's performance is a chemical reaction that creates inorganic polymer complexes of phosphorus and nitrogen on the surface of ferrous and non-ferrous metals. The formulators add the proprietary compound to refined mineral oil which, in turn, users administer to diesel fuel at 1 part additive to 1280 parts fuel ratio during normal operation. An initial dosing rate of 640:1 is utilized in most locomotive applications for a typically 6-8 week break in period.

The complexes, according to Envirofuels statements, smooth and passivate the metal surface, improve reflectivity (or emissivity), and reduce oxygen reactivity. EnviroFuels states that the reduced oxygen reactivity reduces NO<sub>x</sub> formation while the improved emissivity enhances combustion through reduced radiative losses from the flame front. This, combined with improved lubricity, reduces fuel consumption.

EnviroFuels' research indicates that six to eight weeks of regular service are required from the initial fuel treatment for the performance improvements to be fully realized in locomotive service. After that, the fuel must be treated on an ongoing basis to maintain the effects.

## **1.3. TEST SITE AND LOCOMOTIVE DESCRIPTION**

Locomotive testing methods differ from those involving other diesel-powered transportation modes, as they are adapted to the locomotive's design and operating features. Locomotives are powered by an engine through an electric alternator to electric motors that are connected to the drive wheels. This differs significantly from road vehicles, where the relationship between engine revolutions per minute (rpm) and vehicle miles per hour (mph) is mechanically dictated by the transmission and final drive gear ratios. A locomotive engine is operated at a desired power output and corresponding engine rpm without being constrained by locomotive speed because of the electrical coupling between the engine and drive wheels.

Power settings for railroad engines, or throttle position, generally include eight discrete positions or notches on the throttle gate in addition to idle and dynamic brake. Each notch is numerically identified, with notch one being the lowest power setting (other than idle) and notch eight being maximum power. Each throttle notch corresponds to a discrete fuel delivery system setting. The engine can operate at only



eight distinct combinations of fueling rate, power output and engine speed (in addition to idle and dynamic brake). In the dynamic braking position, the traction motors act as generators, with the generated power being dissipated as heat through an electric resistance grid. In dynamic braking mode, the engine generates only enough power to operate the locomotive accessories and the resistance grid cooling fans.

EPA considered these design features while developing the Federal Test Procedure (FTP) for emission measurements from diesel locomotives in Title 40 Code of Federal Regulations (CFR) 92, Subpart B [3]. The FTP is a steady-state test procedure as compared to the transient test procedures previously established for on-highway heavy-duty diesel engines. This verification will employ test methods derived directly from the FTP.

The GHG Center plans to verify the potential fuel consumption and pollutant emission improvements attributable to the catalyzer in a 3000 horsepower model GP40-3 line-haul locomotive built by General Motors' EMD division. Genesee and Wyoming's (G&W) St. Lawrence and Atlantic Railroad operates the locomotive out of Auburn, ME. The GP40, shown in Figure 1-1, is a variant of the SD40 series, the most common model pre-1990 line-haul locomotive in current use in the U.S. The unit to be tested has an EMD 16-645E3 16-cylinder engine. It was built in 1980 and remanufactured to Tier 0 requirements (§92.8(a)(1)(i)) in 2003.



**Figure 1-1. EMD Model GP-40-3 Locomotive**

#### 1.4. PERFORMANCE VERIFICATION PARAMETERS

The Envirofuels Diesel Fuel Catalyzer performance verification parameters are fuel economy, pollutant, and GHG emissions changes due to catalyzer use in the test locomotive. Test personnel will measure the parameters in successive tests using the 40 CFR 92 Subpart B test sequence, as described further below. Changes in fuel economy and emissions will be calculated both on a “per notch” basis and as a weighted average using the FTP’s line-haul weightings. Reported parameters will consist of:

- brake-specific fuel consumption rate change,  $\Delta\text{BSFC}_j$ , for each notch, pounds per brake horsepower hour (lb/bhp-h)
- line-haul weighted brake-specific fuel consumption rate change,  $\Delta\text{BSFC}_{\text{DC}}$ , lb/bhp-h
- brake-specific mass emission rate change for each notch of each emitted pollutant or GHG species,  $\Delta E_{ij}$ , grams per brake horsepower hour (g/bhp-h)
- line-haul weighted brake-specific mass emission rate change for each emitted pollutant or GHG species,  $\Delta E_{i\text{DC}}$ , g/bhp-h

Pollutants and GHGs of concern are:

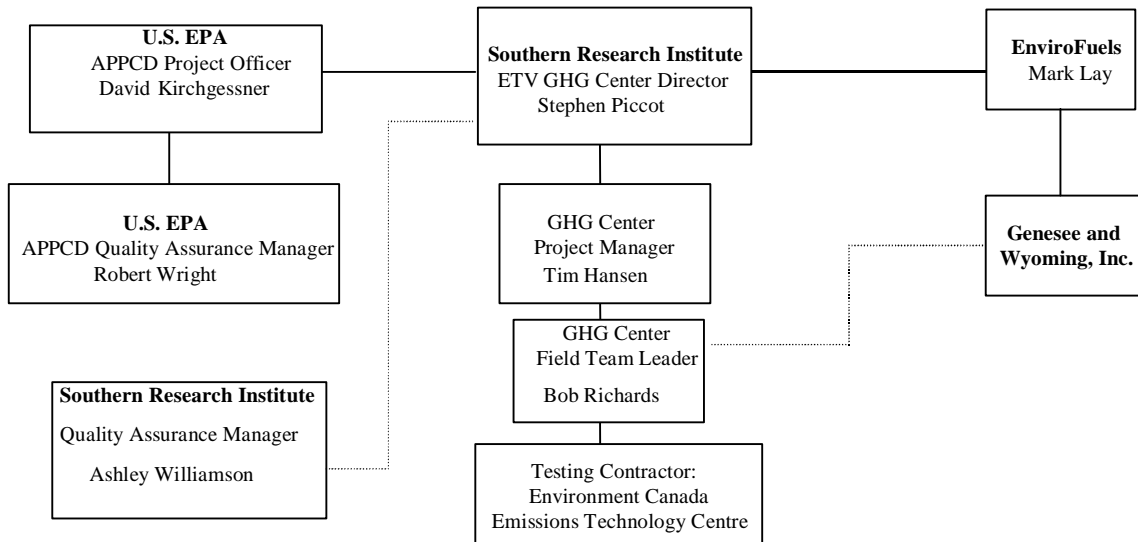
- $\text{CO}_2$
- CO
- $\text{NO}_x$
- total non-methane hydrocarbons (NMHC)
- methane ( $\text{CH}_4$ )
- total hydrocarbons (THC)
- total particulate matter (TPM)
- smoke opacity

The standard locomotive emissions testing procedure is the Federal Test Procedure (FTP) described in 40 CFR 92 Subpart B. Test results will be reported for each notch and as weighted for the locomotive’s duty cycle. While there is no comparable standard for fuel consumption measurement, the FTP does require precise measurement of this quantity simultaneously with the emission measurements. This verification will therefore report fuel consumption changes for each notch and duty cycle-weighted fuel consumption changes. Duty cycle-weighted fuel consumption changes are useful because the FTP duty cycle weightings are considered as reasonably representative locomotive use patterns. The change in duty cycle-weighted fuel consumption should be a valid predictor of expected fuel cost savings.

The verification parameters presented here include only the line-haul duty cycle weighting since locomotives of the size and configuration tested here would not generally be used in switching applications. The switch cycle weighted emissions and fuel consumption will also be calculated and reported for reference purposes, but they are not considered verification parameters.

#### 1.5. PROJECT ORGANIZATION

Figure 1-2 presents the project organization chart.



**Figure 1-2. Project Organization**

The GHG Center has overall verification planning and implementation responsibility. The GHG Center will coordinate all participants' activities; develop, monitor, and manage schedules; and ensure the acquisition and reporting of data consistent with the strategies in this test plan. The GHG Center Director, Mr. Stephen Piccot, will:

- review the test plan and report for consistency with ETV operating principles
- allocate appropriate resources for the verification
- oversee GHG Center staff activities

Mr. Mark Lay of Envirofuels is the technology developer's primary point of contact. He will:

- review the test plan and report especially with respect to accuracy in the technology description and its application
- secure the involvement of the locomotive owner, Genesee and Wyoming, Incorporated (G&W), locomotive operating and maintenance personnel, and facilities where testing will occur
- provide a sufficient supply of the catalyzer to the locomotive owner for the six to eight week break-in period and for the final test period

The GHG Center project manager is Mr. Tim Hansen. His responsibilities include:

- drafting the test plan, report, and Verification Statement
- overseeing the field team leader's activities
- ensuring collection of high-quality data and that all DQOs are met
- maintaining communications with all test participants
- budgetary and scheduling review

The project manager will have authority to suspend testing for health and safety reasons and if the QA/QC goals presented in Section 3.0 are not being met.

The field team leader is Mr. Robert Richards, who will supervise all field operations and the testing contractor's activities. He will assess data quality and will have the authority to repeat tests as deemed necessary to ensure achievement of data quality goals. He will:



- coordinate the installation of the electrical, and fuel metering equipment on the locomotive with the owner
- operate the electrical and fuel metering equipment during the tests
- declare the beginning and end of each test run, with input from the testing contractor
- collect interim test data for use in consultations with the project manager
- supervise and coordinate subcontractor activities
- perform other QA/QC procedures as described in Section 3.0

At the completion of each test run, the field team leader will communicate test results to the project manager. The field team leader and project manager will collaborate on all major project decisions including the need for further test runs or corrective actions.

The GHG Center QA manager, Dr. Ashley Williamson, will review this test plan. He will also review the verification test results, report, and conduct the Audit of Data Quality (ADQ) described in Section 4.0. The QA manager will report all internal audit and corrective action results directly to the GHG Center Director who will provide copies to the project manager for inclusion in the report.

Environment Canada’s Environmental Technology Centre (ETC) will act as the testing contractor. Their responsibilities include:

- coordination and installation of the temporary test duct, emissions testing, ambient monitoring and other necessary equipment on the locomotive
- performance of each test run in accordance with specifications of this test plan and reference methods
- reporting interim test data to the field team leader at the end of each test run
- meeting the Quality requirements specified in this test plan and their subcontract SOW
- analysis of all emissions test data and submittal of a test report within three weeks of the end of the final test series

EPA-ORD will provide oversight and QA support for this verification. The Air Pollution Prevention and Control Division (APPCD) project officer, Dr. David Kirchgessner, and QA manager, Mr. Robert Wright, will review and approve the test plan and report to ensure that they meet EPA QA goals and represent sound scientific principles. Dr. Kirchgessner will be responsible for obtaining final test plan and report approvals.

**1.6. SCHEDULE**

The tentative schedule of activities for the catalyzer verification test is:

<p><b><u>Verification Test Plan Milestones</u></b>                  GHG Center internal draft development                  EnviroFuels review                  Industry peer review and plan revision                  EPA review                  Final test plan posted</p>	<p><b><u>Dates</u></b>                  April 26 - July 9, 2004                  July 9 - July 12, 2004                  July 14 - July 21, 2004                  July 23 - August 6, 2004                  August 9, 2004</p>
<p><b><u>Verification Testing and Analysis Milestones</u></b>                  Initial tests on untreated fuel                  Revenue service break-in period on catalyzer-treated fuel                  Final tests on treated fuel</p>	<p><b><u>Dates</u></b>                  August 16 - August 20, 2004                  August 20 - October 3, 2004                  October 4 - October 8, 2004</p>

**Verification Report Milestones**

GHG Center internal draft development  
EnviroFuels review  
Industry peer review and report revision  
EPA review  
Final report posted

**Dates**

November 1 - November 22, 2004  
November 22 - November 29, 2004  
November 29 - December 13, 2004  
December 13 - December 31, 2004  
January 14, 2005

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## 2.0 VERIFICATION APPROACH

This section describes the GHG Center's verification approach. The following subsections describe the test design, FTP details as applied here, and sampling and analytical methods. A final subsection summarizes specific deviations from the FTP in the planned measurement series.

The FTP forms the basis for this test plan. The step-by-step procedures and tables of measurements supplied in Appendices B and C, as referenced to §92.101 through §92.133 of the FTP, and ETC's Onsite Collection Procedures for Chemical Analysis (for TPM, SO<sub>2</sub>, and sulfates; document number 11.23/1.2/S), will be the standard operating procedures (SOP).

### 2.1. TEST DESIGN

The GHG Center will first determine the locomotive's fuel consumption and emissions while operating on untreated fuel. The mean of at least three and not more than six FTP test runs will serve as a baseline for comparison. After the baseline test runs, railroad personnel will administer the fuel catalyzer to the locomotive's fuel and return it to revenue service for a six to eight-week break-in period. GHG Center personnel will then perform a final test series of at least three and not more than six test runs with the catalyzer-treated fuel. During the break-in period, G&W personnel will record fuel and additive usage.

In order to assure that the test results are not biased by fuel properties other than Catalyzer use, the supplier will provide fuel for both test series from a single fuel lot. Appendix A-1 provides a sample analysis of a recent fuel lot delivered to G&W. The analysis shows that this fuel is within §92.113 diesel fuel specifications. The GHG Center will obtain a similar analysis for the test fuel actually used in this verification and include it in the report. During testing, the locomotive will be fueled from its belly tank, which will be drained, cleaned, and filled with fuel from the test lot prior to testing.

Each test run will consist of a set of emissions measurements while the engine operates at a series of steady-state speed and load conditions. At each steady-state operating mode, measurements are taken of CO<sub>2</sub>, CO, NO<sub>x</sub>, O<sub>2</sub>, THC, CH<sub>4</sub>, TPM, and smoke emissions, generated power, and fuel consumption rate. Emissions are normalized to engine power in terms of brake horsepower-hour (bhp-h), which will be measured electrically. Test personnel will also measure SO<sub>2</sub> and sulfate emissions at notch 8 for information only. These results are not considered part of this verification but will allow an assessment of the Catalyzer's effects on the emissions partitioning of fuel-borne sulfur.

The test sequence is defined in terms of the throttle notches typically available on diesel-electric locomotives. At the beginning of the sequence, the operator brings the engine to normal operating temperature in accordance with the manufacturer's warm-up procedures for in-service locomotives. Warmup will require approximately 1 hour (longer in cold weather). The engine is then operated at notch 8 (full power) for 5 minutes. The operator returns the engine to idle, or low idle if so equipped. Test personnel then begin exhaust emission, fuel consumption, and other measurements. During each test period, an external resistance load bank is connected to the locomotive's power distribution system to dissipate the generated electricity. Test measurements continue while the operator cycles the locomotive (and load bank) through each power setting to notch 8. Table 2-1 shows the test sequence and elapsed time at each notch, as excerpted from Table B124-1 of §92.124.

**Table 2-1. Locomotive Test Sequence**

Mode No.	Notch setting	Time in notch	Emissions, power, and fuel consumption measured
Warmup	Notch 8	5 ± 1 min	No
Warmup	Lowest Idle	15 min maximum	
1a	Low Idle	6 min minimum	All
1	Normal Idle		
2	Dynamic Brake		
3	Notch 1		
4	Notch 2		
5	Notch 3		
6	Notch 4		
7	Notch 5		
8	Notch 6		
9	Notch 7	15 min minimum	
10	Notch 8		

Particulate sampling will begin within ten seconds and end six minutes after the start of each test mode. ETC will sample gaseous concentrations continuously and will calculate steady state concentrations per the FTP as a one-minute average beginning after 300 seconds (840 seconds for notch 8) from the start of each test mode. Sufficient time is allotted after each notch test to change particulate filters and perform any other necessary activities.

If the FTP criteria for steady state concentrations are not fulfilled, the FTP requires an integrated concentration calculation over the mode’s minimum duration (6 or 15 minutes). ETC will correlate the resulting concentrations with fuel consumption and power generation measurements during the last minute of each FTP test mode (or last 3 minutes for idle modes). ETC will analyze and report the gaseous and particulate emissions in conformance to these specifications. This will allow direct comparisons with FTP results from other locomotive tests.

During each notch, test personnel will acquire the following measurements:

- fuel consumption, gallons per hour (gph)
- AR10 main generator power output, kilowatts (kW) and engine mechanical power, brake horsepower (bhp)
- exhaust emissions, grams per brake horsepower-hour (g/bhp-h)
- sample system operating parameters
- engine inlet and cooling air temperature, degrees Fahrenheit (°F)
- ambient barometric pressure, pounds per square inch absolute (psia)
- ambient temperature, °F
- cooling fan(s) operating status, on or off

At the end of the revenue service break-in period, test personnel will repeat this sequence while operating the locomotive on treated fuel.

The field team leader will acquire the power consumption in kW for each cooling fan at each notch during testing. These values, divided by the companion alternator's efficiency, contribute to the accurate determination of engine bhp. During testing, additional parasitic loads (air conditioning, lights, radio, etc.) will be shut off.

## **2.2. REVENUE SERVICE BREAK-IN PERIOD AND FUEL TREATMENT**

At the conclusion of the baseline test runs, the field team leader will release the locomotive for a 6 to 8 week break-in period in regular revenue service during which time it is anticipated the locomotive will consume approximately 30,000 gallons of fuel. If railroad operational issues prevent use of this much fuel, the project manager may extend the break-in period. Envirofuels will supply a calibrated dosing pump which will enable G&W personnel to administer the Fuel Catalyzer during routine locomotive refueling operations.

The initial treated fuel dosing ratio during the break-in period will be 640:1. The dosing rate will be reduced to the maintenance dosage rate of 1280:1 for a minimum of one week prior to the final test period. The dosing pump has a totalizing readout which, when correlated with the fueling station's records, will allow verification that the additive was properly mixed with the fuel. Appendix C8 provides the procedure and a log form.

During the break-in period and final testing, the locomotive will not be scheduled for any maintenance activities to ensure that no modifications are made to the engine that may affect its performance prior to the final test period.

## **2.3. INSTRUMENTATION**

### **2.3.1. Fuel Flow Metering**

Fuel consumption during both test series will be measured using flowmeters supplied by the GHG Center and installed by railroad maintenance staff under the field team leader's supervision. Fuel supply flow in the typical EMD locomotive engine is approximately 2.5 times the anticipated net consumption rate at notch 8, with the balance recirculated to the fuel tank. The excess flow provides injector and fuel system lubrication and cooling. The fuel consumption measurement system therefore consists of two temperature-compensated flowmeters, one each installed in the fuel supply and return pipelines.

This verification will employ a Flow Technologies, Inc. FuelCom model FC05 net fuel metering system. The FuelCom flow meters use two rotating impellers driven by the flowing fuel. Magnets imbedded in the impellers generate a pulsed output signal. Each pulse represents a known volume of fuel that is captured between the impeller lobes. The system includes fuel temperature sensors. A microprocessor in the FuelCom FC900 transmitter uses the pulse and temperature data to compensate for the temperature effects on the fuel viscosity and density, thereby providing a linearized output signal.

The manufacturer specifies accuracy of  $\pm 1.0$  percent at higher fuel consumption rates (notches 2 through 8) and  $\pm 2.0$  percent at lower fuel consumption rates (idle and notch 1) of the net fuel consumption reading. The flowmeter will be accompanied by a current (18-month) National Institutes of Standards and Technology (NIST) - traceable calibration certificate. The manufacturer will calibrate the flowmeter with diesel fuel at 84 data points from 50° F to 140° F over the full flow range.

A datalogger will poll the sensors' 4 - 20 milliamp (mA) outputs once per second and compute and record five-second temperature-compensated inlet, return, and net flow averages during each test run. A separate datalogger and software package will monitor and record the sensors' RS-485 fuel temperature outputs.

### **2.3.2. Power Metering**

Brake-specific emissions calculations require the engine's total horsepower production at each notch. This is the sum of the mechanical power input to locomotive accessories and the main "AR10" generator. The locomotive service manual cites default power consumption values for the following accessories [8]:

- main air blower, 13.5 hp
- traction motor blowers, 75.0 hp
- air compressor (unloaded), 17.0 hp
- auxiliary direct-current (DC) generator, 4.0 hp

Test personnel will record actual power consumption at the radiator cooling fans as described in the following subsection.

Engine mechanical power input to the main generator in bhp is the AR10's real power output in DC kW divided by the generation efficiency (default value of 0.715). AR10 power output is the product of the current and voltage produced at each notch.

The current sensor will be a split-core Hall effect device connected to a signal conditioner. Rated accuracy is  $\pm 1.0$  percent of reading; span is 4000 amperes (A). The voltage transducer rated accuracy is  $\pm 0.25$  percent full scale (FS); span is 1000 volts (V). The combined accuracy will be approximately  $\pm 1.0$  percent, which meets FTP power metering specifications. Both sensors will be accompanied by current (18-month) NIST-traceable calibration certificates.

A datalogger will poll the sensors' 4 - 20 milliamp (mA) outputs once per second and compute and record five-second averages during each test run.

An external resistance load bank will dissipate the power produced by the AR10 generator. Maintenance personnel will connect the load bank to the proper test point in the locomotive's electrical distribution bus according to the locomotive's standard load test procedure. Maintenance personnel will install the current sensor around the two positive output cables at the AR10 terminal block and they will connect the voltage sensor leads to the AR10 positive and negative output terminals or buses.

### **2.3.3. Radiator Cooling Fan Power Consumption**

The field team leader will measure each cooling fan's power consumption as kW with a clamp-on true power digital voltmeter (DVM) prior to the test campaign. This value at each notch divided by the D14 companion alternator efficiency yields the mechanical power in bhp required from the engine. Appendix C7 provides a log form.

During testing, the field team leader will log the power consumption and on/off cycles for the cooling fans. Analysts will add the total power consumption of all operating fans to the AR10 power output for that notch.



### 2.3.4. Emissions Measurements: General

Emissions measurements will be conducted by the Emissions Research and Measurements Division (ERMD) of Environment Canada's Environmental Technology Centre (ETC). ETC will use three sampling modules which generally meet 40 CFR 92.114 specifications: an extractive opacity monitor and portable partial flow dilution sampling systems for gaseous and particulate emissions. FTP §92.114(d)(2) permits sampling after dilution of part or all of the exhaust. ETC personnel will install a temporary test duct onto the locomotive's single exhaust duct with the three sampling modules connected to the test duct. Figure 2-1 illustrates the engine exhaust and provides a test duct schematic. The additional sample ports shown in Figure 2-1 will allow ETC to perform the exhaust gas flow rate cross checks by pitot traverse outlined in Table 3-4.

Equivalent diameter is  $D_{eq} = \frac{2L_1L_2}{L_1+L_2}$ , or 16.1". Approximately two diameters exist below roof hatch.

Specify test duct L1, L2, and egg crate clearance to fit over upper lip of exhaust duct.

Sample ports not to scale. Specify number and size to fit DOES2, LPSS, and smoke meter probes.

For pitot traverses, specify number, size, and spacing per EPA method 1

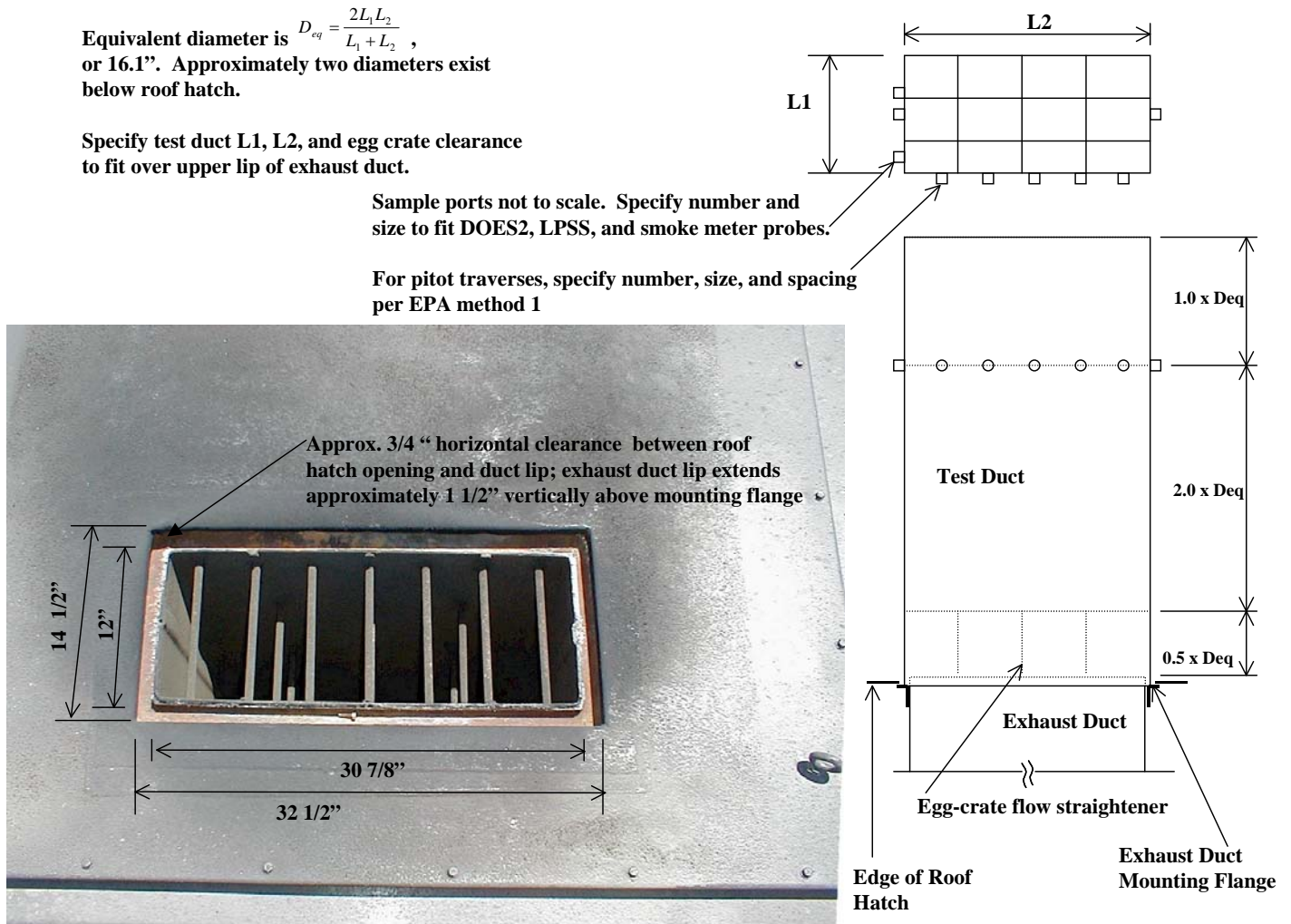


Figure 2-1. Exhaust Duct and Test Duct Schematic



### 2.3.5. Dynamic Off-road Emission Sampling (DOES2) Dilution Sampling System

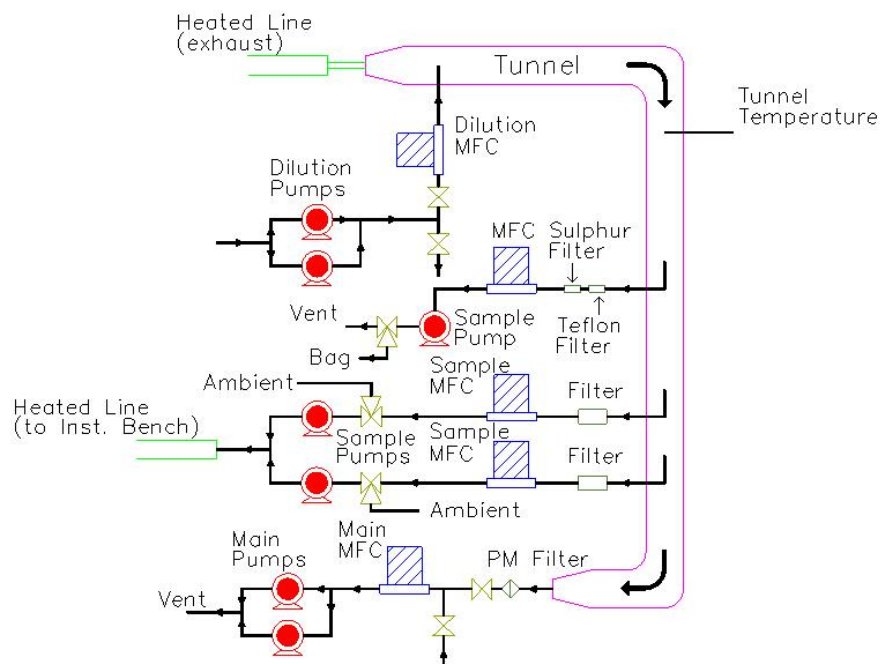
The Dynamic Off-road Emission Sampling System (DOES2) is a partial flow portable sampling system for gaseous emissions. ETC will configure the system according to 40 CFR 92.114(e) requirements.

The DOES2 collects a known quantity of the engine's raw exhaust and mixes it with a known quantity of ambient dilution air. This dilution, while maintaining constant temperature and flow velocity, conditions the sample and minimizes condensation. Sample pumps extract a secondary sample from the diluted stream and route it to the gas analyzers. The analyzers and their detection principles will be:

- THC by heated flame ionization detector (HFID)
- CH<sub>4</sub> by HFID
- NO<sub>x</sub> by chemiluminescence detector
- CO by non-dispersive infrared (NDIR)
- CO<sub>2</sub> by NDIR
- O<sub>2</sub> by paramagnetic detector or equivalent

The sample probe is fabricated from 3/8 inch stainless steel tubing, capped and drilled per Figure B114-2 of §92.114(b)(3). A 25' heated line connects the sample probe to the DOES2 dilution tunnel. Figure 2-2 represents a schematic flow diagram of the dilution tunnel.

The dilution pump forces a controlled volume of air through a pre-filter into the dilution tunnel. That volume combines with the exhaust gas drawn from the sample probe to produce the dilute sample. The main pumps draw the dilute sample through the dilution tunnel and past the instrumental analyzer probes. The dilute sample is thoroughly mixed as it travels more than 10 tunnel diameters before reaching the instrumental analyzer sample probes. Sample pumps, two mass flow controllers, and a heated line convey the dilute sample to the analyzers. Operators monitor the dilute sample temperature to ensure that no moisture condensation occurs.



**Figure 2-2. DOES-2 Schematic**

A Programmable Logic Controller (PLC) will read and record all sensor signals at 0.2 second intervals, calculate the dilution air requirement, control the variable flow solenoid valve and calculate the emission rates. The PLC uses a Compact Flash Card as storage media. Test personnel will copy the data to floppy disks as ASCII text files or Excel worksheets for the field team leader's review.

### **2.3.6. SO<sub>2</sub> and Sulfate Sampling**

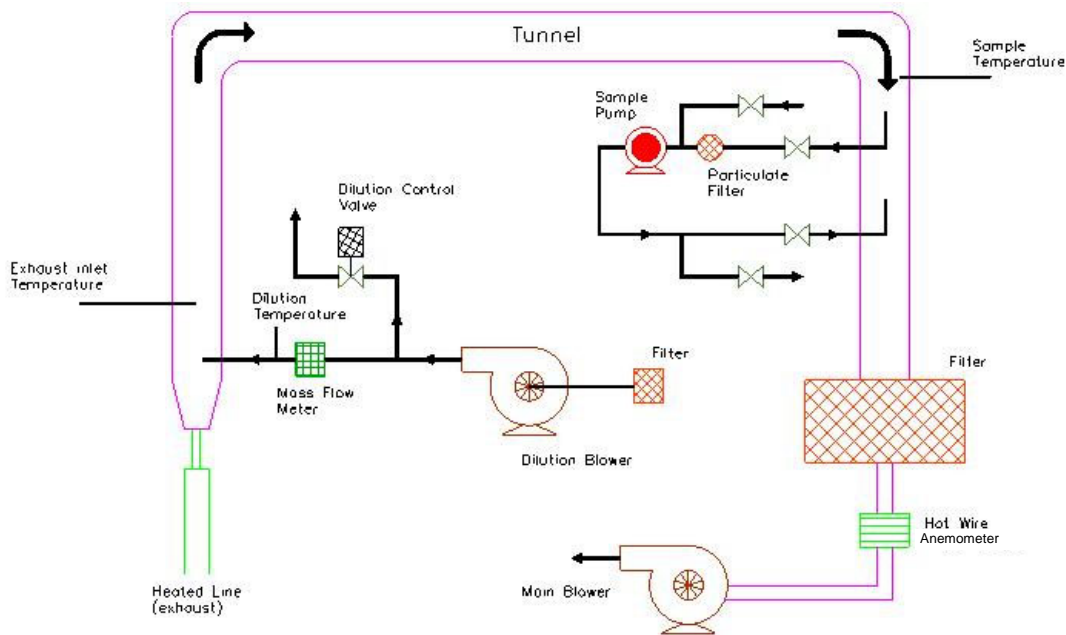
The DOES2 system includes SO<sub>2</sub> and sulfate sampling capabilities. Two separate treated filter media collect gaseous and particulate samples from the diluted gas stream for later extraction by H<sub>2</sub>O<sub>2</sub> for SO<sub>2</sub> or isopropyl alcohol and de-ionized water for sulfates. Analysis is by ion chromatography with a conductivity detector for both species.

Sampling rate for SO<sub>2</sub> and sulfate is 5.0 lpm for the duration of the mode (15 minutes at notch 8). ETC will install a backup filter downstream of the teflon and coated filters to quantify any potential breakthrough. ETC personnel will collect the sample filters and ship them to their laboratory under a signed chain of custody form (Appendix B4) according to their Onsite Collection Procedures for Chemical Analysis, document number 11.23/1.2/S. The ETC laboratory designates the analyses methods as Determination of Anions and Cations on Multi (3) - Ion Chromatography System, document number 6.3/5.0/M, and Determination of Gaseous and Particulate Inorganic Air Pollutants by Ion Chromatography, document number 6.5/1.0/M. The detection limit for sulfate on the teflon filter is 0.2 micrograms per sample. The detection limit for all sulfur species on the coated filter is 0.7 micrograms per sample.

ETC will collect four SO<sub>2</sub> and sulfate samples during notch 8 operations during valid test runs for each fuel condition. Three of the samples will be analyzed with the fourth held in reserve for later analysis if warranted. These measurements will be undertaken and reported for information only.

### **2.3.7. Particulate Emission Sampling: Locomotive Particulate Sampling System**

ETC developed the Locomotive Particulate Sampling System (LPSS) to obtain particulate samples from large engine exhausts. It is similar to the DOES2 but withdraws and dilutes larger amounts of exhaust gas. The higher throughput provides larger amounts of particulate for sampling. The probe is designed according to Figure B114-4 of §92.114(c)(2) to sample at points across the exhaust duct. This yields a representative spatial average of the exhaust flow. As in the DOES2 system, a 25' heated line connects the exhaust probe to the LPSS, where the exhaust is diluted with ambient air at a constant rate. Figure 2-3 presents a LPSS schematic flow diagram.



**Figure 2-3. LPSS Schematic**

A hot wire anemometer is used to measure the tunnel flow. This flow is maintained by choking the outlet of the main blower with a manual valve. The exhaust is drawn through the tunnel through a  $\frac{3}{4}$  inch heated line connected to the probe in the exhaust duct. The dilution flow is introduced approximately 5 inches downstream from where the exhaust is entered. The dilution flow is generated by a smaller blower, and is filtered to prevent ambient air particles from entering the tunnel. The dilution air is then directed through a control splitter which varies the dilution air quantity. Test operators set the dilution and tunnel flows manually because the LPSS was designed for use in steady-state testing.

A sample pump withdraws a metered quantity of the diluted sample through “back to back” 70mm Fluorocarbon-coated glass fiber filters to collect TPM. The particulate filters conform to §92.114 specifications.

ETC personnel will collect the sample filters after each mode, seal the containers, and forward them to their laboratory for gravimetric analysis under a signed chain of custody form (Appendix B4) according to their Onsite Collection Procedures for Chemical Analysis, document number 11.23/1.2/S.

### 2.3.8. Opacity Measurements

A Bosch - RT100A opacity meter will measure smoke emissions. This opacity meter draws a sample of exhaust from the test duct into a viewing chamber where a beam of light is passed through the sample. A detector continuously measures the quantity of transmitted light and a datalogger records the results 2 times per second.

Locomotives generally produce their heaviest smoke emissions during transitions to higher operating notches. ETC will therefore record opacity data continuously to measure smoke emissions during these transients as well as during steady state operations at each notch, as specified in 40 CFR 92.131(b).

**2.4. ANALYTICAL METHODS AND NUMBER OF TEST RUNS**

The FTP includes all the method’s required calculations, so they are not reproduced here. This subsection discusses the generalized emissions and fuel consumption calculations and introduces the statistical methods the field team leader will use to finalize the number of test runs.

In general, more test runs will allow a better characterization of the catalyzer’s effects. The GHG Center will be unable to restore the locomotive to the baseline condition, so the field team leader must estimate the proper number of baseline runs prior to releasing the unit for the break-in period.

He will evaluate the results after the 3<sup>rd</sup> baseline test run to estimate the statistical significance of potential changes. If the baseline test results indicate that the expected 18 percent NO<sub>x</sub> emissions change and 5 percent fuel consumption change may be statistically significant based on sampling variability seen during the first 3 runs, he may end the baseline tests. If not, he may call for additional test runs up to a maximum of 6. A total of 6 baseline runs is the most likely scenario because his evaluation will consider that particulate results will not be available on site. The field team leader will perform similar analyses after the 3<sup>rd</sup> and any subsequent treated fuel test runs. The statistical tests are:

- evaluate the statistical significance of any changes
- establish that the test results have similar variability between the baseline and treated fuel
- calculate the confidence interval on the changes

The subsections below discuss these tests.

**2.4.1. Engine Brake Horsepower**

Engine bhp is:

$$BHP_j = \frac{kW_{AR10}}{\eta_e * 0.7457} + bhp_{fans} + 13.5 + 75 + 17 + 4 \tag{Eqn. 2-1}$$

Where:

- BHP<sub>j</sub> = mean mechanical power for mode j, bhp
- kW<sub>AR10</sub> = mean main generator power output, kW
- η<sub>e</sub> = AR10 electrical efficiency at mode j (default value is approximately 0.715)
- 0.7457 = horsepower per kilowatt
- bhp<sub>fans</sub> = cooling fan kW divided by companion alternator efficiency (default 0.85), hp
- 13.5 = default main air blower mechanical power consumption, hp
- 75 = default traction motor blower mechanical power consumption, hp
- 17 = default unloaded air compressor mechanical power consumption, hp
- 4 = default auxiliary DC generator mechanical power consumption, hp

**2.4.2. Emissions and Fuel Consumption**

The following equations use the FTP nomenclature where possible. The normalized emission rates and fuel consumption for each test mode are:

$$E_{ij} = \frac{M_{ij}}{BHP_j} \quad \text{Eqn. 2-2}$$

and:

$$BSFC_j = \frac{Wf_j}{BHP_j} \quad \text{Eqn. 2-3}$$

Where:

- $E_{ij}$  = brake-specific mass emission rate of pollutant i for mode j, g/bhp-h
- $M_{ij}$  = mean mass emission rate for pollutant i during mode j test, grams per hour (g/h)
- $BHP_j$  = mean brake horsepower for mode j, bhp
- $BSFC_j$  = brake-specific fuel consumption for mode j, lb/bhp-h
- $Wf_j$  = mean fuel mass consumption rate for mode j, lb/h

Measurements taken at each operating mode setting will be weighted according to two duty cycles assumed typical of line-haul and switching operations. EPA derived these duty cycle weightings from actual train time-in-notch measurements and considers them as representative. Table 2-2 summarizes the weighting factors as excerpted from Table B132-1 of §92.132.

Throttle Notch Setting	$F_{mode, \text{line-haul}}$	$F_{mode, \text{switch}}$
Low idle	0.190 <sup>a</sup>	0.299 <sup>a</sup>
Normal idle	0.190 <sup>a</sup>	0.299 <sup>a</sup>
Dynamic brake	0.125	0
Notch 1	0.065	0.124
Notch 2	0.065	0.123
Notch 3	0.052	0.058
Notch 4	0.044	0.036
Notch 5	0.038	0.036
Notch 6	0.039	0.015
Notch 7	0.030	0.002
Notch 8	0.162	0.008

<sup>a</sup> For locomotives equipped with a single idle notch, the combined idle  $F_{mode}$  is the sum of the two values shown

The weighted emissions for each duty cycle are:

$$E_{iDC} = \frac{\sum (M_{ij} * F_j)}{\sum (BHP_j * F_j)} \quad \text{Eqn. 2-4}$$

Where the summation is over all modes j, and:

- $E_{iDC}$  = (line-haul or switch) duty-cycle weighted brake-specific mass emission rate for pollutant i, g/bhp-h
- $M_{ij}$  = mean mass emission rate for pollutant i during mode j test, g/h
- $F_j$  = (line-haul or switch) duty cycle weighting factor for mode j (Table 2-2)
- $BHP_j$  = mean brake horsepower for mode j, bhp

The weighted fuel consumption will be:

$$BSFC_{DC} = \frac{\sum (Wf_j * F_j)}{\sum (BHP_j * F_j)} \quad \text{Eqn. 2-5}$$

Where:

- BSFC<sub>DC</sub> = (line-haul or switch) duty-cycle weighted brake specific fuel consumption, lb/bhp-h
- W<sub>fj</sub> = mean fuel mass consumption rate for mode j, lb/h
- F<sub>j</sub> = (line-haul or switch) duty cycle weighting factor for mode j (Table 2-2)
- BHP<sub>j</sub> = mean brake horsepower for mode j, bhp

The verification parameters for this test are defined in terms of changes, delta (Δ), in these quantities after introduction of the Catalyst fuel additive. Thus, the brake-specific fuel consumption rate changes at each operating mode will be:

$$\Delta BSFC_j = BSFC_{j, \text{baseline}} - BSFC_{j, \text{catalyzer}} \quad \text{Eqn. 2-6}$$

Where:

- ΔBSFC<sub>j</sub> = brake-specific fuel consumption rate change for mode j, lb/bhp-h
- BSFC<sub>j,baseline</sub> and BSFC<sub>j,catalyzer</sub> are computed using Equation 2-3.

The change in the duty-cycle weighted brake specific fuel consumption will be:

$$\Delta BSFC_{DC} = BSFC_{DC, \text{Baseline}} - BSFC_{DC, \text{catalyzer}} \quad \text{Eqn. 2-7}$$

Where:

- ΔBSFC<sub>DC</sub> = change in duty-cycle weighted brake specific fuel consumption, lb/bhp-h
- BSFC<sub>DC,baseline</sub> and BSFC<sub>DC,catalyzer</sub> are computed using Equation 2-5.

The change in mode and duty-cycle weighted emissions will be calculated similarly:

$$\Delta E_{ij} = E_{ij, \text{baseline}} - E_{ij, \text{catalyzer}} \quad \text{Eqn. 2-8}$$

$$\Delta E_{iDC} = E_{iDC, \text{baseline}} - E_{iDC, \text{catalyzer}} \quad \text{Eqn. 2-9}$$

Where:

- ΔE<sub>ij</sub> = brake-specific emission rate change for pollutant i, and mode j, g/bhp-h
- ΔE<sub>iDC</sub> = change in duty-cycle weighted brake-specific emissions rate for pollutant i, g/bhp-h
- E<sub>ij,baseline</sub> and E<sub>ij,catalyzer</sub> are computed using Equation 2-2.
- E<sub>iDC,baseline</sub> and E<sub>iDC,catalyzer</sub> are computed using Equation 2-4.

Note that at the low fuel burn rates expected during the lower modes (low idle through about notch 1), the subtraction error caused by inaccuracies in the two fuel meters may be a large fraction of the burn rate. It may be impossible to show a statistically significant fuel consumption rate change for those individual modes. The overall measurement error for the duty-cycle weighted fuel consumption rates, however, will be small. This is because the duty-cycle weighted fuel consumption rate calculation applies the Table 2-2 weighting factors to each mode. These weighting factors, combined with the much lower fuel meter subtraction error in the higher notches, will yield a satisfactory measurement error. For example, the weighted fuel consumption rate from a pretest visit was 56.35 ± 0.14 gph, for a relative error of 0.25 percent. This is a small fraction of the estimated 5.0 percent fuel consumption change.

**2.4.3. Baseline Versus Treated Fuel Statistical Significance**

The GHG Center will evaluate the statistical significance of the emissions and fuel consumption changes between the baseline and treated fuel conditions. If fuel consumption changes are statistically significant, the GHG Center will calculate the difference’s confidence interval.

After the 3<sup>rd</sup> test run, and after each following run (up to the 6<sup>th</sup>), analysts will calculate a test statistic,  $t_{test}$ , and compare it with the Student’s T distribution value with  $(n_1 + n_2 - 2)$  degrees of freedom as follows [6]:

$$t_{test} = \frac{(\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)}{\sqrt{s_p^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}} \tag{Eqn. 2-10}$$

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \tag{Eqn. 2-11}$$

Where:

- $X_1$  = mean fuel economy with baseline fuel
- $X_2$  = mean fuel economy with treated fuel
- $\mu_1 - \mu_2$  = zero ( $H_0$  hypothesizes that there is no difference between the population means)
- $n_1$  = number of repeated test runs with baseline fuel
- $n_2$  = number of repeated test runs with treated fuel
- $s_1^2$  = sample standard deviation with baseline fuel, squared
- $s_2^2$  = sample standard deviation with treated fuel, squared
- $s_p^2$  = pooled standard deviation, squared

Selected T-distribution values at a 95-percent confidence coefficient ( $t_{0.025, DF}$ ) appear in the following table [6].

$n_1$	$n_2$	Degrees of Freedom, DF ( $n_1+n_2-2$ )	$t_{0.025, DF}$
3	3	4	2.776
4	4	6	2.447
5	5	8	2.306
6	6	10	2.228

If  $t_{test} > t_{0.025, DF}$ , conclude that the data shows a statistically significant difference between the baseline and treated fuel parameters. Otherwise, conclude that a significant fuel economy difference does not exist. If significant, the the difference and its confidence interval will be reported.

**2.4.4. Sample Variance Similarity**

Use of equations 2-10 and 2-11 requires the assumption that the baseline and treated fuel test run results have similar variance. The ratio of the sample variances (sample standard deviation squared) between the two fuel test series is a measure of this similarity [7]. Analysts will calculate an  $F_{test}$  statistic according to



Eqn. 2-12 and compare the results to the values in Table 2-4 to determine the degree of similarity between the sample variances.

$$F_{test} = \frac{s_{max}^2}{s_{min}^2} \tag{Eqn. 2-12}$$

Where:

- $F_{test}$  = F-test statistic
- $s_{max}^2$  = larger of the sample standard deviations, squared
- $s_{min}^2$  = smaller of the sample standard deviations, squared

Table 2-4 [6] presents selected  $F_{0.05}$  distribution values for the expected number of test runs and the acceptable uncertainty ( $\alpha$ ; 0.05).

	$s_{max}^2$ number of runs	3	4	5	6
$s_{min}^2$ number of runs	Degrees of Freedom	2	3	4	5
3	2	19.00	19.16	19.25	19.30
4	3	9.55	9.28	9.12	9.01
5	4	6.94	6.59	6.39	6.26
6	5	5.79	5.41	5.19	5.05

If the F-test statistic is less than the corresponding value in Table 2-4, then analysts will conclude that the sample variances are substantially the same and the statistical significance evaluation and confidence interval calculations are valid approaches. If the F-test statistic is equal to or greater than the Table 2-4 value, analysts will conclude that the sample variances are not the same and will consequently modify the confidence interval calculation according to Satterthwaite’s approximation [7]. The report will discuss Satterthwaite’s approximation if the actual test data indicate that it must be applied.

#### 2.4.5. Baseline Versus Treated Fuel Confidence Interval

If a statistically significant difference in parameters is observed, the 95-percent confidence interval will be calculated. The half width (e) of the 95 percent confidence interval is [6]:

$$e = t_{.025,DF} \sqrt{s_p^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)} \tag{Eqn. 2-13}$$

Analysts will calculate and report per-notch  $\Delta E_{ij}$ , and  $\Delta BSFC_j$ , as well as duty cycle-weighted  $\Delta BSFC_{DC}$  and  $\Delta E_{iDC}$  results for both the FTP and extended steady-state test modes described above. All reported results will include the 95 percent confidence interval, if the results are statistically significant.

### 2.5. COMPARISON WITH THE FTP

The 40 CFR 92 Subpart B FTP is the reference test method for this verification, and test personnel will follow the FTP procedures in detail where practicable. There are, however, some differences which arise because of the equipment used or this verification’s goals.



### General equipment specifications

1. §92.105(e) specifies absolute pressure measurement gauges or transducers must have an accuracy and precision of  $\pm 0.1$  percent of absolute pressure at point or better. ETC uses Viatran model 218 absolute pressure transmitters, which have an accuracy of  $\pm 0.25$  percent of full scale and a repeatability of less than or equal to  $\pm 0.2$  percent of full scale. ETC and the GHG Center consider this difference to be inconsequential.
2. §92.111 specifies an in-situ, duct-mounted smoke measurement system and indicates that the light beam must pass through the longest axis of the entire exhaust smoke plume at right angles. This differs from the way the Bosch RT100A measures opacity because it draws a partial exhaust gas sample from the exhaust stack. The length of  $\frac{1}{2}$ " sample line is kept to a minimum to maintain accuracy. Both devices normalize opacity measurements to the path length. These technique differences are minimal and inconsequential for this test, since any systematic results difference would be common to both baseline and treated fuel tests.

### Dilution system differences

ETC optimized the DOES2 and LPSS dilution sampling systems for in-use field measurements on operating equipment rather than in a test cell environment. Some physical and functional differences between these two systems and those specified in the CFR are the result. ETC and the GHG Center reviewed the results of correlated DOES2 and LPSS tests as compared with 40 CFR 86 test cell instrumentation. (Note that 40 CFR 92 incorporates 40 CFR 86 methods and instrumentation by reference.) The results are comparable for emissions measurements on heavy duty diesel engines. The maximum difference between the two methods was approximately 11 percent for TPM and 4.6 percent for THC.

Some of the method differences are matters of choice and will not affect measurement results. Other specific differences are:

1. The FTP specifies that TPM minimum dilution train inner diameter (ID) should be 4 inches and the extraction probe should be "approximately 1.25 inch" ID. The LPSS dilution train ID is 3.75 inches and its extraction probe is approximately 0.75 inch ID. The LPSS meets the FTP Reynolds number specifications. The GHG Center considers these differences to be inconsequential, as confirmed by the previous correlation testing.
2. The formulas in §92.132(b)(3) provide for calculation of total exhaust flowrate based on the diluted gas concentrations, sample, and dilution air flow rates reported from the DOES2. ETC will modify the formula for TPM emission rate [§92.132(b)(4)] to reflect that TPM is sampled in a different train with a different dilution factor. ETC will substitute the LPSS actual dilution air and sample flowrates into the formula and correlate the measured emissions against the wet total exhaust volume as calculated from the DOES2 sample. These calculations are functionally equivalent to the FTP calculations and thus do not represent a true method difference.
3. The FTP [§92.114(c)(4)(ii)] specifies that the dilution air temperature be at 68 °F or greater. While this can be controlled in a test cell, the dilution air temperature for the LPSS and DOES2 is limited by the daily ambient conditions, and cannot be guaranteed to be above 68 °F during a particular mode at a constant dilution ratio. This is of concern especially during tests in cool, humid conditions. At the end of each test for each mode, ETC operators will inspect the LPSS and DOES2 filter housings for moisture condensation. If any appears, that mode will be voided and the dilution rate adjusted as necessary to eliminate the condensation during the repeated mode.

## 3.0 DATA QUALITY

### 3.1. DATA QUALITY OBJECTIVE

The GHG Center will perform this verification according to Title 40 CFR 92, subpart B (§92.101 ff) procedures with certain modifications as discussed in Section 2.5. All measurement equipment accuracies, analyses, and QA/QC procedures will equal or exceed those specified in the CFR or as described in this test plan if different from the CFR. Achievement of this qualitative DQO will be documented by the QA/QC checks discussed in the following subsections.

The actual fuel consumption and emissions reductions cannot be established until tests are concluded, so this test plan does not adopt explicit quantitative DQOs. The estimated Catalyzer effects (5.0 percent for fuel consumption and 18.0 percent for NO<sub>x</sub> reductions) and the analyses presented in Section 2.4 suggest the following implicit data quality objectives for field personnel.

The implicit DQOs are that the data show statistical significance, variance similarity, and that the 95 confidence interval be refined as much as possible up to a maximum of six test runs.<sup>1</sup> Although the field data may show statistical significance at the 3<sup>rd</sup> test run, the GHG Center will consider additional runs up to a maximum of 6. This is because, given a constant measurement variability, results from more test runs allow a smaller 95 percent confidence interval calculation on the mean result. The ability to report a “5.0 ± 2.0 percent fuel consumption change” will have more value than a “5.0 ± 4.5 percent fuel consumption change” report. The field team leader will use equations 2-10 through 2-13 and the Appendix C4 log forms to perform these evaluations.”

### 3.2. INSTRUMENT SPECIFICATIONS, CALIBRATIONS, AND QA/QC CHECKS

Table 3-1 lists the instruments to be used in this verification test, their expected operating ranges, and accuracy specifications. 40 CFR 92 Subpart B or 40 CFR 86 Subparts D or N are the sources for most of the cited specifications. Table 3-2 provides instrument calibration specifications and schedules, as provided by the FTP or as determined by ETC from other test programs. Table 3-3 summarizes field and laboratory QC checks for the major systems. All calibrations, QA/QC checks, and acceptance criteria for sampling equipment and analyzers that are described in 40 CFR 92, subpart B, are incorporated by reference.

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<sup>1</sup> For reference, if the fuel consumption change is 5.0 percent, the sample standard deviation must be less than 2.2 percent (with respect to the baseline results) if three runs are conducted or 3.9 percent if 6 runs are conducted. Similarly for the estimated 18.0 percent NO<sub>x</sub> reductions, the sample standard deviation must be less than 7.9 percent for 3 test runs and 14.0 percent for 6 test runs for the results to be statistically significant.

**Table 3-1. Instrument and Accuracy Specifications**

Measurement Variable	Expected Operating Range	Instrument Mfg., Model / Type	Instrument Range	Measurement Frequency	Specification	How Verified / Determined
Main traction generator voltage	0 - 900 V	Flex-Core VT8-014E	0 - 1000 V	Continuous, 1 Hz	± 0.25 % FS	Factory calibration
Main traction generator current	0 - 4000 A	Flex-Core CTL-502HS/4000; CTA-215NYXX	0 - 4000 A	Continuous, 1 Hz	± 1.0 % of point	Factory calibration
Fuel flow rate	50 - 400 gph	FuelCom FC-050, (paired meters for supply, return)	50-500 gph	Continuous, 1 Hz	± 1.0 % of point	Factory calibration
DOES2 main flowrate	35 - 45 lpm	MKS mass flow controller model 1559	0-100 lpm	Continuous, 2 Hz	± 1.0 % FS	Factory/laboratory calibration
DOES2 dilution air flowrate	5 - 40 lpm	MKS mass flow controller model 1559	0 - 50 lpm	Continuous, 2 Hz	± 1.0 % FS	Factory/laboratory calibration
DOES2 analyzer sample flowrate	9 lpm	Two parallel MKS mass flow controllers model 179	0-5 lpm, each 10 lpm, total	Continuous, 2 Hz	± 1.0 % FS	Factory/laboratory calibration
LPSS main flowrate	400 lpm	Hot wire anemometer	0 - 8500 lpm	Continuous, 2 Hz	± 1.0 % of point	Factory/laboratory calibration
LPSS dilution air flowrate	275 - 325 lpm	Mass flow meter	0 - 500 lpm	Continuous, 2 Hz	± 1.0 % of point	Factory/laboratory calibration
Temperature LPSS main	<125 °F	National Semiconductor IC Temp Sensor	32 - 392 °F	Continuous, 2 Hz	± 0.9 °F	Factory/laboratory calibration
Diff. pressure, LPSS/DOES	0-5 " H <sub>2</sub> O	MKS 223B	0 - 10 " H <sub>2</sub> O	Continuous, 2 Hz	± 0.5 % FS	Factory/laboratory calibration
Ambient temperature	40 - 90 °F	Vaisala HM141	39 - 212 °F	1 per test run	± 0.2% FS	Factory calibration
Ambient pressure	14.7 psia	Viatran 218 absolute pressure transmitter	0-15 psia	1 per test run	± 0.25% FS	Factory/laboratory calibration
Humidity, ambient	40 - 100 %	Vaisala HM141	0-100% RH	1 per test run	± 1.0 % FS	Factory calibration
CO	0 - 300 ppm	Horiba AIA-23ASWOPE-15	0 - 300 ppm 0 - 50 ppm	Continuous, 1 Hz	± 1.0 % of point	Factory, laboratory, field calibration and drift checks
CO <sub>2</sub>	0 - 3.0 %	Horiba AIA-23/OPE115	0 - 3 %	Continuous, 1 Hz	± 1.0 % of point	
NO <sub>x</sub>	0 - 300 ppm	Horiba CLA 220	0 - 300 ppm 0 - 100 ppm	Continuous, 1 Hz	± 1.0 % of point	
THC	0 - 10 ppm	California Analytical 300M-HFID CE	0 - 10 ppm propane	Continuous, 1 Hz	± 1.0 % of point	
PM Mass	n/a	Sartorius MP5V1 microbalance	0 - 2000 mg	2 per filter	± 5.0 ug	Factory / laboratory calibration
Opacity	0 - 40 %	Bosch - RT100A	0 - 100 %	Continuous, 2 Hz	± 1.0 % opacity	Factory / laboratory calibration

**Table 3-2. Calibration Schedule**

System or Parameter	Description/ Procedure	Procedure Reference	Frequency	Allowable Result
Main traction generator voltage	NIST-traceable calibration with as-found data	n/a	within 18 months	All values within $\pm 0.25\%$ of point
Main traction generator current	NIST-traceable calibration with as-found data	n/a	within 18 months	All values within $\pm 1.0\%$ of point
Fuel flow rate	Calibration with #2 diesel fuel against NIST traceable std meter at 7 temperatures (50 - 160 F) x 12 flow rates in range (10% - 100% FS)	Fuelcom internal; meets §92.107	within 12 months	All values within $\pm 0.25\%$ of point
DOES2 main flowrate	Calibration against Gilibrator standard bubble flow meter	§92.117	Before test (check during)	$\pm 1.0\%$ of FS or $\pm 2.0\%$ of point
DOES2 dilution air flowrate				
DOES2 analyzer sample flowrate				
LPSS main flowrate	Calibration against Meriam laminar flow element	§92.1		Within $\pm 1.7\text{ }^\circ\text{C}$
LPSS dilution air flowrate	Calibration against Gold seal mass flow controller			$\pm 0.1\%$ of absolute pressure at point
Temperature LPSS main	Calibration against Omega temperature calibrator	n/a	Before test (check during)	Within $\pm 1.7\text{ }^\circ\text{C}$
Diff. Pressure, LPSS/DOES	Calibration against Druck pressure calibrator			$\pm 1.0\%$ of absolute pressure at point
Temperature, ambient	Calibrated against laboratory standard	§92.105	Every 4 weeks or before analyzer leaves for field	All values within $\pm 2.0\%$ of point or $\pm 1.0\%$ of FS; zero point within $\pm 0.2\%$ of FS
Pressure, ambient (BP)	Calibration against Druck pressure calibrator	n/a		
Humidity, ambient	Calibrated against laboratory standard			
CO	Gas divider calibration with protocol calibration gases at 11 points evenly spaced throughout span (including zero)	§92.120	Monthly	CO <sub>2</sub> rejection ratio > 5000 to 1 water rejection ratio > 1000 to 1 water rejection ratio > 100 to 1 Converter efficiency > 90%
CO <sub>2</sub>		§92.120		
NO <sub>x</sub>		§92.121		
THC		§92.119		
CO	CO <sub>2</sub> interference check	§92.120, §92.109	Daily	Per §92.110e criteria
CO	Water interference check	§92.120, §92.109		
CO <sub>2</sub>	Water interference check	§92.120, §92.109		
NO <sub>x</sub>	Converter efficiency check	§92.120, §92.109		
PM mass	Balance calibrated by control weights	§92.122	6 months	All values within $\pm 1.0\%$ of nominal opacity
smoke	calibration with NIST traceable ND filters at 0, 10, 20, 40% opacity			

**Table 3-3 System QA/QC Checks**

System or Parameter	QA/QC Check	When Performed/ Frequency	Expected or Allowable Result	Response to Check Failure or Out of Control Condition
Main traction generator voltage	Meter reasonableness check vs. digital voltmeter (DVM)	Performed prior to and during test series	V values within $\pm 2.0\%$ of FS	Find cause and correct or repair
Main traction generator power	Reasonableness: voltage and current within manufacturer's specifications	Performed prior to and during test series	Power within 10 % of nominal for notch	Find cause and correct or repair
Test duct cyclonic flow	Method 1 cyclonic flow determination	Prior to first test run	$< 20^\circ$ cyclonic flow	Modify test duct
Exhaust gas flow rate	FTP exhaust gas flowrate comparison with Method 2 pitot traverse	At each notch prior to and immediately following each series of baseline or treated fuel tests	FTP Flowrate agreement within $\pm 10\%$ of pitot traverse result	Find cause and correct or repair
	Exhaust gas delta P monitoring with stationary pitot at representative sampling location	Throughout all test runs	Within $\pm 15\%$ of the mean Method 2 delta P at that traverse point for each notch	
DOES2 leak checks	Tunnel is capped and drawn from by main pump	Performed daily prior to test	$< 1$ lpm	Find leak and repair
DOES2 flowrate check	piston-type calibrator comparison	Performed prior to testing	$\pm 1.0\%$ of FS or $\pm 2.0\%$ of point	Adjust MFC accordingly and re-calibrate
LPSS leak checks	Tunnel is capped and drawn from by sample pump	Performed daily prior to test	$< 1$ lpm	Find leak and repair
LPSS flowrate check	Each flow device is removed from the system and compared to a calibrated laminar flow element	Performed prior to travel	$\pm 1.0\%$ of FS or $\pm 2.0\%$ of point	Adjust accordingly and re-calibrate
Temperature LPSS main	Each temperature probe is removed and calibrated against a temperature calibrator. This is only done in house.	Performed prior to travel	$\pm 1.7^\circ\text{C}$	Replace temperature probe
LPSS / DOES2 moisture condensation	Inspection of filter holders for moisture	Immediately following each test run at each mode	No visible moisture on the internal surface of any fitting, housing, or filter	Void results for that mode, adjust dilution ratio as necessary, and retest that mode
Diff. Pressure, LPSS/DOES	Each differential pressure transmitter is calibrated against a Druck pressure calibrator	Performed prior to travel	0.1 % of absolute pressure at point	Adjust transmitter accordingly and re-calibrate
Tunnel blank	Run simulation test sequence	One blank taken per day	Blank must not exceed 5.0 % of sample weight	If blank exceeds 5% of sample weight, its weight is taken into account in the calculations for the final sample results
Ambient Pollutant Levels	Disconnect from Exhaust probe and run test trace also serves as warm up run.	One sample per test series	Reasonable ambient levels	Background corrections in formulas
Analyzer zero and span drift check	Analyzer is zeroed and spanned before each reading using on site calibration gases	Each test run	Post-test zero or span drift shall not exceed $\pm 2.0\%$ FS	Assess impacts; Correct or void runs

Note that SO<sub>2</sub> and sulfate QA/QC procedures will conform to the ETC methods 6.3/5.0/M and 6.5/1.0/M. Sample handling procedures will conform to ETC method 11.23/1.2/S.

The entries in Tables 3-2 and 3-3 will serve as the data quality indicators (DQI) for this test campaign. Each DQI links with a corresponding measurement or determination which, in turn, contributes to achievement of the overall qualitative and implicit DQOs. For example, the NO<sub>x</sub> converter must show better than 90 percent efficiency for the NO<sub>x</sub> measurements to be valid. A valid NO<sub>x</sub> measurement then contributes to the proper performance of the FTP, which is the test campaign's DQO.

### **3.3. INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE**

GHG Center personnel, the field team leader, or ETC will subject all test equipment to the QC checks discussed earlier. Before tests commence, operators will assemble and test all equipment as anticipated to be used in the field. They will, for example, operate and calibrate all controllers, flow meters, computers, instruments, and other measurement system sub-components per the specified test methods and/or this test plan. Test personnel will repair or replace any faulty sub-components before starting the verification tests. Test personnel will maintain a small amount of consumables and frequently needed spare parts at the test site. The field team leader, project manager, or ETC will handle major sub-component failures on a case-by-case basis such as by renting replacement equipment or buying replacement parts.

### **3.4. INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES**

ETC calibrations will employ NIST-traceable or EPA Protocol 1 gases supplied either by a gas-divider dilution system or directly from cylinders. Per EPA protocol gas specifications, the actual concentration must be within  $\pm 2$  percent of the certified tag value. Gases certified to  $\pm 1.0$  percent will be used for multipoint gas analyzer calibrations in accordance with 40 CFR 92 specifications. Copies of all EPA protocol gas certifications will be available on-site.

The field team leader will provide technical oversight of the ETC field activities. The GHG Center QA manager will review ETC calibration data and QA/QC check results to verify that emissions measurements conform to 40 CFR 92, Subpart B requirements.





## 4.0 DATA ACQUISITION, VALIDATION, AND REPORTING

### 4.1. DATA ACQUISITION AND DOCUMENTATION

Test personnel (responsible parties are noted below in parentheses) will acquire the following types of data and generate the following documentation during the verification:

- fuel consumption and power data (GHG Center)
- fuel emissions data (ETC)
- manually acquired parameters and printed output data from the ETC sampling systems such as sampling and dilution air flow rates, exhaust gas analyzer concentration, ambient pressure, exhaust gas pressure, temperature, and ambient conditions (ETC)
- QA/QC documentation as described in Section 3.0 (ETC, GHG Center)
- field test documentation (GHG Center)
- corrective action and assessment reports (GHG Center)

ETC will submit copies of all test-run printed outputs, calibration forms, analyses, certificates, etc. to the Field Team Leader as each test run is completed. These submittals must be complete prior to the Field Team Leader's departure after the final test run.

ETC will prepare and submit a report in printed and electronic format to the GHG Center Field Team Leader within three weeks of the field activities' completion. The report will describe the test conditions, document all QA/QC procedures, include copies of calibrations, calibration gas, and the verification test results. The report will include a signed certification which attests to ETC's conformance with all QA/QC procedures and the accuracy of the results. ETC will attach all relevant test data as appendices.

The following subsections discuss each of these items and their role in the test campaign. The GHG Center will archive all electronic data, paper files, analyses, and reports at their Research Triangle Park, NC office in accordance with the QMP.

#### 4.1.1. Fuel Consumption and Power Data

The GHG Center Field Team Leader will obtain fuel consumption and power data during the multimode tests. In addition to documenting the data for use in the report, he will supply these data to ETC staff for their use in the following sections.

#### 4.1.2. Emissions Data

ETC will be responsible for all emissions data, associated QA/QC log forms, paper, and electronic files until they are accepted by the Field Team Leader.

ETC will report emission measurements for each test mode to the Field Team Leader as:

- ppmv (percent for CO<sub>2</sub>) of emissions
- g/bhp-h of pollutants
- calculated exhaust flow rate based on carbon balance methods.
- calculated exhaust flow rate based on Method 2 traverses.



#### **4.1.3. Locomotive Documentation**

The Field Team Leader will document the applicable vehicle and engine specifications. Documentation will generally conform to 40 CFR §92.133 and will include information such as:

- locomotive engine family identification
- alternator generator efficiency specifications
- hourmeter readings prior to the baseline and treated fuel test series
- general duty description
- a description of the service during the break-in period

#### **4.1.4. QA/QC Documentation**

Upon completion of the field test activities, ETC will provide copies of calibrations, pre-test checks, system response time, NO<sub>2</sub> converter efficiency, and other QA/QC documents to the Field Team Leader. Calibration records will include information about the instrument being calibrated, raw calibration data, calibration equations, analyzer identifications, calibration dates, calibration standards used and their traceabilities, calibration equipment, and names of participating staff. These records will provide source material for the Verification Report's Data Quality section, and will be available to the QA Manager during audits.

#### **4.1.5. Field Test Documentation**

The Field Team Leader will obtain copies of all manually and digitally logged data. He will take site photographs and maintain a Daily Test Log which will include the dates and times for setup, testing, teardown, and other activities.

The Field Team Leader will record test run information and observations in the Daily Test Log and on the log forms in Appendix C. The Field Team Leader will submit digital and paper data files, ERMD test results, and the Daily Test Log to the Project Manager.

#### **4.1.6. Corrective Action and Assessment Reports**

A corrective action will occur when audits or QA/QC checks produce unsatisfactory results or upon major deviations from this Test Plan. Immediate corrective action will enable quick response to improper procedures, malfunctioning equipment, or suspicious data. The corrective action process involves the field team leader, project manager, and QA Manager. The GHG Center QMP requires that test personnel submit a written corrective action request to document each corrective action.

The field team leader will most frequently identify the need for corrective actions. In such cases, he or she will immediately notify the project manager. The field team leader, project manager, QA Manager and other project personnel, will collaborate to take and document the appropriate actions.

Note that the project manager is responsible for project activities. He is authorized to halt work upon determining that a serious problem exists. The field team leader is responsible for implementing corrective actions identified by the project manager and is authorized to implement any procedures to prevent a problem's recurrence.

#### 4.2. DATA REVIEW, VALIDATION, AND VERIFICATION

The project manager will initiate the data review, validation, and analysis process. At this stage, analysts will classify all collected data as valid, suspect, or invalid. The GHG Center will employ the QA/QC criteria specified in Section 3.0 and the associated tables. Source material for data classification include factory and on-site calibrations, maximum calibration and other errors, audit gas analyses results, and lab repeatability results.

In general, measurements which:

- meet the specified QA/QC checks,
- were collected when an instrument was verified as being properly calibrated,
- are consistent with reasonable expectations (e.g., manufacturers' specifications, professional judgment)

will form the basis for valid data.

The report will incorporate all valid data. Analysts may or may not consider suspect data, or it may receive special treatment as will be specifically indicated. If the DQO cannot be met, the project manager will decide to continue the test, collect additional data, or terminate the test and report the data obtained.

Data review and validation will primarily occur at the following stages:

- on site -- by the field team leader
- before writing the draft report -- by the project manager
- during draft report QA review and audits -- by the GHG Center QA Manager

The field team leader's primary on-site functions will be to monitor ETC activities and acquire fuel consumption and power generation data. He will review, verify, and validate certain data (DOES2 file data, QA/QC check results, etc.) during testing. He will plan to be on-site during all test activities. Log forms in Appendix A provide the detailed information he will gather.

The QA Manager will use this test plan and documented test methods as references with which to review and validate the data and the draft report. He will review and audit the data in accordance with the GHG Center's QMP. For example, the QA Manager will randomly select raw data and independently calculate the verification parameters. The comparison of these calculations with the results presented in the draft report will yield an assessment of the GHG Center's QA/QC procedures.

#### 4.3. DATA QUALITY OBJECTIVES RECONCILIATION

A fundamental component of all verifications is the reconciliation of the collected data with its DQO. In this case, the qualitative DQO assessment consists of evaluation of whether the stated methods were followed and satisfactory results obtained for the QC checks specified in Section 3.0. As discussed in Section 4.2, the field team leader and project manager will initially review the collected data to ensure that they are valid and are consistent with expectations. They will assess the data's accuracy and completeness as they relate to the stated QA/QC goals. If this review of the test data show that QA/QC goals were not met, then immediate corrective action is feasible, and will be considered by the project manager. DQOs will be reconciled after completion of corrective actions. As part of the internal Audit of Data Quality (ADQ), the GHG Center QA Manager will include an assessment of DQO attainment.

#### 4.4. ASSESSMENTS AND RESPONSE ACTIONS

The field team leader, project manager, QA Manager, GHG Center Director, and technical peer-reviewers will assess the project and the data's quality as the test campaign proceeds. The project manager and QA Manager will independently oversee the project and assess its quality through project reviews, inspections if needed, a scheduled PEA, and an ADQ.

##### 4.4.1. Project Reviews

The project manager will be responsible for conducting the first complete project review and assessment. Although all project personnel are involved with ongoing data review, the project manager must ensure that project activities meet measurement and DQO requirements.

The GHG Center Director will perform the second project review. The director is responsible for ensuring that the project's activities adhere to the ETV program requirements and stakeholder expectations. The GHG Center Director will also ensure that the field team leader has the equipment, personnel, and resources to complete the project and to deliver data of known and defensible quality.

The QA Manager will perform the third review. He is responsible for ensuring that the project's management systems function as required by the QMP. The QA Manager is the GHG Center's final reviewer, and he is responsible for assuring the achievement of all QA requirements.

Envirofuels, G&W, and selected GHG Center stakeholders and/or peer reviewers will then review the report. Technically competent persons who are familiar with the project's technical aspects, but not involved with project activities, will function as peer reviewers. The peer reviewers will provide written comments to the project manager.

The GHG Center will submit the draft report to EPA QA personnel, and the Project Manager will address their comments as needed. Following this review, the report will undergo EPA management reviews, including the GHG Center Director, EPA ORD Laboratory Director, and EPA Technical Editor.

##### 4.4.2. Performance Evaluation Audit

The GHG Center will conduct a performance evaluation audit (PEA) of the emission sampling system and analyzers. The PEA will be performed by introducing a sample of audit gas of known concentration to the system. The performance evaluation audit (PEA) gas will consist of a mixture of 0.5 to 4 percent CO<sub>2</sub> in air, but whose exact concentration is blind to the DOES2 system operator. The field team leader will supply the audit gas to the DOES2 sample probe from the cylinder through one leg of a sample line with a tee fitting. The remaining leg will be open to atmosphere through a rotameter. The cylinder regulator will supply gas at the DOES2 system's normal sampling rate (approximately 40 lpm) with enough surplus such that the rotameter shows flow to the atmosphere. The field team leader will submit the data to the QA Manager, who will incorporate them into a PEA report to the GHG center.

##### 4.4.3. Technical Systems Audit

The GHG Center QA Manager will perform a technical systems audit (TSA) to assess the implementation of the Test/QA Plan. This TSA will include an evaluation of the following specific test equipment as well as the implementation of the test plan requirements:

- Power metering equipment and calibrations
- Fuel metering equipment and calibrations
- ETC Instrumental analyzer system, calibrations
- ETC DOES2 and LPSS sampling systems and calibrations

During the TSA, the QA Manager will verify that the equipment, procedures, and calibrations are as specified in this Test Plan. Should the QA Manager note any deficiencies in the implementation of the Test Plan, corrective actions will be immediately implemented by the project manager. The results of the TSA will be documented in a separate TSA report.

#### 4.4.4. Audit of Data Quality

The ADQ is an evaluation of the measurement, processing, and data analysis steps to determine if systematic errors are present. During the ADQ, the QA Manager, or designee, will randomly select approximately 10 percent of the data. He will follow the selected data through analysis and data processing. The ADQ's scope is to verify that the data-handling system functions correctly and to assess the quality of the analysis. The QA Manager will also include an assessment of DQO attainment.

The QA Manager will route the ADQ results to the project manager for review, comments, and possible corrective actions. Project records will document the results. The project manager will take any necessary corrective action needed and will respond by addressing the QA Manager's comments in the report.

#### 4.5. VERIFICATION REPORT AND STATEMENT

The project manager will coordinate report preparation. The report will summarize each verification parameter's results as discussed in Section 2.0 and will contain sufficient raw data to support findings and allow others to assess data trends, completeness, and quality. The report will clearly characterize the verification parameters, their results, and supporting measurements as determined during the test campaign. It will present raw data and/or analyses as tables, charts, or text as is best suited to the data type. The report will also contain a Verification Statement, which is a 4 to 7 page document describing the technology, the test strategy used, and the verification results obtained.

The report will also include the change in SO<sub>2</sub> and sulfate emissions measured at notch 8, but these results will be for information only and will not be considered as verification parameters.

The Project Manager will submit the draft Report and Statement to the QA Manager and Center Director for review. A preliminary outline of the report is as follows:

*Preliminary Outline  
Envirofuels Diesel Fuel Catalyzer Verification Report*

*Verification Statement*

*Section 1.0: Verification Test Design and Description  
Description of the ETV program  
Catalyzer and Test Locomotive Description  
Overview of the Verification Parameters and Evaluation Strategies*

*Section 2.0: Results  
Fuel Consumption Change  
Emissions Performance*

*Section 3.0: Data Quality*

*Section 4.0: Additional Technical and Performance Data (optional) supplied by vendor*

*References:*

*Appendices: Raw Verification and Other Data*

#### **4.6. TRAINING AND QUALIFICATIONS**

This test does not require specific training or certification beyond that required internally by the test participants for their own activities. The GHG Center's field team leader is a licensed professional engineer with approximately 15 years experience in field testing of air emissions from many types of sources. He is also familiar with engine and vehicle testing, operations, maintenance, and repair. He is familiar with the test methods and standard requirements that will be used in the verification test.

The project manager has performed numerous field verifications under the ETV program, and is familiar with EPA and GHG Center QMP requirements. The QA Manager is an independently appointed individual whose responsibility is to ensure the GHG Center's conformance with the EPA approved QMP.

#### **4.7. HEALTH AND SAFETY REQUIREMENTS**

This section applies to GHG Center personnel only. Other organizations involved in the project have their own health and safety plans - specific to their roles in the project.

GHG Center staff will comply with all known host, state/local and Federal regulations relating to safety at the test facility. This includes use of personal protective gear (e.g., safety glasses, hard hats, hearing protection, safety toe shoes) as required by the host and completion of site safety orientation (i.e., site hazard awareness, alarms and signals).

## 5.0 REFERENCES

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**APPENDICES**