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# Test and Quality Assurance Plan

## Taconic Energy, Inc.
## TEA Fuel Additive

Prepared by:

Greenhouse Gas Technology Center

Operated by
**Southern Research Institute**

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

# Greenhouse Gas Technology Center

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

# Test and Quality Assurance Plan
# Taconic Energy, Inc.
# TEA Fuel Additive

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| U.S. EPA Office of Research and Development | ☒ |

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# Taconic Energy, Inc.
# TEA Fuel Additive

This Test and Quality Assurance Plan has been reviewed and approved by the Greenhouse Gas Technology Center Project Manager and Center Director, the U.S. EPA APPCD Project Officer, and the U.S. EPA APPCD Quality Assurance Manager.

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| °C | degrees Centigrade |
| CFR | Code of Federal Regulations |
| CFO | critical flow orifice |
| CFV | critical flow venture |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| COV | coefficient of variation |
| cP | Centipoise |
| CVS | constant volume sampling |
| CWF | carbon weight fraction |
| DQI | data quality indicator |
| DQO | data quality objective |
| EPA-ORD | Environmental Protection Agency Office of Research and Development |
| ETV | Environmental Technology Verification |
| °F | degrees Fahrenheit |
| FTP | Federal Test Procedure |
| g/mi | grams per mile |
| GHG | greenhouse gas |
| HwFET | Highway Fuel Economy Test |
| Hz | Hertz |
| ISO | International Organization for Standardization |
| Kg/L | kilograms per liter |
| Lbf | pounds force |
| LHV | lower (or net) heating value |
| mpg | miles per gallon |
| NIST | National Institute of Standards and Technology |
| NO | Nitric Oxide |
| $NO_2$ | Nitrogen Dioxide |
| $NO_x$ | Blend of NO, $NO_2$, and other oxides of nitrogen |
| NYCC | New York City Cycle |
| QA | quality assurance |
| QA/QC | quality assurance / quality control |
| QMP | Quality Management Plan |
| RH | Relative Humidity |
| SAE | Society of Automotive Engineers |
| SCFM | standard cubic feet per minute |
| SG | specific gravity |
| SOP | standard operating procedure |
| SRI | Southern Research Institute |
| SRM | standard reference material |
| TEA | Taconic Energy Additive |
| THC | total hydrocarbons (as carbon) |
| TRC | Transportation Research Center |
| TQAP | Test and Quality Assurance Plan |
| VETS | Vehicle Emissions Testing System |
| VEZ | vehicle emission zero (gas) |
| U.S. EPA | United States Environmental Protection Agency |

# 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 through performance verification and information dissemination. The ETV program's goal is to further environmental protection by substantially accelerating the acceptance and use of improved and innovative environmental technologies. Congress funds ETV in response to the belief that there are many viable environmental technologies 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 permitters in the United States and abroad will be better equipped to make informed decisions regarding environmental technology purchase and use.

The Greenhouse Gas Technology Center (GHG Center) is one of six ETV organizations. EPA's partner verification organization, Southern Research Institute (SRI), manages the GHG Center. The GHG Center conducts verification testing of promising GHG mitigation and monitoring technologies. It develops verification protocols, conducts field tests, collects and interprets field and other data, obtains independent peer-review input, and reports findings. The GHG Center conducts performance evaluations according to externally reviewed verification Test and Quality Assurance Plans (Test Plan) and established protocols for quality assurance (QA).

Volunteer stakeholder groups guide the GHG Center's verification activities. These stakeholders advise on specific technologies most appropriate for testing, help disseminate results, and review Test Plans and technology Verification Reports. National and international environmental policy, technology, and regulatory experts participate in the GHG Center's Executive Stakeholder Group. The group also includes industry trade organizations, environmental technology finance groups, governmental organizations, and other interested parties. Industry-specific stakeholders peer-review key documents prepared by the GHG Center and provide verification testing strategy guidance in those areas related to their expertise.

One sector of significant interest to GHG Center stakeholders is transportation - particularly technologies that result in fuel economy improvements. Considering the magnitude of annual fuel consumption, even an incremental improvement in fuel efficiency would have a significant benefit on fleet and business economics, foreign oil imports, and nationwide air quality. Small fuel efficiency or emission rate improvements are expected to have a significant beneficial impact on nationwide greenhouse gas emissions.

Taconic Energy (Taconic) has developed the TEA fuel additive for gasoline passenger vehicles and has requested that the GHG Center independently verify its performance. Throughout development of the additive Taconic has been supported by internal funding and funding from the New York State Energy Research & Development Authority. The development process involved a series of controlled in-use tests operating vehicles over a 32 mile cycle on the Taconic Parkway in upstate New York. During these tests, using a variety of vehicles (model years 2008 to 2010), a fuel economy increase of 1-5% was observed (1).

Taconic's TEA additive is a suitable verification candidate considering its potentially significant beneficial environmental quality impacts and ETV stakeholder interest in verified transportation sector emission reduction technologies. The GHG Center plans to verify the fuel economy performance attributable to the TEA additive in a minivan with greater than 10,000 miles and less than 50,000 miles on the odometer. Verification tests will take place at TRC (Transportation Research Center) in East Liberty Ohio, and will consist of repeated fuel economy tests as described below.

This Test Plan specifies the TEA additive verification parameters and the rationale for their selection. It contains the verification approach, data quality objectives (DQOs), and Quality Assurance/Quality Control (QA/QC) procedures, and will guide test implementation, document creation, data analysis, and interpretation.

The technology developers, TRC, and the EPA 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 requirements of the GHG Center's Quality Management Plan (QMP) and thereby satisfy the ETV QMP requirements. The GHG Center will post the final Test Plan on their Internet site at www.sri-rtp.com and the ETV program site at www.epa.gov/etv.

The GHG Center will prepare a Report and Verification Statement (report) upon field test completion. The same organizations listed above will review the report, followed by EPA-ORD technical review. When this review is complete, the GHG Center Director and EPA-ORD Laboratory Director will sign the Verification Statement, and the GHG Center will post the final documents as described above.

The following section (1.2) describes the TEA additive technology and the verification parameters to be quantified. Section 1.0 concludes with a discussion of key organizations participating in this verification, their roles, and the verification test schedule. Section 2.0 describes the technical approach for verifying each parameter, including sampling and analytical procedures. Section 3.0 identifies the data quality assessment criteria for critical measurements, states the accuracy, precision, and completeness goals for each measurement, and outlines QA/QC procedures. Section 4.0 discusses data acquisition, validation, reporting, and auditing procedures.

It should be noted that this test and verification program is not intended to meet the requirements of the U.S EPA's National Clean Diesel Campaign or California Air Resources Board for listing as a verified emissions reduction technology. Also, although similar test procedures are used, the protocol specified is not intended to fully meet all requirements of the U.S. EPA's Motor Vehicle Aftermarket Retrofit Device Evaluation Program. It is solely designed to independently verify the fuel economy impacts of the Taconic Energy additive using a rigorous test procedure, and results do no t constitute certification or approval by any entity.

## 1.2 ADDITIVE DESCRIPTION

The Taconic Energy fuel economy additive designated TEA-037 and intended to be sold under the product name “Mileage Pro Green” has been registered with the EPA in accordance with the regulations found in 40 CFR Part 79 of the Federal Register. Gasoline containing this registered material retains their EPA baseline fuel designation. The active ingredient of this technology serves primarily as a friction modifier ameliorating the in-cylinder friction losses in a gasoline engine. Taconic Energy has completed development and rigorous testing of TEA-037 in a variety of vehicles. The additive typically improves fuel economy in passenger vehicles by 1-5% and provides associated emission reductions.

The additive has been shown (1) to have an almost immediate effect on fuel economy, with no break-in period required. A slight increase in improvement over time is also observed (1). Finally, impacts of the additive are not immediately eliminated when the additive is removed. There is a carryover effect that requires accumulation of significant mileage to return to the original equipment condition.

TEA-037 consists of an active material and a solvent package to improve handling. The physical properties are primarily determined by the solvent package. Below is a summary of the properties of the active material as well as those of TEA-037 (the full additive package being tested).

**Physical Properties of the active material in TEA-037**

- **Appearance (@ 20°C):** Solid
- **Color:** White to slightly yellow.
- **Odor:** Pungent.
- **Density (@ 20°C):** 0.98
- **Flash Point:** >200ºF (87.2°C)
- **Explosive properties:** Material does not have explosive properties
- **Boiling Point:** 423 ºF (217°C)

**Physical Properties of TEA-037**

- **Appearance (@ 20°C):** Clear liquid
- **Color:** White to slightly yellow.
- **Odor:** Pungent.
- **Density (@ 20°C):** > 0.79
- **Flash Point:** 54ºF (12°C)
- **Explosive properties:** Material has explosive properties above 54ºF (12°C)
- **Boiling Point:** 148ºF (65°C)

## 1.3 PERFORMANCE VERIFICATION PARAMETERS

The GHG Center will verify the fuel economy change (Δ or “delta”) due to TEA additive use. Delta will be the primary performance parameter as quantified by the following equation:

$$\Delta = \textit{Mean Fuel Economy}_{Add} - \textit{Mean Fuel Economy}_{Ref\ Fuel} \qquad \text{(Eqn. 1)}$$

Where:
$\Delta$ = fuel economy change, mpg
Mean Fuel Economy $_{Add}$ = average fuel economy with additized fuel, mpg
Mean Fuel Economy $_{Ref.Fuel}$ = average fuel economy with reference fuel, mpg

Once the fuel economy change is established, a percentage fuel savings will be determined relative to the reference fuel. See the following equation.

$$Percentage\ Fuel\ Savings = \frac{\Delta}{Mean\ Fuel\ Economy_{Ref\ Fuel}} \quad \text{(Eqn. 2)}$$

The Taconic additive is considered primarily an immediate effect additive. Based on previous tests by the vendor, the claimed fuel economy improvement is observed almost immediately after additive dosing occurs. The proposed test plan is designed to evaluate the immediate effect of the additive by comparing a set of baseline and candidate test runs occurring over a very short test period. Because of the short duration of the test program (approximately 750 miles accumulation during test), concerns of vehicle performance drift over long operating periods are minimized. A return to baseline conditions after candidate testing (BCCB or BCBC test sequence), which is a common test sequence may not be valuable. To compound the issue, the additive vendor has noted a small fuel economy improvement which results from residual additive or carryover after the additive dosing is stopped. Although not the primary driver for fuel economy changes, this effect does potentially prevent a return to baseline conditions immediately after stopping dosing. As a result, to return to baseline conditions and eliminate the residual impacts, the vendor has indicated that over 1000 miles of operation on baseline fuel would be required. That being said, the verification will consist of a series of fuel economy tests where the general test sequence will be:

- Preparation of vehicle for testing;
  - Option 1: Return vehicle and procure second vehicle;
- Reference fuel economy baseline test 1 (NYCC);
- Reference fuel economy baseline test 2 (HwFET);
- Removal of reference fuel; preparation for additized fuel economy test (HwFET);
- Additized fuel economy test 1 (HwFET);
  - Option 2: Additized fuel economy test 1A (HwFET);
- Additized fuel economy test 2 (NYCC);

Subtraction of the average reference fuel test results from the average additized fuel test results will yield the fuel economy change attributable to additized fuel as shown in Eqn. 1. This will be completed specific to each test condition (HwFET and NYCC)

Each fuel economy test run will conform to the widely accepted Highway Fuel Economy Test (HwFET) and the New York City Cycle Test (NYCC). Code of Federal Regulations (CFR) Title 40 Part 86, “Control of Emissions from New and In-Use Highway Vehicles and Engines” (2), § 86.115, and Part 600, “Fuel Economy of Motor Vehicles” (3), § 600.109, are the HwFET and NYCC source documents.

Test personnel will operate the test vehicle on a chassis dynamometer located within the laboratories of TRC (Transportation Research Center) in East Liberty, OH according to the load profiles specified in the HwFET and NYCC. The GHG Center will use the fuel economy to determine the fuel economy change for each driving schedule.

Verification testing will be completed operating over controlled duty cycles in a laboratory environment on a chassis dynamometer. Emissions and fuel consumption will be measured over the duty cycle gravimetrically and also by monitoring the tailpipe exhaust emissions.

Southern will ensure that the test facility calibrates and maintains all emissions equipment to the guidelines of the CFR and will implement additional procedures to try to reduce test to test variability to obtain an observable fuel economy change at a level of approximately 1%. These additional procedures include but are not limited to, an increased number of test runs at each condition, a more stringent vehicle preconditioning process, and a rigorous QA/QC protocol.

The vehicle tests will also quantify pollutant and greenhouse gas emissions (CO, $CO_2$, $NO_X$, and THC). Although these parameters are not part of the primary verification, they are of interest to the GHG stakeholder community. The marginal cost of their measurement and reporting, in conjunction with the fuel economy test runs, is minimal. The verification Test Report will also include these results.

### 1.4 ORGANIZATION

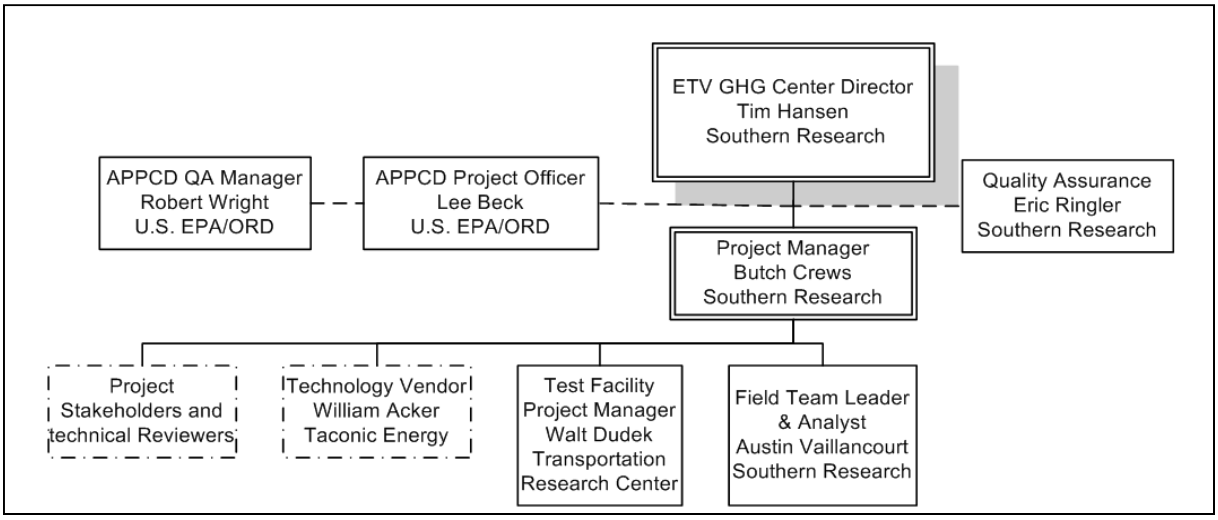


**Figure 1: Project Organization**

Tim Hansen is the ETV GHG Technology Center Director. He will:

- Ensure manpower and material resources are available to complete the demonstration
- Oversee staff and provide management support
- Contribute technical expertise and provide guidance to the development and implementation of the demonstration plan, analysis of the data, and reporting of results
- Interact with stakeholders, vendors and contractors to ensure goals and milestones are met and maintain effective communications between all participants
- Review and submit progress reports and required documents to EPA
- Review the TQAP, Verification Report and Statement, QA Audit Reports, and publication or outreach materials to ensure they conform to ETV guidelines and principles and submit these reports to EPA-ETV

Butch Crews serves as the Project Manager. He will:

- Manage day to day project activities and track the project schedule and budget

- Ensure that manpower and material resources are effectively deployed to achieve project activities
- Assist in the preparation of progress reports
- Ensure that the TQAP, Verification Report and Statement, QA Audit Reports, and publication or outreach materials conform to ETV guidelines and principles and verify that project data and other files are properly collected and stored
- Verify that collected data are regularly reviewed and validated as required and that any problems are identified and effectively addressed
- Ensure that data analyses are properly conducted in a timely manner and that uncertainties in the data are quantified or adequately characterized and fully reported
- Ensure that corrective action is initiated for all issues identified, that problems are resolved and that the impact on data quality is assessed and reported

Austin Vaillancourt serves as the Field Team Leader and Analyst/Engineer. He is responsible for:

- Designing measurements and tests necessary to achieve performance objectives
- Drafting technical and analytical sections of the TQAP
- Reviewing and validating test data and initiating corrective actions if problems are identified
- Conducting data analysis and reporting results
- Quantifying or characterizing uncertainties in the data
- Assessing overall system performance on an ongoing basis and making recommendations for improvements or adjustments
- Providing field support for activities related to all measurements and data collected
- Monitoring and observing the installation and operation of measurement instruments by the Test Facility in accordance with the TQAP;
- Ensuring that QA / QC procedures and documentation requirements are adhered to
- Identifying any problems and initiating corrective actions

The GHG Technology Center QA Manager, Eric Ringler, is administratively independent from the GHG Center Director and the field testing management. Mr. Ringler will:

- Ensure that all measurements and testing are performed in compliance with the requirements of this plan
- Review test results and ensure that applicable internal assessments are conducted
- Assess whether overall data quality is sufficient to satisfy each performance objective
- Conduct or supervise a technical systems audit
- Conduct or supervise an audit of data quality
- Document all audit results and submit these to the Project Manager and Principal Investigator
- Ensure that the impact on data quality of any problems is properly assessed, documented and reported
- Review and approve the demonstration plan and final reports

EPA-ORD will provide oversight and QA support for this verification. The Air Pollution Prevention and Control Division (APPCD) Project Officer, Mr. Lee Beck, is responsible for obtaining final Test Plan and Report approvals. The APPCD QA Manager, Mr. Bob Wright, will review and approve the Test Plan and the Report to ensure they meet the GHG Center QMP requirements and represent sound scientific practices.

### 1.5 SCHEDULE

The tentative schedule of activities for the TEA additive verification testing is outlined in Table 1: Project Task Timelines, below.

**Table 1: Project Task Timelines**

| ID | Task Name | Dates |
|---|---|---|
| 1 | **Verification Strategy Development** | **May 1 - June 15, 2010** |
| 2 | Application Review and Test Strategy | May 1 - June 15, 2010 |
| 3 | Internal Discussion and Modification | May 1 - June 30, 2010 |
| 4 | Contract signature | June 15, 2010 |
| 5 | **Stakeholder Panel Activities** | **June - October 30, 2010** |
| 6 | Addition of New Participants | June 1 - June 30, 2010 |
| 7 | Panel Consultation and Conferences | June 1 - September 30, 2010 |
| 8 | **Verification Plan Development** | **May 1 - October 20, 2010** |
| 9 | Internal Draft Development | June 1 - August 13, 2010 |
| 10 | Taconic Review/Revision | August 13 - August 20, 2010 |
| 11 | Stakeholders Review/Revision | August 20- September 15, 2010 |
| 12 | USEPA QA Review/Revision | September 15 - October 15, 2010 |
| 13 | Final Draft Posted | October 20, 2010 |
| 14 | **Verification Testing & Analysis** | **October 25 - November 29, 2010** |
| 15 | Testing Mobilization | October 21, 2010 |
| 16 | Testing | October 25 - October 29, 2010 |
| 17 | Data Validation & Analysis | October 29 – November 29, 2010 |
| 18 | **Verification Report Development** | **November 1 - December 29, 2010** |
| 19 | Internal Draft Development | November 1 - December 29, 2010 |
| 20 | Preliminary Data Assessment Report (non-verified) | December 19 |
| 21 | Taconic Review/Revision | November 29 - December 4, 2010 |
| 22 | Stakeholders Review/Revision | December 8 - December 19, 2010 |
| 23 | USEPA QA Review/Revision | December 23 - January 13, 2011 |
| 24 | Final Draft Posted | January 12, 2011 |
| 25 | **Outreach*** | **June 1 - May 30, 2011** |
| 26 | Articles, Presentations, Announcements | June 1 - May 30, 2011 |

## 2.0 VERIFICATION APPROACH

### 2.1 INTRODUCTION

As previously discussed, the GHG Center in collaboration with TRC will perform a series of controlled dynamometer tests on a specific test vehicle. For a passenger car with an average fuel efficiency of 16 mpg a total of 6 tests at each condition will be required in order to determine significant differences in fuel efficiency between the additive and reference fuel (See Appendix A).

For a more detailed in depth discussion of these concepts as well as a methodology for selecting the number of tests runs to be conducted, please see Appendix A and Section 3.1.

The following subsections discuss in more detail, the test sequence, laboratory equipment, and the analytical approach.

## 2.2 LABORATORY TEST SEQUENCE OVERVIEW AND STEP-BY-STEP TEST PROCEDURES

Throughout the testing procedure two types of EPA driving schedules will be examined, the Highway Fuel Economy Test Driving Schedule (HwFET) and the New York City Cycle Driving Schedule (NYCC). In the HwFET a total 10.26 miles are traveled over a time period of 765 seconds with an average speed of 48.3 mph, representing highway driving conditions under 60 mph. The HwFET is depicted below in Figure 2: EPA Highway Fuel Economy Test Driving Schedule (2).

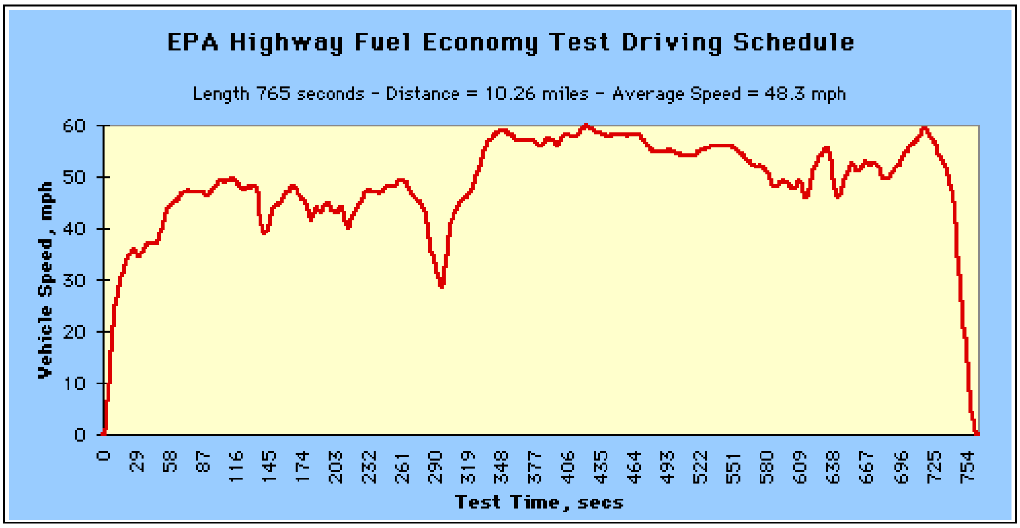


**Figure 2: EPA Highway Fuel Economy Test Driving Schedule**

In the NYCC a total 1.18 miles are traveled over a time period of 598 seconds with an average speed of 7.1 mph, representing low speed stop-and-go traffic conditions. The NYCC is depicted below in Figure 3: EPA New York City Cycle Driving Schedule (2).

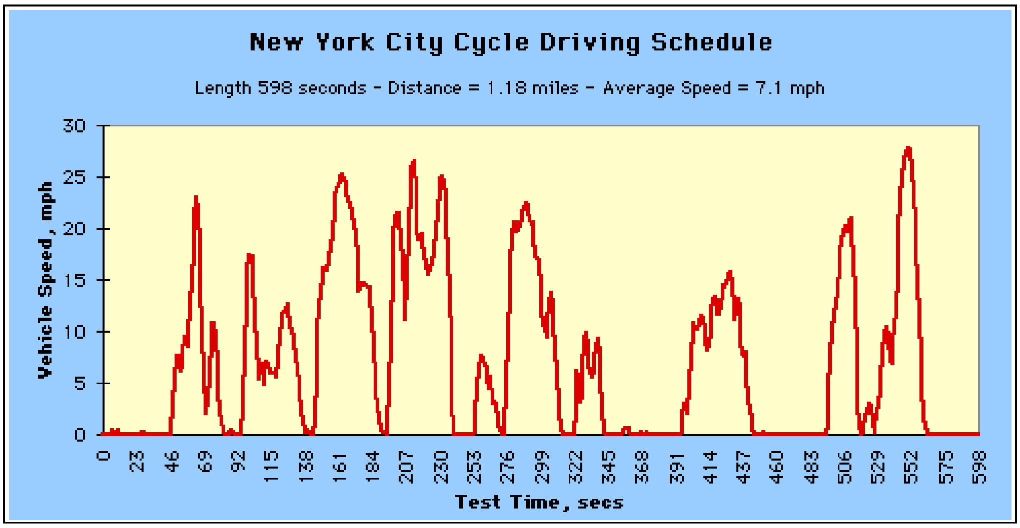


**Figure 3: EPA New York City Cycle Driving Schedule**

See, **Table 2: Procuring, Preparing, and Testing Action Steps** below for a summary of the test procedure steps.

**Table 2: Procuring, Preparing, and Testing Action Steps**

| Steps | Details | Day |
|---|---|---|
| **Procure vehicle from rental agency** | Conduct a chassis dynamometer setup for the vehicle, driver practice. | 1 |
| | Run vehicle at 55 mph for 70 miles | |
| | Precondition with 2 HwFET's and then run 4 HwFET's | |
| | Evaluate data for repeatability. | |
| | ***Option 1: Return vehicle and procure second vehicle** | 1a |
| **Prepare vehicle for Baseline - NYCC** | Perform vehicle alignment and brake rotor run-out | 2 |
| | Setup vehicle for measuring gravimetric fuel consumption. | |
| | Setup vehicle for recording engine oil temperature. | |
| | Fill vehicle with baseline fuel. | |
| | Perform an engine oil double flush. | |
| | Condition vehicle with 5 NYCC's and soak overnight | |
| **Baseline - NYCC** | Run vehicle at 55 mph for 70 miles | 3 |
| | Preondition vehicle with 5 NYCC's. | |
| | Run 8 (3 Sample + 2 Warm-Up + 3 Sample) NYCC's and evaluate data for repeatability | |
| **Prepare vehicle for Baseline - HwFET** | Condition vehicle with 5 HwFET's and soak overnight | |
| **Baseline - HwFET** | Run vehicle at 55 mph for 70 miles | 4 |
| | Precondition vehicle with 5 HwFET's. | |
| | Run 8 (3 Sample + 2 Warm-Up + 3 Sample) HwFET's and evaluate data for repeatability | |
| **Prepare vehicle for Additive - HwFET** | Switch to additized fuel and flush fuel lines. | |
| **Additive - HwFET** | Run vehicle at 55 mph for 70 miles | |
| | Precondition vehicle with 5 HwFET's. | |
| | Run 8 (3 Sample + 2 Warm-Up + 3 Sample) HwFET's and evaluate data for repeatability & comparison | |
| | **Option 2: Additive 2 - HwFET (2nd set of additive tests)** | 4a |
| **Prepare vehicle for Additive - NYCC** | Condition vehicle with 5 NYCC's and soak overnight | |
| **Additive - NYCC** | Run vehicle at 55 mph for 70 miles | 5 |
| | Precondition vehicle with 5 NYCC's. | |
| | Run 8 (3 Sample + 2 Warm-Up + 3 Sample) NYCC's and evaluate data for repeatability & comparison. | |

Testing will begin with procurement of a suitable test vehicle that is representative of the population of interest. Based on Taconic Energy's desired target fleet, the test vehicle will be a high volume selling minivan. Previous experience indicates it is important to obtain a vehicle with greater than 10,000 miles and less than 50,000 miles on the odometer. This ensures that the engine is properly broken in and still within reasonable range of the manufacturer's warrantee. The test vehicle will be rented by TRC from a local rental agency.

The test vehicle choice will be approved by Taconic prior to acquiring the vehicle for testing. Prior to testing, the vehicle will be checked for on board diagnostic (OBD) issues. If any OBD problems are found Southern project management will discuss with Taconic on how to proceed with these issues.

When technicians have set up the chassis dynamometer and mounted the vehicle on it, the driver assigned to this test program will familiarize himself with the vehicle's operation by conducting multiple HwFET and NYCC dynamometer test sequences previously shown in Figure 2 & Figure 3. This "practice" stage will continue until the driver is comfortable with operating the vehicle and can repeatedly follow the dynamometer driving trace according to 40 CFR § 86.115 specifications. The upper limit is 2 mph higher than the highest point on the trace within 1 second of the given time. The lower limit is 2 mph lower than the lowest point on the trace within 1 second of the given time (See Figure 6). The same individual will operate the vehicle during all test runs.

The engine oil will then be conditioned on the dynamometer at a steady speed of 55 mph for 70 miles. To verify that the vehicle will show the repeatability needed for the test program, it will be preconditioned over 2 HwFETs then immediately tested over 4 HwFET cycles using the non-additized fuel. Based on the repeatability criteria (see Section 3.9) the results will be reviewed by Southern and the testing laboratory to decide whether the subject vehicle will be used for the test program. In past experience, it has been observed that some vehicles, for no particular reason, do not produce repeatable data. Therefore, it is important that the vehicle is proven to be repeatable prior to moving on throughout the test program. If this vehicle is not chosen it is understood that additional charges may be incurred for selection and preparation of a second vehicle. When a vehicle is selected for the test program, it will undergo further examination, a front end alignment, and verification of brake rotor run-out. Also, the vehicle's alternator will also be disabled. An external charging system will be set up to power the vehicle's electrical system during tests and fuel lines will be configured to accept fueling from a secondary fuel tank. Prior to testing the vehicle's fuel tank and the external fuel rig (see Section 3.6) must be flushed and filled with the non-additized fuel and an engine oil flush will be performed. The vehicle will then be conditioned with 5 NYCC's and soaked overnight.

After the vehicle has soaked overnight, the engine oil will be conditioned on the dynamometer at a steady speed of 55 mph for 70 miles followed by 5 preconditioning NYCC's. Immediately following the preconditioning cycles the vehicle will be tested and sampled over 6 NYCC's. Because 6 back-to-back iterations are not possible since normal sampling setup is limited to 4 bags maximum, 3 NYCC's can only be performed with the subsequent analyses at a time. After the initial 3 tests are performed the vehicle will undergo 2 warm-up NYCC's and the remaining 3 NYCC's performed in the same manner. After the completion of testing the test results of the 6 NYCC's will be reviewed by Southern for fuel economy repeatability (see Section 3.9). The vehicle will then be conditioned with 5 HwFET cycles and soaked overnight.

After the vehicle has soaked overnight, the engine oil will be conditioned on the dynamometer at a steady state speed of 55 mph for 70 miles followed by 5 HwFET preconditioning cycles. Immediately following the preconditioning cycles the vehicle will be tested and sampled over 6 HwFET cycles. Because 6 back-to-back iterations are not possible since normal sampling setup is limited to 4 bags maximum, 3 HwFET cycles can only be performed with the subsequent analyses at a time. After the initial 3 tests are performed the vehicle will undergo 2 HwFET warm-up cycles and the remaining 3 HwFET test cycles performed in the same manner. After the completion of testing the test results of the 6 HwFET cycles will be reviewed by Southern for fuel economy repeatability (see Section 3.9).

After the completion of the baseline testing the fuel lines will be flushed and the fuel cart will be switched to additized fuel. The engine oil will be conditioned on the dynamometer at a steady state speed of 55 mph for 70 miles followed by 5 HwFET preconditioning cycles. Immediately following the preconditioning cycles the vehicle will be tested and sampled over 6 HwFET cycles. Because 6 back-to-back iterations are not possible since normal sampling setup is limited to 4 bags maximum, 3 HwFET cycles can only be performed with the subsequent analyses at a time. After the initial 3 tests are performed the vehicle will undergo 2 HwFET warm-up cycles and the remaining 3 HwFET test cycles performed in the same manner. After the completion of testing the test results of the 6 HwFET cycles will be reviewed by Southern for fuel economy repeatability and for fuel use reductions (see Section 3.9). If the repeatability criteria are not met there is an option to retest the additized fuel the following day. The testing will be performed in the same manner as the Additive 1 Test. It is assumed that every set of baseline tests up to this point will produce repeatable data. Since another variable (additized fuel) will be introduced for this set of tests, it was decided to allow an option for supplemental testing as a precautionary measure. The vehicle will then be conditioned with 5 NYCC's and soaked overnight.

After the vehicle has soaked overnight, the engine oil will be conditioned on the dynamometer at a steady state speed of 55 mph for 70 miles followed by 5 preconditioning NYCC's. Immediately following the preconditioning cycles the vehicle will be tested and sampled over 6 NYCC's. Because 6 back-to-back iterations are not possible since normal sampling setup is limited to 4 bags maximum, 3 NYCC's can only be performed with the subsequent analyses at a time. After the initial 3 tests are performed the vehicle will undergo 2 warm-up NYCC's and the remaining 3 NYCC's performed in the same manner. After the completion of testing the test results of the 6 NYCC's will be reviewed by Southern for fuel economy repeatability and for fuel use reductions (see Section 3.9).

TRC will receive certification-grade test fuel in 55-gallon drums. Each lot delivered for testing includes a manufacturer supplied certificate of analysis (COA) for fuel properties (See Appendix C). Using the COA, values for the carbon content and net heating value of this fuel will be used in the calculation of fuel economy (See Section 2.4). Fuel additive will be supplied by Taconic to the test facility, including an MSDS, and directions for blending the additive with the test fuel.

Anytime the fuel system must be flushed, technicians will perform this task in accordance with 40 CFR § 86.113-94 specifications. The field team leader will review the test fuel analysis to ensure that the methods and results conform to the test fuel properties specified in Table 3.

**Table 3: Test Fuel Properties**

| QA/QC Check | When Performed / Frequency | Expected or Allowable Result | Response to Check Failure or Out of Control Condition |
|---|---|---|---|
| Octane, Research | Prior to being put into service | 87 minimum | Repeat analyses to confirm results. Reject fuel and use a different batch meeting CFR requirements. |
| Sensitivity (Research Octane minus Motor Octane) | | 7.5 minimum | |
| Lead | | 0.050 g/U.S. gal maximum | |
| Distillation Range<br>Initial Boiling Point<br>10 pct. Point<br>50 pct. Point<br>90 pct. Point<br>End Point | | <br>75 to 95 °F<br>120 to 135 °F<br>200 to 230 °F<br>300 to 325 °F<br>415 °F maximum | |
| Sulfur | | 0.10 wt. percent maximum | |
| Phosphorus | | 0.005 g/US gallon maximum | |
| Reid Vapor Pressure | | 8.0 to 9.2 psi | |
| Hydrocarbon composition<br>Olefins, max. pct<br>Aromatics, max. pct<br>Saturates | | <br>10 % maximum<br>35 % maximum<br>remainder | |

Prior to testing, TRC and the Field Team Leader will verify that all equipment calibrations are current according to the schedules in 40 CFR § 86.116. Table 4 summarizes the relevant calibrations, Title 40 CFR citations, and their frequencies. Section 3.0 discusses calibrations and QA/QC checks in more detail.

| Table 4: Equipment Calibrations Summary | | |
|---|---|---|
| **Equipment Description** | **Title 40 CFR Procedure** | **Calibration Frequency** |
| CO analyzer | § 86.122 | Monthly |
| $CO_2$ analyzer | § 86.124 | Monthly |
| HC analyzer | § 86.121 | Monthly |
| $NO_X$ analyzer | § 86.123 | Monthly |
| Chassis dynamometer | § 86.118 | Daily |
| CVS system | § 86.119 | Weekly |

Following test site calibration verifications and driver practice sessions, the GHG Center will authorize initiation of the fuel economy test protocol.

## 2.3 TEST EQUIPMENT AND INSTRUMENT DESCRIPTION

This verification's test equipment falls into four major groups:

Chassis dynamometer
CVS system
Emissions analyzers

This subsection briefly describes the test equipment, while Sections 3.2 through 3.4 summarize the relevant specifications, calibrations, and QA/QC checks.

### 2.3.1 Emissions Chassis Dynamometer & Test Chamber Descriptions

| Table 5: Emissions Chassis Dynamometer Description | |
|---|---|
| **Manufacturer / Type** | AVL 48" Roll Dual Axle 2WD/4WD Dynamometer |
| **Maximum Inertia Simulation** | 12,000 lbs. in AWD<br>8,000 lbs. in 2WD mod<br>Maximum Vehicle Speed: 125 MPH |
| **Repeat Tolerance of Inertia and Road Simulation** | ≤ 1% |
| **Maximum vehicle wheel width** | 107 in (2725mm) |
| **Maximum vehicle Axle Weight** | 10,000 lbs. per axle |

| Table 6: Emissions Chassis Dynamometer Test Chamber Description | |
|---|---|
| **Maximum Temperature** | 125° |
| **Minimum Temperature (during driving)** | 20°F |
| **Nominal Temperature with Humidity Control** | 75°F |
| **Humidity Control** | 35% to 75% RH ±5%RH |
| **Chamber Ceiling Clearance Height** | 9 Feet |
| **Chamber Depth** | 40 Feet |
| **Chamber Width** | 28 Feet |
| **Vehicle Cooling Fan Max Airspeed at vehicle** | 32mph at 0.5 $m^2$ discharge |

The dynamometer control unit commands a power converter which delivers regulated alternating current to an electric motor connected to the dyno roll. This electric motor exchanges power with the roll (and the vehicle). Based on feedback from roll torque measurement and velocity sensors, the power exchange motor acts as both a power source and absorber to control the forces exerted on the test vehicle's tires. A preprogrammed road load curve, specific to the test vehicle, is the basis for the required force during each second of the driving schedule.

### 2.3.2 Emissions Constant Volume Sampler (CVS) and Analyzer Descriptions

| Table 7: Constant Volume Sampler (CVS) Description | |
|---|---|
| **Manufacturer / Type** | Horiba Analytical |
| **Dilution Tunnel** | 12” Diameter |
| **Cyclonic Separator** | Yes |
| **Nominal Flow Rate** | 200, 350, or 550 SCFM |
| **Calibration Method** | Laminar Flow Element (LFE) |
| **Sample System** | Continuous Dilute or Tedlar Bag Method. |

Figure 4 is an example of a CVS system schematic.

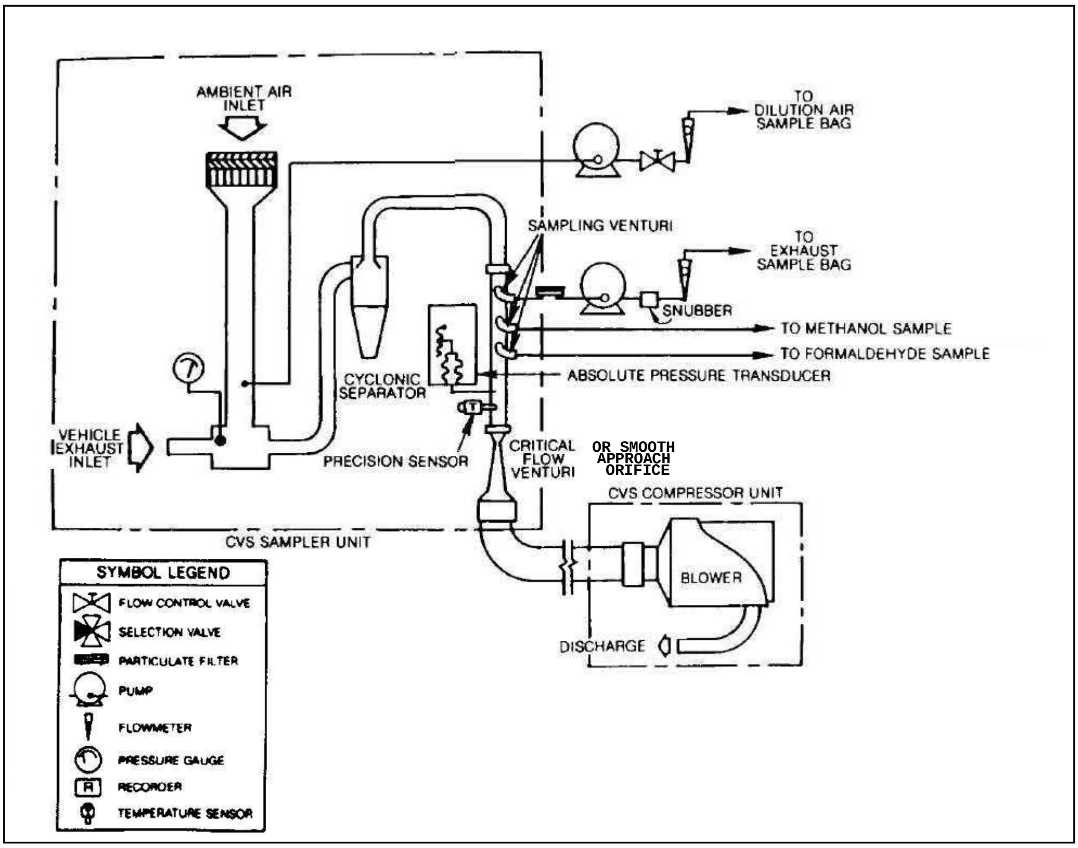


**Figure 4: CVS System Schematic**

Test technicians first connect the vehicle exhaust pipe to the CVS inlet. While the vehicle operates on the dynamometer, an adjustable-speed turbine blower dilutes the exhaust with ambient air. This dilution prevents the exhaust moisture from condensing and provides controllable sampling conditions. A sample pump and a control system transfers diluted exhaust aliquots to several different Tedlar bags during specific phases of each NYCC and HwFET test run. A regulating needle valve maintains a constant sample flow rate into the bags.

| **Table 8: Analyzer Bench Description** | |
|---|---|
| **Manufacturer / Type** | Horiba 9000 Series |
| **AIA-220 Non-Disperse Infrared Analyzer $CO_2$** | 0-2 & 6% |
| **AIA-220 Non-Disperse Infrared Analyzer CO (Low)** | 0-25, 50, 250 ppm |
| **AIA-220 Non-Disperse Infrared Analyzer CO (High)** | 0-500, 1000, 3000 ppm |
| **CLA-220 Chemiluminescent NOx Analyzer** | 0-25, 50, 100 ppm |
| **FIA-220 Flame Ionization Detector (THC)** | 0-10, 30, 300, 1000 ppmC |
| **GFA-220 CH4 Gas Chromatography Analyzer** | 0-5, 10 ppm |

A Horiba analytical bench equipped with a 9000-Series instrumental analyzer will determine CO, $CO_2$, THC, and $NO_X$ concentrations in the dilute exhaust. Sample pumps transfer the dilute exhaust from the sample bags to each analyzer as commanded by the control system.

### 2.4 ANALYTICAL APPROACH AND RELEVANT CALCULATIONS

During each fuel economy test run, the vehicle will operate over specified cycles which represent city and highway driving conditions. The chassis dynamometer will simulate road, aerodynamic, and vehicle inertial loads during acceleration, deceleration, and at varied velocities. As previously discussed two types of EPA driving schedules will be examined, the Highway Fuel Economy Test Driving Schedule (HwFET) and the New York City Cycle Driving Schedule (NYCC). The change in fuel economy attributable to the TEA additive will be examined for both the HwFET and NYCC driving schedules.

The fuel economy determination stems from the carbon in the emissions measured during the two driving cycles correlated with the known amount of carbon in the fuel, based on the COA (See Appendix C), and the distance driven on the dynamometer. This determination method, as specified in 40 CFR § 600.113, is known as the "carbon balance" method. Carbon mass in the fuel per unit volume divided by carbon mass in the emissions yields the fuel economy in mpg. Dimensional analysis is as follows:

$$^{mi}\!/_{gal}\ (or\ mpg) = \frac{g_{carbon,\,fuel}/gal}{g_{carbon,emissions}/mi} \qquad \text{(Eqn. 3)}$$

The calculation relies on measured CO, $CO_2$, and HC mass emission rates (in grams per mile or g/mi), the measured test fuel carbon weight fraction, fuel specific gravity, and net heating value. The COA for fuel properties provides TRC with the necessary information using the following test methods:

Specific gravity -- ASTM D 4052
Carbon weight fraction -- ASTM D 5291
Net heating value (Btu/lb) -- ASTM D 240

From 40 CFR § 600.113, the NYCC or HwFET fuel economy will be:

$$mpg = \frac{(5174 * 10^4) * CWF * SG}{[CWF * HC + (0.429 * CO) + (0.273 * CO_2)] * [0.6 * SG * LHV + 5471]} \qquad \text{(Eqn. 4)}$$

Where:

mpg = Miles per gallon
CWF = Carbon weight fraction in the fuel
SG = Fuel specific gravity
HC = Hydrocarbon emission rate, g/mi
CO = Carbon monoxide emission rate, g/mi
$CO_2$ = Carbon dioxide emission rate, g/mi
LHV = Fuel lower (or net) heating value, Btu/lb

The overall average fuel economy (to be used as input to Equation 1) for either the baseline or additized fuel will be:

$$Mean\ Fuel\ Economy = \sum_{1}^{n} \frac{mpg}{n} \qquad \text{(Eqn. 5)}$$

Where:

Mean Fuel Economy = Average of all test runs (HwFET or NYCC specific), mpg
n = Number of test runs

Referring to Equation 3, the exhaust emission rates in g/mi are the result of the dilute exhaust bag sample instrumental analyses correlated with the CVS dilute exhaust volume, miles traveled on the dynamometer, ambient barometric pressure, ambient pollutant concentrations, etc. 40 CFR § 86.144 contains the detailed calculations. They need not be repeated here. The following figure, however, illustrates how the measurements contribute to the train of calculations. Each of the measured values shown in Figure 5 have associated instrument specifications and QA/QC checks which Section 3.0 discusses in greater detail.

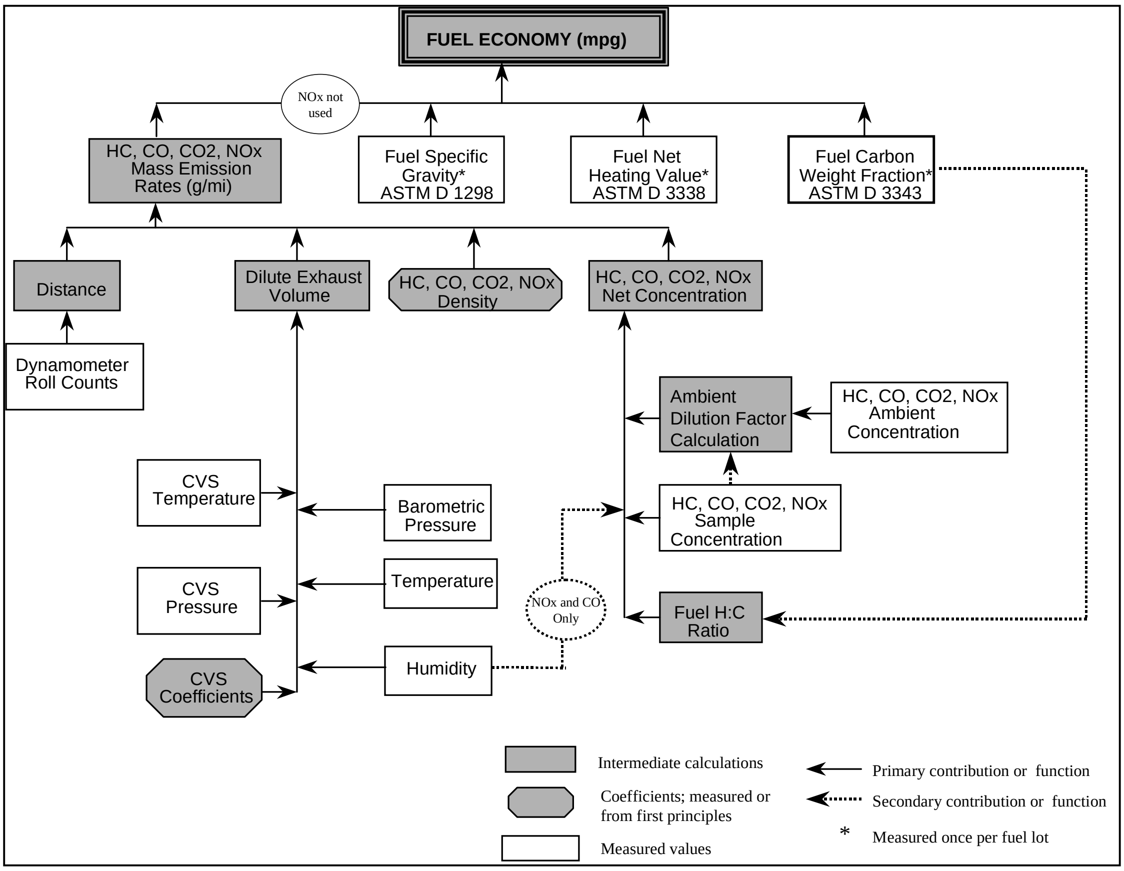


**Figure 5: Fuel Economy Calculation Conceptual Flow**

To interpret Figure 5, consider humidity as an example. Humidity measurements, combined with the CVS operating coefficients, CVS temperature, CVS pressure, ambient temperature, and ambient barometric pressure, contribute to the dilute exhaust sample volume determination. Humidity measurements also contribute to $NO_X$ and CO net concentration correction factors. The dilute exhaust sample volume, in turn, contributes to the mass emission rate calculation for each pollutant and GHG gas. The vehicle emissions test system integrates the measured CO, $CO_2$, and HC mass emission rates into Equation 2 to determine the fuel economy for each dynamometer test phase, and then employs Equation 3 to calculate the test run's composite fuel economy.

TRC will also determine fuel economy by gravimetric method as a cross-check against the carbon balance method. The gravimetric method correlates the weight of gasoline consumed, its specific gravity, and the dynamometer distance traveled to yield mpg. Section 3.6 discusses this QA/QC check in more detail.

### 2.5 POLLUTANT AND GHG EMISSIONS

Section 1.3 indicated that the vehicle tests will also quantify pollutant and greenhouse gas emissions (CO, $CO_2$, $NO_X$, and THC). Although these parameters are not part of the primary verification, they are of interest to the GHG stakeholder community.

Section 2.4 showed the relationship of pollutant and greenhouse gas emissions measurements with the fuel economy determination. Pollutant and GHG emissions in g/mi are an intermediate determination. The instrument description in Section 2.3, therefore, applies to these measurements as well. Although $NO_X$ values do not contribute to the mpg results, the $NO_X$ instrumentation and measurement techniques are integrated with the other analyses so the marginal cost of reporting $NO_X$ emissions is negligible.

Section 3.0 summarizes the relevant instrument specifications and QA/QC checks.

# 3.0 DATA QUALITY

## 3.1 DATA QUALITY OBJECTIVES

The GHG Center selects methodologies and instruments for all verifications to ensure a stated level of data quality in the final results. The GHG Center specifies DQOs for each verification parameter before testing as a statement of data quality.

This verification's DQO will be the fuel economy change's desired confidence level. Appendix A discusses the achievable confidence intervals based on sample data. For this verification, the DQO statement is as follows:

*The data quality objective is to determine a statistically significant fuel economy improvement of 2 percent or better (1 percent is desirable). For the desired target vehicle with a minimum fuel economy of 16 mpg (4), this corresponds to detecting a mean fuel economy improvement of 0.32 mpg with a 95 percent confidence interval of less than +/- 0.32 mpg.*

*Based on previous experience (5), statistically significant mean fuel economy improvements as low as 0.12 mpg should be detectable using the procedures and methods in this plan. That is, fuel economy improvements of less than 1 percent should be detectable for a target vehicle with mean fuel economy of 16 mpg.*

Recalling that the expected fuel economy change will be small this DQO represents the most economically feasible DQO goal for the expected Δ range which corresponds to the lowest number of test runs (6) to meet the 60 percent target. While this DQO is adequate to demonstrate the significance of fuel economy changes expected by Taconic Energy, statistical significance of fuel economy changes less than 0.12 mpg may not be demonstrable under this Test Plan.

The test site, sampling and analytical methodologies, and test procedures will all adhere to Title 40 CFR Part 86, (2) and Part 600 (3) requirements. To achieve the DQO, additional procedures will be followed, including but not limited to, an increased number of test runs at each condition, a more stringent vehicle preconditioning process, and a rigorous QA/QC protocol. If all testing meets the CFR specifications and the mean fuel economy change confidence interval is within the range stated above, then the DQO will be achieved.

Each CFR testing, sampling, and analytical method will produce results that contribute to the overall fuel economy change determination. If each contributing measurement conforms to the applicable method specifications, then the GHG Center will conclude that the data and the resulting confidence interval calculation are valid.

The CFR methods associate specific accuracy determinations, QA/QC, or analytical procedures with each contributing measurement. These quantitative or qualitative protocols will constitute this verification's DQI goals. The GHG Center will compare the achieved DQIs - most often stated in terms of measurement accuracy, precision, repeatability, completeness, etc. - with the DQI goals outlined below. Achievement of the DQI goals will imply that the contributing measurement conforms to the applicable method specifications and its use in calculating the achieved DQO is valid.

TRC Inc. is registered to the ISO 9001 Quality and ISO 14001 Environmental Quality Standards. Within the emissions laboratory, the quality control measures employed on a daily, weekly, and yearly basis closely follow the equipment, calibration, and precision specifications to the governing inherent to the U.S. Environmental Protection Agency and associated ISO and SAE Procedural Specifications.

### 3.2 DYNAMOMETER SPECIFICATIONS, CALIBRATIONS, AND QA/QC CHECKS

Table 9 summarizes the dynamometer's specifications.

**Table 9: Chassis Dynamometer Specifications and DQI Goals**

| Measurement Variable | Operating Range Expected in Field | Instrument Manufacturer / Type | Instrument Range | Measurement Frequency | Data Quality Indicator Goals | |
|---|---|---|---|---|---|---|
| | | | | | Accuracy | How Verified / Determined |
| Speed | 0 to 60 mph | AVL 48" Roll Dual Axle 2WD/4WD Dynamometer | 0 to 125 mph | 10 Hz with reporting at 1 Hz | ± 0.02% FS | Sensors calibrated and verified during original installation. |
| Load | 0 to 500 lbf | | ± 8,000N | | ± 0.1% FS | |

TRC and the manufacturer verified the speed and torque sensor accuracies during initial installation and startup. The QA/QC checks outlined in Table 10 are daily operational checks which confirm that the dynamometer is functioning properly. If the daily QA/QC checks conform to these specifications, then it is reasonable to conclude that the dynamometer measurements achieve the specified accuracy. Re-verification or recalibration of the speed and load sensors occurs only when the daily QA/QC checks suffer consistent and repeatable failures. In that event, recalibrations serve as diagnostic troubleshooting tools. The Field Team Leader will monitor TRC's QA/QC check performance. See Table 20 located in Appendix B for the appropriate log form.

| Table 10: Chassis Dynamometer QA/QC Checks | | | |
|---|---|---|---|
| **QA/QC Check** | **When Performed / Frequency** | **Expected or Allowable Result** | **Response to Check Failure or Out of Control Condition** |
| Road load horsepower calibration | Before initiating test program | Triplicate coastdown checks within ± 2.0% of target curve | Repeat road load horsepower calibration |
| Dyno calibration certificate inspection | Once during the test program | Sensor accuracies conform to Table 9 specifications | Recalibrate or verify dyno sensor performance |
| Parasitic friction verification | Before initiating test program | ± 2.2 lbf from existing settings | Perform new parasitic loss curve |
| Dyno warmup verification | Before initiating test program | Daily vehicle-off coast down at 6,000 lbs within ± 2 lbf | Identify cause of any problem and correct. |
| Roadload and inertia simulation check | 55-45 coast down at end of each FTP test run | ± 0.3 second average over the entire FTP driving sequence | Identify cause of any problem and correct. Repeat test if dynamometer equipment fault. |
| Valid driver's trace | End of each test run | No deviation from tolerances given in 40 CFR § 86.115 | Repeat test |

Prior to each day's testing the operator will verify that the daily dynamometer coast down has been performed. This is an automated check built into the dyno's control computer. It will be completed each day prior to testing.

The road load horsepower calibration will occur before the first test run. This calibration's purpose is to determine dynamometer settings based on actual road load data. TRC will conduct an iterative vehicle coast down process to establish the dyno settings which best simulate the vehicle's road load data. When calibrated, the dyno must impose forces on the vehicle that are within ± 2.0% of the actual road load curve over three separate coastdown runs.

Test operators will perform a dynamometer parasitic friction before initiating the test program. Roll friction measurements at several speeds serve as input to generate a third-order parasitic loss curve. All forces must be within ± 2.2 lbf at every point on the curves.

Following each test run, the dyno control computer will print a test summary sheet. This printout will contain the average positive and negative simulation errors recorded during testing. These errors should be no more than ± 0.3 percent average over the entire driving sequence.

The test summary report also validates the drivers' ability to follow the trace according to CFR provisions. Title 40 CFR § 86.115 specifies the tolerances within which the driver must conform to the required dynamometer speed. In general, for a given time t, the speed must be within 2 mph of that required for t minus one second or t plus one second. Figure 6 illustrates the concept (2). The upper half is typical of dynamometer traces with a steadily increasing or decreasing speed. The lower half is typical for those portions of the trace which include a maximum or minimum value.

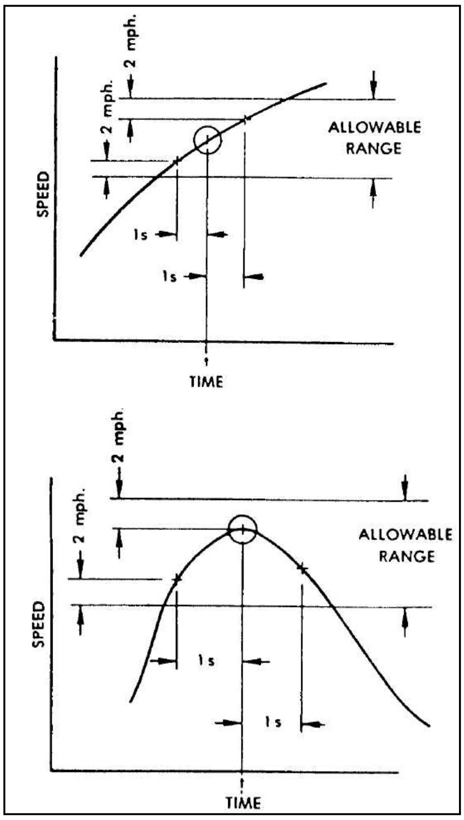


**Figure 6: Driver's Trace Allowable Range**

If the driver's trace exceeds the tolerances, the test summary report will flag the starting time, ending time, and duration. If this occurs, the Field Team Leader will declare the run void and TRC will repeat it.

As an additional QA/QC check, the Field Team Leader will inspect the most recent dynamometer speed and load sensor installation calibrations.

### 3.3 CVS SAMPLING SYSTEM SPECIFICATIONS, CALIBRATIONS, AND QA/QC CHECKS

Table 11 summarizes the Horiba Analytical CVS system specifications.

**Table 11: CVS Specifications and DQI Goals**

| Measurement Variable | Operating Range Expected in Field | Instrument Description | Range | Measurement Frequency | Data Quality Indicator Goals | | |
|---|---|---|---|---|---|---|---|
| | | | | | Accuracy | How Verified / Determined | Completeness |
| Pressure | 950 to 1050 millibar | Horiba Analytical Constant Volume Sampler | 0-150 psia | 1 Hz | ± 0.2 % full scale | Pressure yearly, temperature every 6 months | 100 % |
| Temperature | 20 to 45 °C | | 0-600 °C | | ± 0.05% resistance versus temperature | | |
| Volumetric Flow Rate | 350 to 500 $ft^3$/min | | 200, 350, or 550 scfm | | Calculated | | |

Similar to the chassis dynamometer, TRC and Horiba verified the CVS sensor accuracies during initial installation and startup. The QA/QC checks outlined in Table 12 are daily operational checks which confirm proper CVS function. If the daily QA/QC checks conform to specifications, then it is reasonable to conclude that the CVS measurement variables achieve the specified accuracy. CVS sensor re-verification or recalibration occurs only during troubleshooting of consistent and repeatable failure of the daily QA/QC checks. As an additional QA/QC check, the Field Team Leader will inspect the most recent CVS sensor calibrations.

**Table 12: CVS System QA/QC Checks**

| QA/QC Check | When Performed / Frequency | Expected or Allowable Result | Response to Check Failure or Out of Control Condition |
|---|---|---|---|
| New propane tank composition verification | Prior to placing new propane tank in service | Verify against supplier analysis | Reject new propane tank; obtain and verify another |
| CVS critical flow orifice calibration certificate inspection | Lifetime calibration | NA | NA |
| Propane injection check | Daily | difference between injected and recovered propane ≤ ± 2.0 %. | Identify cause of any problem and correct; if no problems are identified, recalibrate CVS |
| Flow rate verification | Daily | ± 5 cfm of appropriate nominal set point | Verify temperature and pressure measurement |
| Sample bag leak check | Before each test run | Maintain 10 " Hg vacuum for 10 seconds | Identify cause of any problem and correct; replace bag if necessary |

The Field Team Leader will monitor TRC's QA/QC check performance. See Table 21 located in Appendix B for the appropriate log form.

Test operators will compare each new propane cylinder against the provided supplier analysis before releasing the new cylinder for CVS calibrations.

TRC will verify CVS calibration and proper function with a daily injection test that conforms to 40 CFR § 86.119 specifications. Technicians will inject a known quantity of propane into the CVS system over a specified time period. A calibrated THC analyzer will measure the total hydrocarbon concentration, as diluted and injected into a sample bag. The propane mass recovered and reported by the CVS (and Data Acquisition System) must be within ± 2.0 percent of the mass injected. This procedure will also verify the CVS flow rate because it and the sample dilution ratio are part of the propane mass recovery calculation.

TRC will check the sample bags for leaks prior to each test. The test operator will evacuate each bag to a vacuum of at least 10" Hg. Each bag must maintain the achieved vacuum for at least 10 seconds. The technician will discard and replace bags which do not meet the specification.

Prior to starting each test run, the operator will visually confirm the indicated CVS flow rate to ensure that the system is operating at the desired set point.

### 3.4 EMISSIONS ANALYZER SPECIFICATIONS, CALIBRATIONS, AND QA/QC CHECKS

**Table 13: Emissions Analyzer Specifications and DQI Goals**

| Measurement Variable | Expected Operating Range | Instrument Manufacturer / Type | Instrument Range | Measurement Frequency | Data Quality Indicator Goals | | |
|---|---|---|---|---|---|---|---|
| | | | | | Accuracy* | How Verified / Determined | Completeness |
| Low CO | 0 - 200 ppm | Horiba 9000 Series | 0-25, 50, 250 ppm | Monthly | ± 1.0 % FS or ± 2.0 % of the calibration point | Gas divider with protocol calibration gases at 11 points evenly spaced throughout span (including zero) | 100 % |
| CO | 0 - 1000 ppm | | 0-500, 1000, 3000 ppm | | | | |
| $CO_2$ | 0 - 2.0 % (vol) | | 0-2 & 6 % | | | | |
| $NO_X$ | 0 - 100 ppm | | 0-25, 50, 100 ppm | | | | |
| THC | 0 - 250 ppm (carbon) | | 0-10, 30, 300, 1000 ppmC | | | | |

*The most stringent accuracy specification applies for each calibration point.

TRC will verify each analyzer's performance through a series of zero and calibration gas challenges. Each zero and calibration gas must be NIST-traceable. Table 14 summarizes the applicable QA/QC checks. If all calibration gases and QA/QC checks meet their specifications, then TRC and the GHG Center will infer that the emissions analyzers meet Table 13's accuracy specifications.

**Table 14: Emissions Analyzer QA/QC Checks**

| QA/QC Check | When Performed/Frequency | Expected or Allowable Result | Response to Check Failure or Out of Control Condition |
|---|---|---|---|
| NIST-traceable calibration gas verifications | Prior to being put into service | Average of three readings must be within ± 1% of verified NIST SRM concentration | Identify cause of any problem and correct; discard bottle and replace if necessary |
| Zero-gas verification | Prior to being put into service | HC < 1 ppmC<br>CO < 1 ppm<br>$CO_2$ < 400 ppm<br>$NO_x$ < 0.1 ppm<br>$O_2$ between 18 and 21% | Discard bottle and replace |
| Gas divider linearity verification | Every 2 Years | All points within ± 2% of linear fit<br>FS within ± 0.5% of known value | Identify cause of any problem and correct; replace gas divider if necessary |
| Analyzer calibrations | Monthly | All values within ± 2% of point or ± 1% of FS;<br>Zero point within ± 0.2% of FS | Identify cause of any problem and correct; recalibrate analyzer |
| Wet $CO_2$ interference check | Quarterly | CO 0 to 300 ppm, interference ≤ 3 ppm<br><br>CO > 300 ppm, interference ≤ 1% FS | |
| $NO_X$ analyzer interference check | Monthly | $CO_2$ interference ≤ 3 % | |
| $NO_X$ analyzer converter efficiency check | Monthly | $NO_x$ converter efficiency > 95% | |
| Calibration gas certificate inspection | Once during testing | Certificates must be current; concentrations consistent with cylinder tags | Obtain gases with current certificates |
| Bag cart operation | Prior to analyzing each bag | Post-test zero or span drift shall not exceed ±2% full-scale | Zero and span the affected analyzer again and read the BACKGROUND and SAMPLE bags again. |

TRC will verify all new Standard Reference Material (SRM) or other NIST-traceable reference gas concentrations with an emissions analyzer that has been calibrated within the last 30 days. The operator will first zero the analyzer with a certified zero grade gas and then span it with a NIST SRM (or equivalent) three times to ensure stability and minimal analyzer drift.

The operator will then introduce the new reference gas into the analyzer and record the concentration, followed by reintroduction of the NIST SRM to ensure that the analyzer span point does not drift more than ± 0.1 meter divisions. The operator will repeat these last two steps until three consistent values are obtained. The mean of these three determinations must be within one percent of its NIST SRM concentration. TRC will then consider the reference gas as suitable for emissions analyzer calibrations.

TRC will verify each new working zero air (or $N_2$) cylinder's impurities to ensure that it is suitable for emissions analyzer zero checks. Comparisons between a certified Vehicle Emission Zero (VEZ) Gas (or equivalent) and the candidate zero gas will serve this purpose. TRC will employ an emissions cart (or suite of instruments) that has been calibrated within the last 30 days for this procedure. The operator will zero the analyzers with certified VEZ gas and span them with NIST-traceable reference gases to ensure stability and minimal analyzer drift. The operator will then introduce the candidate cylinder's zero gas to the sample train and record the HC, CO, $CO_2$, and $NO_x$ values. The results must fall within the ranges given in Table 14 for the zero gas to be deemed suitable for instrumental analyzer calibrations.

Prior to the monthly exhaust emission analyzer calibrations, TRC will verify the calibration gas divider linearity with an HC analyzer known to have a linear response and an HC span gas. The operator will first zero and then span the instrument such that the span occupies 100 meter or chart divisions. The operator will operate the divider in each of its settings in descending order and compare the observed results with a linear scale. The difference between the commanded and observed concentrations must be within ± 2.0 percent of the commanded concentration. Also, this difference must be less than ± 0.5 percent of the span value.

NIST-traceable calibration gases, in conjunction with a verified gas divider and zero gas, will create individual gas concentrations with which to challenge each instrumental analyzer. The gas divider will generate 11 concentrations in 10 percent increments from 0 to 100 percent of each analyzer's span (the CFR requires 7 points). Analyzer response at each point must be within ± 2.0 percent of the concentration or ± 1.0 percent of span, whichever is more stringent. Zero gas response must be within ± 0.2 percent of span (the CFR requires ± 0.3 percent). If any point is outside these limits, operators will generate a new calibration curve.

The CO analyzer wet $CO_2$ interference check will occur quarterly. This procedure determines the analyzer's response to water vapor and $CO_2$. The operator will turn the analyzer on, allow it to stabilize, and challenge it with 14-percent $CO_2$ in $N_2$ bubbled through water. Analyzer response to the interference gas must be ≤ 3 ppm for spans below 300 ppm; response must be ≤ 1.0 percent of span for higher ranges.

The $NO_X$ analyzer $CO_2$ interference (quench) check will occur in conjunction with the monthly calibration. $CO_2$ can quench the analyzer's NO response. A verified gas divider will dilute NIST-traceable $CO_2$ (concentration of 80 to 100 percent of the maximum range expected during testing) by 50 percent with NIST-traceable NO. The operator will calculate the expected dilute NO concentration and record the analyzer's actual response to this challenge. The difference between the calculated NO and measured NO concentrations must be ≤ 3.0 percent.

$NO_X$ analyzer converter efficiency checks will occur monthly. This procedure will use a $NO_X$ generator which dilutes NIST-traceable NO with air. An ozone generator then converts a quantitative portion of the air's oxygen to $O_3$ which, in turn, converts the same proportion of NO to $NO_2$. This will create a $NO_X$ blend (NO plus $NO_2$) of known concentration. The difference between the analyzer's NO response and $NO_X$ response will be the measure of the $NO_X$ to NO converter efficiency. TRC will require that the $NO_X$ converter efficiency be > 95 percent (the CFR requires 90 percent).

The Field Team Leader will review certificates for all calibration and zero gases used during the test program. All certificates must be current and the cylinder tag concentrations must match those on the applicable certificate. He will also monitor TRC's QA/QC check performance. See Table 22 in Appendix B for the appropriate log form.

### 3.5 TEST FUEL SPECIFICATIONS

The test gasoline must conform to 40 CFR § 86.113 specifications. TRC will receive certification-grade test fuel in 55-gallon drums. Each lot delivered for testing includes a manufacturer supplied certificate of analysis (COA) for fuel properties (See Appendix C). No additional analysis beyond the provided COA will be performed. Table 15 lists the expected or allowable results. TRC will reject fuel lots for testing which do not conform to these requirements. The Field Team Leader will obtain a copy of the manufacturer's certification and compare it with the Table 15 specifications.

The Field Team Leader will review the analysis results during the test program. See Table 23 located in Appendix B for the appropriate log form.

**Table 15: Test Fuel Properties**

| QA/QC Check | When Performed / Frequency | Expected or Allowable Result | Response to Check Failure or Out of Control Condition |
|---|---|---|---|
| Octane, Research | Prior to being put into service | 87 minimum | Repeat analyses to confirm results. Reject fuel and use a different batch meeting CFR requirements. |
| Sensitivity (Research Octane minus Motor Octane) | | 7.5 minimum | |
| Lead | | 0.050 g/U.S. gal maximum | |
| Distillation Range<br>Initial Boiling Point<br>10 pct. Point<br>50 pct. Point<br>90 pct. Point<br>End Point | | <br>75 to 95 °F<br>120 to 135 °F<br>200 to 230 °F<br>300 to 325 °F<br>415 °F maximum | |
| Sulfur | | 0.10 wt. percent maximum | |
| Phosphorus | | 0.005 g/US gallon maximum | |
| Reid Vapor Pressure | | 8.0 to 9.2 psi | |
| Hydrocarbon composition<br>Olefins, max. pct<br>Aromatics, max. pct<br>Saturates | | <br>10 % maximum<br>35 % maximum<br>remainder | |

### 3.6 FUEL ECONOMY GRAVIMETRIC CROSS CHECKS

TRC and the GHG Center will cross check the carbon balance method fuel economy results with separate gravimetric fuel economy determinations. The external fuel rig allows vehicle operation from one of two external tanks (5 gal DOT containers). The fuel rig operates from its own fuel pump, adjustable pressure regulator and power source. Fuel supply can be "hot switched" between tanks via electronic control pad, thus providing the ability to segregate an "On-Test" fuel tank for accurate gravimetric measurements. The fuel rig is designed to work with ISO-B quick disconnects. See Figure 7 for a schematic of the fuel rig.

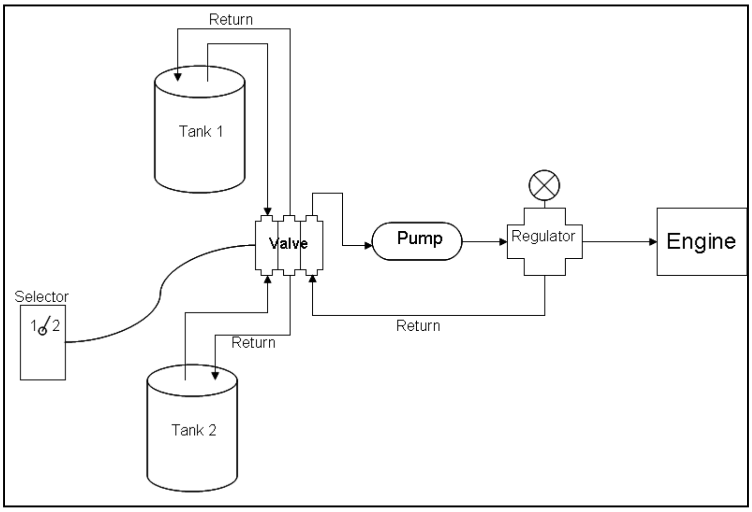


**Figure 7: External Fuel Rig**

After each set of 3 test runs at each testing condition, the Field Team Leader will calculate and compare the carbon balance and gravimetric means and COVs. It is expected that the two methods will have some degree of bias. This difference in measurements, with respect to each test condition, will be monitored. If the bias does not remain consistent throughout testing, the Field Team Leader will declare a testing halt. Testing will not recommence until all possible problems are diagnosed and solved. The Field Team Leader may require that individual test runs be invalidated or repeated

Differences between paired determinations in excess of 0.2 mpg will be investigated for a cause of systematic bias that might compromise the accuracy of the carbon mass balance results. Specific to each test condition, a carbon balance method COV which is more than 0.3 percent greater than that determined via the gravimetric method will indicate that the CFR test method's variability is more than should be reasonably expected. In this case, the Field Team Leader will declare a testing halt. Testing will not recommence until all possible problems are diagnosed and solved. The Field Team Leader may require that individual test runs be invalidated or repeated. Based on previous experience (5), a systematic bias between gravimetric and carbon balance mpg results may occur. If this difference is consistent run to run within each test condition (COV less than 0.3 percent), the difference may be attributed to method bias and the carbon balance results will be reported.

Table 24 in Appendix B contains a log form with which the Field Team Leader will track the carbon balance and gravimetric fuel economy results. They also provide space for COV calculations and comparisons.

## 3.7 INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE

GHG Center personnel, the Field Team Leader, and/or TRC will subject all test equipment to the QC checks discussed earlier in Sections 3.2. 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, and/or TRC management will handle major sub-component failures on a case-by-case basis (e.g., by renting replacement equipment or buying replacement parts).

## 3.8 INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

TRC Calibrations will employ 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 ± 2 percent of the certified tag value. Copies of all EPA protocol gas certifications will be available on-site.

TRC test fuel lots will be analyzed by the supplier and all certificates validating this analysis will be available on-site.

Fuel additive will be supplied by Taconic to the test facility, including an MSDS, and directions for blending the additive with the test fuel.

## 3.9 REPEATABILITY CRITERIA

Given a target vehicle with a minimum fuel economy of 16 mpg (4), detecting a 2 percent change in fuel economy requires that a fuel economy difference of 0.32 mpg (2 percent of 16 mpg) between baseline and candidate tests must be determined with statistical confidence. Using the approach outlined in Appendix A (standard student's 't' statistics for the difference between two means at 95% confidence level) it can be determined that, to meet this criteria, the standard deviation of a set of fuel economy determinations under replicate conditions must be no more than 0.14 mpg. This assumes a sample size of 3. For larger samples, larger standard deviations can be tolerated without loss of statistical significance. For a sample size of 6, the standard deviation must be less than 0.25 mpg to yield acceptable results. Since six test runs at each condition are planned, field acceptance criteria for repeatability of 0.14 mpg sample standard deviation for each set of test runs is conservative.

# 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 economy and emissions data (TRC)
Manually acquired parameters and printed output data from the Data Acquisition System such as dynamometer operating traces, CVS sampling rates, exhaust gas analyzer concentration, ambient pressure, exhaust gas pressure, temperature, and ambient conditions (TRC)
Documents which describe the vehicle, engine, tire pressures, and cold soak temperatures. (TRC)
Documents such as fuel composition and density certifications traceable to the test fuel lot and NIST-traceable calibration gas certificates (TRC)
QA/QC documentation as described in Section 3.0 (TRC, GHG Center)
Field test documentation (GHG Center)
Corrective action and assessment reports (GHG Center)

TRC will submit copies of all test-run printed outputs, calibration forms, fuel 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.

TRC will prepare and submit a letter report in printed and electronic (Microsoft Word) 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, and include copies of calibrations, calibration gas, and the verification test results. The report will include a signed certification which attests to TRC's conformance with all QA/QC procedures and the accuracy of the results. TRC will attach all relevant test data as appendices.

The following subsections discuss each of these items and their role in the test program. 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 Data Acquisition System

The Data Acquisition System will collect dynamometer data continuously. It will compute and log instantaneous or averaged values as needed. During field testing, the Field Team Leader will review and validate the electronically collected data at the end of each test run. After the sixth test run for each fuel condition, he will determine the mean mpg and confidence interval and apply the statistical tests described in Appendix A.

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### 4.1.2 Vehicle and Engine Documentation

TRC will document the applicable vehicle and engine specifications. Documentation will generally conform to 40 CFR §600.005-81 and will include information such as:

Vehicle, engine, drive train, fuel system, emission control system components, exhaust after-treatment device specifications, vehicle weight, and statement of representativeness with respect to the fleet from which the vehicle was selected
Odometer mileage prior to the reference and additized fuel tests.
A description of the mileage accumulation procedures and a detailed mileage accumulation log for the reference and additized fuel which will include the operator(s) name(s), dates, and times
Overnight cold-soak temperature synopsis
Tire pressures prior to each test run

#### 4.1.3 Test Fuel Composition

TRC will receive certification-grade test fuel in 55-gallon drums. Each lot delivered for testing includes a manufacturer supplied certificate of analysis (COA) for fuel properties (See Appendix C). The COA for the test fuel used will be reviewed to ensure it's within compliance with 40 CFR §86.113-04 and §86.113-94.

#### 4.1.4 QA/QC Documentation

Upon completion of the field test activities, TRC will provide copies of calibrations, pre-test checks, system response time, $NO_2$ 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 trace abilities, 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. He will use the Test Sequence Tracking Form located in Appendix B to ensure the sequence of events are occurring as planned.

The Field Team Leader will record test run information and observations in the Daily Test Log and on the log forms in Appendix B. The Field Team Leader will submit digital and paper data files, TRC 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 (as defined by the DQO or DQIs) 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 (CAR) to document each corrective action (See Appendix D).

The Field Team Leader will most frequently identify the need for corrective actions. In such cases, the Field Team Leader will immediately notify the Project Manager. He will then, in collaboration with the QA Manager and other project personnel, take and document the appropriate action.

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 DQIs and 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 Verification 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 DQI goals cannot be met due to excessive data variability, 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 Verification Report -- by the Project Manager
- During draft Verification Report QA review and data audit -- by the GHG Center QA Manager

The Field Team Leader's primary on-site function will be to monitor TRC's activities. He will be able to review, verify, and validate certain data (i.e., Emissions & MPG data, QA/QC check results, technical system audits, etc.) during testing. He will plan to be on-site during all test activities. This will provide the best opportunity to conduct site audits, manage the test program's progress, and perform other data validation and/or review. 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 draft Verification 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 (generated mpg's) and independently calculate the verification parameter. The comparison of these calculations with the results presented in the draft Verification 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. As discussed in Section 4.2, the Field Team Leader and Project Manager will 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 DQI goals. Section 3.0 discussed the verification parameter and each contributing measurement in detail. Section 3.0 also specified the required field procedures for each measurement which would ensure achievement of all DQIs. If the test data show that DQI goals were met, and the resulting fuel economy change confidence interval conforms to the specifications in Section 3.1, then analysts will conclude that DQO was achieved; DQIs and the DQO will therefore be reconciled.

## 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 program proceeds. The Project Manager and QA Manager will independently oversee the project and assess its quality through project reviews, inspections if needed, 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 QA Manager will perform the second review. He is responsible for ensuring that the project's management systems function as required by the QMP. The QA Manager is responsible for verifying that QA requirements are met.

The GHG Center Director will perform the third 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 review all activities to 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 Director is the GHG Center's final reviewer.

TRC 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 Verification Report and Statement will undergo EPA management reviews, including the GHG Center Program Manager, EPA ORD Laboratory Director, and EPA Technical Editor.

### 4.4.2 Technical Systems Audit

The Field Team Leader will perform a technical systems audit (TSA) of the following test components:

Chassis dynamometer equipment, calibrations, and setup
CVS equipment, calibrations
Instrumental analyzer system, calibrations
Fuel delivery system (including volumetric and gravimetric measuring equipment) and calibrations.

During the TSA, the Field Team Leader will verify that the equipment and calibrations are as described in this Test Plan. Note that the "Calibration and QA/QC Audit Checklist" forms in Appendix B will serve for gathering TSA calibration information.

#### 4.4.3 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 follow each data stream leading to a final result or verification parameter from raw data collection through calculation of final results and uncertainties. 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 report 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 Manger's comments in the final verification Report.

### 4.5 VERIFICATION REPORT AND STATEMENT

The Project Manager will coordinate preparation of a draft Verification Report and Statement within 8 weeks of completing the field test, if possible. Preliminary data will be delivered after a short QA/QC period. The Verification 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 program. 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 3 to 4 page summary of the TEA additive technology, the test strategy used, and the verification results obtained.

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***

*Verification Statement*

*Section 1.0:* *Verification Test Design and Description*
*Description of the ETV program*
*TEA Additive and test vehicle description*
*Overview of the verification parameters and evaluation strategies*

*Section 2.0:* *Results*
*Fuel Economy 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

The GHG Center's project manager has performed numerous transportation emissions testing programs for the U.S. EPA and other clients and has previously managed mobile source emission testing laboratories. He is very familiar with the requirements mandated by the EPA and GHG Center QMPs. The QA Manager is an independently appointed individual whose responsibility is to ensure the GHG Center's activities are performed according to the EPA approved QMP. He has been providing QA services for the ETV program for many years and is familiar with the requirements.

The GHG Center's field team leader is a degreed chemical engineer with experience in the design and execution of technology testing and evaluation programs, including direct measurement of flows, temperatures, pressures, and other parameters. He is familiar with the requirements of all of the test methods and standards that will be used in the verification test and quality assurance procedures. His efforts will be supported by the project manager and GHG Center Director, both of whom have extensive experience in vehicle emissions and fuel economy testing, to ensure that he receives adequate training in mobile source emissions testing prior to completing the verification test program.

### 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 site, 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

1. *Application for Testing, Taconic Energy Inc.,* Southern Research Institute, Greenhouse Gas Technology Center. Durham, NC. 2010.

2. *40 CFR Part 86, Control of Emissions from New and In-Use Highway Vehicles and Engines*, Federal Register, U.S. Environmental Protection Agency Code of Federal Regulations. Washington, DC. Feb. 18, 2000.

3. *40 CFR Part 600, Fuel Economy of Motor Vehicles,* Federal Register, U.S. Environmental Protection Agency Code of Federal Regulations. Washington, DC. Aug. 3, 1994.

4. *Fuel Economy Guide*, U.S. Department of Energy, Office of Energy and Renewable Energy, U.S. Environmental Protection Agency, 2010.

5. *Test and Quality Assurance Plan, ConocoPhillips Fuel-Efficient High Performance SAE 75W90 Rear Axle Gear Lubricant,* Southern Research Institute, Greenhouse Gas Technology Center. Durham, NC. March 2003.

6. *Statistics Concepts and Applications*, D.R. Anderson, D.J. Sweeney, and T.A. Williams. West Publishing Company. St. Paul, MN. 1986.

7. *A Modern Approach to Statistics*, R.L. Iman and W.J. Conover. John Wiley & Sons. New York, NY. 1983.

## APPENDIX A

## FUEL ECONOMY CHANGE STATISTICAL SIGNIFICANCE

Fuel economy change (Eqn. 1), will be the difference between the reference fuel and additized fuel mean mpg results. Each mean value is the result of a limited number of test runs. Statistical theory (6, 7) shows that the variability between test runs determines how accurately the mean characterizes all possible fuel economy values within a fuel type (i.e. reference fuel or additized fuel). If each individual test run result is very close to the mean value, or if variability is small, the mean can be sharply characterized. The difference between two such means would also be sharply characterized, and small differences would be statistically significant.

Large run-to-run variabilities can, however, exist. In these cases, the mean "spreads out" over a larger range of possible values. For example, it could be not statistically significant to report a "0.2 mpg" fuel economy change if the reference fuel mpg was 16.12 ± 0.2 mpg while the additized fuel mpg was 16.32 ± 0.2 mpg. The difference between two such means may not be statistically significant if the reference fuel mean falls within the additized fuel confidence interval (stated here as " ± 0.2 mpg").

The GHG Center will therefore evaluate the statistical significance of the difference between the baseline fuel and additized fuel by the following hypothesis test:

$H_o$: $|\mu_1 - \mu_2| = 0$

$H_1$: $|\mu_1 - \mu_2| > 0$

Where:

$H_o$ = Hypothesis that there is no statistically significant difference in fuel economy
$H_1$ = Hypothesis that there is a statistically significant difference in fuel economy
$\mu_1$ = Mean fuel economy for the population of vehicles operated with additized fuel
$\mu_2$ = Mean fuel economy for the population of vehicles operated with reference fuel

Rejection of $H_o$ allows the reader to conclude that the fuel economy difference is significant and that it is useful to calculate the difference's confidence interval. However, if the test is unable to reject $H_o$, the conclusion will be that the additized fuel does not show a significant fuel economy change. Note that this is a "two-tailed" hypothesis test which means that the fuel economy change could be either an increase or a decrease.

Analysts will test the hypothesis by first calculating a test statistic, $t_{test}$, and then comparing it with the Student's T distribution value with ($n_1 + n_2 - 2$) degrees of freedom as follows (6):

$$t_{test} = \frac{(\overline{X}_1 - \overline{X}_2) - (\mu_1 - \mu_2)}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \qquad \text{(Eqn. 6)}$$

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \qquad \text{(Eqn. 7)}$$

Where:

| | | |
|---|---|---|
| $X_1$ | = | Mean fuel economy with additized fuel |
| $X_2$ | = | Mean fuel economy with reference fuel |
| $\mu_1 - \mu_2$ | = | Zero ($H_o$ hypothesizes that there is no difference between the population means) |
| $n_1$ | = | Number of repeated test runs with additized fuel |
| $n_2$ | = | Number of repeated test runs with reference fuel |
| $s_1^2$ | = | Sample standard deviation with additized fuel, squared |
| $s_2^2$ | = | Sample standard deviation with reference fuel, squared |
| $s_p^2$ | = | Pooled standard deviation, squared |

Selected T-distribution values at a 95-percent confidence coefficient appear in the following table (6).

**Table 16: T-distribution Values**

| $n_1$ | $n_2$ | 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 |
| 7 | 7 | 12 | 2.179 |
| 8 | 8 | 14 | 2.145 |
| 9 | 9 | 16 | 2.120 |

The decision rule for the hypothesis test is:

*Do not reject $H_o$ if $t_{test} \leq t_{0.025,DF}$. Conclude that the data cannot show a statistically significant difference. The report will show that there is no statistically significant fuel economy difference between additized fuel vs. the reference fuel.*

*otherwise,*

*Reject $H_o$ if $t_{test} > t_{0.025,DF}$. Conclude that a significant fuel economy difference exists between the additized fuel vs. reference fuel. The report will show the difference and its confidence interval.*

This concept is best understood with the following example. Provided below is fuel economy data from a series of 12 different engine lubrication oil tests. Three test runs were conducted (36 total) and reported mean mpg and sample standard deviation for each lube oil condition. Means were around 16.12 mpg, fuel economy changes were approximately 0.29 mpg (or 1.8 percent of the mean value), and sample standard deviations ranged between 0.02 and 0.18 mpg, or approximately 0.12 to 1.12 percent of the mean values. The sample standard deviation divided by the mean and multiplied by 100 (the 0.12 to 1.12 percent cited here) is also known as the coefficient of variation (COV). It is helpful to consider the COV as a “normalized” standard deviation.

Based on this data set, 99 percent of all sample standard deviations will fall between 0.054 and 0.129 mpg. If we assume that the verification test results happen to show the higher standard deviation, the following table summarizes the t-test results for increasing numbers of test runs.

| **Table 17: Sample Data T-test Results Summary** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. fuel mean fuel economy, mpg** | 16.12 | | | | | | |
| **Additized fuel mean fuel economy, mpg** | 16.41 | | | | | | |
| **Ref. fuel Std. Dev., mpg** | 0.129 | | | | | | |
| **Additized fuel Std. Dev., mpg** | 0.129 | | | | | | |
| **Test runs, each** | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| $s_p^2$ | 0.0166 | | | | | | |
| $t_{0.025, DF}$ | 2.776 | 2.447 | 2.306 | 2.228 | 2.179 | 2.145 | 2.120 |
| $t_{test}$ | 2.753 | 3.179 | 3.554 | 3.894 | 4.206 | 4.496 | 4.769 |
| **Significant difference? (reject $H_o$?)** | No | Yes | Yes | Yes | Yes | Yes | Yes |

Table 17 shows that with three test runs each, the difference between the reference fuel and additized fuel mpg is not statistically significant. The difference between the two is significant for 4 or more test runs each, and the resulting change in fuel economy is meaningful.

The assumption that the reference fuel and additized fuel test run results have similar variability is fundamental to this process. The ratio of the sample variances (sample standard deviation squared) between the two fuels is a measure of this similarity and falls somewhere on an F distribution (6).

Analysts will calculate an $F_{test}$ statistic according to Eqn. 8 and compare the results to the values in Table 18 to determine the degree of similarity between the sample variances according to Eqn. 8.

$$F_{test} = \frac{s^2_{\max}}{s^2_{\min}} \qquad \text{(Eqn. 8)}$$

Where:

$F_{test}$ = F-test statistic
$s^2_{max}$ = Larger of the reference fuel or additized fuel sample standard deviations, squared
$s^2_{min}$ = Smaller of the reference fuel or additized fuel sample standard deviations, squared

The number of test runs for each fuel and the acceptable uncertainty (α; 0.05 for this verification) determine the shape of the F distribution. Table 18 (6) presents selected $F_{0.05}$ distribution values for the expected number of test runs.

| **Table 18: $F_{0.05}$ Distribution** | | | | | |
|---|---|---|---|---|---|
| | **$s^2_{max}$ number of runs** | **4** | **5** | **6** | **7** |
| **$s^2_{min}$ number of runs** | **Degrees of Freedom** | **3** | **4** | **5** | **6** |
| **4** | **3** | 9.28 | 9.12 | 9.01 | 8.94 |
| **5** | **4** | 6.59 | 6.39 | 6.26 | 6.16 |
| **6** | **5** | 5.41 | 5.19 | 5.05 | 4.95 |
| **7** | **6** | 4.76 | 4.53 | 4.39 | 4.28 |

If the F-test statistic is less than the corresponding value in Table 18, then analysts will conclude that the sample variances are substantially the same and the hypothesis test for statistical significance and confidence interval calculations are valid approaches. If the F-test statistic is equal to or greater than the Table 18 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 (6). Satterthwaite's approximation describes how to use a modified Student's T-distribution value in the confidence interval calculation for samples with unequal variances. This is unlikely based on the sample data set considered here. The Verification Report will discuss Satterthwaite's approximation if the actual test data indicate that it must be applied.

## FUEL ECONOMY CHANGE CONFIDENCE INTERVAL

If hypothesis $H_o$ can be rejected, it becomes meaningful to calculate the confidence interval. The test results will provide an estimate of the fuel economy change based on a limited sample. Ninety-five percent of the time, the true fuel economy change will be within a certain range of values centered on the test results. This range is known as the 95-percent confidence interval. A narrow confidence interval implies that the fuel economy change is sharply characterized. Conversely, a large confidence interval implies that the data spread across a wide range and the resulting mean fuel economy change could have limited utility.

The half width (e) of the 95 percent confidence interval is (6):

$$e = t_{.025,DF} \sqrt{s_p^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)} \qquad \text{(Eqn. 9)}$$

TRC and the GHG Center will calculate and state the mean fuel economy change as:

$\Delta$ *Fuel Economy (Equation 1)* $\pm$ *e (Equation 9)*

For example "fuel economy changed by 0.29 ± 0.17 mpg."

## REFINEMENT OF FUEL ECONOMY CHANGE CONFIDENCE INTERVAL AND NUMBER OF REQUIRED TEST RUNS

As the number of test runs increase, the resulting confidence interval decreases. The following table continues the example given in Table 17 by showing the 95-percent confidence intervals in absolute units and as proportions (percent) of the mean fuel economy change.

**Table 19: Sample Data Confidence Intervals**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Mean fuel economy change, Δ, mpg** | 0.29 | | | | | | |
| **Test runs, each** | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **$s_p^2$** | 0.0166 | | | | | | |
| **$t_{0.025,\ DF}$** | 2.776 | 2.447 | 2.306 | 2.228 | 2.179 | 2.145 | 2.120 |
| **95 % confidence interval, mpg** | ± 0.29 | ± 0.22 | ± 0.19 | ± 0.17 | ± 0.15 | ± 0.14 | ± 0.13 |
| **Confidence interval as percent of mean fuel economy change** | ± 100.8 | ± 77.0 | ± 64.9 | ± 57.2 | ± 51.8 | ± 47.7 | ± 44.5 |

This table also provides a different way of understanding why three test runs each do not yield statistically significant results. The confidence interval is slightly larger than the mean fuel economy change itself.

The confidence interval width shrinks quickly between 4 and 7 test runs, but more slowly thereafter. Figure 8 is a graph of the relationship.

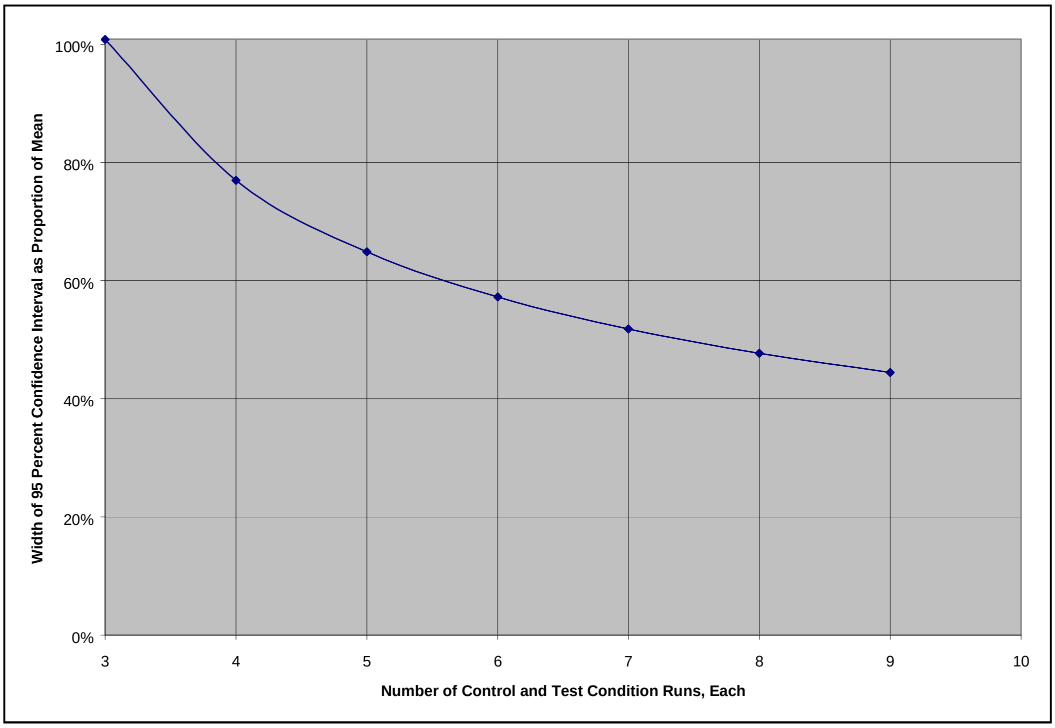


**Figure 8: Confidence Interval Decrease Due to Increased Number of Test Runs**

Based on this analysis, the GHG Center plans to conduct 6 samples at each test point with an option to test additional samples with the additized fuel if the results show a consistent trend in one particular direction.

**APPENDIX B**

## CHASSIS DYNAMOMETER QA/QC CHECKLIST

| Table 20: Chassis Dynamometer QA/QC Checklist | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Southern Research Project Number: | 13134 |
| **QA/QC Check** | **When Performed / Frequency** | **Expected or Allowable Result** | **Initials** | **TRC QA/QC Check Date** | **GHG Center Audit Date** | **OK? (✔)** | **Audit Data Source (personal observation, data/document review, interview, etc.)** |
| Dyno Cal Cert. Review | Once during the test program | Sensor accuracies conform to Table 9 specifications | | | | | |
| Road load horsepower calibration | Before initiating test program | Triplicate coastdown checks within ± 2.0% of target curve | | | | | |
| Parasitic friction verification | Before initiating test program | ± 2.2 lbf from existing settings | | | | | |
| Dyno warmup verification | Before initiating test program | Daily vehicle-off coast down at 6,000 lbs within ± 2 lbf | | | | | |
| Roadload and inertia simulation check | 55-45 coast down at end of each FTP test run | ± 0.3 second average over the entire FTP driving sequence | | | | | |
| Valid driver's trace | End of each test | No deviation from tolerances given in 40 CFR § 86.115 | | | | | |

## CVS SYSTEM QA/QC CHECKLIST

**Table 21: CVS System QA/QC Checklist**

**Southern Research Project Number: 13134**

| QA/QC Check | When Performed / Frequency | Expected or Allowable Result | Initials | TRC QA/QC Check Date | GHG Center Audit Date | OK? (✔) | Audit Data Source (personal observation, data/document review, interview, etc.) |
|---|---|---|---|---|---|---|---|
| Propane critical orifice cal. cert. review | Prior to placing new propane tank in service | Verify against supplier analysis | | | | | |
| CVS cal. cert. inspection | Lifetime calibration | NA | | | | | |
| Propane injection check | Daily | Difference between injected and recovered propane ≤ ± 2.0% | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Flow rate verification | Daily | ± 5 cfm of appropriate nominal set point | | | | | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |
| Sample bag leak check | Before each test run | Maintain 10 " Hg vacuum for 10 seconds | | | | | |
| | | | | | | | |
| | | | | | | | |
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## EMISSIONS ANALYZER QA/QC CHECKLIST

| Table 22: Emissions Analyzer QA/QC Checks | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Southern Research Project Number:** | | | | | | | | **13134** |
| **QA/QC Check** | **When Performed / Frequency** | **Expected or Allowable Result** | | **Initials** | **TRC QA/QC check Date** | **GHG Center Audit Date** | **OK? (✓)** | **Audit Data Source (personal observation, data/document review, interview, etc.)** |
| NIST-traceable calibration gas verifications | Prior to being put into service | Average of three readings must be within ± 1% of verified NIST SRM concentration | CO | | | | | |
| | | | $CO_2$ | | | | | |
| | | | $NO_X$ | | | | | |
| | | | THC | | | | | |
| Zero gas verification | Prior to being put into service | HC < 1 ppmC<br>CO < 1 ppm<br>$CO_2$ < 400 ppm<br>$NO_x$ < 0.1 ppm<br>$O_2$ between 18 and 21% | | | | | | |
| Gas divider linearity verification | Every 2 years | All points within ± 2% of linear fit<br>FS within ± 0.5% of known value | | | | | | |
| CO, $CO_2$, $NO_X$, THC Analyzer calibrations | Monthly | All values within ± 2 % of point or ± 1% of FS; Zero point within ± 0.2 % of FS | CO | | | | | |
| | | | $CO_2$ | | | | | |
| | | | $NO_X$ | | | | | |
| | | | THC | | | | | |
| Wet CO2 interference check | Quarterly | CO 0 to 300 ppm, interference ≤ 3 ppm<br><br>CO > 300 ppm, interference ≤ 1% FS | | | | | | |
| $NO_X$ analyzer interference check | Monthly | $CO_2$ interference ≤ 3 % | | | | | | |
| $NO_X$ analyzer converter efficiency check | Monthly | $NO_x$ converter efficiency > 95% | | | | | | |
| Calibration gas certificate inspection | Once during testing | Certs. must be current; concentrations consistent with cylinder tags | | | | | | |
| Bag Cart Operation | Prior to analyzing each bag | Post-test zero or span drift shall not exceed ± 2.0% full-scale | | | | | | |
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**TEST FUEL ANALYSIS REVIEW**

Obtain a copy of the test fuel lot analysis.
Review all analysis results and test method documentation.
Test gasoline properties and test methods must conform to the specifications given in the following table.

Audit Date: _____________ Signature: ________________________________________

Fuel Lot ID: __________________ Date Received: ___________ Date Analyzed: ______________

| **Table 23: Test Fuel Specifications** | | | |
|---|---|---|---|
| **Southern Research Project Number:** | | | **13134** |
| **Description** | **Spec. Value** | **Analysis Value** | **OK? (✔)** |
| Research Octane* | 87 Octane minimum | | |
| Sensitivity (Research Octane minus Motor Octane) | 7.5 Octane minimum | | |
| Organic Lead | 0.05 g/gal, maximum | | |
| Distillation Range:<br>IBP<br>10 % point<br>50 % point<br>90 % point<br>Endpoint | <br>75 - 95 $^{o}$F<br>120 - 135 $^{o}$F<br>200 - 230 $^{o}$F<br>300 - 325 $^{o}$F<br>415 $^{o}$F max. | | |
| Sulfur | 0.10 wt % maximum | | |
| Phosphorous | 0.005 g/gal, maximum | | |
| Reid Vapor Pressure | 8.0 - 9.2 psia | | |
| Hydrocarbons:<br>Olefins<br>Aromatics<br>Saturates | <br>10 % max.<br>35 % max.<br>Balance | | |
| Specific Gravity | Approx. 6.1 lb/gal | | |
| *Reference value only | | | |

Notes: ______________________________________________________________________________

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## CARBON BALANCE AND GRAVIMETRIC CROSS CHECKS

Table 24 is an exported table from an excel spreadsheet where this information will be entered as it is generated. See below and Appendix A for the appropriate equations related to the following table.

| Table 24: Carbon Balance and Gravimetric Cross Checks | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Southern Research Project Number: | | | | | | | | 13134 | |
| Run | Test | Date | Start Time | End Time | Fuel Container Weight (lbs) | | MPG (Carbon Balance) | MPG (Gravimetric) | MPG Difference |
| | | | | | Start | End | | | |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| | | | | | Average | | | | |
| | | | | | Standard Deviation | | | | |
| | | | | | COV | | | | |
| | | | | | | | | | |
| | | | | | Specific Gravity of Fuel (lbs/gal): | | | | |
| | | | | | Average Difference in MPG | | | | |
| | | | | | Difference in COV's | | | | |

$$COV = \frac{Standard\ Deviation}{Average}$$

**TEST SEQUENCE TRACKING FORM**

| Test Sequence Tracking Form | | | |
|---|---|---|---|
| | | **Southern Research Project Number:** | **13134** |
| **STEP** | **DATE & TIME** | **INITIALS** | **DESCRIPTION** |
| 1. | | | ☐ Conduct a chassis dynamometer setup for the vehicle, driver practice. |
| 2. | | | ☐ Run vehicle at 55 mph for 70 miles. |
| 3. | | | ☐ Precondition with 2 HwFET's and then run 4 HwFET's |
| 4. | | | ☐ Evaluate data for repeatabliity |
| 5. | | | ☐ ****Option 1:** If data is not repeatable return vehicle and procure second vehicle. If data is repeatable, proceed to step 8. |
| 6. | | | ☐ Conduct a chassis dynamometer setup for 2nd vehicle. |
| 7. | | | ☐ Run vehicle at 55 mph for 70 miles. |
| 8. | | | ☐ Precondition vehicle with 2 HwFET's and then run 4 HwFET's |
| 9. | | | ☐ Evaluate data for repeatability. |
| 10. | | | ☐ Perform vehicle alignment and brake rotor run-out. |
| 11. | | | ☐ Setup vehicle for measuring gravimetric fuel consumption. |
| 12. | | | ☐ Setup vehicle for recording engine oil temperature. |
| 13. | | | ☐ Fill vehicle with baseline fuel. |
| 14. | | | ☐ Perform an engine oil double flush. |
| 15. | | | ☐ Condition vehicle with 5 NYCC's and soak overnight. |
| 16. | | | ☐ Run vehicle at 55 mph for 70 miles. |
| 17. | | | ☐ Precondition vehicle with 5 NYCC's |
| 18. | | | ☐ Run 8 (3 Sample + 2 Warm-Up + 3 Sample) NYCC's and evaluate data for repeatability. |
| 19. | | | ☐ Condition vehicle with 5 HwFET's and soak overnight. |
| 20. | | | ☐ Run vehicle at 55 mph for 70 miles. |
| 21. | | | ☐ Precondition vehicle with 5 HwFET's. |
| 22. | | | ☐ Run 8 (3 Sample + 2 Warm-Up + 3 Sample) HwFET's and evaluate data for repeatability |
| 23. | | | ☐ Switch to additized fuel and flush fuel lines. |
| 24. | | | ☐ Run vehicle at 55 mph for 70 miles. |
| 25. | | | ☐ Precondition vehicle with 5 HwFET's. |
| 26. | | | ☐ Run 8 (3 Sample + 2 Warm-Up + 3 Sample) HwFET's and evaluate data for repeatability & comparison. |
| 27. | | | ☐ ****Option 2:** Additive 2 - HwFET (2nd set of additive tests) |
| 28. | | | ☐ Condition vehicle with 5 NYCC's and soak overnight |
| 29. | | | ☐ Run vehicle at 55 mph for 70 miles |
| 30. | | | ☐ Precondition vehicle with 5 NYCC's. |
| 31. | | | ☐ Run 8 (3 Sample + 2 Warm-Up + 3 Sample) NYCC's and evaluate data for repeatability & comparison. |

# APPENDIX C

## CERTIFICATE OF ANALYSIS FOR FUEL PROPERTIES

Chevron Phillips Chemical Company LP

CoA Date: 07/08/2009
Repeat printout

### Certificate of Analysis

**Shipped To:** TRANSPORTATION RESEARCH CENTER INC
10820 STATE RTE 347 BLDG #
EAST LIBERTY OH 43319-0367
USA

**Recipient:**
**Fax:**

**PO #:** 059214
**CPC Delivery #:** 87874091
**Ship Date:** 06/18/2009
**Package/Mode:** 54 GAL DRUM
**Quantity:** 22 EA
**Certification Date:** 06/11/2009
**Transportation ID:** 1350009252
**Shelf Life:** Undetermined

Product: UTG 96, 54 GAL DRUM

Material Code:1021669

Lot Number: 09EPU9601

| Property | Test Method | Specification | Value | Unit |
|---|---|---|---|---|
| Specific Gravity 60/60 | ASTM D-4052 | 0.7343 - 0.7440 | 0.7439 | |
| API Gravity | ASTM D-4052 | 58.7 - 61.2 | 58.7 | |
| Corrosion (3 hrs @ 50C) | ASTM D-130 | | 1A | |
| Existent Gums, Washed | ASTM D-381 | <= 5.0 | 4.6 | mg/Hml |
| Sulfur | ASTM D-5453 | 15.0 - 40.0 | 25.2 | ppm |
| Vapor Pressure | ASTM D-5191 | 8.7 - 9.2 | 9.0 | PSI |
| Lead | ICP/OES | <= 0.0050 | < 0.0009 | g/gal |
| Phosphorus | ICP/OES | <= 0.005 | < 0.001 | g/gal |
| Hydrogen | ASTM D-5291 | | 12.8 | WT% |
| Carbon | ASTM D-5291 | | 87.2 | WT% |
| Carbon Density | Calculated | 2,401 - 2,441 | 2438 | g/gal |
| Oxidation Stability | ASTM D-525 | >= 1,440 | 1440 | min |
| Net Heat of Combustion | ASTM D-240 | 18,283 - 18,683 | 18581 | BTU/LB |
| Sensitivity | Calculated | >= 7.5 | 8.5 | |
| Distillation - IBP | ASTM D-86 | 75 - 95 | 86 | FAH |
| Distillation - 5% | ASTM D-86 | | 110 | FAH |
| Distillation - 10% | ASTM D-86 | 120 - 135 | 120 | FAH |
| Distillation - 20% | ASTM D-86 | | 138 | FAH |
| Distillation - 30% | ASTM D-86 | | 162 | FAH |
| Distillation - 40% | ASTM D-86 | | 194 | FAH |
| Distillation - 50% | ASTM D-86 | 200 - 230 | 220 | FAH |
| Distillation - 60% | ASTM D-86 | | 233 | FAH |
| Distillation - 70% | ASTM D-86 | | 246 | FAH |
| Distillation - 80% | ASTM D-86 | | 267 | FAH |
| Distillation - 90% | ASTM D-86 | 300 - 325 | 313 | FAH |
| Distillation - 95% | ASTM D-86 | | 345 | FAH |

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CoA Date: 07/08/2009
CPC Delivery #: 87674091
PO #: 059214

# Certificate of Analysis

Product: UTG 96, 54 GAL DRUM

Material Code:1021669

| | | | | |
|---|---|---|---|---|
| Distillation - EP | ASTM D-86 | <= 415 | 388 | FAH |
| Distillation - Loss | ASTM D-86 | | 0.8 | ML |
| Distillation - Residue | ASTM D-86 | | 1.0 | ML |
| Aromatics | ASTM D-1319 | <= 35.0 | 31.9 | LV% |
| Olefins | ASTM D-1319 | <= 10.0 | 1.6 | LV% |
| Saturates | ASTM D-1319 | | 66.5 | LV% |
| Research Octane Number | ASTM D-2699 | >= 96.0 | 96.2 | |
| Motor Octane Number | ASTM D-2700 | | 87.7 | |
| Anti-Knock Index | Calculated | | 92.0 | |
| Oxygenates | Chromatography | <= 0.0 | 0.0 | LV% |
| Benzene | Chromatography | | 0.73 | LV% |

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP. However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.

K E Inkrott

Ken Inkrott
Quality, Applications and Technical Service Manager

For CoA questions contact Kim Lindley at 806-275-5577

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**APPENDIX D**

**CORRECTIVE ACTION REPORT**

Verification Title:________________________________________

Verification Description:____________________________________

Description of Problem:_____________________________________

Originator:____________________ Date:__________

Investigation and Results:_________________________________

Investigator:____________________ Date:__________

Corrective Action Taken:___________________________________

Originator:____________________ Date:__________
Approver:____________________ Date:__________

Carbon copy: GHG Center Project Manager, GHG Center Director, SRI QA Manager, APPCD Project Officer