

US EPA ARCHIVE DOCUMENT

**TEST/QA PLAN FOR THE VERIFICATION TESTING OF
SELECTIVE CATALYTIC REDUCTION CONTROL TECHNOLOGIES FOR
HIGHWAY, NONROAD, AND STATIONARY USE DIESEL ENGINES**

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List of Acronyms and Abbreviations

ADQ	audit of data quality
AE	Automotive Engineering
APCT Center	Air Pollution Control Technology Center
CFO	critical flow orifice
CFR	Code of Federal Regulations
CI	compression-ignition
CO	carbon monoxide
CO ₂	carbon dioxide
CVS	constant volume sampler
DQIG(s)	data quality indicator goal(s)
DQO(s)	data quality objective(s)
EEVRD	Engine, Emissions and Vehicle Research Division
EPA	U.S. Environmental Protection Agency
EPA-ORD	U.S. Environmental Protection Agency's Office of Research and Development
ER&DD	Emissions Research and Development Department
ETIS	Emissions Test Information System
ETV	Environmental Technology Verification
FRIS	Filter Room Interface Software
FTIR	Fourier Transform Infrared
FTP(s)	Federal Test Procedure(s)
GVP	generic verification protocol
HC	hydrocarbons
HD	heavy-duty
HFID	heated flame ionization detector
Hz	hertz
in. H ₂ O	inches of water
kPa	kilopascals
lb-ft	pound-feet
mm Hg	millimeters of mercury
MSDS	material safety data sheet
N ₂	nitrogen
NDIR	non-dispersive infrared
NH ₃	ammonia
NIST	National Institute of Standards and Technology
NO	nitric oxide
NO ₂	nitrogen dioxide
NO _x	nitrogen oxides
O ₂	oxygen
PDP	positive displacement pump
PEA(s)	performance evaluation audit(s)
PM	particulate matter
ppm	parts per million
ppmC	parts per million carbon

PTFE	polytetrafluoroethylene
QA	quality assurance
QC	quality control
QM	quality manager
QMP	quality management plan
QSA	quality system audit
RTI	Research Triangle Institute
SCR	selective catalytic reduction
SET	supplemental emissions test
SOP(s)	standard operating procedure(s)
SOW(s)	statement(s) of work
SwRI	Southwest Research Institute
TIP(s)	test and inspection procedure(s)
TO	test organization
TQAP	test/quality assurance plan
TSA(s)	technical systems audit(s)VR verification report
µg	microgram

A3: Distribution List

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BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) directs the Environmental Technology Verification (ETV) program to verify performance of innovative technologies that have the potential to improve protection of the environment. The ETV program's goal is to supplement environmental protection by accelerating the entrance of new technologies into marketplaces. ETV is a voluntary program that makes objective performance information available to support assessment by potential users. From performance data generated under ETV, technology buyers, financiers, and permittees in the U.S. and abroad will be better informed to make decisions regarding environmental technology purchases. The ETV verification provides actual performance of a technology under specific, pre-determined criteria or protocols and a strong quality management system. ETV does not endorse, certify, or approve technologies.

The Air Pollution Control Technology Center (APCT Center) is one of six ETV centers. EPA's partner verification organization, RTI International (RTI), manages the APCT Center. The APCT Center conducts verification testing of potential air pollution control technologies. The APCT Center conducts performance evaluations according to externally reviewed verification Test/Quality Assurance Plans (TQAP), technology specific Test Plan addenda or Statements of Work (SOWs), and established protocols for quality assurance.

Emissions testing for air pollution control technologies to be used on mobile sources (on-highway or nonroad vehicles with diesel engines) and some stationary source diesel engines is conducted at Southwest Research Institute (SwRI), an independent, not-for-profit, applied and developmental research organization. Southwest Research Institute's Emissions Research and Development Department (ER&DD) has had significant experience with automotive emissions testing. ER&DD has worked with the EPA to develop automotive emissions sampling and analytical techniques, and to develop test procedures used for regulatory purposes. ER&DD maintains ISO 9001: 2008 certification and ISO 17025: 2005 accreditation. The APCT Center has selected SwRI as a test organization to perform ETV testing for mobile sources.

GROUP A: PROJECT MANAGEMENT

A4: Project/Task Organization

The EPA has overall responsibility for the ETV program for the APCT Center. The APCT Center is managed by RTI International. SwRI is a test organization performing ETV for mobile source technologies for the APCT Center.

Management and testing of selective catalytic reduction (SCR) control technologies for mobile sources within the APCT Center are performed in accordance with procedures and protocols defined by a series of quality management documents. The primary source for the APCT Center quality system is EPA's Policy and Program Requirements for the Mandatory Agency-wide Quality System, EPA Order 5360.1 A2 (May 2000). The quality system is in compliance with the following:

- *EPA Requirements for Quality Management Plans (EPA QA/R-2)*
- *EPA's Environmental Technology Verification Program, Quality Management Plan (EPA ETV QMP) for the overall ETV program*
- *APCT Center's Verification Testing of Air Pollution Control Technology - Quality Management Plan (APCT Center QMP)*
- *APCT Center's Generic Verification Protocol (GVP) for Determination of Emissions Reductions from Selective Catalytic Reduction Control Technologies for Highway, Nonroad, and Stationary Use Diesel Engines*
- *SwRI's Automotive Engineering (AE) Standard Operating Procedures (SOPs)*
- *SwRI's EEVRD test and inspection procedures (TIPs)*
- *This test/quality assurance plan (TQAP).*

Appendix A lists full citations for these documents. This TQAP is in conformance with *EPA Requirements for Quality Assurance Project Plans*, (EPA QA/R-5), *EPA Guidance for Quality Assurance Project Plans*, (EPA QA/G-5), and the documents listed above.

As an APCT Center qualified test organization (TO), SwRI will verify the emissions reductions of SCR systems intended for on-highway, nonroad, and stationary diesel engines. SwRI will perform the testing, evaluate the data, and submit a report documenting the results to RTI. RTI will use the data to prepare the verification reports and verification statements. The various QA and management responsibilities are divided among SwRI, RTI, and EPA key personnel as defined below. The lines of authority among key personnel for this project are shown on the project organization chart in Figure 1.

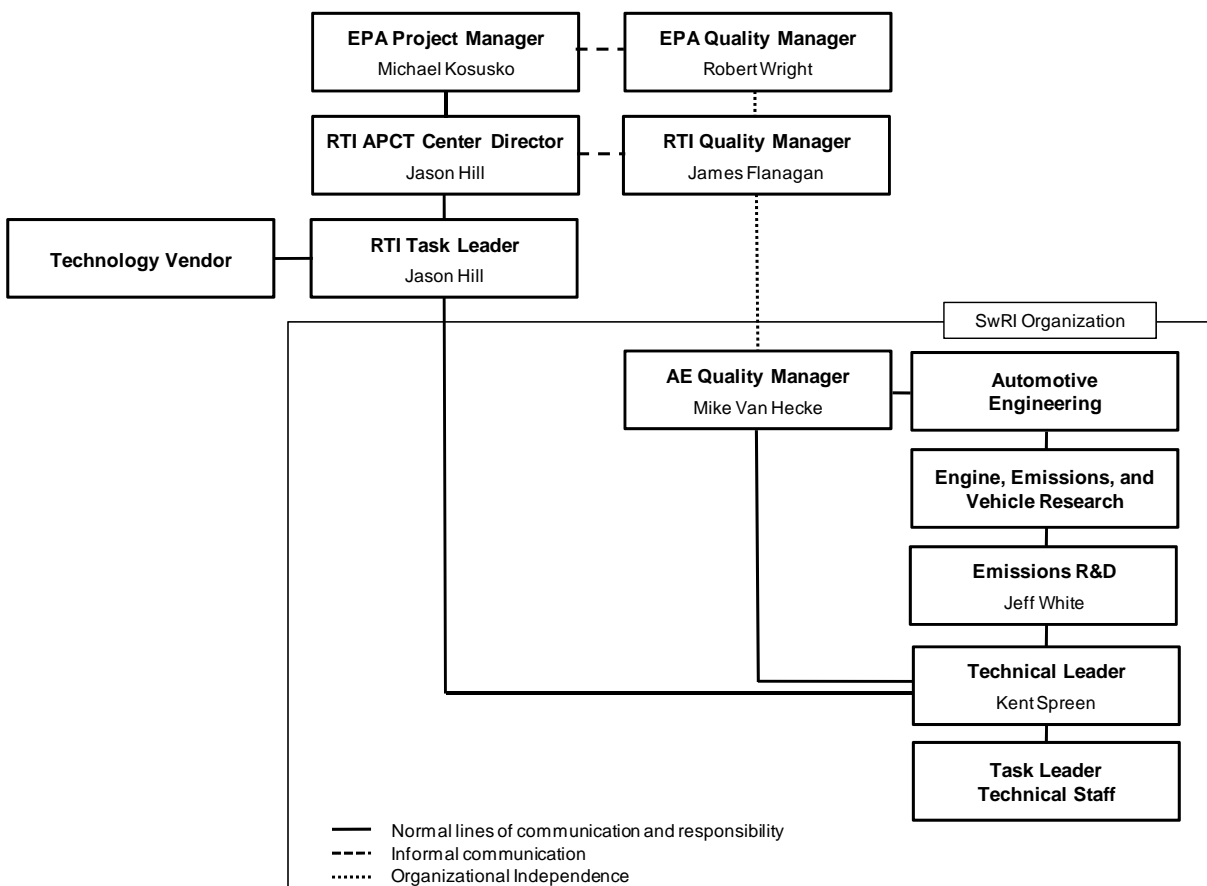


FIGURE 1. ORGANIZATIONAL CHART

A4.1. Management Responsibilities

Project management responsibilities are divided among the SwRI, RTI, and EPA staff as described below.

A4.1.1. EPA Project Manager

The EPA project manager, Michael Kosusko, has overall technical responsibility for the program. He is responsible for granting final approval of GVPs, TQAPs, and reports, and he recommends the resources necessary to meet project objectives and requirements.

A4.1.2. RTI APCT Center Director

The RTI APCT Center director is Jason Hill. He has overall responsibility for liaison with the EPA project manager, technical and administrative oversight of the APCT Center and the QA program in the APCT Center and for technology-specific verification tests. He will assign technology verification task leaders; oversee verifications; review technical panel makeup; and review generic verification protocol and test-specific quality documents. These responsibilities are described in greater detail in Section 2 of the APCT Center's QMP.

A4.1.3. RTI Task Leader

The RTI task leader is Jason Hill. He will:

- Define task objectives,
- Develop a detailed test scope,
- Work with vendors and stakeholders,
- Prepare test-specific addenda to this document,
- Review work progress to ensure that task budgets and schedules are met, and
- Prepare verification reports and verification statements.

Hill has overall responsibility for coordinating verification of technologies between applicants and the APCT Center qualified testing organization.

A4.1.4. SwRI Technical Leader

The SwRI technical leader is Kent Spreen. He will:

- Assist the RTI task leader with the test scope,
- Review/prepare operating procedures applicable to the testing,
- Review test apparatus and procedures prior to commencement of testing,
- Oversee testing of the SCR systems,
- Review test data/results for attainment of data quality objectives (DQOs) and reasonableness,
- Initiate corrective actions when needed,
- Review test results, and
- Submit test results to the RTI task leader.

Spreen has overall responsibility for technical and administrative activities, and exercises technical leadership to promote quality in project performance. He will also function as liaison for clients in specific technical areas and supervise the activities of project leaders.

A4.1.5. SwRI Task Leader

Task leaders assigned by the SwRI technical leader will:

- Review the statement of work,
- Develop specific instruction for test work,
- Interface between test operations and vendor, and
- Review and communicate results to RTI.

A4.2. Quality Assurance Responsibilities

QA responsibilities are divided among the EPA, RTI, and SwRI personnel as listed below.

A4.2.1. EPA Quality Manager

The EPA quality manager (EPA QM), Robert Wright, will conduct audits of RTI's QA system and of specific technical activities on the project. He will be available to resolve any QA issues relating to performance and EPA's QA requirements. Specific functions and duties of the EPA QM include approving the contents of this TQAP and subsequent revisions and reviewing QA reports prepared by RTI, including QA evaluations and audits. In addition, the EPA QM will:

- Communicate quality systems requirements, quality procedures, and quality issues to the EPA project manager and the RTI project manager,
- Review and approve APCT Center quality systems documents to verify conformance with the quality provisions of the ETV quality systems documents,
- Perform technical systems audits (TSAs) and performance evaluation audits (PEAs) of verification tests, as appropriate, and
- Provide assistance to APCT Center personnel in resolving QA issues.

For each technology tested under this TQAP, the EPA QM (or his designee) will perform the following specific activities associated with the verification tests:

- Review and approve the GVP for selective catalytic reduction technologies,
- Review and approve this SwRI-specific TQAP and each test-specific addendum,
- Review and approve each verification report and each verification statement, and
- Perform a PEA of the verification test of SwRI's ETV testing operations.

A4.2.2. RTI Quality Manager

The RTI APCT Center quality manager (RTI QM), James Flanagan, is organizationally independent of the RTI APCT Center director and is responsible for ensuring that QA/quality control (QC) procedures described in this TQAP are followed. In addition, Flanagan will:

- Maintain regular communication with the EPA QM and APCT Center staff regarding QA issues,
- Report on the adequacy, status, and effectiveness of the QA program on a regular basis to the task leader and the APCT Center director,
- Conduct audits of lab activities as necessary and prepare audit reports,
- Ensure that corrective action, if necessary, is properly implemented and documented,
- Review and approve GVPs, TQAPs, TQAP addenda, and SOPs,
- Review the audit of data quality (ADQ) report of the SwRI quality manager (SwRI QM),
- Review and approve test (including QC) reports, and
- Prepare the QA section of each verification statement and verification report.

A4.2.3. SwRI Quality Manager

The SwRI QM, Mike Van Hecke, plays a central role in the introduction, implementation, and consistent application of continuous quality improvement at SwRI's AE. He fulfills the role as quality management representative for the department and is organizationally independent of the unit generating the data. He will:

- ensure the official, approved version of this document is maintained,
- review and approve test-specific addenda to this document,
- reconcile test results with DQOs via attainment of data quality indicator goals (DQIGs),
- conduct audits of all pertinent quality standards to ensure compliance, and
- conduct the test-specific ADQ as described in Element C1.3 and prepare the ADQ report.

A5: Problem Definition/Background (Verification Approach)

The objective for ETV testing of air pollution control technologies is to quantify emissions reduction capability and determine effectiveness for “commercial ready” technologies. Air pollution control technologies for mobile sources are effectively used to reduce emissions from older diesel engines. This use of engine pollution control technologies as diesel retrofit requires proper integration with an engine or group of engines to decrease emissions, but integration is not necessarily intended to bring the engine to current or any prior emission regulation levels. Performance of a diesel retrofit technology to decrease emissions is verified with ETV. Verification of diesel retrofit technologies is in the spirit of introducing innovative technologies that have potential to improve environmental protection. Verified technologies are performance-proven by independent and objective testing using test procedures used for air pollution regulation, established protocols, and an EPA-approved quality management system. This TQAP is specific to the SCR emission control technology that reduces NO_x emissions. A test-specific addendum (Test Plan SOW) will provide additional information to this TQAP to conform to Element A5 of EPA QA/R-5.

A6: Project/Task Description

A6.1. Description

The SCR pollution control technologies covered by this ETV TQAP are intended for use on on-highway heavy-duty (HD) diesel engines and nonroad compression-ignition (CI) engines. Emissions test procedures for the candidate technology devices will use procedures for emission regulation of on-highway HD and nonroad CI engines. Federal Test Procedures (FTPs) are documented in CFR Title 40 Part 86, Subpart N for on-highway HD engines and 40 CFR Part 89 for nonroad CI engines. Procedures in 40 CFR Part 86, Subpart N include the transient FTP for heavy-duty diesel engines and the supplemental emissions test (SET). It is important to state that as of January 2010 these test procedures are obsolete and replaced by revised procedures. It is assumed that candidate technology devices are intended for engines manufactured before 2010; therefore, appropriate test procedures will come from 40 CFR Parts 86 and 89. The use of 40 CFR Part 1065 emission test procedures will be specifically stated in a test-specific addendum to

this TQAP document, also known as the Test Plan SOW.

Primary measurement will include regulated emissions of total hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and total particulate matter (PM). Based on the specific technology, the type of FTP and number of tests are determined to conform to the *Generic Verification Protocol for Determination of Emissions Reductions from Selective Catalytic Reduction Control Technologies for Highway, Nonroad, and Stationary Use Diesel Engines*, Sections 5.1 and 2.4 to satisfy test design requirement and data quality objectives. These sections of the SCR GVP give information on test design and objectives to determine confidence intervals that differences in mean emission levels are measured.

A description of the specific technology, test engine, and test-specific details will be documented as a test-specific addendum to this TQAP that will be prepared by RTI task leader, reviewed by the SwRI technical leader, and submitted for EPA review and approval prior to beginning of the ETV test program. The test-specific addendum will provide additional information to this TQAP to conform to Element A6 of EPA QA/R-5.

A7: Quality Objectives and Criteria

In order to determine the emissions performance of a technology, test quality must be assured. Emissions testing by FTP must follow a large number of quality requirements given in 40 CFR Part 86 (on-highway engine tests) or Part 89 (nonroad engine tests) to deem the data as valid. All emissions sampling and measurement equipment along with ambient condition measurements and engine parameter measurements have requirements in 40 CFR for accuracy and traceability to standards.

For this ETV testing, achieving data quality objectives (DQOs) requires that test methods and procedures adhere strictly to 40 CFR Part 86, Subpart N or 40 CFR Part 89. Test DQOs given in Section 2.4 of the GVP give reference to the number of individual emissions tests to be conducted to achieve desired confidence intervals that differences in mean emission levels are detected. At a minimum, three repeated tests using a specific test cycle (Part 86 or Part 89) are conducted. The number and type of emission tests will be specified in the test-specific addendum to this TQAP.

Each individual measurement within an emissions test has specific data quality indicators that must be met to ensure project DQOs. The data quality indicator goals (DQIGs) for individual measurements are listed in Tables 1 through 4.

TABLE 1. TEST EQUIPMENT SPECIFICATIONS AND DQIGs

Measurement Variable	Accuracy Specification	Frequency	40 CFR
Speed	± 2% of absolute standard	Monthly	86.1308-84 86.1318-84
Torque	± 3% of true torque ^a	Weekly	86.1316-94
CVS Volumetric Flow Rate	Measured mass ± 2% of injected propane mass	Weekly	86.1319-90 86.1316-94
Propane analysis	--	When replaced	--
Mass flow verification using a critical flow orifice (CFO)	--	Annually	--
PM Double Dilution Flow Rate			86.1320-90
Dilution meter	± 1% of total flow through PM filter	Semi-annually	
Sample meter	± 2% of point / ± 1% full scale	Semi-annually	
System Pressures	± 0.4 kPa (± 3 mm Hg) (± 1.6 in. H ₂ O)	Semi-annually	86.1309-90
System Temperatures	± 1.9 °C (± 3.4 °F)	Semi-annually	86.1309-90

^a Torque accuracy also defined as ± 2.5 lb-ft for full-scale values up to and including 550 lb-ft, ± 5 lb-ft for full-scale values up to and including 1050 lb-ft, and ± 10 lb-ft for full-scale values over 1050 lb-ft.

TABLE 2. GAS ANALYSIS EQUIPMENT SPECIFICATIONS AND DQIGs

Measurement Variable	Accuracy or Result Specification	Frequency	40 CFR
HC	± 2% of point	Monthly	86.1321-94
CO	and		86.1322-84
CO ₂	± 0.3% of full scale at zero ^a		86.1324-84
NO _x			86.1323-2007
NO _x Converter Efficiency	> 90%	Monthly	86.1323-2007
NO _x /CO ₂ Quench	≤ 2%	Annually	86.1323-2007
CO/CO ₂ Interference	≤ 3 ppm (Range 0-300 ppm) ≤ 1% full scale (Range > 300 ppm)	Annually	86.1322-84
NH ₃	^b	^b	^b

^a Emission measurement accuracies in 86.1338-2007 also apply.
^b FTIR operated as specified in EPA CTM-038 and 40 CFR Part 63, Appendix A, Method 320.

TABLE 3. CALIBRATION GAS SPECIFICATIONS AND DQIGs

Gas	Specification	40 CFR
HC CO CO ₂ NO _x	Named to ± 1% of NIST Value and NO ₂ < 5% of NO	86.1314-94
Zero Air	< 1 ppmC HC < 1 ppm CO < 0.04% CO ₂ ≤ 0.1 ppm NO _x 18 to 21% O ₂ remainder N ₂	86.1314-94
HFID Fuel	40 ± 2% H ₂ < 1 ppmC HC remainder helium	86.1314-94

TABLE 4. EMISSION TEST DATA DQIGs

Variable	Specification	40 CFR
CVS sample zone temperature	191 °C max.	86.1310-90 ^a 86.1330-90
PM filter face temperature	52 °C max.	
Primary dilution temperature	25 °C ± 5 °C	
HC (HFID) sample train temperature	191 °C ± 11 °C	
Engine intake air temperature	25 °C ± 5 °C	
Post-test span & zero drift	± 2% full scale (CO, CO ₂ , NO _x) ± 3% full scale (HC) of initial	86.1340-94
Transient cycle validation	per 40 CFR 86.1341	86.1341-98
Cold-Start soak temperature (transient)	> 20 °C	86.1330-90
PM weigh chamber Conditioning temperature Conditioning humidity Sample filter checkout time Reference filter weight change	22 °C ± 3 °C Dew point 9.4 °C ± 3 °C and relative humidity 45% ± 8% < 1 hour < 40 µg change	86.1312-88 ^b 86.1339-90
^a Exhaust gas sampling and analytical system for gaseous and particulate emissions can follow methods in 40 CFR 86.1310-2007 if stated in test-specific addenda. ^b PM filters can be high efficiency membrane media if specified in test-specific addenda; filter conditioning and weighing facility will conform to 40 CFR 86.1312-2007.		

A8: Special Training Requirement/Certifications

The ER&DD is certified to International Organization for Standardization (ISO) 9001:2008 “Model for Quality Management Systems.” This independently assessed system provides the basis for quality management procedures that are applied to all emissions tests processes at ER&DD.

ER&DD is accredited to ISO/IEC 17025 “General Requirements for the Competency of Calibration and Testing Laboratories.” Under American Association for Laboratory Accreditation Certificate Number 0702-01, ER&DD has been accredited to perform evaluations of automotive fluids; fuels; emissions; and automotive component, engine and powertrain performance and durability using stationary engine dynamometer test stands (light-duty, heavy-duty, and nonroad) vehicle dynamometer facilities, and automotive fleets (see <http://www.a2la.org/scopepdf/0702-01.pdf>). The certificate accredits ER&DD to use specific standards and procedures, including dynamometer procedures for regulated emissions testing.

All ER&DD personnel supporting the project will be qualified as described by AE SOP 4.18.

A9: Document and Records

The scope of test documents and records to be maintained by SwRI is given in Part A, Section 5.3 of the ETV program QMP. Section 3.6 of the APCT QMP states that project documentation will be retained by SwRI or APCT for 7 years. These documents include: TQAP, SwRI SOPs and TIPs, calibration data and certificates of standards, raw test data, emission results, and final project reports.

Test plan documentation such as this TQAP and test-specific addenda will be maintained by the SwRI quality manager. SOPs and TIPs are maintained and accessible at the EEVRD website. Calibration records will be maintained in central storage locations at ER&DD. Records of traceability to standards and certificates of standards will be maintained in the same storage locations. Each individual test’s data are recorded manually on pre-formatted data sheets at the facility as the test is conducted. Test data will be assembled into a data packet and transferred to a central location for entry into a database. Emissions calculations are conducted using compiled software within the database. The database information and test results will be archived electronically and the paper data packets will be stored in central storage locations. The procedure for storage of test data forms and calibration records is documented in AE SOP 4.16. The subagreement, subagreement modifications, correspondence between SwRI and RTI, final reports and billing information will be maintained in central storage locations.

GROUP B: DATA GENERATION AND ACQUISITION

B1: Sampling Process Design (Experimental Design)

The experimental design follows the FTP for the respective on-highway or nonroad application with the number of separate FTP tests for a specific technology determined by the algorithm specified in Section 5.1 of the GVP. The rationale for the number of FTP test cycles will be included in the test-specific addendum to this document, which will conform to required Element B1 of EPA QA/R-5. Primary measurements will include brake specific emissions of HC, CO, NO_x, and PM. Noncritical emission measurements for SCR include nitrogen dioxide (NO₂) and ammonia slip. Additional emissions measurements and methods will be specified in the test-specific addendum. Implementation of procedures from 40 CFR Parts 86 or 89 are documented in EEVRD Test and Inspection Procedures (TIPs) listed in Elements B3 through B10.

B2: Sampling Methods

The emissions sampling system is a constant volume sampler (CVS) system, described in 40 CFR 86.1310-90 for on-highway applications and 40 CFR 89.419 for nonroad applications, onto which gaseous and particulate emission measurement systems are attached. An illustration of the sampling system is given in Figure 2. This is a typical design with some variation at individual test cells due to their instrumentation configuration.

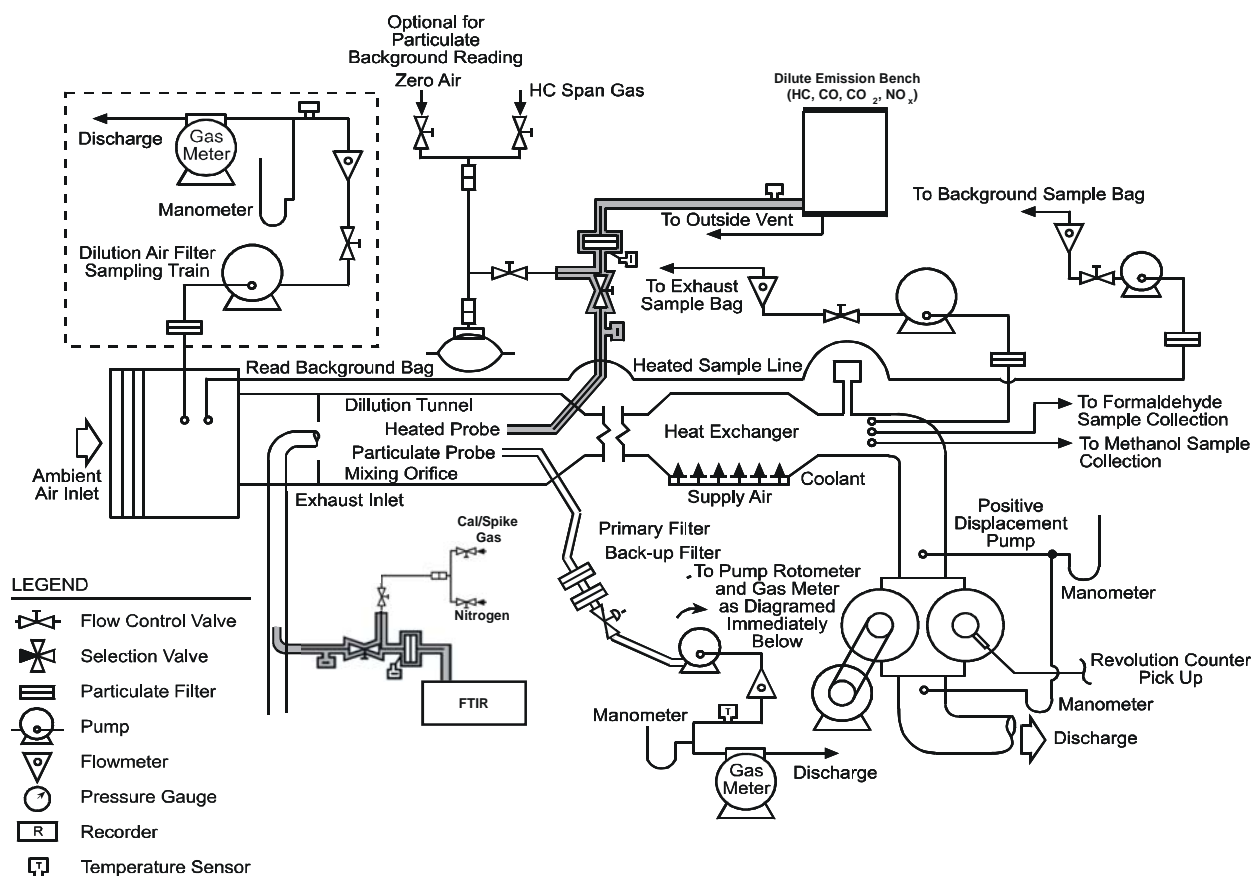


FIGURE 2. GASEOUS AND PARTICULATE EMISSIONS SAMPLING SYSTEM

B2.1. Exhaust Gas Sampling System

The exhaust gas sampling system conforms to 40 CFR 86.1310-90 or 40 CFR 89.419 in construction, performance, and calibration requirements. CVS systems at SwRI use a positive displacement pump (PDP) with heat exchanger. The CVS flow is sufficient to maintain a dilute exhaust stream below 191 °C and above temperatures that would allow water condensation. Sample probes are placed in the CVS at a position where dilution air and exhaust are well mixed (at least ten tunnel diameters downstream from where the exhaust enters the CVS). A heated sample probe, sample system, and analyzer for continuous HC measurement are maintained at 191 °C ± 11 °C. Continuous measurement of CO, CO₂, and NO_x is sampled from one common heated sample probe and pump. The NO_x sample system is maintained at 191 °C ± 11 °C up to the NO₂/NO converter. A separate probe leads to a double dilution system for PM measurement. Ammonia slip measurement will be sampled directly from the exhaust stack downstream of the SCR system.

B2.2. Particulate Sampling System

PM emission mass is determined by filtration of a portion of the dilute exhaust. Particulate samples are collected on a pair of polytetrafluoroethylene (PTFE)- or Teflon-coated glass fiber filters using a double dilution technique as outlined in 40 CFR 86.1310-90. A portion of the diluted exhaust from the primary CVS tunnel is routed into a secondary dilution system, where it is further diluted in order to control the temperature of the sample stream to 52 °C or less. Particulate sample filters are conditioned and weighed according to procedures described in 40 CFR 86.1312-88 and 86.1339-90 (see Element B4.3 for specific sample filter weighing procedures). Sample filter weighing is conducted at a central location separate from the engine/dynamometer emissions test facility.

The double dilution technique as outlined in 40 CFR 86.1310-2007 can be used if it is stated in the test-specific addenda. With this 2007 technique, a single PTFE- or Teflon-coated borosilicate glass fiber high efficiency filter or PTFE or Teflon high efficiency membrane filter is used.

Particulate sampling for nonroad applications is specified in 40 CFR 89.112 which references the California Code of Regulations for new 1996 and later heavy-duty off-road diesel cycle engines. There is a reference from the California Air Resources Board that particulate sampling uses procedures from ISO 8178. ISO procedures agree with 40 CFR Part 86 with an additional requirement for sampling gas face velocity through the filter to be between 35 and 80 cm/s and a recommended pressure drop increase less than 25 kPa, between the beginning and end of the test.

B2.3. Corrective Action for Sampling

Any deviation of emissions sampling from requirements of the CFR that include equipment malfunctions, nonconformances, and/or testing problems are reported by the test personnel (technical staff) to the technical leader or task leader as per AE SOP 4.10.2. Corrective action from any deviations to CFR procedures is conducted according to AE SOP 4.13.

B3: Sample Handling and Custody

Collection of emissions data is performed within one building at ER&DD. Therefore, sample handling and custody are straightforward. No data or samples are transferred to/from outside locations. The PM sample filters and raw test data forms involve manual handling from test facilities (test cells) to central processing locations.

B3.1. Particulate Filter Handling Custody

The PM sample filters are prepared and processed according to EEVRD TIP 07-020 (Particulate Filter Conditioning and Weighing in Accordance with CFR Title 40 Parts 86 and 89). The TIP specifies sample handling and custody procedures as well as a method of conditioning and weighing filters used for PM sampling during emissions tests. The handling and custody procedures in TIP 07-020 include: A pair of sample filters are placed into a petri dish with a cover. Using the Filter Room Interface Software (FRIS), a unique bar code number is generated for the petri dish and the dish with the filter set is placed inside the conditioning chamber (see Element B4.3) for at least one hour prior to taking a tare weight. FRIS is used to record the time, tare weight, temperature, dew point, humidity, and barometric pressure associated with the filter set's bar code. The petri dish is returned to the conditioning chamber until the filter set is needed for a test. When a dish is removed from the chamber for testing, FRIS is used to record the time. The sample filter set is removed from the petri dish at the test cell and immediately placed into the sampling system (see Element B2.2). A used filter set is replaced into the petri dish and returned to the conditioning chamber within one hour of the removal time using FRIS to record the check-in time. Filter sets not used within one hour are returned to the conditioning chamber for a new tare weight unless the filters are kept in a sealed container. The filter set will remain in the conditioning chamber for one hour prior to taking gross weight. FRIS is used to record the time, gross weight, temperature, dew point, humidity, and barometric pressure.

B3.2. Raw Data Handling Custody

Quantitative data as required in 40 CFR 86.1342-94, 86.1343-88 and 86.1344-94 or 40 CFR 89.405 and 89.424 are recorded on formatted forms. All raw data forms are prepared according to EEVRD TIP 07-009 (Emissions Testing During Heavy-Duty Diesel Engine Transient Cycle) and TIP 07-038 (Steady-State Dilute Emissions Testing of Heavy-Duty Engine Using Horiba MEXA-7200D Emissions Bench). The forms are given a unique test number, dated, and assembled into a test packet according to respective TIPs 07-009 and 07-038. Raw data that are recorded on the forms include CVS and double dilution information for calculation of volume flow rates, exhaust gas analyzer concentrations and background levels, engine air temperature and dew point, dilution air temperature and wet bulb temperature, barometric pressure, cycle work or horsepower, and the particulate filter bar code number. The packet is transferred to a central location for entry into a database that is used to calculate emission test results.

B4: Analytical Methods

Gaseous emissions of HC, CO, and NO_x are measured by gas analyzers that sample a dilute exhaust stream from the CVS. Particulate emissions are determined by the net weight gain of samples filters. Ammonia slip is determined by Fourier Transform Infrared (FTIR) spectroscopy.

B4.1. Gaseous Analyzers

The gaseous analytical system, as illustrated in Figure 3, conforms to 40 CFR 86.1310-90 or 40 CFR 89.309. ER&DD test facilities use Horiba MEXA 7200D analyzer benches. Analyzer operation is specified in EEVRD TIP 07-009 (Emissions Testing During Heavy-Duty Diesel Engine Transient Cycle) and TIP 07-038 (Steady-State Dilute Emissions Testing of Heavy-Duty Engine Using Horiba MEXA-7200D Emissions Bench).

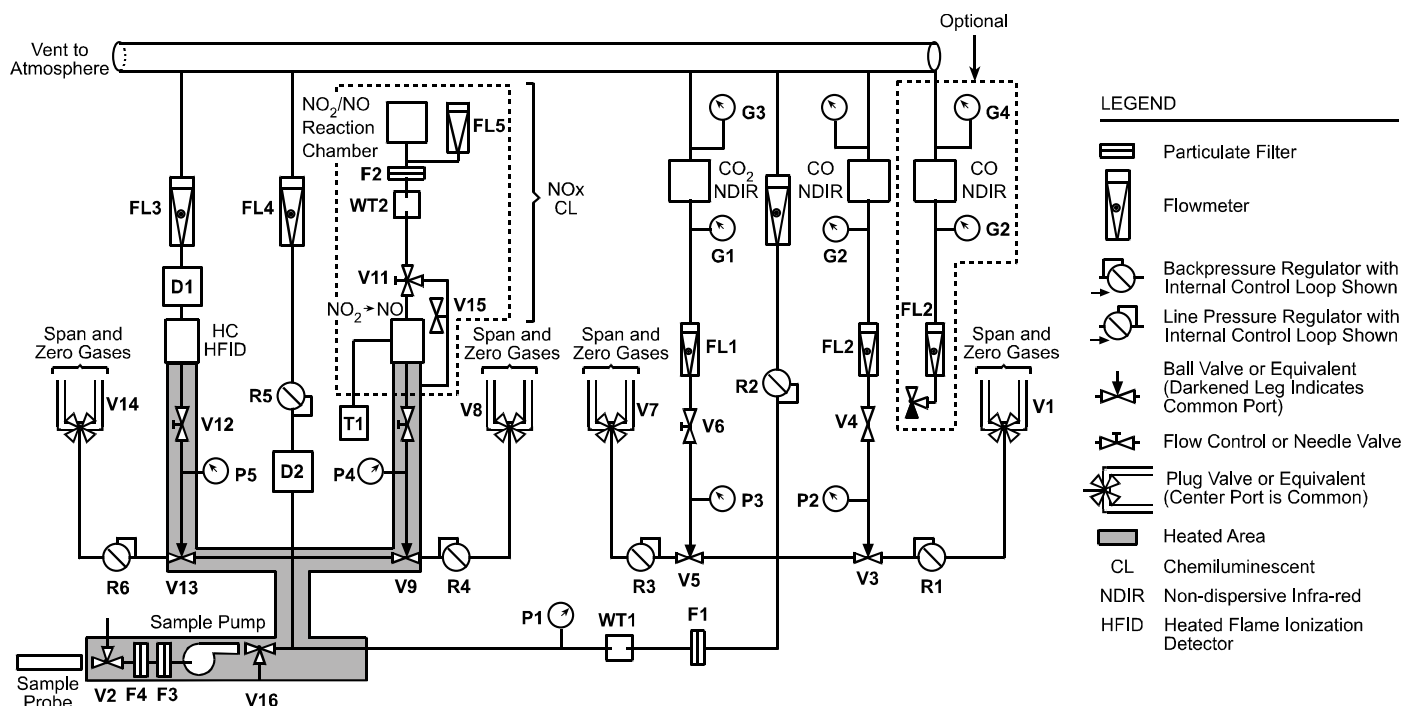


FIGURE 3. EXHAUST GAS SAMPLING AND ANALYTICAL SYSTEM

The analyzer for ammonia slip is an FTIR that conforms to EPA-CTM-038 and 40 CFR Part 63, Appendix A, Method 320 with exception that measurement is based on continuous sampling and analysis giving results at a 1 Hz rate. FTIR operation is specified in EEVRD TIP 07C-019 (Measurement of Exhaust Emissions by Fourier Transform Infrared (FTIR) spectroscopy).

B4.2. Corrective Action for Analyzers

Any deviation of gas analysis from requirements of the CFR that include equipment malfunctions, nonconformances, and/or testing problems is reported by the test personnel (technical staff) to the technical leader or task leader as per AE SOP 4.10.2. Corrective action

from any deviations to CFR procedure is conducted according to AE SOP 4.13.

B4.3. Filter Weighing

Particulate sample filters are conditioned in temperature and humidity controlled chambers that conform to 40 CFR 86.1312-88 according to EEVRD TIP 07-020 (Particulate Filter Conditioning and Weighing in Accordance with CFR Title 40 Parts 86 and 89). Weighing process conforms to 40 CFR 86.1339-90 and the weighing chamber conforms to 40 CFR 86.1312-88. Procedure given in TIP 07-020 for filter weighing is summarized in Element B3.1.

Use of high efficiency membrane filters for PM will be specified in the test-specific addendum. These filters are conditioned and weighed in chambers that conform to 40 CFR 86.1312-2007 according to EEVRD TIP 07-045 (Particulate Filter Conditioning and Weighing in Accordance with CFR Title 40 Part 1065). The ambient temperature and humidity conditions for stabilizing and weighing these filters are identical between 40 CFR 86.1312-2007 and 40 CFR 1065.190. Membrane filter handling custody and weighing procedures are the same as summarized in Element B3.1 except one filter is used instead of a pair of filters, conditioning time is 30 minutes before tare and gross weights are recorded, and the weighed filter is placed into a cassette, while the filter remains in the clean environment of the conditioning chamber, that holds the filter for sampling.

B5: Quality Control

Quality control limits in 40 CFR Part 86 (on-highway engine tests) are mostly the same or in a few cases more stringent than 40 CFR Part 89 limits (nonroad engine tests). Quality control limits for testing under this TQAP will adhere strictly to 40 CFR Part 86. Quality control activities for calibrations of the dynamometer, CVS, analytical equipment, pressures, and temperatures are documented in AE SOP 4.11.1 and SOP 4.10.2 and EEVRD TIPs listed in Appendix A Table 4-1. The control limits from 40 CFR Part 86 and acceptance criteria in the TIPs listed in Appendix A are given in Tables 1 through 3 of Element A7. Quality control activities for individual emissions tests are documented in AE SOP 4.10.2 and EEVRD TIP 07-009 for on-highway engine tests and TIP 07-038 for nonroad engine tests. TIP 07-020 includes QC activities for PM sample filter handling, conditioning and weighing. These TIPs include calibration or test methods, control limits or acceptance criteria, and personnel responsible for assessment. The test control limits in 40 CFR Part 86 and acceptance criteria in the above TIPs are given in Table 4 of Element A7. QC activities for data entry and reduction are documented in AE SOP 4.15.2. QC for PM sample filters is assisted by FRIS. The software will alert the user to filter conditioning data or reference filter weight changes that exceed CFR requirements.

Procedures for corrective action for calibration or test equipment nonconformance are documented in AE SOP 4.13.

B6: Instrument/Equipment Testing, Inspection, and Maintenance

Inspection and maintenance activities for the dynamometer, CVS, and analytical equipment are documented in EEVRD TIPs listed in Appendix A Table 4-1. These TIPs include acceptance criteria and personnel responsible for review.

B7: Instrument/Equipment Calibration and Frequency

Calibration frequency of analyzers, instruments, and equipment will conform to 40 CFR 86.1316-94 for on-highway engine tests or 40 CFR 89.305 for nonroad engine tests. EEVRD TIPs listed in Appendix A Table 4-1 include the calibration frequency of emissions sampling and measurement equipment, the applicable standards to be used and acceptance criteria. The calibration frequencies in these TIPs are given in Tables 1 and 2 of Element A7. Overall QC activities for calibrations are documented in AE SOP 4.11.1.

B7.1. Gaseous Analyzer Calibration

Emissions gas analyzers for HC, CO, CO₂, and NO_x are contained in a Horiba MEXA 7000 Series analyzer bench.

B7.1.1. Hydrocarbon Analyzer

The hydrocarbon analyzer is a heated flame ionization detector (HFID) instrument calibrated in conformance with 40 CFR 86.1321-94 and 40 CFR 89.319. Calibration and other HFID operational requirements are conducted according to EERVD TIP 06-012 (Monthly Calibration of Analyzers for Continuous Gaseous Exhaust Using Horiba Emissions Bench), TIP 06-050 (HC Analyzer and Sample System Response Checks of Horiba MEXA 7000 Series Emissions Benches), and TIP 06-044 (Hydrocarbon Analyzer Optimization).

B7.1.2. Carbon Monoxide Analyzer

The CO analyzer is a non-dispersive infrared (NDIR) instrument calibrated in conformance with 40 CFR 86.1322-84 and 40 CFR 89.320. Calibration and other CO analyzer operational requirements are conducted according to EEVRD TIP 06-012 (Monthly Calibration of Analyzers for Continuous Gaseous Exhaust Using Horiba Emissions Bench) and TIP 06-049 (Wet CO₂ Interference Check of CO Analyzer Integrated in Horiba MEXA 7000 Series Emissions Benches).

B7.1.3. Oxides of Nitrogen Analyzer

The NO_x analyzer is a chemiluminescent instrument calibrated in conformance with 40 CFR 1323-2007 and 89.321. Calibration and other NO_x analyzer operational requirements are conducted according to EEVRD TIP 06-012 (Monthly Calibration of Analyzers for Continuous Gaseous Exhaust Using Horiba Emissions Bench), TIP 06-002 (NO_x Converter Efficiency Determination), TIP 06-051 (NO_x Analyzer and Sample System Response Checks of Horiba MEXA 7000 Series Emissions Benches), and TIP 06-041 (NO_x Analyzer CO₂ Quench Check).

B7.1.4. Carbon Dioxide Analyzer

The CO₂ analyzer is a NDIR instrument calibrated in conformance with 40 CFR 86.1324-84 and 89.322. Calibration is conducted according to EEVRD TIP 06-012 (Monthly Calibration of Analyzers for Continuous Gaseous Exhaust Using Horiba Emissions Bench).

B7.1.5. Ammonia Analyzer

The ammonia (NH₃) analyzer is an FTIR instrument calibrated in conformance with EPA-CTM-038. FTIR operation is specified by EEVRD TIP 07C-019 (Measurement of Exhaust Emissions by Fourier Transform Infrared (FTIR) Spectroscopy).

B7.2. Constant Volume Sampler (CVS)

The CVS calibration is verified in conformance with 40 CFR 86.1319-90 or 40 CFR 89.422. CVS calibration is verified according to EEVRD TIP 06-011 (Propane Recovery Check).

B7.3. Gas Meter Calibration

Particulate sampling requires flow instrumentation or gas meters to determine secondary dilution and sample flows. The gas meter calibration is verified in conformance with 40 CFR 86.1320-90. Calibration verification is conducted according to EEVRD TIP 06-046 (Calibration of Gas Meter).

B7.4. Miscellaneous Instruments

Engine speed and torque, signal conditioning, and readouts are calibrated within specifications given in 40 CFR 86.1308-84, 86.1318-84, and 86.1316-94. Speed calibration is verified according to EEVRD TIP 06-018 (Engine Speed Readout Verification) and torque calibration is verified according to EEVRD TIP 06-017 (Torque Meter Calibration Check). Pressure and temperature instruments, signal conditioning and readouts are calibrated within specifications given in 40 CFR 86.1309-90. Pressure calibration is verified according to EEVRD TIP 06-020 (Pressure Calibration and Verification) and temperature calibration is verified according to EEVRD TIP 06-013 (Temperature Calibration and Thermocouple Verification).

B7.5. Analyzer Calibration Gases

The gases used for analyzer calibration conform to 40 CFR 86.1314-94 and 40 CFR 89.312. Concentrations of calibration gases are verified according to EEVRD TIP 06-007 (Naming Monthly Calibration Gases) and zero gases are verified according to TIP 06-036 (Verification of Zero Gas).

B8: Inspection/Acceptance of Supplies and Consumables

Supplies and consumables for SCR ETV include test fuel, calibration and zero gases, PM sample filter media, and mechanical and electrical supplies for mounting the test engine in the emissions facility.

B8.1. Test Fuel

Test fuel is purchased from suppliers on the EEVRD Approved Supplier List. Test fuel will conform to specifications in 40 CFR 86.1313-2007 unless otherwise stated in the test-specific

addendum. Batch fuels are stored in underground tanks. Receipt of test fuel is accompanied by a certificate of analysis from the supplier and a material safety data sheet (MSDS). The analytical results are compared to CFR specifications before the fuel is used for emissions testing.

B8.2. Calibration Gases

Calibration gases are purchased from the EEVRD Approved Supplier List. Calibration gases are verified per Element B7.5.

B8.3. Particulate Matter (PM) Filter Media

PM sample media are purchased from the EEVRD Approved Suppliers List in batches. Individual sample filters are cut from the batch sheet and a pair of filters is placed into a petri dish with a cover. The membrane filters are received pre-cut and individual filters are placed into a petri dish with a cover.

B9: Non-Direct Measurements

No non-direct measurements are used for SCR ETV for calculation of emissions results or the SwRI final report.

B10: Data Management

Quantitative data as required in 40 CFR 86.1342-94 and 86.1343-88 or 40 CFR 89.424 are recorded on formatted forms. Element B3 gives the chain-of-custody for data forms for an emissions test. Raw data forms are prepared according to EEVRD TIP 07-009 (Emissions Testing During Heavy-Duty Diesel Engine Transient Cycle) and 07-038 (Steady-State Dilute Emissions Testing of Heavy-Duty Engine Using Horiba MEXA-7200D Emissions Bench). The forms are given a unique test number, dated, and assembled into a test packet. The packet is transferred to a central location for entry into the Emissions Test Information System (ETIS) database that is used to calculate emission test results. Raw data entry into the ETIS is conducted by designated personnel according to EEVRD TIP 08-005 (Data Transfers and Calculations of Dilute Steady-State Engine Data) and 08-016 (Heavy-Duty Transient Test Data Processing). Personnel responsible for database entry verification and validation are documented in AE SOP 4.15.2. ETIS contains features that will alert the user to data that exceed CFR requirements or equipment calibration limits. PM sample filter data, conditioning and weights, are electronically collected using FRIS. The software will alert the user to filter conditioning data or reference filter weight changes that exceed CFR requirements. Management of test and equipment QC data is illustrated in Figure 4.

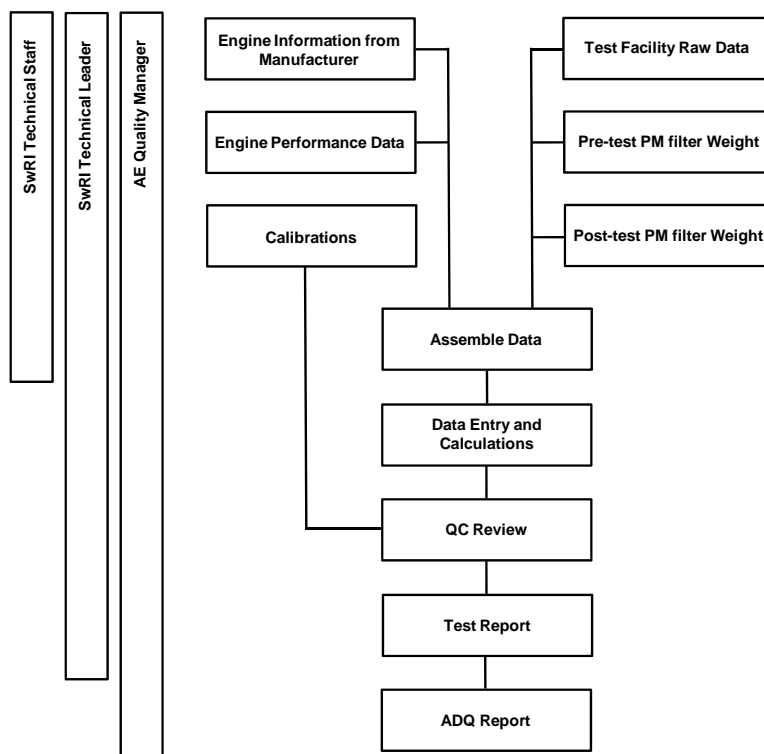


FIGURE 4. ETV DATA MANAGEMENT

GROUP C: ASSESSMENT AND OVERSIGHT ELEMENTS

C1: Assessments and Response

As a testing organization to APCT Center, SwRI's quality and technical systems will be evaluated according to ETV QMP Part A Section 9.0, APCT Center QMP Section 3.4, and SCR GVP Section 11.0.

C1.1. Internal Audits

Internal audits of AE, EEVRD, and ER&DD are conducted for compliance to ISO 9001 and ISO 17025. Procedure for internal audits is documented in AE SOP 4.17.

C1.2. External Audits

External audits by APCT Center and EPA include quality system audits (QSAs) or technical system audits (TSAs) as described in SCR GVP Section 11.1. The APCT Center or an EPA designate will conduct a QSA before tests begin using this TQAP. Additional assessments of SwRI's quality system will be determined by the APCT Center QM. The APCT Center or an EPA designate will conduct a TSA before tests begin under this TQAP. Subsequent technical systems audits will be conducted once a year or prior to testing of a candidate technology. QSAs will be conducted in accordance with EPA QA/G-3 and TSAs will be conducted in accordance to EPA QA/G-7

C1.3. Audits of Data Quality

In accordance to ETV QMP Part A Section 9.0, APCT Center QMP Section 3.4, and SCR GVP Section 11.0, the SwRI QM will conduct an ADQ by examining at least a 10 percent random sample of all verification test data. The QM's review of the test data will be performed after all data are collected and 100 percent are verified by project personnel. The QM's review will include data recording, transfer, summarizing, and reporting. Because data calculations are performed from the emissions database using compiled software, the QM will not be required to perform hand calculations. Verification of database calculations can be forwarded to APCT Center upon request.

The ADQ report will include a detailed review of QA/QC data as required by DQOs and DQIGs. The report will summarize project equipment malfunctions, nonconformances, and/or testing problems that resulted in lost data and subsequent corrective actions.

C1.4. Corrective Action

Corrective action that results from an audit or assessment is performed according to AE SOP 4.13.

C2: Reports to Management

Internal assessment reports will be reviewed by the SwRI QM, who will respond to APCT Center. A written report for the ADQ will be submitted to APCT Center approximately the same time as the final test report.

GROUP D: DATA VALIDATION AND USABILITY ELEMENTS

D1: Data Review, Verification, and Validation

Procedures for recording and verifying/validation test and calibration data are given in AE SOP 4.10.2 and SOP 4.15.2. The EEVRD TIPs listed in Appendix A Tables 4-1 and 4-2 contain procedures for data acceptance criteria and personnel responsible for data verification.

D2: Verification and Validation Methods

The majority of test and calibration data are reviewed and verified manually from data forms and calibration sheets. Verification of test data that are entered into the ETIS database is a manual review of transcribed data. Personnel responsible for data entry verification/validation are given in AE SOP 4.15.2. ETIS contains features that will alert the user to data that exceed CFR requirements or equipment calibration limits. Data that are determined to be out of limits are verified for correct entry otherwise the data are a test nonconformance. QA for PM sample filters is assisted by FRIS. The software will alert the user to filter conditioning data, checkout time, or reference filters weight changes that exceed CFR requirements. Filter data that are determined to be out of limits are test nonconformances.

D3: Reconciliation with User Requirements

Emission results for an engine or emission control device are normally accepted as-is provided that all QA/QC information is reconciled with CFR requirements. Limits for accuracy or precision are not normally set or determined for emission results. Test data will be acceptable for ETV if all DQOs and DQIGs are met.

APPENDIX A: APPLICABLE DOCUMENTS AND PROCEDURES

1. EPA Documents

EPA. *Policy and Program Requirements for the Mandatory Agency-wide Quality System*. EPA Order 5360.1 A2. U.S. Environmental Protection Agency. May 2000.

EPA. *EPA Requirements for Quality Management Plans*. EPA QA/R-2, EPA Publication No. EPA/240/B-01/002. U.S. Environmental Protection Agency, Office of Environmental Information. Washington, DC. March 2001.

EPA. *Environmental Technology Verification Program, Quality Management Plan*. EPA Publication No. EPA/600/R-08/009. <http://www.epa.gov/etv/pubs/600r08009.pdf>, Office of Research and Development, U.S. Environmental Protection Agency. Cincinnati, OH. January 2008.

EPA. *EPA Requirements for Quality Assurance Project Plans*. EPA QA/R-5, EPA Publication No. EPA/240/B-01/003. Office of Environmental Information, U.S. Environmental Protection Agency, March 2001.

EPA. *Guidance for Quality Assurance Project Plans*. EPA QA/G-5, EPA Publication No. EPA/240/R-021/009. Office of Environmental Information, U.S. Environmental Protection Agency, December 2002.

EPA. *Guidance on Technical Audits and Related Assessments for Environmental Data Operations*. EPA QA/G-7, EPA Publication No. EPA/600/R-99/080. Office of Environmental Information, U.S. Environmental Protection Agency, January 2000.

2. APCT Center Documents

APCT Center. *Verification Testing of Air Pollution Control Technology – Quality Management Plan*. RTI International. Research Triangle Park, NC. March 2010.

APCT Center. *Generic Verification Protocol (GVP) for Determination of Emissions Reductions from Selective Catalytic Reduction Control Technologies for Highway, Nonroad, and Stationary Use Diesel Engines*. Research Triangle Institute, Research Triangle Park, NC. September 2003.

3. SwRI AE Standard Operation Procedures

These documents are proprietary but will be made available to APCT Center and EPA staff during on-site assessments.

QSM	Quality System Manual – Rev. 3, February 2009
AE SOP 4.10.2	Test Conduct and Recording of Test and Calibration Data
AE SOP 4.11.1	Calibration and Maintenance
AE SOP 4.13	Nonconformance, Preventive and Corrective Action, Customer Complaints
AE SOP 4.15.2	Data Control and Reporting

AE SOP 4.16	Quality Records
AE SOP 4.17	Internal Quality Audits
AE SOP 4.18	Training

4. SwRI EEVRD Test and Inspection Procedures

These documents are proprietary but will be made available to APCT Center and EPA staff during on-site assessments.

TABLE 4-1. CALIBRATION PROCEDURES

TIP 06-002	NO _x Converter Efficiency Determination
TIP 06-007	Naming Monthly Calibration Gas
TIP 06-011	Propane Recovery Check
TIP 06-012	Monthly Calibration of Analyzers for Continuous Gaseous Exhaust Using Horiba Emissions Bench
TIP 06-013	Temperature Calibration and Thermocouple Verification
TIP 06-017	Torque Meter Calibration Check
TIP 06-018	Engine Speed Readout Verification
TIP 06-020	Pressure Calibration and Verification
TIP 06-036	Verification of Zero Gas
TIP 06-041	NO _x Analyzer CO ₂ Quench Check
TIP 06-044	Hydrocarbon Analyzer Optimization
TIP 06-046	Calibration of Gas Meter
TIP 06-049	Wet CO ₂ Interference Check of CO Analyzer Integrated in Horiba MEXA 7000 Series Emissions Benches
TIP 06-050	HC Analyzer and Sample System Response Checks of Horiba MEXA 7000 Series Emissions Benches
TIP 06-051	NO _x Analyzer and Sample System Response Check of Horiba MEXA 7000 Series Emissions Benches

TABLE 4-2. TEST PROCEDURES

TIP 07-009	Emissions Testing During Heavy-Duty Diesel Engine Transient Cycle
TIP 07-020	Particulate Filter Conditioning and Weighing in Accordance with CFR Title 40 Parts 86 and 89
TIP 07-038	Steady-State Dilute Emissions Testing of Heavy-Duty Engine Using Horiba MEXA-7200D Emissions Bench

TABLE 4-3. CHEMISTRY ANALYTICAL PROCEDURES

TIP 07C-019	Measurement of Exhaust Emissions by Fourier Transform Infrared (FTIR) Spectroscopy
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TABLE 4-4. DATA ENTRY PROCEDURES

TIP 08-005	Data Transfers and Calculations of Dilute Steady-State Engine Data
TIP 08-016	Heavy-Duty Transient Test Data Processing