# Populations, Activity and Emissions of Diesel Nonroad Equipment in EPA Region 7

## Quality Assurance Project Plan
## Appendix N

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by
Eastern Research Group, Inc. (ERG)
EPA Contract No. EP-C-06-080

United States Environmental Protection Agency

EPA-420-R-12-009
July 2012

# Quality Assurance Project Plan

## Populations, Activity, and Emissions of Diesel Nonroad Equipment in EPA Region 7

## Revision 5

EPA contract #: EP-C-06-080
Work Assignment #: 0-1/1-1

Prepared for:

U.S. Environmental Protection Agency

Prepared by:

Eastern Research Group

August 6, 2008

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QAPP REVISION HISTORY
Original: December 8, 2006
Revision 1: March 2, 2007
Revision 2: May 21, 2007
Revision 3: August 20, 2007
Revision 4: September 25, 2007
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## A2. TABLE OF CONTENTS

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## A3. DISTRIBUTION LIST

The following individuals will receive a copy of the approved Quality Assurance Project Plan (QAPP), along with any subsequent revisions:

Rob Santos, Urban Institute
Atul Shah, Sensors, Inc.
William Crews, SRI
Sandeep Kishan, ERG
Tim DeFries, ERG
Michael Sabisch, ERG
Mia Zmud, NuStats
Constance Hart, EPA Project Officer and WAM
James Warila, EPA Alternate WAM

## A4. PROJECT/TASK ORGANIZATION

Sandeep Kishan has overall responsibility for this contract and Work Assignment (WA). He will serve as the primary point of contact to the EPA WAM and will oversee administrative requirements. He will also facilitate communications between EPA, ERG, and ERG subcontractors through meetings and monthly reports, and he will coordinate ERG technical assignments. Michael Sabisch will serve as the alternate Project Manager, and will be the point of contact for all project activities in Sandeep's absence. Michael will be responsible for updates and distribution of the project QAPP. Tim DeFries will serve as an independent QA evaluator; he will not have direct involvement with collection or evaluation of data, but will provide QC oversight to ensure compliance with ERG QA standards.

The leaders for each task of the WA are shown below. An overview of each of these tasks is provided in Section A.6:

Task 1 – Work Plan and Survey Design – Sandeep Kishan
Task 2 – Develop Draft QAPP – Michael Sabisch
Task 3 – Ownership Screening Survey and QAPP Revision - Mia Zmud
Task 4 – Emissions and Activity Measurements and QAPP Revision – Michael Sabisch
Task 5 – Data Processing and Submission – Michael Sabisch
Task 6 – Draft Report Preparation – Sandeep Kishan
Task 7 – Final Report Preparation – Sandeep Kishan

In addition to the task leaders listed above, other individuals will serve in key roles on the project. These include:

Rob Santos of the Urban Institute will lead development of the survey design plan (as outlined in the Work Plan), monitor progress and analyze results from the Establishment Sample and the Equipment Sample, and assist with reporting.

William Crews of the Southern Research Institute (SRI) will provide management of SRI personnel who assist with emissions and activity measurements to be performed in Task 4.

Dr. Atul Shah of Sensors, Inc. will provide management of Sensors' resources used in support of the emissions and activity measurements to be performed in Task 4. Dr. Shah will also be responsible for equipment to be provided as part of this study and will assist the ERG Team during the "System Integration" (equipment preparation) task to be conducted prior to the commencement of field activities (Task 4A).

Andrew Burnette of ERG has extensive experience in operating portable emissions measurement system (PEMS) units - the SEMTECH-G in particular - as well as instrumenting heavy-duty diesel equipment with activity monitors. Andrew assisted with training field personnel.

Dr. Tim DeFries will serve as an independent QA evaluator for this Work Assignment.

Table A4-1 presents contact information for key project personnel involved with this WA. Figure A4-1 shows group hierarchy and lines of communication among the various group members.

## Table A4-1: National PEMS Nonroad Testing Personnel Contact Information

| Company | Name | Phone | Email |
|---|---|---|---|
| USEPA<br>2000 Traverwood Dr.<br>Ann Arbor, Mi 48105 | Connie Hart | 734-214-4340 | Hart.Connie@epamail.epa.gov |
| | Robert Giannelli | 734-214-4790 | Giannelli.Bob@epamail.epa.gov |
| | Carl Fulper | 734-214-4400 | fulper.Carlr@epa.gov |
| | James Warila | 734-214-4951 | Warila.James@epamail.epa.gov |
| | John Koupal | 734-214-4942 | koupal.john@epamail.epa.gov |
| Southern Research Institute<br>Environment and Energy Department<br>3000 Aerial Center Pkwy, Ste 160<br>Morrisville, NC 27560 | William Crews | 919-806-3456, x 29 | de41@mindspring.com<br>crews@sri.org |
| | Tim Hansen | (919) 806-3456 (office) | hansen@sri.org |
| | Kevin Hicks | (919) 806-3456 | hicks@sri.org |
| | Sarah Fisher | (919) 806-3456 | fisher@sri.org |
| NuStats<br>3006 Bee Caves Road<br>Suite A-300<br>Austin, Tx 78746<br>Toll Free #: 800-275-2209<br>Fax – 512-306-9077 | Mia Zmud | 512-306-9065 x2224 | mia@nustats.com |
| | Grady Morris (contract mgr) | 512-306-9065 x2271 | gmorris@nustats.com |
| | Stacey Brika | 512-306-9065, x2240 | sbricka@nustats.com |
| | Sudeshna Sen | 512-306-9065 | ssen@nustats.com |
| | Chris Simek | 512-306-9065 | csimek@nustats.com |
| ERG/Franklin<br>4121 West 83rd St, Suite 108<br>Prairie Village, KS 66208 | Bill Franklin | 913-649-2225 x232 | wfranklin@fal.com |
| | Lori Snook | 913.649.2225 x0 | lsnook@fal.com |
| Sensors, Inc.<br>6812 S. State Road<br>Saline, Mi 48176 | Atul Shah | 734-429-2100, ext 204 | ashah@sensors-inc.com |
| | Carl Ensfield | 734-429-2100, ext 225 | censfield@sensors-inc.com |
| | | | |
| | | | |
| ERG<br><br>5608 Parkcrest Drive<br>Suite 100<br>Austin, Tx 78731 | Daryl Hudson | 571-215-9401 | Daryl.Hudson@erg.com |
| | Andy Loll | 703-633-1645 | Andrew.Loll@erg.com |
| | Alan Stanard | 512-689-1892 | alans.austin@gmail.com |
| | Sandeep Kishan | 512-407-1830 | Sandeep.kishan@erg.com |
| | Scott Fincher | 512-407-1826 | Scott.fincher@erg.com |

| Company | Name | Phone | Email |
|---|---|---|---|
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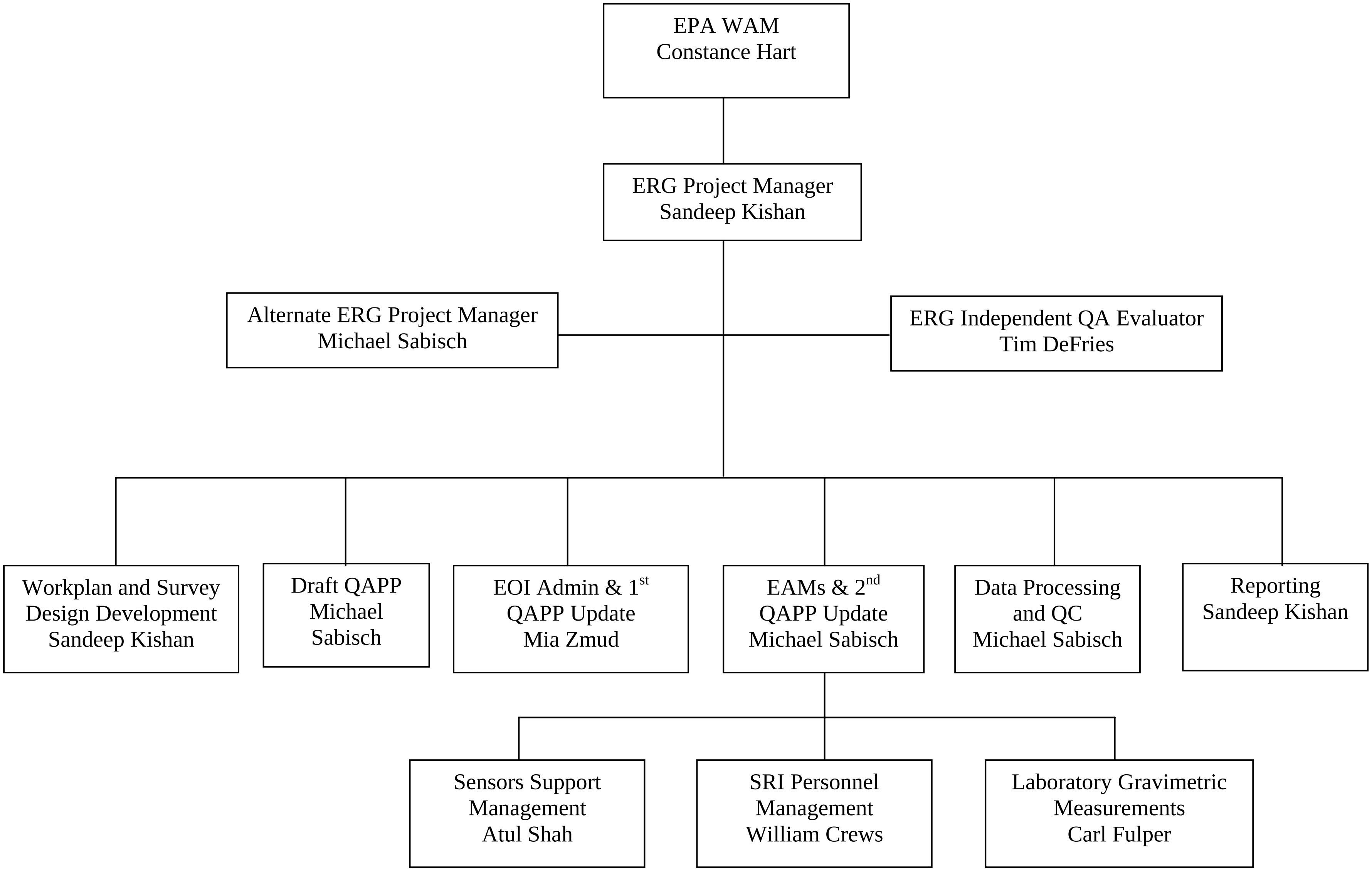
| | Gopi Manne | 916-548-8548 | Gopi.Manne@erg.com |
| The Urban Institute 2100 M Street, NW Washington, DC 20037 | Rob Santos | 202 261-5904 | rsantos@ui.urban.org |

**Figure A4-1: Region 7 Nonroad Personnel Organization Chart**



## A5. PROBLEM DEFINITION/BACKGROUND

As described in the original Work Assignment, nonroad equipment contribute substantially to mobile-source emissions, with their contribution in relative terms expected to increase as emissions from highway vehicles are controlled (Kean, Sawyer & Harley 2000). Based on estimates derived from diesel fuel sales published by the Energy Information Administration (EIA 2001) and estimates from the NONROAD model, fuel consumption in nonroad equipment accounts for 15-18% of all diesel fuel supplied to the U.S. market in 2000 (57.2 billion gallons), where "diesel" includes No. 1 and No. 2 distillates (excluding kerosene, jet fuel and fuel oils). In addition, the sector selected for inclusion in this survey (construction) is important in terms of diesel fuel consumption and emissions. In the same year, this sector accounted for approximately 20% of nonroad diesel fuel consumption, which corresponds to approximately 4% of all diesel fuel consumed by mobile sources (44.9 billion gallons) where mobile sources include highway vehicles, locomotives, marine vessels and nonroad equipment.

Generally, nonroad equipment includes vehicles powered by combustion engines, designed to perform a wide variety of tasks other than street or highway transportation. Thus, the term "nonroad equipment" covers a broad variety of machines including forklifts, crawler dozers, tractors, and excavators.

At the request of Congress, the National Academy of Sciences published a report on EPA's emissions inventory modeling for mobile sources (NRC 2000). A committee of technical experts was given the primary charge of conducting a detailed review of the MOBILE model, which estimates fleet average emission factors for motor vehicles. Nonetheless, the report bears mention in the context of nonroad equipment inventories because the committee also took the opportunity to make comments concerning EPA's inventory modeling for nonroad equipment. Under the heading of "Technical Issues Associated with the MOBILE Model," the committee remarked that

> *As future Tier 2 vehicle standards and corresponding sulfur-reduction regulations reduce on-road mobile-source emissions, non-road emissions will become a larger fraction of the total emissions. The NONROAD model is extremely data driven, and there are many gaps in the available data. EPA should place more emphasis on improving both the emissions factors and activity data in this model. (p. 74)*

In the executive summary, the committee emphasized the need for EPA to design and implement programs to expand and improve the data used to support emissions inventory estimation for nonroad equipment, and added that:

*The plan should include the population and activity data and real-world emissions factors for gasoline and diesel engines (p. 13).*

The recommendations in the NRC report have influenced the concept and design of EPA's new inventory model for highway vehicles, the Motor Vehicle Emissions Simulator (MOVES). Similarly, this Work Assignment is intended as the first step in a program to respond to recommendations concerning the quantity and representativeness of the data supporting inventory modeling for nonroad engines.

## A6. PROJECT/TASK DESCRIPTION

This Work Assignment is in support of the EPA's National Portable Emissions Measurement System (PEMS) Deployment contract, and is intended to serve as a research project designed to improve the methods and tools used to estimate emissions from nonroad equipment. This Work Assignment is a pilot study in which ERG and EPA will work together in order to integrate statistical sampling techniques, the latest in-use activity and emissions measurement technology, and rigorous quality assurance and quality control methods to characterize in-use, real-world emissions from 50 nonroad diesel engines. Prior to the fieldwork, establishments will be briefly interviewed regarding their equipment ownership and use.

During this pilot study, portable on-board instruments will be used to measure gaseous exhaust emissions, particulate exhaust emissions (composite and continuous) and usage of commercial nonroad diesel engines in the construction sector. Statistical sampling will be applied prior to and during fieldwork in order to randomize the recruitment and screening of participants and the selection of equipment to be instrumented.

Fieldwork for this study will be conducted in EPA Region 7 in the states of Iowa, Kansas and Missouri. Information gathered during the course of this study will be used to help refine methods and protocols for a larger-scale project to estimate the population, usage and emissions of nonroad equipment in various economic sectors. This data will be analyzed and quality assured and stored in OTAQ's Mobile Source Observation Database, where it may be used to help expand and improve the data currently used to support emission inventory modeling for nonroad engines.

A summary of the tasks to be performed in support of this Work Assignment follows. Additional details regarding each of these tasks may be found in the Work Plan developed for this study.

**Task 1: Work Plan and Survey Design**

A draft Work Plan was submitted to EPA October 11, 2006 for review, revision and approval. The survey design to be utilized for this study was developed as part of the Work Plan and is summarized in Section B.1, Sampling Process Design, of this QAPP. The final Work Plan, which addressed EPA's review comments, was submitted to EPA November 17, 2006.

**Task 2: Develop Draft QAPP**

This document is the project QAPP, developed in support of this task. This QAPP is intended to fulfill the requirements listed in Section 2.1 of the Work Assignment and conform to the EPA ANSI/ASQC E-4 standard. Standard Operating Procedures necessary for executing this Work Assignment are included as appendices to this document. This QAPP will be revised in both Tasks 3 and 4, as described below.

**Task 3: Ownership Screening Survey and QAPP Revision**

The primary objective of Task 3 is to administer Equipment Ownership Interviews (EOIs) to all study participants in both the Establishment and Equipment Samples (Appendix A). Several sub-tasks will be conducted in order to support this objective:

- Attempts will be made to secure study support from area trade associations,
- An advance mailing will be made to prospective respondents that contains a letter and brochure informing them about the survey and assuring study confidentiality. The purpose of the letter is to provide advance notice about study with the goal of increasing participation rates. In addition, incentives will also be offered to 50% of the eligible Equipment Sample at the conclusion of the EOI interview, in an effort to evaluate incentive influence on participation rate.
- Cognitive testing / structured interviews will be conducted in an effort to optimize the EOI wording and recruitment approach, with emphasis on the incentive test process.

Task 3 was intended to be conducted in two phases. In Phase I, only the first primary sampling unit (PSU) (Jackson, MO) of the Establishment Sample was sampled. Although the target was 100 completed Establishment Sample interviews, the high number of ineligible establishments reduced this to slightly over 60 completes. This is described in more detail in Section B1, Sampling Process Design. During this phase, slight modifications were made to the survey instrument, as described in Section 2.2.3.2 of the Work Plan, and this QAPP has been revised based on information learned during Phase 1. Pending the EPA approval of revisions of the revised QAPP, Phase II data collection will continue with the remaining establishments in the four original Establishment Sample PSUs (which include Linn, IA; Scott, IA; Clay, MO and Shawnee, KS). However, due to the higher than expected ineligibility rate seen in Phase 1, the decision was made to fully integrate the Phase II Establishment and Equipment samples into a single, unified design. This sample integration is defined in more detail in Section B1.

With the integrated sample approach, our next step will be to administer EOIs to the first Equipment Sample PSU as a preliminary step to conducting Task 4. These are the establishments in PSU 1 which have not yet been contacted. This will involve administering the same EOI questionnaire as was done for the Establishment Sample, as well as the 7 questions drawn from Appendix A.2 of the original Work Assignment. The questionnaire is presented in Appendix A. These 7 follow-up questions will serve as preliminary questions for the On-Site Equipment Inventory for establishments willing to participate in onsite inventories and emissions and activity measurements. These 7 questions will be administered during the initial phone contact with the Equipment Sample establishment, after the initial EOI has been completed. NuStats will forward contact information for Equipment Sample establishments willing to receive onsite inventories and equipment instrumentations (for emissions and activity measurements) to ERG for scheduling. The Equipment Sample EOIs for the remaining four Equipment Sample PSUs will be conducted during Task 4, prior to the on-site equipment inventories and instrumentation. Note that with the new integrated sample approach, the pool of establishments consists of both the prior Establishment Sample and Equipment Sample establishments, which increases the likelihood of procuring sufficient establishments in order to allow the team to acquire the target goals of 25 emissions measurements and 25 activity measurements (plus oversampling), as listed in the project Work Plan.

**Task 4: Emissions and Activity Measurements and QAPP Revision**

As with Task 3, this task will be performed in multiple phases in order to allow a refinement of task execution procedures. Phase 1 will be limited to one PSU where a target of 5 emissions and 5 activity measurements will be conducted (plus oversampling). Phases II and III of this task will consist of site inventories and equipment instrumentations necessary to achieve targets of 10 emissions and 10 activity measurements (per phase). As with Task 3, revisions to the QAPP will be made following Phase 1 in order to streamline processes based on experience gained during Phase 1. EPA review and approval of the revised QAPP will be required before commencing Phase II, and an EPA contract authorization will be requirement prior to conducting Phase III (Phase III is an optional task to the current Work Assignment).

To begin Task 4, information regarding establishments in the Equipment Sample who are willing to participate in the on-site inventory and instrumentation activities will be forwarded from NuStats to the ERG team for scheduling. ERG will schedule an appointment with the site contact for an on-site inventory and selection of equipment for instrumentation (items 8 through 11 of Appendix A.2 of the Work Assignment, included as Appendix B of this document). Site inventories will be conducted early in each phase of this task, followed by installation of the activity monitors (site inventories will commence prior to but continue during activity monitor installations). After all activity monitors have been installed, emissions measurements will be initiated and will continue until the required number of valid measurements have been acquired. After one month (approximately 4 weeks) the activity measurement equipment will be removed from the equipment. Activity measurement devices will be monitored during this one-month measurement period to ensure the monitoring and data recording equipment is operating properly. Preliminary review of emissions data will be performed throughout this task to ensure data quality. Interim review of activity data (during the month-long sampling period) will be performed, if possible.

A Web-based field management system will be used for scheduling and tracking field activities. Data from this system will also be used in developing monthly project status reports for the EPA. The Web-based system will allow in-field technical staff to receive their interview, inventory, or instrumentation assignments, and report the status of assignment disposition (i.e., completed, in-progress, or rescheduled). The system will be managed by ERG and the NuStats Data Collection Task Manager and will be used by both NuStats and the ERG team for monitoring the field activities, posting daily assignments, and tracking the field inventory and equipment instrumentation status. The NuStats Data Manager will provide summary reports for the ERG team and Project Director and the EPA Work Assignment Manager.

After NuStats posts information regarding Equipment Sample establishments willing to participate in the study to field management system, ERG personnel will schedule an on-site interview. The ERG team will schedule an interview with appropriate personnel at the establishment site, and personnel in ERG’s Kansas City office will attempt to confirm all inventory appointments by telephone prior to the day of the appointment. Once on-site, ERG personnel will gather equipment inventory information as specified in Appendix A-2 of the Work Assignment and included in Appendices B (onsite questionnaire) and C (onsite inventory) of this document.

ERG's Kansas City office, Franklin Associates, will provide local support to the project. Personnel from this office will assist with project coordination, scheduling and confirming site visits, finding appropriate site contacts, assisting with lodging and travel accommodations, and assisting with shipping and receiving equipment and materials for the project, such as FID and calibration gases, PEMS repair and maintenance parts, equipment requiring repair, etc. NuStats will track overall EOI and emission and activity measurement status, and task-level managers will regularly communicate progress to NuStats using the field management system. ERG's Project Manager, or an assigned Task Leader, as appropriate, will perform Independent tracking of special issues.

After the on-site inventory has been performed, the equipment to be instrumented will be selected as described in the "Equipment Sampling Per Site" subsection in Section 2.2.1.5, "Sampling Methods" of the project Work Plan. Equipment sampling will not exceed four pieces of equipment per establishment (two emissions and two activity). Following equipment piece selection, the onsite inventory personnel will administer questions 8 through 11 of the "Onsite Equipment Inventory" (included in Appendix B of this document) to the site contact, at which time permission to instrument the specific pieces of equipment will be sought, and the site contact will also be asked about annual and monthly usage of the equipment, as well as the anticipated usage during the measurement period. If the site contact indicates the equipment will not be used or is scheduled for maintenance or repairs during the anticipated measurement period, an alternate piece of equipment will be selected for instrumentation. Information on all equipment selected for instrumentation will be logged, even if the permission is not obtained for testing or if the equipment is found to be ineligible during the measurement period. As with the equipment ownership questionnaire, the draft version of the on-site equipment inventory questionnaire included in Appendix B will be reviewed and revised through the course of this study. EPA approval will be required for any questionnaire changes.

To optimize the emissions and activity measurement task, all portable activity measurement system (PAMS) installations will be completed prior to the commencement of PEMS testing. Three to four-person teams will perform the emissions and activity measurements (most likely two Sensors people and one SRI or ERG person), with a fourth person (an ERG person) providing fieldwork management, testing oversight and on-site data analysis QC support. Staffing scenarios (ERG/Sensors/SRI) may vary from this plan depending on availability of appropriate staff and fieldwork logistics.

In order to avoid interference with normal work schedules, Instrumentation Teams will attempt to perform installations during facility non-working hours. However, depending on policies at establishments where testing is occurring, “off-hour” access may not always be granted. We anticipate 50 to 60 hour work-weeks will be required, in addition to travel time.

Fieldwork duration schedules are shown in Figures A6-1 and A6-2. Counties to be sampled are shown in Figure A6-3.

**Figure A6-1: Phase 1 Field Schedule**

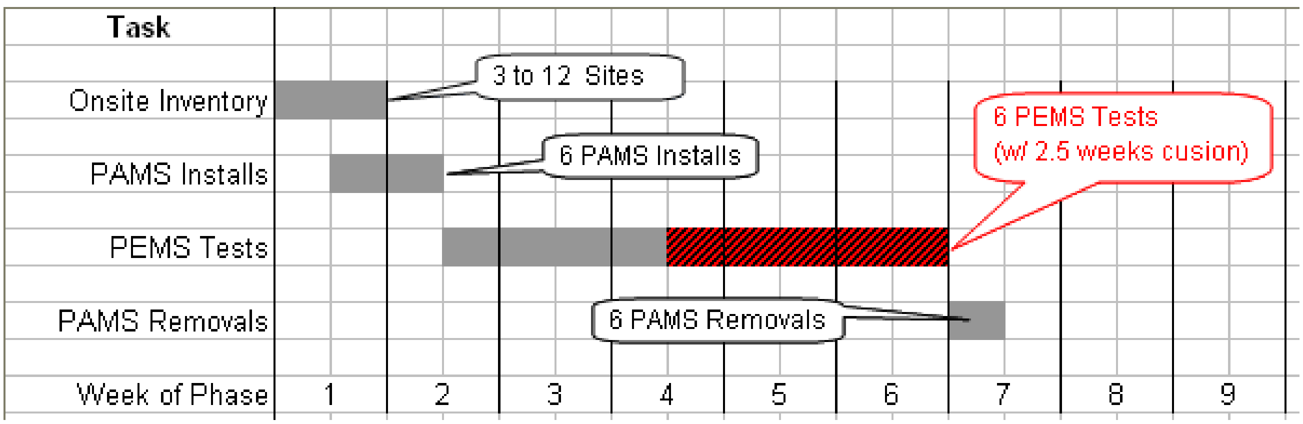
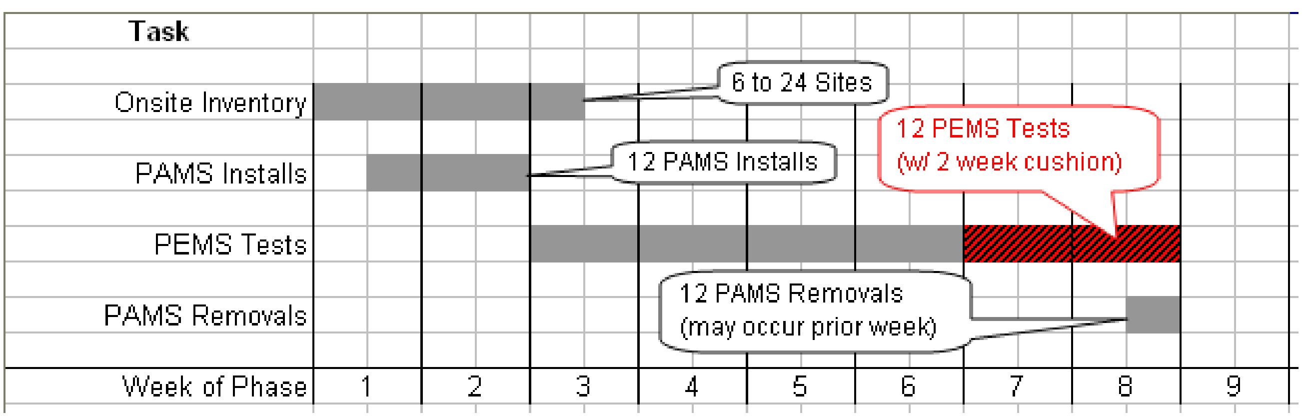
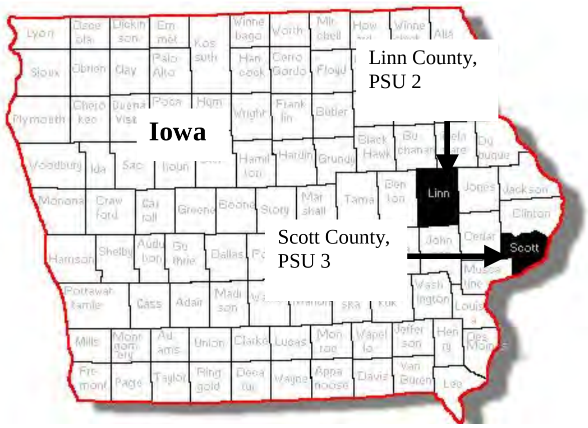


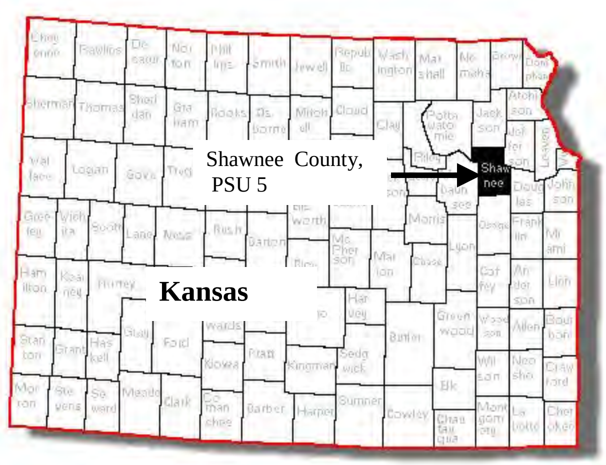

**Figure A6-2: Field Schedule for Phases 2 and 3 (each)**



## Figure A6-3: Iowa, Missouri, and Kansas Counties to be Sampled







**Task 5: Data Processing and Submission**

For this task, all data files (excluding cQCM data) will be processed, QC-screened, and submitted to EPA in an MSOD-compatible format. Raw data files (unprocessed) as well as survey instruments and inventory results will also be provided to the EPA. Processed PEMS and PAMS data will be evaluated in an effort to identify erroneous measurements. All potentially anomalous results will be identified, but the raw (uncorrected) data will be retained. If collected, raw data files from the EPA's cQCM will be provided to EPA for processing, analysis, and QC.

**Task 6: Draft Report Preparation**

In the draft report, ERG will document all statistical methods and steps used to draw second-stage establishment samples from sample frames in each PSU. Recruitment efforts will be summarized by PSU, by establishment size class and by outcome code. The draft report will also include a summary of results for emissions and activity measurements and an overview of testing activities, such as a description of equipment installation and operation procedures, problems, resolutions and lessons learned. All quality assurance checks applied to the data will also be described.

**Task 7: Final Report Preparation**

Revisions to the draft report based on EPA comments will be included in the final report to be submitted in support of this Work Assignment.

A project schedule listing, including start and end dates for each task of this Work Assignment, is provided in Section 3.0 of the Work Plan.

# A7. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

## A7-1. Overall Scope and Objectives of Work Assignment

As defined in the original Work Assignment, this study is a pilot effort designed to inform development of methods and protocols for a larger-scale project designed to estimate the population, usage and emissions of nonroad equipment. The pilot will answer specific research questions, including:

- What fraction of establishments in the targeted economic sector use diesel nonroad equipment? Estimates of this parameter will inform estimation of the numbers of establishments in each sector to be drawn to obtain desired samples of eligible engines.
- What proportion of establishments in the targeted sectors employed at least one person on a part-time or full-time basis during the previous twelve months? This objective contributes to establishment frame development by estimating proportions of establishments in the frame that are not members of the target population.
- Can selection of counties and establishments on the basis of probability proportional to size (PPS) effectively reduce differences in sampling probabilities between individual engines?
- Across establishments, how does the number of persons employed correlate with the number of equipment pieces used?
- What are variances in key variables? Pilot results will inform sample size estimation for subsequent data collection efforts.
- What is the average number of diesel engines used per establishment? How variable is this parameter?
- Are regulatory Tier and engine size meaningful stratification variables for emission rates for diesel engines?
- What proportion of equipment operation takes place during a five-day Monday-Friday work week?
- What level of effort and expense is required to successfully measure gaseous, composite PM, and continuous PM emissions and usage of heavy nonroad equipment during normal operation? Field testing of portable emissions and activity measurement systems (PEMS and PAMS) will inform the development of measurement methods and protocols, and the estimation of cost for future projects.

Variables to be surveyed or measured throughout this Work Assignment include:

- Equipment Use Fraction: The fraction of establishments that use nonroad equipment, where “use” means “own, rent, or lease.” Only establishments that use equipment are eligible respondents for emissions or activity measurement, but eligibility cannot be determined in advance from the sample frame.

- Equipment Density: This variable is defined as the average number of diesel engines per establishment. Density can be multiplied by numbers of establishments to estimate equipment populations at local or regional scales.

- Equipment Activity: This variable represents equipment usage, expressed in terms of operating time per reference period (e.g., hours/week, hours/month, hour/year).

- Emission Rates: This variable represents exhaust or “tailpipe” emissions, expressed in terms of mass rates (g/sec, g/hr), or normalized to fuel consumption (g/gal, g/kg). Emissions will be measured for the following exhaust constituents:

    Carbon dioxide ($CO_2$),
    Oxides of nitrogen ($NO_x$),
    Carbon monoxide (CO),
    Total hydrocarbon (THC),
    Composite particulate matter (PM) (gravimetrically measured)
    Continuous particulate matter (via Quartz Crystal Microbalance)

The following tasks are designed to meet the objectives of this Work Assignment.

## A7-2. Survey Design and Execution:

Detailed procedures for drawing the establishment and equipment samples in order to meet the sampling objectives outlined in the Work Assignment are provided in the Work Plan.

Questionnaires are designed with the following in mind: the statistical requirements of the project, the administrative requirements of data collection organization, the requirements for data processing (e.g., pre-specified acceptable range limits for relevant items, pre-coded open-ended responses, etc.) and the nature and characteristics of the respondent population, including eligibility requirements. Good questionnaires impose low respondent burden while remaining both respondent and interviewer-friendly. Survey design will maximize the efficiency of data collection, with a minimum number of errors, while facilitating the coding and capture of data and minimizing the amount of editing and imputation that is required.

NuStats will review the study instruments, the “Equipment Ownership Questionnaire” and the “On-site Equipment Inventory” (Appendices A and B) for the following:

- Introduction. NuStats will ensure the introductions introduce the subject of the research project, identify the U.S. Environmental Protection Agency (EPA) as the authority on whose behalf the project has been undertaken, explain the purpose, request the respondent's cooperation, explain how the research data will be used, and describe what confidentiality protection will be afforded.

- Screening Questions. The opening questions will be applicable to all respondents, easy and interesting to complete, and establish that the respondent is a member of the target population. In the case of the Equipment Sample, we will add a question to ensure the respondent is a "prime contractor."

- Core Questions. In reviewing the core questions, NuStats anticipates pre-coding appropriate open-ended responses to streamline the interviewing and post-data cleaning processes and review the criteria for allowable responses for each question.

- Concluding Question. NuStats will add a concluding question to assess participation levels for the Equipment Sample EOI and Measurement portion of the study.

Once revised, the study instrument(s) will be tested and evaluated prior to being finalized and used for data collection.

- For Phase I of the Establishment Sample Equipment Ownership Interview (EOI), this entails conducting in-house tests of the computer assisted telephone interview (CATI) program prior to interviewer training and prior to conducting Phase I of the study. During interviewer training, NuStats will observe mock interviews (e.g., dummy interviews using "fake" respondents) and provide feedback to each interviewer.

- During the Phase I interviews, NuStats will conduct cognitive testing of the instrument. Cognitive testing is an evaluation of the survey instrument involving one-on-one structure interviews. The testing objectives are often related to the question-answering process of potentially complex questions and to assess the adequacy of the questionnaire flow. In this case, because we are conducting the cognitive testing during the Phase I interviews, some question flow and wording adjustments may be made based on the Phase I interviewing experience. Conducting the cognitive testing during the Phase I interviews allows us to collect more meaningful insights on the survey from the perspective of respondents who had recently completed it (versus conducting the survey during the cognitive test interview) and probe on their actual responses. As such, our focus will be to conduct interviews with the person who completed the telephone interview. We will probe on issues such as the correlation of number of employees and equipment size, likeliness to participate in the Equipment Sample EOI (and whether the use of EPA letterhead and/or trade association support would contribute positively to their decision-making) and ascertain an incentive amount that would be deemed effective in the Equipment Sample EOI (with the understanding that our incentive disbursements fall under OMB guidelines). As described in Section 2.2.1.3 of the workplan, an incentive test will be employed during the EOI to assess the effectiveness of a monetary incentive in improving response. An experiment will be conducted in which an incentive will be offered to half of eligible respondents and no incentive will be offered to the other half.

Establishments to which an incentive has been offered will be “flagged” in the database according to their incentive test assignment.

- For each subsequent phase of the study, a “pretest” will be conducted for each data collection effort as part of interviewer training. This pretest will serve as a “dress rehearsal” to assess how all the survey operations, including CATI programming, sample database, and interviewers work together in practice.

As part of the questionnaire development sequence of activities, NuStats will construct a data matrix that captures all of the data elements/variables (questions), response options, and any requisite quality assurance/quality control instructions for coding and/or processing data. This ensures the database table and nomenclature is consistent with that specified in Appendix B (proposed data tables and formats) of the Work Assignment (included in Appendix H of this document). This effort also establishes the database structure and ensures final database construction captures relevant data. Doing so provides assurance in data quality and provides a tool for monitoring for and correcting response patterns during data collection. Response patterns of two types are monitored under these QA guidelines. Item response pertains to the number of data items answered by a respondent; unit response pertains to the number of sampled units that responded at all to the survey. Businesses will be considered non-responders if they do not complete all questions except for the optional final concluding question.

Regarding execution of the survey, NuStats and Eastern Research Group will share in its administration:

- NuStats will conduct the entire Establishment Sample EOI for all phases of the study.
- For the Equipment Sample, NuStats will conduct the EOI interview and the first seven questions of the on-site inventory (Appendix A) and ERG’s field inventory teams will conduct the last four questions at the site (Appendix B) and perform the selection of equipment to be instrumented (Appendix C).

NuStats will continuously track the performance of the sample and data quality during telephone and on-site data collection. NuStats has a fully documented and proven management system for research surveys. This system is not a pre-packaged, one-size-fits-all approach. It is a customized “toolbox” of software applications, quality control procedures, CATI programs, well-tested measures for achieving high participation rates, geocoding techniques, and a diagnostic and reporting process that anticipates difficulties prior to their becoming serious problems. This integrated and proprietary “Continuous Data Flow” System (CDF) leads to a flow of data that is collected and delivered to clients faster, cleaner, and cheaper. CDF works throughout the entire project, covering all phases from sample-generation, to interviewing, data processing, edit checking and data delivery. The "sample number" (or unique identifier) that is attached to each establishment when it is generated is essential to managing and tracking the survey progress.

### A7-3. Respondent and Participant Confidentiality

As defined in the Work plan for this Work Assignment, the following pledge of confidentiality will be included in the initial mailout to all potential responding establishments:

> *"The information your establishment provides will be used for statistical purposes only. In accordance with the Confidential Information Protection provisions of Title 5, Subtitle A, Public Law 107-347 and other applicable Federal laws your responses will be kept confidential and will not be disclosed in identifiable form to anyone other than employees or agents without your consent. By law, every EPA employee as well as every agent, such as interviewers and technicians, is subject to a jail term, a fine or both if he or she discloses ANY identifiable information about your establishment."*

The ERG Team will not disclose any study results, whether obtained through survey instruments or measurement instruments, to any person other than the EPA Work Assignment Manager. In addition, no identifying information that could allow the identification of any participating establishment will be disclosed to any person other than the EPA Work Assignment Manager. All members of the ERG team (ERG and subcontractor staff) will be bound by signed confidentiality agreements. The ERG team (ERG and subcontractor staff) will also prevent the disclosure of any publicly available information that might allow identification of an establishment as a respondent to this study, to any person other than the EPA Work Assignment Manager. Training will be provided to all personnel regarding obligations of and responsibilities for participant confidentiality.

NuStats and its team members, who will be conducting the EOIs, observe strict practices to ensure and protect respondent confidentiality. The team members adhere to practices advocated by the Council of American Survey Research Organizations and the American Association of Public Opinion Research. All interviewers sign a confidentiality statement as part of their employment contract. Steps to protect respondent confidentiality include:

- All project staff are given explicit training in the need to uphold confidentiality protocols and commitments. We train staff in reasons why this is such an important responsibility.
- A unique number in the survey response database identifies each study participant so that names are not associated with responses to questions. Moreover, the data file containing the link between name and ID number will be stored separately from the data files containing question responses. Telephone numbers will be purged from the data file and

replaced with case identification numbers after interviewing and data processing have been completed.

- All confidential information will be stored in password-protected files by the holders of this information. Analytic files contain neither names, addresses, nor telephone numbers.
- During data collection and processing, access to all data files will be carefully controlled and restricted internally through a system of passwords. These files are not accessible through Internet routes.
- Only a minimal amount of respondent-identifiable information is kept in the data files that are delivered to team members.

To maintain confidentiality and maximize respondent cooperation, all EOI survey respondents will be assured that their survey answers will remain confidential and that no personal information that they give will be individually identified with them.

All study results collected for this study will be stored in a secure manner. Unique identification codes will be used to mask establishments, and release of establishment information will be limited to those team members who require the information to fulfill their obligations. All electronic data collected for the study will be securely stored and password protected, and hardcopy information will be also be securely stored in a locked cabinet. All data transmission will be via a secure method, such as a password-protected FTP site dedicated exclusively to this project. Access to this site will be limited to those team members who require access in order to complete their tasks (as well as the EPA WAM).

## A7-4. Field Measurements:

The ERG team will examine data files acquired from the PEMS and PAMS units on a daily basis (as available) to verify data quality and to identify any issues requiring immediate attention. In addition, ERG will deliver data files containing emissions and activity measurements to the EPA WAM on an on-going, as-acquired basis. This includes a timely delivery of gravimetric PM filter data. Raw continuous PM data will be provided directly to EPA for processing and analysis. All electronic data files will be transferred by a secure method such as secure file-transfer protocol. If any issues or concerns about data quality occur, ERG will immediately bring these to the attention of the EPA WAM. Additional information on onsite inventory team leader responsibilities and onsite installation manager duties are presented in Appendices J and K, respectively.

### A7-4a. Gaseous Emissions Measurements

SEMTECH-DS PEMS, manufactured by Sensors, Inc. and provided by EPA, will be used for all gaseous emissions measurements to be performed for this study. The SEMTECH-DS is a fully integrated in-use emissions analyzer designed for real-time emissions testing of all classes of vehicles and equipment under real-world operating conditions. The data acquisition and control software is composed of a graphical user interface based on Labview. In addition, there is imbedded C code on the microprocessor chips in the instrumentation which do signal processing and control of the actual devices (valves, pressure transducers, etc.). which make up the different units. The microprocessors use a CAN communication protocol. The Labview code is on the computer and talks to the microprocessors via CAN to RS232 (serial) converter.

Emissions from any engine type (depending on the model) may be measured at the tailpipe, engine-out, or at any stage of after-treatment, and the SEMTECH-DS also records the output of a vehicle's on-board electronic control system, if so equipped, as well as ambient conditions. This system is fully 40 CFR Part 1065 compliant. The SEMTECH-DS meets combustion engine (CE) compliance specifications, ensuring that the system is not susceptible to electromagnetic or radio frequency interference, and that it will not interfere with the equipment's electrical or electronic systems.

During factory calibration of the SEMTECH, interferences among different species of gases are accounted for so that the instrument is in compliance with 40 CFR Part 1065. For example, the interference of $CO_2$ on CO is built into the factory calibration. Interference from $H_20$ on the NDIR and NDUV readings are eliminated by the thermo-electric chiller, which removes the water vapor to low levels.

Field calibrations of the SEMTECH will be performed with NIST-traceable 40 CFR Part 1065-compliant gases. Zeroing of gas analyzers will be performed automatically using the AutoZero feature of the SEMTECH-DS. Zeroing will occur after each hour of testing, using ambient air. The ambient air is first filtered with a carbon filter to remove contaminants.

The SensorTech host software provided with the SEMTECH-DS is designed to provide feedback to the user. There are over 150 different fault codes that the SEMTECH will automatically report to the user and store in the test record if a problem occurs. These quality assurance (QA) checks include the EFM exhaust flowmeter as well as the SEMTECH-DS analyzer. In addition, there are 24 warning codes that will also automatically be reported and stored in the test record when potential problems exist. These warning codes indicate to the user when to change filters, when to change the flame ionization detector (FID) fuel bottle, when to zero the instrument, etc.

Special software was prepared for this study so that the SEMTECH-DS data logger records all data from each test, including data from the MPS and Gravimetric filter system. Those devices transmit their data through a CAN network. A CAN to Serial converter sends the data to the SEMTECH-DS for real-time monitoring and recording. The SensorTech-PC software, which normally controls only the SEMTECH-DS, was also modified to allow certain controls over the MPS and Gravimetric filter system. This includes Zeroing of the MPS pressures sensors, and also switching of the gravimetric filter positions. This is extremely useful, because the SensorTech-PC software communicates wirelessly to the system, and operators do not have to stop the vehicle to perform these functions.

Tables A7-1 through A7-5 list specifications of the various gaseous and environmental measurement systems provided with the SEMTECH-DS. Data from all devices is transmitted at a 2 hz data rate, with the exception of the CO2/CO analyzer which is limited to 0.8 Hz.

## Table A7-1: Total Hydrocarbon Heated FID Specifications

| Range | 0 – 100 ppmC | 0 – 1,000 ppmC | 0 – 10.000 ppmC | 0 – 40,000 ppmC |
|---|---|---|---|---|
| **Accuracy** | ±2.0 % of reading or ±5 ppmC, whichever is greater | ±2.0 % of reading or ±5 ppmC, whichever is greater | ±2.0 % of reading or ±25 ppmC, whichever is greater | ±2.0 % of reading or ±100 ppmC, whichever is greater |
| **Resolution** | 0.1 ppmC | 1.0 ppmC | 1.0 ppmC | 10.0 ppmC |
| **Linearity** | Intercept < 0.5 % of range.<br>0.990 < Slope < 1.01<br>SEE < 1.0 % of range<br>$r^2 > 0.998$ | | | |
| **Repeatability** | ±1.0 % of reading or ±2 ppmC, whichever is greater | ±1.0 % of reading or ±2 ppmC, whichever is greater | ±1.0 % of reading or ±10 ppmC, whichever is greater | ±1.0 % of reading or ±40 ppmC, whichever is greater |
| **Noise** | ±2 ppmC | ±2 ppmC | ±10 ppmC | ±40 ppmC |
| **Span drift (over 8 hours)** | ±1.0 % of reading or 3 ppmC, whichever is greater | ±1.0 % of reading or 3 ppmC, whichever is greater | ±1.0 % of reading or 15 ppmC, whichever is greater | ±1.0 % of reading or 60 ppmC, whichever is greater |
| **Zero drift (over 2 hours)** | ±5 ppmC | ±5 ppmC | ±10 ppmC | ±20 ppmC |
| **Response time** | T90 < 2 seconds | T90 < 2 seconds | T90 < 2 seconds | T90 < 2 seconds |
| **Flow rate** | 2 lpm | 2 lpm | 2 lpm | 2 lpm |
| **Data rate** | Up to 4 Hz, configurable | Up to 4 Hz, configurable | Up to 4 Hz, configurable | Up to 4 Hz, configurable |
| **Operating temperature** | 191 °C | 191 °C | 191 °C | 191 °C |

## Table A7-2: NDIR CO, CO2 and HC Specifications

| Gas | CO | CO2 |
|---|---|---|
| **Range of measurement** | 0 – 8 % | 0 – 20 % |
| **Accuracy** | ±3 % of reading or 50 ppm, whichever is greater | ±3 % of reading or ±0.1%, whichever is greater |
| **Resolution** | 10 ppm | 0.01% |
| **Linearity** | Intercept < 0.5 % of range.<br>0.990 < Slope < 1.01<br>SEE < 1.0 % of range<br>$r^2 > 0.998$ | |
| **Repeatability** | ±2 % of reading or 20 ppm, whichever is greater | ±2 % of reading or ±0.05 %, whichever is greater |
| **Noise** | ±20 ppm | ±0.02% |
| **Span drift (over 8 hours)** | ±2 % of reading or 20 ppm, whichever is greater | ±2 % of reading or 0.1 %, whichever is greater |
| **Zero drift (over 2 hours)** | ±0.005 % (50 ppm) | ±0.1 % |
| **Response time** | T90 < 3 seconds | T90 < 3 seconds |
| **Data rate** | 0.833 Hz | 0.833 Hz |
| **Flow rate** | 2 - 4 lpm | 2 - 4 lpm |

## Table A7-3: NDUV NO and NO2 Specifications

| Gas | NO | NO2 |
|---|---|---|
| **Range of measurement** | 0 to 2,500 ppm | 0 to 500 ppm |
| **Accuracy** | ±3 % of reading or 15 ppm, whichever is greater | ±3 % of reading or 10 ppm, whichever is greater |
| **Resolution** | 1 ppm | 1 ppm |
| **Linearity** | Intercept < 0.5 % of range.<br>0.990 < Slope < 1.01<br>SEE < 1.0 % of range<br>$r^2 > 0.998$ | |
| **Repeatability** | ±2 % of reading or 5 ppm, whichever is greater | ±2 % of reading or 5 ppm, whichever is greater |
| **Noise** | ±2 ppm | ±2 ppm |
| **Span drift (over 8 hours)** | ±2 % of reading or 20 ppm, whichever is greater | ±10 ppm |
| **Zero drift (over 2 hours)** | ±10 ppm | ±10 ppm |
| **Response time** | T90 < 2 seconds | T90 < 2 seconds |
| **Data Rate** | Up to 4 Hz, configurable | Up to 4 Hz, configurable |
| **Flow rate** | 3 lpm | 3 lpm |

## Table A7-4: Oxygen Sensor Specifications

| | |
|---|---|
| **Range of measurement** | 0 to 25 % |
| **Accuracy** | ±1 % oxygen |
| **Resolution** | 0.1 % |
| **Linearity** | ±0.5 % of reading or ±0.5 %, whichever is greater |
| **Repeatability** | ±0.25 % of reading or ±0.3 % oxygen, whichever is greater |
| **Noise** | ±0. l % oxygen |
| **Span drift** | ±1.0 % of reading or ±0.5 % oxygen, whichever is greater |
| **Response time** | T90 < 6 seconds |
| **Flow rate** | 0.5 to 3 lpm |

### Table A7-5: Weather Probe and Ambient Pressure Specifications

| Sensor | Temperature | Relative Humidity | Ambient Pressure |
|---|---|---|---|
| **Range of measurement** | -39 °C to 60 °C | 0.8% to 100% RH | 15 to 115 kPa |
| **Accuracy** | ±0.2 °C | ±2% RH at 0 to 90% RH<br>±3% RH at 90 to 100% RH | ±1.5% 0 to 85 °C |
| **Response time** | | T90 < 10 seconds at 20 °C | T90 < 4 seconds |

## A7-4b. Exhaust Flow Measurements

The SEMTECH Exhaust Flow Meter (EFM) to be provided by EPA will be used in conjunction with the SEMTECH-DS mobile emission analyzers for continuous, direct measurement of exhaust for emissions measurements for this Work Assignment. The SEMTECH EFM is a pressure differential device that operates under the Bernoulli principle. The SEMTECH EFM provides greater accuracy over a wider dynamic range than traditional instruments based on similar technology through the use of four differential pressure transducers, each designated for different portions of the total flow range.

An automatic zero calibration feature in the SEMTECH EFM enables pressure transducers to perform a zero calibration every 2 minutes during testing, without loss of data. This is achieved by alternately zero calibrating two of the four pressure sensors every 60 seconds. This feature eliminates any drift from the pressure sensors during the test event due to changing environmental conditions, which is extremely important for low flow accuracy.

The SEMTECH EFM utilizes a proprietary device to dampen pressure pulsations while maintaining a response time of 1 second, resulting in much more stable readings, even at low flow rates. Also, a purge function allows the user to back-purge the pressure lines before and after each test. This will ensure that the sample ports and pressure lines remain clear. A dry, compressed air source will be used for line purging. Table A7-6 lists specifications of the SEMTECH EFM.

### Table A7-6: SEMTECH EFM Specifications

| **Flow Tube Outer Diameter** | **2 inches 51 mm** | **2 ½ inches 64 mm** | **3 inches 76 mm** | **4 inches 102 mm** | **5 inches 127 mm** |
|---|---|---|---|---|---|
| Recommended vehicle application | Light-Duty Gasoline < 2 liters<br>Light-Duty Diesel < 1.5 liters | Light-Duty Gasoline 2 to 5 liters<br>Light-Duty Diesel 1.5 to 4 liters | Light-Duty Gasoline > 5 liters<br>Light-Duty Diesel 4 to 6 liters | Heavy-Duty Diesel 6 to 12 liters | Heavy-Duty Diesel 12 to 18 liters |
| Flow rate[1] at back-pressure of 10 inches $H_2O$ (24.91 mbar) | 175 SCFM<br>4.96 $m^3$/min | 425 SCFM<br>12.0 $m^3$/min | 600 SCFM<br>17.0 $m^3$/min | 1,100 SCFM<br>31.2 $m^3$/min | 1,700 SCFM<br>48.1 $m^3$/min |
| Flow rate[1] at back-pressure of 15 inches $H_2O$ (37.36 mbar) | 215 SCFM<br>6.09 $m^3$/min | 550 SCFM<br>15.6 $m^3$/min | 775 SCFM<br>22.0 $m^3$/min | 1,350 SCFM<br>38.2 $m^3$/min | 2,100 SCFM<br>59.5 $m^3$/min |
| Exhaust temperature upper limit[2] | 1292 °F<br>700 °C | 1292 °F<br>700 °C | 1292 °F<br>700 °C | 1292 °F<br>700 °C | 1292 °F<br>700 °C |
| Exhaust temperature accuracy | ±1 % of reading or ±2 °C, whichever is greater | ±1 % of reading or ±2 °C, whichever is greater | ±1 % of reading or ±2 °C, whichever is greater | ±1 % of reading or ±2 °C, whichever is greater | ±1 % of reading or ±2 °C, whichever is greater |
| Flow measurement linearity[3] | < 1.0 % full scale | < 1.0 % full scale | < 1.0 % full scale | < 1.0 % full scale | < 1.0 % full scale |
| Flow measurement accuracy[3] | ±2.5 % of reading, or ±1.5 % of full scale, whichever is greater | ±2.5 % of reading, or ±1.5 % of full scale, whichever is greater | ±2.5 % of reading, or ±1.5 % of full scale, whichever is greater | ±2.5 % of reading, or ±1.5 % of full scale, whichever is greater | ±2.5 % of reading, or ±1.5 % of full scale, whichever is greater |
| Warm-up time[4] | 15 minutes | 15 minutes | 15 minutes | 15 minutes | 15 minutes |
| Response time | $T_{90}$ < 1 s | $T_{90}$ < 1 s | $T_{90}$ < 1 s | $T_{90}$ < 1 s | $T_{90}$ < 1 s |
| Data rate | 1 – 4 Hz | 1 – 4 Hz | 1 – 4 Hz | 1 – 4 Hz | 1 – 4 Hz |
| Power requirements | 12 $V_{DC}$, 50 W | 12 $V_{DC}$, 50 W | 12 $V_{DC}$, 50 W | 12 $V_{DC}$, 50 W | 12 $V_{DC}$, 50 W |
| Communications | RS-232, CAN | RS-232, CAN | RS-232, CAN | RS-232, CAN | RS-232, CAN |
| Flow tube length | 18 in<br>457 mm | 22.5 in<br>572 mm | 27 in<br>686 mm | 28 in<br>711 mm | 35 in<br>889 mm |
| Flow tube weight | 3.2 lbs<br>1.5 kg | 4.5 lbs<br>2.0 kg | 5.9 lbs<br>2.7 kg | 7.0 lbs<br>3.2 kg | 12.2 lbs<br>5.5 kg |

### A7-4c. On-board Dilution Sampler

In addition to measurement of gaseous pollutants, vehicle and environmental parameters, gravimetric particulate matter (PM) measurements will be collected for this Work Assignment. In order to accomplish this, EPA will provide a portable dilution sampler, the SEMTECH Micro-Proportional Sampler (MPS), for use during this study. The MPS extracts a sample from the raw exhaust at a rate proportional to the overall exhaust mass flowrate, and also dilutes the sample with a pre-determined minimum dilution ratio (typically 5 – 8). The diluted, proportional exhaust is supplied to the gravimetric filters for PM measurement.

The MPS is capable of proportional sampling and dilution of exhaust from any Tier 0, Tier 1, and Tier 2 vehicles, with or without particulate traps. Daily cleaning of the primary sample capillary is required for high PM emitting vehicles however. This is achieved by simply removing the capillary and backflowing with compressed air. Subsequent flow calibration of the capillary is standard operating procedure.

The SEMTECH MPS, manufactured by Sensors' Inc, conforms to the specifications listed in Table A7-7.

**Table A7-7: SEMTECH MPS System Specifications**

| SEMTECH MPS System | Specifications |
|---|---|
| **Accuracy** | < 3% |
| **Response time** | 70 – 100 ms ($T_{90}$) |
| Total Flowrate | 12.5 slpm (as setup for this study) |
| Major Dilution Flow range | 0 - 12 slpm |
| Minor Dilution Flow range | 0 – 5 slpm |
| Sample Flow range | 0 – 3 slpm |
| Minimum Dilution Ratio | User configurable. Typically 5 – 8 for optimal performance |
| Proportionality | SEE < 3.5% of Mean for loaded test conditions typical of NTE operation. |
| **Dimensions** | 35cm x 15cm x 10cm (enclosure only) |
| **Weight** | < 5kg |
| **Operating temperature** | Up to 45˚C (please see Section VI.B.4.2 for lower temp operating limit) |
| **Operating humidity** | 0 to 95% RH, non-condensing |
| **Power input** | 9-15 VDC |
| **Communication** | RS 232 with PC, CAN 2.0b network to other Sensors products |
| **Software** | Labview® platform |

### A7-4d. Gravimetric PM

EPA will provide a three-stage 47-mm gravimetric sampler developed by Sensors for this study. Each sampler will have the capacity to automatically collect (and automatically switch) multiple sequential 47mm Teflon filter samples for gravimetric mass analysis. The filter samplers will have the capability to initiate and cease sampling on receipt of electronic signals from the PEMS, switch filters automatically after a prescribed operating time, and maintain a constant flow rate throughout the sampling periods. The automated collection of multiple samples allows collection of samples over specific periods of interest, such as cold or hot starts. Filters will be installed in pre-loaded cartridges to avoid contamination. An on-board gasoline-powered generator also used with the PEMS unit will provide power for the sampler and air pump.

Table A7-8 lists the specifications for the SEMTECH Portable Gravimetric Sampling System.

**Table A7-8: SEMTECH Portable Gravimetric Sampling System Specifications**

| SEMTECH MPS System | Specifications |
|---|---|
| Total Flowrate | 18 slpm (as setup for this study) |
| Flow Measurement | Mass Flow Controller; accuracy 1% of point |
| Makeup air | HEPA filtered supply |
| PM 2.5 separation | Cyclonic separator |
| Temperatures | Filter holders, cyclone separator, ball valves and all transport tubing heated to 50 deg C nominal |
| Filter switching mechanism | Pneumatically actuated stainless-steel ball valves (compact, compressed N2 bottle provided) |
| Dimensions | 12 in x 12 in x 36 in approximate |
| Weight | < 30 Kg approximate |
| Operating temperature | Up to 50˚C ambient |
| Operating humidity | 0 to 95% RH, non-condensing |
| Power input | 120 VAC |
| Communication | CAN 2.0b network to other Sensors products |
| Software | Labview® platform |

The US EPA maintains overall responsibility for gravimetric filter measurements done for this Work Assignment. Carl Fulper will be the primary contact at US EPA and will coordinate project activities, information, and data transfer with ERG.

EPA will supply pre-weighed Teflon filters to the field personnel, who will collect the exhaust samples according to procedures listed in Appendix F. After collection, samples will be returned to EPA for strictly controlled gravimetric measurements using approved laboratory procedures and equipment. Five percent of all filters will be designated as field blanks to follow handling procedures, except for actual sampling. In addition, an attempt will be made to collect approximately 5% dynamic blanks by placing an unused filter into one of the three filter sampler holders but not subjecting this filter to actual exhaust.

The following data quality indicators typically used to characterize gravimetric filter measurements are listed below.

**Precision**: Precision is the degree of mutual agreement among individual measurements under prescribed conditions. Measurements, where possible, will be made of analytical precision and overall precision. The goal for analytical precision of gravimetric mass is ±5% CV as determined from replicate weighings.

**Bias**: Bias is the systematic or persistent distortion of a measurement process that causes error in one direction. Bias may be determined through performance audits and or by inter-comparisons of the performance of similar instruments.

**Accuracy**: Accuracy is the correctness of data and refers to the degree of difference between a measured value and a known or “true” value. For particulate measurements, there are no known true values. Relative accuracy may be determined by comparing a measured value with a presumed reference or standard. Sampler accuracy will be measured by performance (flow rate) checks and audits between the sampler and a certified flow meter. The goal is ± 5% relative percent difference (RPD) or better.

**Detectability**: Detectability is the low range critical value that a method-specific procedure can reliably discern. The minimum detection limit is typically 3 times the standard deviation of field blanks or 3 times the standard deviation of the noise of an instrument when subjected to clean air.

**Completeness**: Completeness is the percentage of valid data compared to the total expected data. For this Work Assignment, 20% oversampling has been utilized in order to meet project measurement objectives.

**Representativeness**: Representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environment condition. For this Work Assignment, representativeness will be achieved through utilization of the statistical survey design described in Section 2.2.1 of the Work Plan for all measurements.

**Comparability**: Comparability reflects how confidently one data set can be compared with another. Using similar reporting units and measurement times may enhance comparability. For a research project such as this that will be testing state-of-the-art instruments and methods, comparability becomes more difficult to estimate. Under such circumstance inferential methods may be used to assess comparability. These may include comparisons of related, but dissimilar measurements such as measurements that may represent both the gaseous and particulate phases of a constituent with measurements of only the particulate phase of that constituent. In addition, trend analyses may be used including, but not limited to, regression analyses, agreement with model results such as stochastic chemistry, or typical ratios of atmospheric parameters.

As part of the QC process, the ERG team will conduct a gravimetric filter blind study during the system integration stage of the study. This blind study will be conducted with DRI (our original gravimetric filter subcontractor) in the following sequence:

1) DRI will pre-weigh and send five (5) Teflon filters with unique identification numbers to EPA in EPA-provided filter holders (URG-2000-30FL filter cassettes). DRI will provide these pre-weights, along with filter ID, to ERG.

2) EPA will weigh these filters (obtain pre-weights) and provide filters to Sensors to use for blind-study testing during the equipment preparation phase of the study. Two of these filters will be treated as field/transport blanks. EPA will provide these pre-weights, along with filter ID, to ERG.

3) After collecting samples on three of the filters, Sensors will return all five filters (including the two blanks) to DRI. DRI will remove a tiny portion from a filter ring on one of the blank filters that is comparable to the magnitude of weight changes from actual sampling. DRI will then weigh all five filters (three sampled filters, one altered blank, and one intact blank) and provide these post-weights, along with filter ID, to ERG. DRI will send these five filters to EPA.

4) EPA will then weigh all five filters and provide these post-weights, along with filter ID, to ERG

5) ERG will provide all data sets to EPA and DRI simultaneously

### A7-4e. Continuous PM Measurements

Continuous PM measurements are not being performed in this work assignment. In the future, continuous PM measurements could be gathered using carousel-equipped Quartz Crystal Microbalances (cQCMs) manufactured by Sensors, Inc. The SEMTECH cQCM dynamically determines the aerosol particulate mass deposited on a substrate from a known volume of air using a piezoelectric crystal as a sensitive microbalance. Electrostatic precipitation results in the collection of aerosol particles on the surface of the piezoelectric crystal. The crystal is excited in its natural frequency, which decreases with increasing mass load on its surface. Thus, the particulate mass collected on the crystal can be determined by measuring the change in the crystal's natural frequency. This is an ideal solution for measuring environmental and ultra-fine particulates. As large particles (around 10µm and above) cannot couple to the crystal, they do not contribute to the measured mass of a microbalance.

The cQCM operating time for any one crystal is limited by saturation of the crystal. The saturation time is a simple function of the physical mass of PM deposited on the crystal surface, which is determined by the PM concentration in the exhaust and the dilution rate. Due to the rapid saturation rate, it is impractical to use single dilution to measure PM emissions for any non-particulate trip-equipped piece of diesel equipment. Therefore, a secondary dilution system would be required in order to use the cQCM for this study. Using two MPS diluters in series has been successfully demonstrated as a solution for high-emitting PM vehicles (when used in conjunction with an 8-crystal carousel). With a dual-dilution system, this will allow continuous operation for 8 hours. Although the current equipment is not setup for dual dilution, this will be considered for future testing.

The SEMTECH cQCM features traceable and precise mass measurement, very fast response with high sensitivity, and is configurable to respond to short high mass deposits or long-term sampling. It is easy to maintain and service, and measures all critical parameters affecting mass rates. Table A7-8 presents system specifications for the SEMTECH cQCM (for future reference).

### Table A7-8: SEMTECH cQCM System Specifications

| SEMTECH QCM System | Specifications |
|---|---|
| **Accuracy** | Mass resolution 10ng |
| **Response time** | > 2 seconds |
| **Quartz crystal frequency** | 5 MHz |
| **Frequency loading** | < 4 kHz |
| **Coating** | Gold or platinum/titanium |
| **Dimensions** | TBS |
| **Weight** | TBS |
| **Operating temperature** | Up to 45˚C (please see Section V.B.4.2 for lower temp operating limit) |
| **Operating humidity** | 0 to 95% RH, non-condensing |
| **Power input** | 12VDC |

### A7-4f. Activity Measurements

The ERG team has procured six Corsa, six Isaac, and one HEMDATA activity monitor for use in this Work Assignment. These systems are being used to measure and record engine on and off events and engine speed, along with an associated date/time stamp, over a one-month duration on a 1 Hz basis. In addition to independent collection of engine speed, these PAMS are equipped with a CAN/ECM module that may be configured to record a number of system parameters using communication protocols such as SAE J1939 and SAE J1708. It should be noted that the precision, accuracy, and repeatability of onboard data streams for vehicle activity will relate directly to the precision, accuracy, and repeatability of the individual engine sensors and engine control map, and the accuracy of the onboard information may be further compromised by engine deterioration rates, which exceed the limits of the engine map. Table A7-9 presents specifications for PAMS equipment that is currently being used for use in the project. With the exception of RPM calibration, no other PAMS calibration or maintenance is required for this study. PAMS RPM calibration procedures, and all PAMS installation and operation procedures, are provided in Appendix G.

## Table A7-9: Summary of PAMS Equipment Specifications

| **Core Unit Requirements** | **Corsa EZII Datalogger** | **Isaac V8** | **Hemdata DAWN-LOG16** |
|---|---|---|---|
| Date / Time Stamp | Yes | Yes | Yes |
| Engine on / off | Yes | Yes | Yes |
| RPM | Yes | Yes | possible |
| | | | |
| **Engine Module Requirements** | | | |
| RPM | Yes | Yes | Possible |
| exhaust temperature (°C) | Yes | Yes | Possible |
| humidity (% r.h.) | possible | Yes | Possible |
| barometric pressure (kPa) | Yes | Yes | Possible |
| ambient temperature (°C) | Yes | Yes | Possible |
| date/time stamp | Yes | Yes | |
| | | | |
| **GPS Module Requirements** | ***Not currently*** | Yes | Yes |
| longitude (<5 m accuracy) | | Yes | yes |
| latitude (<5 m accuracy) | | Yes | yes |
| altitude (<0.1 m accuracy) | | No | no |
| vehicle speed (distance/time) | | Yes | Yes |
| | | | |
| **CAN/ECM Module Requirements** | | | |
| SAE J1850 | ***Not currently*** | Yes | Yes |
| ISO 14230 | ***Not currently*** | ***No*** | Yes |
| ISO 9141-2 | ***Not currently*** | Yes | Yes (optional) |
| ISO 11898 | ***Not currently*** | Yes | Yes |
| ISO 15765 | ***Not currently*** | Yes | Yes |
| SAE J1587 / J1708 | ***No*** | Yes | Yes |
| SAE J1939 | Yes | Yes | Yes |
| | | | |
| **Other Requirements** | | | |

| Core Unit Requirements | Corsa EZII Datalogger | Isaac V8 | Hemdata DAWN-LOG16 |
|---|---|---|---|
| 3-months data acquisition for core | yes | Yes | yes internal CF |
| Sleep and power-up on signal | yes | Yes | Yes |
| Power off vehicle, < 1% output increase | Yes | Yes | Yes |
| < 1 % output increase from power draw | Yes | Yes | |
| Record power draw | | | |
| Adjustable acquisition rate | Yes | Yes | Yes |
| Acquisition rate 1 Hz capable | Yes | Yes | Yes |
| User-friendly GUI | Yes | Yes | Yes |
| Core Weight < 10 lbs | Yes | | |
| Core dimensions < 1'x1'x6" | Yes | Yes | 1.25"H x 9.5"D x 5.25"W |
| Comp Weight < 20 lbs | Yes | | |
| Comp dims < 1.5'x1.5'x1' | Yes | | |
| Water/dust resistant | Yes | Yes | Somewhat |
| -40 to 40 C Temp Range | No | Yes | -40 to + 85 |
| -40 to 0 C Thermal Shock Range | | | |
| Shock/Vibration Resistant | | | |
| 1 year warranty w/ 5- day turnaround | | | |
| # open input channels? | 20+, 40 w/ CAN | 4 / 4 | 16 |
| Wiring harnesses included/available? | Yes | Yes | |

## A8. SPECIAL TRAINING/CERTIFICATION

NuStats data collection interviewers are expertly trained in data collection techniques and are continuously monitored for quality assurance. Each research project has explicit and constantly monitored standards. For this Work Assignment, NuStats will conduct training with its staff as well as the ERG field inventory staff to ensure these standards are understood and followed. Training will be provided to all personnel regarding obligations of and responsibilities for participant confidentiality.

For many study participants, interviews with our staff are the only contact they have with the study, and project-specific training helps interviewers become knowledgeable and professional representatives of the studies and clients they represent. Our training also gives interviewers practice and skills in gaining respondent cooperation and avoiding refusals so that our surveys yield an optimum response rate. Interviewers also learn how to accurately administer the survey questions, effectively probe, and correctly enter the data respondents provide.

Training begins with an overview (which clients are encouraged to attend or even conduct) of the project goals. Project training continues with a discussion of disposition coding and contact procedures that ensure that interviewers know how to code call or on-site visit outcomes as well as interact with respondents to encourage their cooperation and conduct any needed screening to identify the most appropriate survey respondent. Training includes question-by-question walkthroughs of the survey and data collection instruments to help interviewers understand the specific objectives of each question and the possible responses, and conclude with mock interviews that allow practice reading the script aloud using the CATI and Internet-based Sample and Field Data Manager.

Prior to conducting the Equipment Sample field data collection, NuStats will conduct a training session with the field team. This training session will be consistent with the Establishment Sample training conducted with telephone interview specialists. The training will encompass the following:

- Study Overview, including study background, purpose, sample goals
- Survey Administration, including review of on-site data collection processes and team member's roles and responsibilities, review and practice use of the on-line system for scheduling and reporting field activities, and

- Data Collection Protocols, including review respondent of confidentiality obligations and other industry data collection standards, introduction of team to all survey instruments, conducting test interviews and practicing equipment selection process.

All field personnel will have appropriate scientific and technical degrees and experience in performing field emissions measurement studies. Personnel to be involved in emissions and activity measurements will receive equipment installation and operation training during Task 4A (Equipment Prep) of this Work Assignment, and training will cover all maintenance, calibration, and operation of equipment which will be necessary to conduct this study. Guidance regarding specific field and equipment operations for this project will be provided to all field personnel in the form of data collection checklists, guidance documents, SOPs, and other material included with this QAPP.

Laboratory personnel who will be performing gravimetric filter preparation, weighing, and results analysis have appropriate degrees, background, and experience appropriate for their roles in the project.

## A9. DOCUMENTS AND RECORDS

ERG recognizes the importance of regular review and revision of this QAPP, to ensure it reflects all QA procedures currently in place. Review and update of the QAPP and appendices will occur through the duration of the project. EPA reviews of QAPP revisions will occur in Task 3 and again in Task 4, as outlined in the Work Assignment schedule. Michael Sabisch is responsible for maintaining the latest version of the QAPP, and will distribute the QAPP to the distribution list in Section A3 as revised versions are generated.

Electronic documents and records associated with the project will be stored at ERG's Austin office, on a secure, password-protected server. Access to project records will be restricted to individuals who are directly working on the project. Automated backups of all of ERG's Austin servers are made on a daily and weekly basis.

ERG's Austin office maintains electronic project records indefinitely. Upon project completion, data are retained on active project servers for a period of 1-to-2 years, at which point they are archived to back-up electronic media and stored securely. In addition, at the conclusion of the project, all raw data will be transferred to EPA in a manner deemed acceptable by the ERG Project Manager (e.g., portable hard drive, DVD-ROM, or secure FTP).

All equipment maintenance and calibrations will be reported as specified in Sections B6 and B7 of this document. Data input will be both manual and automatic. Data to be input manually will include items such as equipment descriptions, calibration gas values, equipment maintenance and testing notes. The PEMS and PAMS units will log other data automatically. Raw test records will be downloaded after each test when possible, and will be archived at the end of each test day. The raw data will be processed and reviewed on site, archived, and also posted on a secure site for remote retrieval and review by team members and the EPA. Remedial or corrective actions taken as a result data issues which may arise from field, laboratory, or data audits will also be documented. This information will be summarized in the project report to be developed for this Work Assignment.

Sections B6 and B7 of this document provide additional details about how each of these documentation and recording processes will take place.

# B. Data Generation and Acquisition

## B1. SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The population of inference for the proposed pilot study is twofold. First, the Establishment sample will collect data on construction companies (establishments) that employ eligible equipment at their worksites. Inferences on this population will flow from the EOIs collected as part of the Establishment Sample.

Another population of inference of the pilot study is composed of all nonroad diesel-powered equipment operated in specified counties within EPA Region 7 (in the states of Iowa, Kansas, and Missouri) by establishments in the construction sector, NAICS 23. A comprehensive registration list of such equipment does not exist. Therefore, elements of the target population will be identified and selected through the constituent establishments that operate the equipment. These establishments may own or lease their equipment, so ERG will use a multi-stage cluster sample design, with eligible equipment clustered by the owning/leasing establishment.

The term *sampling frame* denotes the list from which a sample is drawn. Ideally the list is all-inclusive of the target population. For WA #1 we will employ the Comprehensive Business Samples (CBS) supplied by Survey Sampling International (SSI) of Fairfield, Connecticut as our sampling frame. This CBS will be the most recent sample available at the time the task is initiated, and will be used (and not updated) throughout the duration of this Work Assignment (to avoid pulling the sample from two pools). Specifically, the sampling frame will be comprised of establishments in the SSI database that are located within Region 7 with NAICS code 23.

The original objectives of the survey were to collect a total of 550 observations from two independent samples of establishments. In that design, a sample of 500 –we call the Establishment Sample --would be required for a telephone survey involving only the administration of the equipment ownership interview (EOI). Then, a second sample – we call the Equipment Sample -- would be drawn to conduct 50 equipment measurements – 25 emissions measurements and 25 activity measurements. However, at the conclusion of Phase I of the Establishment Sample EOI, it became clear that a full integration of the Phase II Establishment and Equipment Samples into a single, unified design would be required. This was partly due to the skewed nature of the establishments according to the measure of size (MOS , which caused a large number of self-representing units that need to be shared by the Establishment and Equipment Samples). Another factor was the finding of lower net yield rates relative to what we had planned and expected. (The net yield rate is the number of sampled establishments required to secure one completed EOI survey.) The Phase 1 Establishment Sample demonstrated that yield rates were half that of the expected rates, meaning that *twice* the sample than was originally planned are needed for the Phase 2 Establishment and Equipment Samples. Taken together, these factors suggest that even a census of all establishments in PSUs 2-5 would fail to produce the targeted number of EOIs in order to achieve the study's Equipment sample targets.

Our revised design calls for the conduct of a single EOI data collection effort integrated with the recruitment of establishments for instrumentation at the end of the EOI. All self-representing and non-self representing units would be sampled concurrently.

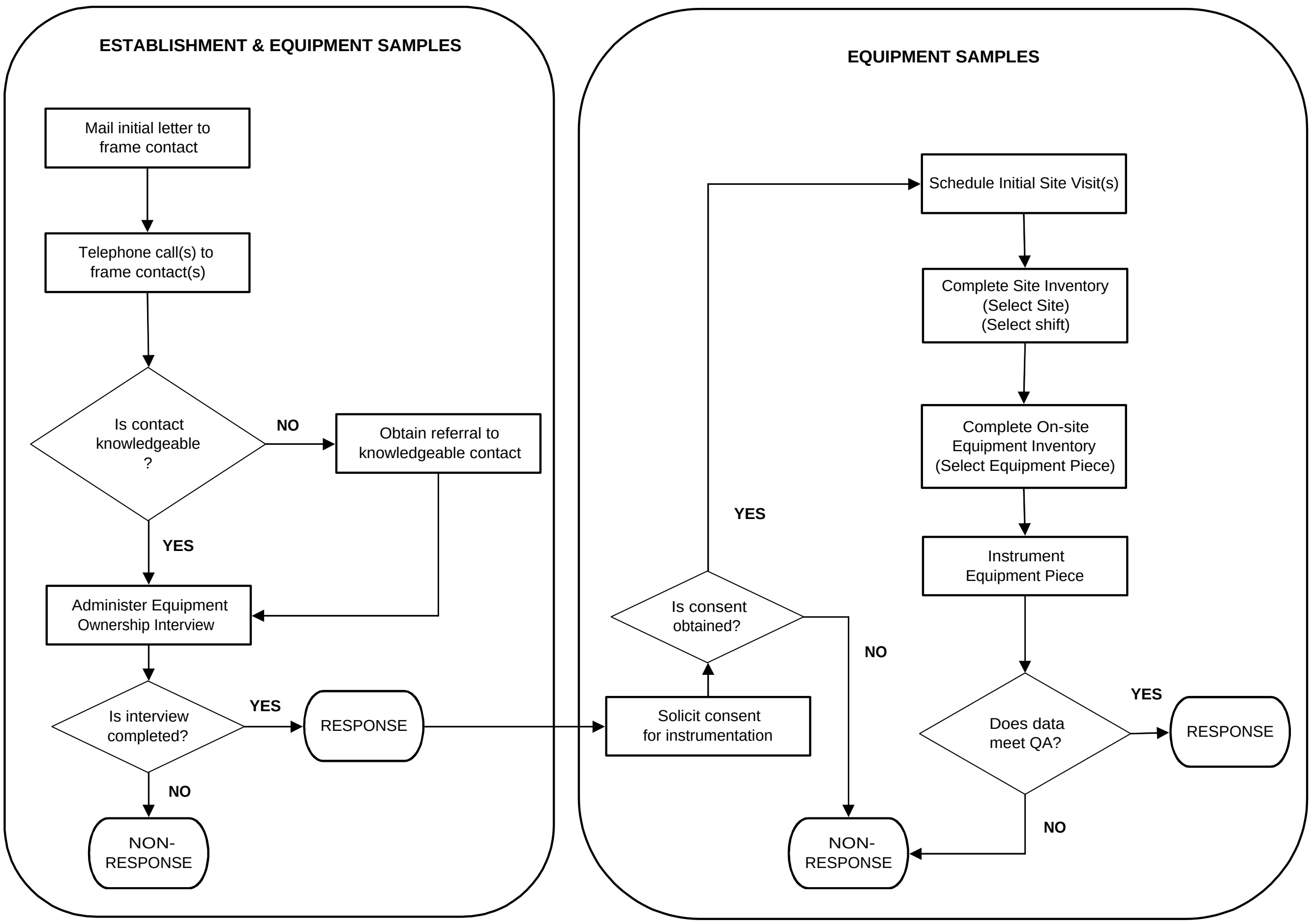
Specific targets are provided for the numbers of establishments and pieces of equipment for which data are to be collected. Table B1-1 presents the targeted distribution of observations by measurement type. Note that even though we believe there is a risk of falling short of the desired 50 instrumentations, we want to retain that goal and strive to achieve it through the integrated Phase 2 design described above.

**Table B1-1: Targeted Distribution of Observations by Measurement Type**

| | **Measurement Type** | **Establishment Sample** | **Equipment Sample** | |
|---|---|---|---|---|
| | **A** | **B** | **C** | **D** |
| **Economic Sector** | **Total—All Measurement Types** | **Equipment Ownership Only** | **Emissions Measurement** | **Activity Measurement** |
| Construction | 550 | 500 | 25 | 25 |

Figure B1-1 provides an overview of the data collection process for both the Establishment and Equipment samples.

## Figure B1-1: Establishment and Equipment Sample Data Collection Process




The remainder of this pilot study will now be implemented in up to two implementation phases for the integrated Establishment/Equipment Samples. The use of one or two implementation phases depends on funding levels and continued observed performance of the sample.

Phase 1 of the pilot commenced with the EOIs of PSU 1 of the Establishment Sample. We will now proceed with the Phase 1 Equipment Sample for PSU 1, followed by the Integrated Establishment/Equipment Samples for PSUs 2-5, With regard to the Phase 1 Equipment Sample in PSU 1, data collection will commence with the conduct of EOIs, followed by recruitment to instrumentation (including the incentive experiment) among eligible establishments. This will be followed by a preliminary “onsite equipment inventory” interview (first seven questions of Appendix A-2 of the Work Assignment) conducted during the same EOI/recruitment call. In turn, this will be followed by a face-to-face visit with the establishment to conduct a site inventory, and finally selection of equipment and the emissions and activity measurements. Moreover, because the EOI is the precursor to the site equipment inventory and equipment measurement, we expect that a number of establishments will participate in the EOI interview and agree to a face-to-face visit but then decline to participate in the inventory and/or the emissions and/or activity testing (despite earlier indications of cooperation). As such, the EOI sample sizes for the Equipment Sample must be planned larger than the final targeted number of equipment measurements in order to allow for inevitable attrition. The impact of this on the number of EOI interviews conducted in the Equipment Sample is shown in the second data row of Table B1-2. Column F of the second row shows that 185 EOI interviews are expected in order to secure 60 total combined activity and emissions measurements (which incorporates a 20% oversampling rate). Table B1-2 also presents the expected distribution of equipment measurements (emissions, activity) by Phase. Again, we note that according to the Phase 1 Establishment Sample we believe it could be challenging to achieve these targeted completion goals. In fact, we are planning censuses of PSUs 2-5 in pursuit of EOI and instrumentation goals. We have left the original targets intact because our integrated sampling strategy maximizes the potential to achieve the original goals, and we believe it is in the best interests of the project to be optimistic. Even though we anticipate performing censuses of PSUs 2-5, the sample will be fielded in replicate while conducting the EOIs (and EAM recruitment for eligible establishments).

**Table B1-2: Expected Distribution of Completions by Sample and Measurement Type and Phase**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| **Completes by Type** | **Estab Sample Phase 1** | **Estab Sample Phase 2** | **Equipmt Sample Phase 1** | **Equipmt Sample Phase 2** | **Equipmt Sample Phase 3** | **TOTAL** |
| **EOS - Establishment Sample** | 100 | 400 | | | | 500 |
| **EOS - Equipment Sample** | | | 37 | 74 | 74 | 185 |
| **EOIs (inventory)** | 0 | 0 | 12 | 24 | 24 | 60 |
| **EM measurements** | 0 | 0 | 6 | 12 | 12 | 30 |
| **EA measurements** | 0 | 0 | 6 | 12 | 12 | 30 |

Table B1-3 presents the sample size goals by study phase and sample type that will be needed to achieve the target number of completions for the pilot. A total of 3541 selections will be needed to complete the EOIs for the Establishment Sample and the EOI portion of the

Equipment Sample. A total of 185 completed EOIs (who ALSO agree to be instrumented) will be needed (including reserve sample) for conducting the equipment inventories and activity and emissions measurements in the Equipment Sample (see bottom row of Table B1-3). It should be noted that substantially more than 185 EOIs will need to be conducted in order to get 185 establishments agreeing to be instrumented. As seen in the first row of Table B1-3, Columns C-E, a total of 3,298 EOIs would need to be conducted under the current design parameters. However, this assumes that only ***one*** instrumentation will occur per piece of equipment (i.e., either an activity measurement or an emissions measurement, but not both). To the extent that dual activity/emissions measurements are feasible, the required sample for the Equipment Sample can be reduced accordingly. As such these expected dispositions can be viewed as conservative estimates of the required sample effort to achieve the stated objectives.

**Table B1-3: Total Sample Needed to Achieve Establishment and Equipment Sample targets for the Pilot Study**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| **Type of Data Collection:** | **EOI Phase 1** | **EOI Phase 2** | **EM_EA Phase 1** | **EM_EA Phase 2** | **EM_EA Phase 3** | **TOTAL** |
| CATI -- EOI | 243 | n/a | 404 | 1522 | 1372 | 3541 |
| Inventory & EAS | 0 | 0 | 37 | 74 | 74 | 185 |

Table B1-4 shows the sample sizes needed per Primary Sampling Unit (PSU), by study phase. It reflects our integrated design and Phase I Establishment Sample experience by showing censuses conducted for PEMS/PAMS Phases II and III (see Cols. D and E). A second stage sample will need to be drawn only within PSU 1 for the PEMS/PAMS in order to achieve the targeted sample size specified in the survey objectives. For the other PSUs, we are conducting censuses of all establishments in order to maximize the possibility of achieving the targeted numbers of EOIs and instrumentations.

**Table B1-4: Approximate Sample Needed per PSU by Study Phase**

| | A | B | C | D | E |
|---|---|---|---|---|---|
| | **EOS Phase I** | **EOS Phase II** | **PEMS/PAMS Phase I** | **PEMS/PAMS Phase II** | **PEMS/PAMS Phase III** |
| **CATI -- EOI** | 245 | n/a | 404 | censuses | censuses |
| **EM_EA (EOI Iws)** | 0 | 0 | 40 | 40 | 40 |

The sample design for this pilot study employs stratified multi-stage probability sampling with probabilities proportional to size. The number of selection stages varies by the type of data collection (i.e., establishment vs. equipment samples). The survey of establishments in Phases I and II employs two-stages of selection, while the equipment samples involve a three-stage design.

- **First Stage.** The first stage of selection is utilized by all samples in the study and involves a sample of 5 counties (primary sampling units or PSUs) with probabilities proportional to size (pps) from the collection of counties selected within EPA Region 7. EPA has designed the sample and selected these counties, and they appear in Table B1-5.

- **Second Stage.** For the integrated Equipment/Establishment Samples in PSUs 2-5, we will conduct censuses of commercial establishments (which comprise the secondary sampling units (SSUs)). For PSU 1 we retain independent samples for the Establishment and Equipment Samples (since the sample wasn't integrated until after the first wave of Establishment Sample EOIs was performed).

  Within PSU 1, commercial establishments were be drawn with selection probabilities based on the same measure of size used to draw the first-stage sample, namely the number of employees in an establishment. NuStats applied stratification to the second-stage sample. Specifically, establishments were stratified by numbers of employees (size), and geography (urbanicity). On this basis, establishments were divided into self-representing strata and a nonself-representing stratum. The self-representing strata was composed of large to very large establishments that were included in both Establishment and Equipment samples with certainty. The non-self-representing strata were sampled with probabilities proportional to the number of employees. Self-representing establishments are be part of BOTH the Establishment and Equipment Samples for PSU 1, and the integrated sample for all PSUs. Size and urbanicity stratification will be applied to the Integrated Sample in PSUs 2-5.

- **Third Stage.** The third stage of selection is relevant to the sampling of equipment from the equipment inventory for instrumentation.

### Table B1-5: Primary Sampling Units for the Pilot Study

| PSU | FIPS | State | County | Est. No. Employees | Sampling Probability |
|---|---|---|---|---|---|
| 1 | 29095 | MO | Jackson | 63,800 | 0.3063 |
| 2 | 19113 | IA | Linn | 25,400 | 0.1216 |
| 3 | 19163 | IA | Scott | 18,500 | 0.4277 |
| 4 | 29047 | MO | Clay | 16,500 | 0.3813 |
| 5 | 20177 | KS | Shawnee | 13,000 | 0.3006 |

## B2. SAMPLING METHODS

Appropriate sample control procedures are in place for drawing sample and monitoring data collection operations. Such procedures track the acquisition of sample through processing and drawing the sample based upon the required sample design (presented in B1) to monitoring the status of sampled units from the beginning through the completion of data collection so that survey managers and clients can assess progress at any point in time.

### B2-1. Sample Control

Sample control procedures and feedback from them are also used to ensure that every sampled unit is processed through all data collection steps, with a final status being recorded. Steps to ensure the sample is drawn and processed and verified include:

1. Purchase all available sample for the five PSUs. We know that we will initially draw sample a much larger number of establishments that will be needed for the study, so the number will be larger than that contained in the aforementioned tables.

2. Process the sample, upon receipt to ascertain each sample item is complete (e.g., contains phone, address, name of company and other relevant information necessary for the study).

3. Create the second stage calculations and determine stratifications.

4. Draw a simulated sample and evaluate it for completeness. Make adjustments if needed (e.g., conduct Lexus/Nexus searches to obtain missing business information such as address or phone).

5. Draw the real sample, assigning unique identification (ID) numbers to each sample item. These ID or sample numbers will allow tracking of sample disposition throughout the data collection effort, regardless of the study phase.

### B2-2. Telephone Interviews

"As described in Section 2.2.3.2 of the attached Workplan, an Equipment Ownership Interview (EOI) will be administered to all study participants in both the Establishment and Equipment Samples. This section provides significant detail regarding how the interview will be revised and implemented.

An overview of the sequence of events is provided is Section B.1. As stated in B.1, completion of the Equipment Ownership Interview concludes the contact with participants in the Establishment Sample. For the Equipment Sample, the first 7 questions of the Onsite Equipment Inventory (Appendix A-2 of the Work Assignment) are administered over the telephone, at which time a site visit is scheduled for each Equipment Sample participant. During this site visit, the on-site inventory will be conducted, during which time the equipment pieces to be instrumented will be selected."

Specific data collection control procedures include:

- For the Establishment Sample, daily monitoring of interviews to ensure targets are met.
- For the Equipment Sample, first conduct daily monitoring of interviews to ensure targets are obtained. Second, close monitoring of scheduled on-site appointments with daily adjustments in scheduling and equipment measurement installments. Other steps include:

NuStats will initially overbook on-site appointments to minimize the effect of cancellations. Daily adjustments to the schedule will be made until the target equipment measurements are obtained.

Daily communications with on-site field team using the projects online scheduling and data management system (monitoring scheduled on-site visits, documenting completed interviews and equipment measurements).

## B2-3. On-site Interviews and Measurements

Because the on-site inventory and instrumentation of equipment requires substantial technical understanding, the ERG team will conduct this stage of the study with close participation by NuStats project and sample management tracking and monitoring of inventory and instrumentation dispositions.

Following the initial telephone interview of establishments in the Equipment Sample who demonstrate a willingness to participate in the inventory and instrumentation tasks, ERG staff will schedule an appointment for a site visit to inventory the site and select which pieces of equipment will be instrumented. After this initial site visit, another appointment will be scheduled for equipment instrumentation by the ERG team.

### B2-3a. Inventory Data Collection

Once on-site, ERG personnel will gather equipment inventory information as specified in Appendices C and E of this QAPP (originally from Appendix A-2 of the Work Assignment). Sufficient information will be gathered in order to allow determination of equipment model year, power, and speed ratings through the use of supplemental information such as EquipmentWatch or other commercially available equipment specification resources, as needed. At a minimum, the following information will be obtained for each piece of equipment:

- equipment type
- equipment manufacturer
- equipment model
- equipment model year
- equipment serial #

Digital photographs of serial numbers and equipment specification tags will taken whenever possible, to help correct any inaccurate information recorded during on-site inventories. Inventory information collected in the field will be sent to ERG's Austin office (either by fax or secure FTP posting) to allow independent confirmation of data collected in the field. Equipment specifications and serial numbers will be verified by Austin staff using the *Specification Reference* Book ($11^{th}$ Ed.) and the *2007 Serial Number Guide* ($39^{th}$ Ed.), both published by Equipment Watch. Field staff will re-visit sites to resolve any discrepancies or problems identified during the office review of inventory information.

### B2-3b. Emissions Measurements

ERG will use the portable emissions measurement systems (PEMS) provided by the USEPA for collection of emissions data for this Work Assignment

Detailed guidelines for installation, operation and quality assurance of the PEMS units are provided in SOPs included in Appendix F of this QAPP. All results of quality control procedures will be documented, either electronically or manually (if electronic record creation is not possible). Quality control steps will be integrated into all fieldwork to ensure data collected is accurate.

For emissions measurements, the following information will be collected in one-second intervals, as specified in Section 1.4.6.3 of the Work Assignment:

- engine speed (revolutions per minute, rpm),
- oxygen concentration in the exhaust stream ([$O_2$], percent by weight, wt%),
- carbon-dioxide concentration in the exhaust stream ([CO2], percent by weight, wt%),
- oxides of nitrogen concentration in the exhaust stream ([$NO_x$], parts per million, ppm),
- carbon monoxide concentration in the exhaust stream ([CO], percent by weight, wt%)
- total hydrocarbon concentration in the exhaust stream, ([THC] parts per million, ppm)
- aggregate particulate matter by gravimetric methods (g),
- ambient temperature ($^{\circ}$C),

- exhaust temperature (°C),
- exhaust mass flow rate (via the Sensors EFM)
- relative humidity (%), and
- barometric pressure (kilo-Pascals, kPa).
- date/time stamp.
- relevant data from ECU datastream on electronically-controlled equipment (when available)

The following derived measurements, also specified in the Work Assignment, will be provided for all emissions measurements.

- exhaust flow volume (adjusted to standard temperature and pressure, cu. ft/min (scfm)),
- fuel flow volume (kg/sec),
- carbon dioxide emission rate (kg/sec, kg/gal),
- pollutant emission rates for NOx, CO, THC, and PM, (g/sec, g/gal).

An integrated equipment enclosure, designed and provided by Sensors, inc., houses all of the emissions measurement devices, including the SEMTECH-DS, MPS dilution sampler, portable gravimetric filter system, and exhaust flowmeter hardware. It also contains a small air compressor and filtration unit to operate the MPS, and a rotary vane pump to operate the gravimetric filter system. There is also a 12V power supply and battery backup, all packaged in one housing that protects the equipment from dust and precipitation. Access doors provide the ability to change PM filters, and perform routine maintenance on the equipment without removing any panels.

The equipment enclosure is approximately 24” x 24” x 36” deep, and weighs approximately 400 lbs. It is typically mounted on top of the roll cage of the non-road construction equipment. It is hoisted to this position using a small crane mounted to the rear of a 4x4 one-ton flatbed pickup truck provided by Sensors, Inc. The equipment is powered by a portable generator, which is also mounted to the test vehicle. The generator can provide power for approximately 3.5 hours before refueling is required. It is possible to operate two generators in parallel for extended, uninterrupted operation.

EPA will supply pre-weighed 47 mm Teflon filters to the field personnel, who will collect the exhaust samples with samplers provided by the EPA. All emissions measurements will include gravimetric filter sampling, using a micro-proportional sampling system (MPS) and gravimetric filter housing provided by the EPA. The filter sampler to be provided will automatically switch gravimetric filters, based on an integral timer. One filter will capture the first start at the beginning of the day or shift, a second filter will capture the second or additional starts during the day or shift, and a third filter will capture running operation not included in either of the other two filters. Each “start” episode will be defined as the first ten (10) minutes of operation after the engine is turned on. Samples will be returned to EPA for gravimetric measurements. Three to six filters will generally be collected for each equipment emissions measurement.

Sensor’s, Inc, will be responsible for operation of the PEMS and gravimetric filter samplers to be used in this study. Sensor’s personnel will adhere to all PM measurement SOPs included in Appendix F. Sensors will provide initial and final flow checks during each sampling phase and provide technical support as required.

After dilution in the MPS, the proportional PM sample is routed to the portable gravimetric filter sampling system where it is first passed through a low particulate loss 2.5 um cut point pre-classifier. The mass-flow controller in the gravimetric filter sampling system is setup for 18 slpm flowrate across the filters. The MPS total flowrate is only 12.5 slpm, so the makeup air is pulled through a HEPA filter teed at the outlet of the MPS. This was to ensure that the MPS performance was not compromised by any backpressure or vacuum pressure. The additional dilution also provides some additional sampling time for the gravimetric filters.

ERG will attempt to schedule installations in such a way as to maximize soak times prior to performing gaseous pollutant and PM emission measurements. However, although desirable, this may not always be possible due to equipment usage at a facility, on and off-hour facility access, and other logistics. If a full twelve hour soak time is found not to be feasible for a given piece of equipment, field staff will attempt to maintain soak times of at least eight to ten hours, and as close to twelve hours as is possible. Emission measurements will be conducted regardless of the length of soak prior to the commencement of the test. Soak times for all installations will be recorded.

Operation of all PEMS units will be monitored by field staff throughout the duration of each test. Detailed information for installation, operation, calibration and maintenance of all field equipment will be provided in the operational SOPS included in Appendix F of this QAPP. In addition, SOPS are also included which provide guidelines for data processing and data quality checks to be performed both in the field and in the office (Appendix I). The ERG team will examine data files acquired from the PEMS and PAMS units after each test to verify data quality and to identify any issues requiring immediate attention. In addition, ERG will deliver data files containing emissions and activity measurements to the EPA WAM on an on-going, as-acquired basis. The files shall be transferred via a method to be proposed by ERG and approved by the EPA WAM, e.g., secure file-transfer protocol. If any issues or concerns about data quality occur ERG will immediately bring these to the attention of the EPA WAM.

As described earlier in this plan, all PEMS units used in this study will undergo a complete warm-up, zero and calibration sequence to ensure CO, CO2, NOx, and THC measurement accuracy. A post-calibration audit will be performed after any calibration to verify measurement accuracy. Any piece of equipment that fails this post-calibration audit will be removed from service until repaired by onsite repair personnel. Finally, a post-test calibration is performed on the equipment to determine span drift. The concentrations and tolerance of all gasses used for auditing and calibrating will be recorded, and data files will be generated during all audits to preserve records of system performance.

All PEMS system flows and pressures will be verified and recorded for each installation, and ambient conditions as measured by the PEMS will be recorded and verified with independent weather station verification measurements. A sample system leak check will be performed to verify sample system integrity, and a FID fuel leak check will also be performed. System temperatures (FID oven and chiller) will also be verified and recorded, and all sample rates and transport delay settings will be verified. Additional checks will be made to ensure that the equipment is collecting data for the MPS, gravimetric filter sampler, GPS, exhaust flow and other parameters – and that these parameters appear reasonable. These are covered in detail in the SOPs provided in the appendix.

All pertinent audit, verification, and calibration information will be recorded on data collection sheets, as shown in the Equipment Instrumentation Data Collection Forms included in Appendix E. Also included in these forms are detailed usage guidelines to provide the PEMS technician item-specific instructions along with appropriate SEMTECH user manual references. PEMS units will be removed from service if any out “out of range” operating conditions are identified.

After each day of testing, the raw (XML) files will be uploaded daily to the secure project FTP site for processing and review by other ERG team members and the EPA in order to help ensure any equipment or issues that could affect test results are identified and corrected.

### B2-3c. Activity Measurements

ERG has provided “core” portable activity measurement systems (PAMS) conforming to Section 1.4.6.4 and Appendix C of the Work Assignment. These systems measure and record engine on and off events and engine speed, along with an associated date/time stamp, over a one-month duration for each activity instrumentation. Details of the systems in use for this study are provided in Section A7-4 and Appendix G of this document. The SOPS included in Appendix G also provide detailed guidelines for data processing and data quality checks to be performed in the field, and activity measurement processing steps for the office are provided in Appendix I. Table B2-1 below presents the specifications required by EPA for PAMS equipment; Table A7-9 presents specifications for the PAMS units acquired for use in this study.

**Table B2-1. Required EPA Specifications for PAMS Equipment**

| |
|---|
| **Core Unit Requirements** |
| Date / Time Stamp |
| Engine on / off |
| RPM |
| |
| **Engine Module Requirements** |
| RPM |
| exhaust temperature (°C) |
| humidity (% r.h.) |
| barometric pressure (kPa) |
| ambient temperature (°C) |
| date/time stamp |
| |
| **GPS Module Requirements** |
| longitude (<5 m accuracy) |
| latitude (<5 m accuracy) |
| altitude (<0.1 m accuracy) |
| vehicle speed (distance/time) |
| |
| **CAN/ECM Module Requirements** |
| SAE J1850 |
| ISO 14230 |
| ISO 9141-2 |
| ISO 11898 |
| ISO 15765 |
| SAE J1587 / J1708 |
| SAE J1939 |
| |
| **Other Requirements** |
| 3-months data acquisition for core |
| Sleep and power-up on signal |
| Power off vehicle, < 1% output increase |
| < 1 % output increase from power draw |
| Record power draw |
| Adjustable acquisition rate |

| |
|---|
| Acquisition rate 1 Hz capable |
| User-friendly GUI |
| Core Weight < 10 lbs |
| Core dimensions < 1'x1'x6" |
| Comp Weight < 20 lbs |
| Comp dims < 1.5'x1.5'x1' |
| Water/dust resistant |
| -40 to 40 C Temp Range |
| -40 to 0 C Thermal Shock Range |
| Shock/Vibration Resistant |
| 1 year warranty w/ 5- day turnaround |

### B2-3d. Fuel and Oil Sampling

ERG will collect fuel and oil samples from equipment as required for the study. Appropriate protocols will be followed for storage and shipment of these samples to the appropriate laboratories for analysis. Samples will be collected directly from the equipment in such a way as to avoid contamination or spark hazards using dedicated sampling equipment. More detail on fuel and oil procedures are provided in the applicable SOPs in Appendix M. Elemental analyses to be performed on fuel and oil samples are described in Section 5.0 of the workplan under option 5.

## B3. SAMPLE HANDLING AND CUSTODY

### B3-1. EOI Records

Once the initial sample is drawn, it will then be partitioned into a large number of replicates (say 20-30) each of which represents a random sample of the population. Replicates will then be released sequentially over the course of data collection. This allows a tighter control over the final sample size (ensuring that targets are achieved) and also helps to increase response rates (by reducing or eliminating the possibility of a self-selected sample of 'easy cases.' Tracking is accomplished through the use of assigned unique identification numbers (assigned during the sampling process identified in section B2).

To facilitate tight control over the telephone interviews and recruitment of establishments during the Equipment Sample and to monitor fieldwork status, the project team will rely on NuStats' Internet-based "*Field Data Manager*", a proprietary software application that provides real-time tracking of assignment status (assigned, in progress or completed). The on-site fieldwork management team will update the "*Field Data Manager*" program continuously to provide real time monitoring. Reports can be quickly generated and shared with the project team, including EPA, for virtual data collection status updates.

## B3-2. Handling of Gravimetric Filters in the Field

Teflon filters will be pre-loaded in filter cartridges at EPA's laboratory and shipped to field personnel, who will collect the gravimetric exhaust measurements with samplers provided by the EPA. Three gravimetric filters are expected to be collected for each emissions test. One filter will capture the first start at the beginning of the day or shift, a second filter will capture the second or additional starts during the day or shift, and a third filter will capture running operation not included in either of the other two filters. The "hot start" filter will be exposed to the hot-start diluted exhaust stream for the same time duration as the "cold start" filter is exposed to the cold-start diluted exhaust stream. This will either be facilitated by auto-switching by the gravimetric sampling equipment software, or this will be switched manually if the auto-switching software is not available.

Field filter handling SOPs are presented in Appendix L. A field log will be used to record filter, equipment and establishment identification codes, as well as which portion of the test each filter was used to collect. After the emissions test is complete, the filters will be returned (in the original holding cartridge) to EPA, where stabilization and gravimetric measurements will occur. A copy of the sample identification log will also be forwarded to EPA. A copy of the log will also be transmitted to ERG's Austin office for archival. After the completion of each phase of emissions measurements, the field log will also be archived in ERG's Austin office.

After sample collection, filters will remain sealed to prevent sample presence changes. Filters will be transported via commercial courier with tracking numbers. All filters will have unique numbers identifying each sample in the shipping container, which correspond to the filter log. This unique identification number will be assigned by EPA during the pre-loading process. This identification number will be affixed to the filter cartridge and will remain with the filter through the duration of the study. In addition to the filter identification number, each filter cartridge will be labeled with the unique identification number of the equipment which it sampled, a code which can be used to identify the establishment where the sampling took place, and a designation of the phase of the test during which sampling took place (cold-start, hot start, or hot operation).

## B3-3. Handling of Gravimetric Filters in the EPA Laboratory

All samples will follow the chain-of-custody requirements and standard Good Laboratory Practices required for labeling, recording, and tracking all samples from collection through database archival. It will be the responsibility of the laboratory personnel to maintain internal logbooks and records that provide a custody record throughout sample analysis.

A sample will be considered in custody of the laboratory when received by the laboratory receiving department from an official package courier. At this time, the sample will be logged into the general receiving logbook. Sample identifications will be entered into the respective Laboratory Information Management System (LIMS) and properly stored. Damaged shipping containers, evidence of damage and/or tampering, etc., will be brought to the attention of the Laboratory Director and QA Manager. An assessment will be made to determine whether the damage compromised the integrity and/or quality of the sample. Sample storage rooms will be locked when not in use and the building will have limited access (i.e., locked from 1730 to 0730 weekdays and 24 hours weekends to prevent access by unauthorized personnel).

When a sample is analyzed, its unique identification number is recorded in a written logbook for each instrument (e.g., run list) and/or the LIMS. These unique identification numbers allow the sample to be tracked through LIMS and/or written records during sample preparation, analysis, and data validation. Teflon filters for gravimetric sampling will be archived for at least one year following the completion of the project.

Several types of laboratory records will be routinely maintained for this Work Assignment. Written records include receiving logbooks, shipping logbooks, chain-of-custody forms, project folders, instrument logbooks, instrument service logbooks, and calibration records which include a calibration standard logbook. Computerized records include LIMS, method files, calibration files, raw data files, processed data files, and combined data files.

Written records will be maintained in the appropriate location in the laboratory. Written records are always maintained in non-erasable ink so that alterations are easily noted. Project folders include sample lists and other information regarding the sample and project. Instrument logbooks record each sample analyzed and pertinent information regarding the analysis. All calibrations are also recorded. Service logbooks and files show services and/or modifications done to the instruments. Logbooks are kept on file in the laboratory for a minimum of 5 years.

Computerized records are maintained on a central computer (the LIMS file server). The data collection system includes a history record that maintains lists of files created or modified, and the name of the person creating or modifying the file. An original report is printed after analysis and documents the method and calibration file used including the last modification date of the file. Backups of computerized records, including but not limited to removable media (floppy disks) and tapes, are stored in the LIMS manager's office for off-site storage.

### B3-4. Handling Fuel and Oil Samples

Special containers suitable for collection, storage, and shipping of fuel and oil samples will be used during the study. Identifying labels will be attached to each fuel and oil sample container. Label information will include the unique vehicle or equipment identifier, date/time of collection, and sampler initials. To protect the label from water and solvent damage, each label will be waterproof. The sample labels permanently identify each sample collected and link each sample to the vehicle/equipment from which it was collected.

## B4. ANALYTICAL METHODS

### B4-1. Gravimetric Filters

The Teflon filters to be used for this Work Assignment will be equilibrated before performing initial weights in the EPA laboratory. Each filter will be individually examined over a light table prior to use for discoloration, pinholes, creases, or other defects. All analytical procedures will follow EPA- or ASTM-approved methods. In addition to laboratory blanks, 5% of all filters will be designated as field blanks to follow handling procedures, except for actual sampling. In addition, an attempt will be made to collect 5% dynamic blank filters by placing into the gravimetric sampler but not exposing the filter to vehicle exhaust.

After the laboratory receives the sampled filters (and field blanks), these unexposed and exposed Teflon-membrane filters will be equilibrated at a temperature of 21.5 ±1.5°C and a relative humidity of 35±5% for a minimum of 24 hours prior to post-test weighing. Weighing will be performed on a microbalance with ±0. 1 µg sensitivity. The charge on each filter will be neutralized by exposure to a polonium source for 30 seconds prior to the filter being placed on the balance pan. The balance will be calibrated with a 200 mg Class M weight and the tare will be set prior to weighing each batch of filters. After every 10 filters are weighed, the calibration and tare will be re-checked. If the results of these performance tests deviate from specifications by more than ±5 µg, the balance will be re-calibrated. If the difference exceeds ±15 µg, the balance will be recalibrated and the previous 10 samples will be re-weighed. 100% of the initial and at least 30% of the final weights will be re-weighed by an independent technician. Previous ten samples will be reweighted if these check-weights do not agree with the original weights within ± 10 µg for initial weights and ± 15 µg for final weights. Pre- and post-weights, check weights, and re-weights (if required) will be recorded on data sheets as well as entered by filter number into the filter data base.

### B4-2. Fuel and Oil Samples

All fuel and oil samples collected in the field will be provided to EPA for future analysis. The types of analysis to be performed, as well as information pertaining to the associated laboratory analytical methods, is pending.

## B5. QUALITY CONTROL

All PEMS and PAMS units will be calibrated according to SOP guidelines and as summarized in Section B7-1 of this QAPP. Testing and environmental conditions will be verified prior to all testing, and post-testing data analysis and review will help ensure quality data is collected. Review of calibration and PEMS and PAMS operation records will ensure proper procedures are being used for emissions and activity measurements and equipment is functioning correctly.

Five percent of the Teflon filters used for gravimetric sampling will be provided as field blanks to follow handling procedures (except for actual sampling). Five percent of the Teflon filters will also be used as “dynamic” blanks, where they will be placed into one of the unused sample holders in the gravimetric sampler. Equipment exhaust will not be directed to this “dynamic” blank. An additional five percent of the Teflon filters will be used as laboratory blanks.

Due to the varying nature of equipment usage anticipated for this study, “replicate” sampling in the conventional sense cannot be conducted. Analysis of temporal emission trends on individual pieces of equipment, as well as analysis of emissions variations between differing types of equipment, may be used to assess emission trends and repeatability.

## B6. INSTRUMENT/EQUIPMENT INSPECTION, TESTING, AND MAINTENANCE

Inspection, testing, and maintenance procedures for specific components of the measurement systems are described below.

### B6-1. Maintenance of the SEMTECH-DS

Prior to field deployment, all PEMS units will be evaluated to ensure current firmware is installed, and all host computers will be updated with current operating software. Regular maintenance will be performed on all PEMS units. A field log will be kept listing all maintenance and repair procedures performed on all equipment, and who performed the maintenance and repairs. Maintenance and repairs will be performed when system malfunctions are identified (either through performance deviations or through faults and warnings automatically set by the measurement system) and also on regular schedules, as detailed in Section 12 of the SEMTECH-DS user's manuals and summarized below.

- The SEMTECH-DS heated filter will be replaced after each full (complete 8-hour) emission measurement session. The silicone O-rings and flat washer gasket will be inspected during each filter replacement and will be replaced as necessary.

- The SEMTECH-DS drain bowl filter will be monitored using pressure sensors in the SEMTECH-DS. The SensorTech-PC software will alert the operators when these filters begin to restrict the drain flows. Similarly, the SEMTECH-DS drain pump filters (two disposable in-line plastic filters) will be monitored using pressure sensors in the SEMTECH-DS. The SensorTech-PC software will alert the operators when these filters begin to restrict the drain flows.

- The SEMTECH-DS carbon filters will be evaluated on a weekly basis by comparing ambient port HC readings with bottled zero-air HC readings. If the ambient air readings are at least 3 ppm higher than the zero air bottle readings, the carbon filters should be replaced, as described in the manual.

- The in-line SEMTECH-DS filters will be inspected for fuel, moisture, or other contamination on a monthly basis, and will be replaced if any signs of contamination are seen.

- Pressure differentials between various zones of the SEMTECH-DS sampling system should be evaluated prior to each test in order to ensure no filters require replacement. This process will be integral with the PEMS installation process and is included in the Emissions Measurement Guidelines and Equipment Instrumentation Data Collection Forms (Appendices F and E of this QAPP). System pressures will be recorded in Appendix E.

In addition to the above manual checks, any warnings or faults that arise during equipment setup and installation will be investigated and corrected. Equipment with any warnings or faults that cannot be corrected will be removed from service until repairs are made and confirmed. The Sensors on-site technician will make every attempt to repair equipment in the field, but equipment that cannot be repaired in the field will require shipment back to Sensors' Saline facility.

## B6-2. Maintenance of the Quartz Crystal Microbalance

The cQCM device is currently not being used in the study. Maintenance procedures will be provided if the cQCM is included in future work.

## B6-3. Maintenance of the Micro-Proportional Sampler

The daily MPS maintenance includes removal and cleaning of the sample flow capillary with compressed air. With the high-emitting PM vehicles, this step is essential.

In addition, the operators will confirm and/or adjust the Major and Minor Block pressures. These pressures are set using pressure regulators contained inside the equipment enclosure.

There are also two HEPA filters that provide filtered compressed air for the Major and Minor dilution air. These will be replaced between PSUs, or as needed.

## B6-4. Maintenance of the Sequential Gravimetric Filter Sampler

The daily maintenance of the portable gravimetric filter sampling system includes:

a. Change filters prior to test
b. Check pressure of N2 bottle used for operation of pneumatic switching valves
c. Verify switching of solenoids to change filter paths
d. Set flowrate from mass flow controller to 18 slpm
e. Verify operating temperature
f. Verify communications and data transfer to SEMTECH data logger

The HEPA filter used for the make-up air will be changed between PSUs.

## B6-5. Maintenance of the Exhaust Flow Meter

The most important procedure involving the exhaust flowmeter is to switch flow tubes depending on the size of the engine to be tested. A table is provided to the operators that estimates the maximum exhaust flowrates from various sized engines, both turbo-charged and non-turbocharged. When a flow tube is replaced, it is critical that the operator select the appropriate tube SN / diameter in the SEMTECH PPMD host software.

Next, the operator must enter their best estimate of the maximum exhaust flowrate into the SEMTECH PPMD host software, so it can determine the proper proportionality constant for the minimum dilution ratio specified. Again, the operator uses the tables provided, but the SOP includes a pre-test operation of the engine to verify this value.

Prior to testing, the EFM pressure lines are backpurged using dry gas to ensure no condensation, particulates, or other contamination is restricting the pitot-tube style pressure sensors.

Further details of these procedures are included in the SOPs in the appendix.

### B6-6. Maintenance of the Activity Measurement Systems

PAMS units will be investigated after each monthly-testing episode to verify system integrity and functionality. Any malfunctioning units will be removed from service until repairs are made and verified. This QAPP and associated SOPS will be updated with specific requirements for PAMS maintenance as they become known.

## B7. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Each piece of equipment or instrument will be calibrated according to established guidelines and schedules described in the following sections. Records of calibrations will be stored in logs as well as in electronic data files collected by the PEMS units.

### B7-1. Calibration of the SEMTECH-DS

Prior to each test, all PEMS units will undergo a full warm-up, zero and calibration, sequence to verify CO, CO2, NOx, and THC measurement accuracy. A post-calibration audit will also be performed after any calibration to verify measurement accuracy. Any equipment that fails this post-calibration audit will be removed from service until repaired by onsite repair personnel. The concentrations and tolerance of all gasses used for auditing and calibrating will be recorded, and data files will be generated during all audits to preserve records of system performance. The concentrations of all gasses used for auditing and calibrating will be recorded electronically during the audit and calibration process and will be included in the emissions result data files will generated by the PEMS units. Concentrations of calibration and audit gas blends to be used are listed in Appendix F, Emissions Measurement Guidelines. This appendix also lists the blend of recommended FID fuel to be used with the SEMTECH-DS. This information is also provided in Section 14 of the SEMTECH-DS User manual.

The default limits for gas audits as listed in the SEMTECH-DS user manual will be used for this Work Assignment. These limits, listed in Chapter 14 of the SEMTECH-DS user manual, are listed in Table 7-1.

**Table B7-1: Default SEMTECH-DS Audit Limits**

| Gas | Absolute Tolerance Limit | Relative Tolerance Limit |
|---|---|---|
| CO | 0.005% | 3.0 % of bottle value |
| CO2 | 0.2 % | 3.0 % of bottle value |
| 02 | 0.5 % | 3.0 % of bottle value |
| NO | 15.0 ppm | 3.0 % of bottle value |
| NO2 | 12.0 ppm | 3.0 % of bottle value |
| HC | 4.0 ppmC6 | 3.0 % of bottle value |
| THC (100 ppmC) | 6.0 ppmC | 2.0 % of bottle value |
| THC (1,000 ppmC) | 6.0 ppmC | 2.0 % of bottle value |
| THC (10,000 ppmC) | 27.0 ppmC | 2.0 % of bottle value |
| $CH_4$ (100 ppmC) | 5.0 ppmC | 5.0 % of bottle value |
| $CH_4$ (1,000 ppmC) | 10.0 ppmC | 5.0 % of bottle value |
| $CH_4$ (10,000 ppmC) | 25.0 ppmC | 5.0 % of bottle value |

Prior to each test, all PEMS system flows and pressures will be verified and recorded, and ambient conditions as measured by the PEMS will be recorded and verified with independent measurements. A sample system leak check will be performed to verify sample system integrity, and a FID fuel leak check will also be performed. System temperatures (FID oven and chiller) will also be verified and recorded, and all sample rates and transport delay settings will be verified. All information not automatically recorded in the electronic test file will be written on Equipment Instrumentation Data Collection Forms, Appendix E. These forms will serve as a tool for collecting written information, and will also guide the installation personnel through all the installation, calibration, and verification steps, ensuring each installation is complete and all systems are functioning appropriately. Any malfunctioning equipment will be removed from service until repaired and the repairs are verified.

## B7-2. Calibration of the Quartz Crystal Microbalance

The cQCM device is currently not being used in the study. Maintenance procedures will be provided if the cQCM is included in future work.

## B7-3. Calibration of the Micro-Proportional Sampler

The daily MPS calibration routines include:

- Zero all pressure sensors with no exhaust flow and with compressor off

- Generate Lookup Tables (mapping solenoid combinations vs measured flows)
- Validate Lookup Tables
- Calibrate Sample Flow Capillary
- Set MPS to proportional flow and check major/minor/sample flows

In addition, there is weekly MPS calibrations that include:

- Check/adjust critical orifice flowrates
- Perform Major & Minor dilution Flow calibrations

### B7-4. Calibration of the Sequential Gravimetric Filter Sampler

No routine maintenance is required for the gravimetric sampler assembly. Temperature verification and functionality checks are performed daily.

### B7-5. Calibration of the Exhaust Flow Meter

Exhaust flowmeter calibration was performed at the factory prior to deployment, and should not be required during this Work Assignment. If review of test records suggests biased readings from any of the flowmeters, the flowmeter assembly will be removed from service, repaired as necessary, and recalibrated. Flowmeters will be purged with dry gas prior to each test to ensure no blockages exist in the pitot-tube sampling system.

### B7-6. Calibration of the Activity Measurement Systems

PAMS "calibration" activities consist of functionality and integrity checks of the units themselves. In addition, PAMS RPM and time calibrations will be performed for each install, using procedures described in Appendix G.

## B8. INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Staff are authorized to acquire property and supplies from vendors, and are authorized to make appropriate transactions, in accordance with EPA procurement guidelines. Consumables to be acquired for this Work Assignment may include calibration, audit, and FID fuel gases, filters for gravimetric sampling, replacement quartz crystals for the cQCM continuous PM measurements (to be provided by EPA), and replacement PEMS filters as listed in Section B6 of this QAPP. Gravimetric filters will be provided by EPA as part of their laboratory services in support of this work assignment. These filters will be pre-loaded in filter cartridges at EPA's laboratory and will not be directly handled in the field. Procedures for field-handling of the filter cartridges are described in Section B3-2 of this QAPP, and laboratory inspecting and handling procedures for PM filters are provided in Section B3-3 of this QAPP. Procurement of non-consumables is also anticipated in order to perform the tasks necessary for this Work Assignment. Vendors for various purchases will vary based on item availability, timeliness, quality, and cost. Staff will verify that consumables will meet product and performance specifications (for example, NIST-traceable analytical gases, minimum performance specs for Teflon filters, and so forth) before purchase. The Project Manager or Acting Project Manager must authorize all property that is acquired in execution of this Work Assignment.

Upon arrival, property will be examined to determine quantity received, condition, and to identify transit related discrepancies. When shortages or damages are identified at time of delivery, the carrier representative's signature will be obtained. Shipped items will be checked from a copy of the original invoice and the packing slips to document quantities received and condition, and will be moved to a protected area for distribution. Full accountability is established once the invoice has been compared to the purchase order, prices have been adjusted for all items ordered and shipped, and the invoice has been submitted for payment. If an overage, shortage, or damage upon receipt is discovered, necessary actions will be taken directly with the vendor or supplier.

All calibration and audit gases used in this study will be minimally traceable to National Institute of Standards and Technology (NIST) standards with an assurance to at least ±2% accuracy

## B9. NON-DIRECT MEASUREMENTS

We will be receiving the totality of records of construction establishments from SSI for each county in the pilot study. Thus, we will have access to the 'sampling frame universe information' according to the variables that accompany the SSI file. After finalizing the (Phase II) sample design for construction establishments, we will conduct a simulation (e.g., draw 10-20 independent samples) and assess the extent to which they collectively reflect the sampling frame universe (e.g., comparing the marginal distributions of the auxiliary variables to those of the universe). (NOTE: Recall that the Phase I sample is a subjective small sample, so there is no need for simulation with that.)

If excessive variability across samples is detected using the auxiliary variables that accompany the SSI frame, then the source of the variability will be identified and built into the stratification process, resulting in an enhanced sample design. Then the simulation will be repeated and the sample design enhanced until such time as the samples accurately reflect the sampling frame universe.  Once that determination is made, the final sampling design will be set (i.e.,” final") and the actual sample will be drawn.

## B10.   DATA MANAGEMENT

### B10-1.   Management of EOI Data

The effective use of available technology promotes improvement of the efficiency and quality of the data collection and data management process. NuStats relies on Computer Assisted Telephone Interviewing (CATI) technology that will be used in this study to interview respondents and collect data.  The system is also used to track productivity and manage data as it is being collected.  Under our system of a continuous data flow (CDF) model, data is processed in a continuous fashion which enables the moving of the editing step to the early stages of the survey process so that we can look upstream to reduce errors rather than cleaning up at the end.  In editing data, automated procedures (such as edit check programs) are relied upon to the degree possible because with them editing can be done more expediently.  Manual procedures are responsible for the high cost of editing, and we strive to find an appropriate balance between error detection and cost.

Data quality evaluation is the process of evaluating the final product in light of the original objectives of the statistical activity, in terms of the data’s accuracy and reliability.  Such information allows clients to make more informed interpretations of the survey results and is used to improve the way surveys are designed and implemented.

Data quality evaluations must meet the following minimum requirements:  a measure of coverage error, a response rate and / or imputation rate, and measures of item nonresponse rates and / or sampling error for key characteristics.  Managerial discretion is used to determine the appropriate amount of data quality evaluation for a given study.  Factors considered include the uses of the data, the potential for error and its significance to the use of the data, the cost of the evaluation relative to the cost of the study, and whether or not the survey will be repeated or not.

Internal methods to evaluate data quality include:

- Checks of consistency with external sources of data,
- Internal consistency checks, for example calculation of ratios that are known to lie within certain bounds (e.g., gender ratios, trip rate estimates),

- Unit-by-unit reviews of the largest contributions to errors in estimates (e.g., geocoding precision),
- Calculation of data quality indicators such as nonresponse rates, imputation rates, and coefficients of variation,
- Debriefings with staff involved in the collection and processing of the data.

Sources of errors that are considered for evaluation include the following:

- Coverage errors, which consist of omission, erroneous inclusions, and duplications in the frame used to conduct the survey.
- Nonresponse errors, which occur when the survey fails to get a response to one, possibly all, of the questions.
- Measurement errors, which occur when the response received differs from the “true” value and can be caused by the respondent, the interviewer, the questionnaire, the mode of collection, or the respondent’s record-keeping system. Such errors can be random in nature, or can introduce a systematic bias into the results.
- Processing errors, which can occur at the subsequent steps of data editing, coding, capture, imputation, and tabulation.
- Sampling errors, which occur when the results of a survey are based on a sample of the population rather than the entire population.

Documentation constitutes a record of the statistical activity, including the underlying concepts, definitions, and methods used in the production of the data. It serves as a record for clients of what was done in order to provide a context for effective and informed use of the data. The level of detail provided in the documentation will depend on its intended audience, the type of data collection, the data sources, the analysis, range and impact of uses of the data, and the total budget of the study.

Documentation may include the following:

- Objectives;
- Content of the questionnaire;
- Tests of the questionnaire and the process;
- Methodological overview and discussion of technical issues;
- Data systems (data files structures, algorithms used to construct or define variables, weighting and expansion factors);
- Results of monitoring reports;
- Operations issues (training, feedback or debriefing reports;
- Implementation steps and challenges;
- Quality control indicators; and

- Data quality measures

## B10-2. Management of Field Data

Onsite equipment inventories will be collected on hardcopy forms similar to the "Onsite Inventory Data Collection Forms" included in Appendix C of this QAPP (and specified in the original Work Assignment). Engine serial numbers and other unique information will also be collected, as available. Photographs will be taken of unique identifiers such as serial numbers to serve as conformation information (and to correct/clarify transcription errors and discrepancies). Site inventory information will be transmitted to an ERG office (most likely ERG's Kansas City office) for entry into a spreadsheet or database. Transmission will either be via fax or tracked commercial courier. Entered information will be reviewed (and decoded as possible) in order to verify accuracy and identify any potential discrepancies. Any potential discrepancies will be resolved through subsequent site revisits, as necessary.

During emissions and activity measurements, information will be collected on hardcopy forms similar to the "Equipment Instrumentation Data Collection Forms" forms shown in Appendix E of this QAPP (and specified in the original Work Assignment). Similar to the onsite equipment inventory data entry process, these hardcopy forms will be sent to an ERG office for entry into a spreadsheet or database and reviewed for accuracy. Any identified discrepancies will be investigated and corrected as necessary. All equipment operation and calibration information, which is not electronically recorded, will be manually recorded on equipment instrumentation forms, as shown in Appendix E.

At the end of each emissions and activity test, raw test data will be retrieved from the PEMS or PAMS instrument and stored on a field computer. The PEMS or PAMS storage device (such as a flash card) will be replaced with a storage device with no test data. The original storage device will be archived for a period of time until successful retrieval of all valid test data from a remote office has been confirmed, at which time the storage device will be erased and rotated back into service.

All emission and activity test files will be posted to a secure project FTP site, where they will be retrieved by the appropriate team members in remote offices (most likely Sensors in their Saline, Michigan office and ERG in the Austin, Texas office). The EPA will also have access to all test data as soon as it's available. The ERG Austin office will serve as the central repository for all project data.

Information pertaining to establishment sites that have been inventoried, and emissions and activity measurements that have been performed will be provided to NuStats via the field management system for updates to their project sampling database. NuStats will provide summaries regarding fieldwork progress (site inventories, emissions measurements and activity measurements) to ERG for Work Assignment progress management.

ERG ensures the quality of the information we produce, maintain, and disseminate by adhering to procedures consistent with the requirements outlined in Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the Environmental Protection Agency (EPA /260R-02-008, October 2002 with 2004 addendum).

All areas that house computers are secure and temperature-controlled, and power to computer units are conditioned to prevent spiking and surging in the power supply. The ERG team ensures information protection by operating up-to-date security systems and virus protection programs. Further, wide area networks are secured by firewalls, eliminating unauthorized access and maintaining system security.

To ensure the security of our hardware and project files, the information on file servers is copied to magnetic tape as a weekly backup. Incremental backups are scheduled for weekday nights. When files are no longer needed on the server, they are moved to tape for indefinite long-term storage.

All raw data generated during the project data will be initially be reviewed in the field for any problems, and then read into SAS for automated quality checking and formatting consistent with the Work Assignment specifications and procedures discussed in section D of this QAPP. All processed and validated data will be provided in a format suitable for input into EPA's MSOD database, similar to data tables shown in Appendix H. All original data will be retained, and validated/revised data will be provided along with a list of changes. All results of data analysis observations (including results of analysis that seem to indicate data is suspect or requires additional review) will be provided along with the final data submission. All software and code used for processing and validating project data will be provided to the EPA.

All project acquisitions (consumables and other equipment) will be documented as described in Section B8 of this QAPP. All receipts will be maintained throughout the duration of this Work Assignment and will be provided to EPA upon request. Overall project status information will be provided to the EPA on a monthly basis in reports conforming to requirements listed in Attachment 2 of the parent National PEMS Deployment contract (contract

ID EP-C-06-080). Draft and Final reports will be provided to the EPA as described in Sections 2.2.6 and 2.2.7 of this Work Plan for this Work Assignment.

# C. Assessment and Oversight

## C1. ASSESSMENT AND RESPONSE ACTIONS

As highlighted in the Work Plan, maintaining data quality will be a continual priority throughout this study. NuStats Continuous Data Flow process (CDF) is a fully documented and well-tested system that lays the foundation for establishing procedures, standards and guidelines, and producing quality data. This system is not a pre-packaged, one-size-fits-all approach—it is a toolbox of software applications, quality control procedures, and diagnostic and reporting processes.

The ability to efficiently collect, clean, code and process data in a timely manner is provided through NuStats' CDF system. The CDF system operates as a pipeline or assembly line; constantly channeling data from one stage to the next, preventing data that is "not finished" with one stage from progressing to the next, without impeding the overall flow of data. Our CDF process will be employed throughout the entire study, covering all phases from sample-generation to data collection, edit-checking/processing, analysis and data delivery.

In addition to use of the CDF as a management tool, project management will regularly discuss progress on the project, in particular whether policies and procedures outlined in this QAPP are currently being adhered to. Deficiencies in any procedures will be brought to the attention of the project manager. Task leaders and field managers will have responsibility for ensuring all procedures are in compliance with QAPP guidelines. Any QAPP guidelines found to be obsolete will be revised by ERG management in consultation with the EPA WAM.

Regular assessment of fieldwork procedures and knowledge and training of personnel conducting fieldwork will be performed. If any deficiencies are identified, corrective action will be implemented. The system to be used for corrective action is the "closed loop" system, including the following elements.

- Problem definition
- Assignment of responsibility for investigation of the problem
- Problem investigation
- Determination of appropriate corrective action
- Implementation of corrective action
- Verification of problem correction
- Implementation/dissemination of procedural changes, if any

To enhance the timeliness of corrective action and minimize the generation of unacceptable data, problems identified by internal QC checks (such as the review of field data as described in Section B10 of this QAPP) will be resolved at the lowest possible management level. Problems involving any change in scheduling, the sample work plan, or performance of analytical tasks will be handled in a manner agreed upon by the Project Manager and the EPA WAM. The Project Manager will perform periodic spot checks of project activities, recording and archiving of data, and response to EPA communications. Timely review of electronic calibration records and data collected via “Equipment Instrumentation Data Collection Forms” (as shown in Appendix E) will ensure non-compliant procedures are quickly identified and corrected.

The Project Manager will perform monthly spot checks of project activities, evaluation of response to EPA and ERG communications, completion of QC data by laboratory personnel, and recording and archiving of data. In addition, a monthly summary of any quality issues identified will be included in the Monthly Progress Report to document the overall QA program activities and findings for project activities.

## C2. REPORTS TO MANAGEMENT

ERG will provide four copies of monthly progress reports as specified in Attachment 2 of National PEMS Deployment contract (contract ID EP-C-06-080). These progress reports will be developed by the ERG Project Manager or Alternate Project Manager, and 3 copies will be distributed to the EPA Project Officer and 1 copy provided to the EPA Administrative Contracting Officer. A monthly summary of any quality issues identified will be included as part of the Monthly Progress Report, along with information on corrective actions implemented and any potential impact of the quality issues.

Pending contract authorization, draft and final reports will be prepared as described in Sections 2.2.6 and 2.2.7 of the Work Plan. In the draft report, ERG will document all statistical methods and steps used for drawing samples for this Work Assignment, and the outcome of interviews and recruitment efforts will be summarized. The draft report will also include a summary of results for emissions and activity measurements and an overview of testing activities, such as a description of equipment installation and operation procedures, problems and resolutions and lessons learned. All quality assurance checks applied to the data will be described. ERG will develop a final report by revising the draft report based on EPA’s review recommendations. One electronic copy and three hard copies of the final report will be delivered to the EPA Work Assignment Manager at the USEPA National Vehicle and Fuel Emissions Laboratory at Ann Arbor Michigan. ERG will deliver the report in Microsoft Word® format.

# D. Data Validation and Usability

## D1. DATA REVIEW, VERIFICATION, AND VALIDATION

Data and testing parameters will be reviewed in the field and again at ERG's Austin office to ensure test conditions and data are valid. Data review will occur as soon as possible in order to quickly identify and correct any procedural errors or equipment issues, which could affect data integrity. Initial reviews of processed files will be performed by ERG and Sensors personnel in order to identify any outlying data or parameters. PEMS and PAMS data will then be read into SAS® where it will undergo additional "engineering" review, as described in the following section.

## D2. VERIFICATION AND VALIDATION METHODS

Several controls will be in place to help ensure accurate data is collected throughout the study. As mentioned in Section A8 of this QAPP, all personnel to be involved in data collection will be thoroughly trained in all procedures necessary to meet the goals of this Work Assignment. Strict sampling methods, sample handling procedures, laboratory procedures, equipment maintenance and calibration procedures, and data management and review processes, as described throughout this document, will be in place in order to ensure data collected throughout this Work Assignment is of the highest quality. Standard Operating Procedures will be used for all relevant processes, and regular review of all operations will be conducted to ensure procedures are in compliance with project quality guidelines.

Reliable collection of data requires immediate review of the collected and/or returned data. NuStats will review each field team member's completed surveys when turned in after completion of an assignment. Immediate feedback will be provided about the quality of their work, response rates, and other data collection performance observations.

Data editing is the application of checks that identify missing, invalid, or inconsistent entries or that point to data records that are potentially in error. In this study, the goals of editing are three-fold: to provide the basis for future improvements in study designs and implementation, to provide information about the quality of the survey data, and to tidy up the data for analysis.

While NuStats recognizes that fatal errors (e.g., invalid or inconsistent entries) should be removed from the data sets in order to maintain data accuracy and to facilitate further automated data processing and analysis, our culture guards against *over editing* which is not only costly in terms of financing, timeliness, and increased response burden, but can also lead to severe biases resulting from "changing" respondent reported information to fit some implicit model of data correctness.

NuStats processes data in a continuous fashion under our continuous data flow (CDF) model, which enables us to move the editing step to the early stages of the survey process so that we can look upstream to reduce errors rather than cleaning up at the end. In editing data, NuStats relies on both manual (but efficient) and automated procedures (i.e., edit check programs) to the degree possible because with them editing can be done quickly and as expediently as possible.

Data quality evaluation is the process of evaluating the data's accuracy and reliability. Such information allows clients to make more informed interpretations of the survey results and is used by NuStats to improve the way surveys are designed and implemented.

Internal methods to evaluate data quality include:

- Checks of consistency with external sources of data,
- Calculation of data quality indicators such as non-response rates (both overall, or unit non-response and for specific variables, or item non-response),
- Debriefings with staff involved in the collection and processing of the data,
- "Reasonableness" checks by knowledgeable subject matter experts (both internal and external to NuStats).

Emissions and activity data collected throughout this study will be read into SAS® and analyzed. Scripts and programs will be used as much as possible, to provide repeatable steps for the verification stage and documentation. In the first import stage, the raw input data will be loaded into SAS® datasets. The data will be imported into datasets that mimic, to the extent possible, the design of the original files. In this way, each raw input file will map to one or more specific SAS® datasets, with close agreement in table content and layout. While some data cleanup may be needed for a successful data import, no data manipulation (such as unit conversions or factor manipulation) will be performed at this stage. Minor data cleanup may be required because of conflicts between file types, such as end-of-record or end-of-data discrepancies, differences in character sets, conflicting numeric formats, or data types that do not convert directly. Once the data is imported, the raw import data will be considered "read only" and no updates will be made unless the import process is modified and repeated. After the data is loaded into the raw datasets, it will be reviewed for data integrity and completeness.

PEMS and PAMS data will be analyzed to identify outlying values, such as exhaust flow rates which deviate from those of similarly sized engines, pollutant spikes or exhaust dilution ratio anomalies, RPM spikes, inappropriate system test parameters and conditions, and tests where other parameters seem unreasonable. Other checks may also be applied to the data as well, and a draft list of analysis queries is provided in Appendix I. All tests with suspect data will be reviewed in order to determine whether data problems truly exist, to attempt to identify the source of the problem and whether or not data from other tests could be affected because of this problem, and finally whether any data corrections could be appropriately applied. Results of all analysis performed will be fully documented, including any corrections applied to any study data. Raw, uncorrected data will also be retained whenever any data is modified throughout the study.

Once the data review and correction process is complete, the raw import datasets will remapped and all required conversions and data manipulation will be performed (in SAS®) to prepare the data for conversion into the text files to be used for MSOD loading. These text files will be imported directly into MSOD load tables (in DBF format) supplied by EPA. The final step in the process will involve running EPA's EPAVAL program against each of the DBF import tables, which will quality assure each of the tables and log all errors encountered. Each of the errors will then be reviewed and addressed accordingly. Guidelines for preparing the MSOD data tables will conform the criteria specified in the MSOD User Guide (available at http://www.epa.gov/otaq/models/msod/420b04004.pdf). Once the import tables for each dataset are complete they will be delivered to EPA for further verification and loading into the MSOD.

## D3. RECONCILIATION WITH USER REQUIREMENTS

In order to end up with a final interview database that is error-free, processing will be performed simultaneously with data collection. The final interview database will stand-alone and contain all of the supporting documentation that potential data users might need. After weighting and adjustment and prior to tabulation production, data will be validated to ensure reasonableness and consistency. At this point, the data items matrix for the database will be updated and verified. The data items matrix is an Excel document that includes survey questions, variable names, valid variable values, allowable variable widths, exact coding categories, and other specifications for the data. These matrices outline the mutually agreed upon database structure and serve as a "road map" for understanding the database.

Field verification and in-house validation of emissions and activity data will be performed as described in Sections B7, D1, and D2 of this QAPP. Issues that arise will be discussed with the EPA Work Assignment Manager as soon as possible. If necessary, modification to the sampling approach in order to meet the Establishment and Equipment sample objectives of this Work Assignment will be implemented, in consultation with EPA and ERG Team statisticians to ensure study design integrity is maintained. All issues identified through the data validation process will be reported in the draft and final reports.

Root-cause analysis will be performed on any issues identified with field or laboratory measurements in order to find and correct the source of any faulty data. "Real-time" verification and validation (as feasible) will help ensure problems are identified and corrected in a timely manner. Any systematic issues identified through field measurement equipment maintenance and calibration (described in Sections B6 and B7 of this QAPP) will be addressed through immediate discussions with the EPA Work Assignment manager and ERG. Any equipment found to not be performing according to specifications will be removed from service until repairs are made and verified.

Overall sample totals for the Establishment and Equipment Samples will be compared with project totals to ensure sample goals were met.

# Appendix A:  Equipment Ownership Interview Questionnaire / Supplemental Equipment Ownership Interview Questions for Equipment Sample

[Derived from Appendix A1 of Work Assignment 0-1 / Derived from Questions 1-7 of Appendix A2 of Work Assignment 0-1]

Populations, Usage and Emissions of Diesel Nonroad Equipment in EPA Region 7
Full Interview
PSU 4& 5

INTRO PHASE 01

Hello. May I speak with <FIRST NAME> <LAST NAME>? My name is ________ and I am calling on behalf of the Environmental Protection Agency. We are conducting a study with companies about the equipment used in their daily operations.

REPEAT INTRO ONLY IF REFERRED TO A MORE KNOWLEDGEABLE RESPONDENT

Hello, Mr./Ms. <FIRST NAME—DO NOT READ> <LAST NAME>? My name is ________ and I am calling on behalf of the Environmental Protection Agency. We are conducting a study with companies about the equipment used in their daily operations. IF NEEDED: Examples of the types of equipment that we're interested in include,

| | | |
|---|---|---|
| Loaders | Dozers | Generator sets |
| Cranes | Excavators | Backhoes |
| Paving/surfacing equipment | Backhoes | Forklifts |
| Graders | Off-highway trucks | |

We would like to do a brief survey with you that lasts less than ten minutes. Your company was scientifically selected for this study. Your participation is voluntary and your name and company will not be connected with your answers in any way.

1. First, I would like to verify that your organization is <Establishment Name> and that your address is <Establishment Address>. Is this correct?

| | |
|---|---|
| YES | 01 |
| NO | 02 |
| DK | 08 |
| RF | 09 |

IF 'NO,' OBTAIN UPDATED ADDRESS OR ESTABLISHMENT NAME.

2. Now, I would like to verify that your organization's primary function is construction-related. Please specify whether you perform one or more of the following construction-related services.

| | | |
|---|---|---|
| NO CONSTRUCTION SERVICES | 00 | |
| Building, developing and general contracting | 01 | |
| Heavy construction | 02 | |
| Special trade contractor | 03 | |
| Concrete contractor | 04 | |
| Water well drilling | 05 | |
| Structural steel erection | 06 | |
| Excavation | 07 | |
| Wrecking and demolition | 08 | |
| Machinery or equipment installation | 09 | |
| OTHER (SPECIFY) | 97 | |
| DK | 98 | TERMINATE 01 |
| RF | 99 | TERMINATE 01 |

3. A. Within your organization, what percentage of your equipment runs on GASOLINE?

| | | |
|---|---|---|
| 100% | 01 | |
| Between 99% - 75% | 02 | |
| Between 74% - 51% | 03 | |
| Between 50% - 26% | 04 | |
| Between 25% - 1% | 05 | |
| Less than 1% | 07 | |
| DK | 08 | ASK FOR MORE KNOWLEDGEABLE PERSON |
| RF | 09 | ASK FOR MORE KNOWLEDGEABLE PERSON |

B. How about the percentage of your equipment that runs on DIESEL?

| | | |
|---|---|---|
| 100% | 01 | |
| Between 99% - 75% | 02 | |
| Between 74% - 51% | 03 | |
| Between 50% - 26% | 04 | |
| Between 25% - 1% | 05 | |
| Less than 1% | 07 | TERMINATE |
| DK | 08 | ASK FOR MORE KNOWLEDGEABLE PERSON |
| RF | 09 | ASK FOR MORE KNOWLEDGEABLE PERSON |

INTERVIEWER PROBE, IF NEEDED: JUST TO CLARIFY, NOT EVEN 1 PIECE OF EQUIPMENT RUNS ON DIESEL IS THAT CORRECT?

4. Aside from owners, proprietors or partners, did your organization have one or more paid employees at any time during the last twelve months?

| | | |
|---|---|---|
| YES | 01 | |
| NO | 02 | SKIP to Q.7 |

IF NECESSARY, CLARIFY THAT 'PAID EMPLOYEE' INCLUDES FULL OR PART TIME, PERMANENT, TEMPORARY OR SEASONAL EMPLOYEES.

5. How many paid employees work for your organization?

| | | |
|---|---|---|
| Specify Number | __________ | SKIP to Q.7 |
| DK ➔ PROBE FOR BEST GUESS Q.6 | 99998 | |
| RF ➔ PROBE FOR BEST GUESS Q.6 | 99999 | |

6. I'm going to read you some numbers. Stop me when you think I get to the one that best describes your organization.

| | |
|---|---|
| 2 to 4 employees | 01 |
| 5 to 9 employees | 02 |
| 10 to 19 employees | 03 |
| 20 to 49 employees | 04 |
| 50 or more employees | 05 |
| DK | 08 |
| RF | 09 |

7. *Earlier you mentioned that you owned, rented or leased at least one piece of diesel equipment. About how many pieces of diesel equipment or machinery are used by your organization?*
*SPECIFY NUMBER* _________ *SKIP to Q.9*
*DK 99998*
*RF 99999*

8. *I'm going to read you some numbers. Stop me when you think I get to the one that best describes the number of equipment units or machines are used by your organization*

| | |
|---|---|
| *1 to 4 pieces* | *01* |
| *5 to 9 pieces* | *02* |
| *10 to 19 pieces* | *03* |
| *20 to 49 pieces* | *04* |
| *50 or more pieces* | *05* |
| *DK* | *08* |
| *RF* | *09* |

9. *Of the equipment you've told me about, does at least one piece have a 25-horsepower or larger engine?*
*YES 01*
*NO 02 Skip to Q11*
*DK 08*
*RF 09*

10. *Does at least one piece have a 50-horsepower or larger engine?*
*YES 01*
*NO 02*
*DK 08*
*RF 09*

11. *Do you buy any or have you bought any of the equipment that you use?*
*YES 01*
*NO 02 GO TO Q.13*
*DK 08 GO TO Q.13*
*RF 09 GO TO Q.13*

12. *When your company buys equipment, do you finance the purchase?*
*YES 01*
*NO 02*
*DK 08*
*RF 09*

13. *Would you say that your company is a prime contractor, a subcontractor, or both? (IF NEEDED: By "prime contractor" I mean that your company typically has a direct contract for an entire project; as the "prime contractor" you may, in turn, assign portions of the work to subcontractors.)*
    *PRIME CONTRACTOR 01*
    *SUBCONTRACTOR 02*
    *BOTH 03*

*PROGRAMMER NOTE: FLAG SUBCONTRACTORS*

*<SCRIPT NOTE: END OF EOI. WHEN QUOTA ON INVENTORY RECRUITMENT (Q14-Q22 IS MET, INTERVIEW CAN QUIT HERE.>*

*KEEP "COIN TOSS" RANDOM ASSIGNMENT (50/50) FOR INCENTIVE*

*IF FLAGGED FOR INCENTIVE, CONTINUE WITH THE FOLLOWING:*
*Thank you for cooperating with us and answering these questions. Now, we will continue onto the next part of the study. I want to let you know that we will be mailing your company a $100 check. Ok….*

<INTERVIEWER NOTE: IF NEEDED, READ EXACTLY: The $100 check will be sent to your company regardless of your participation in the study. It's just for your consideration and not for participation.>

*14-INTRO: FOR ALL RESPONDENTS:*

*To help EPA gather emissions data on diesel off-road equipment we'd like to list the equipment your company uses and then take measures on one or two pieces. This would involve sending a technical specialist to inventory the equipment at one of your worksites and scientifically selecting one or two pieces for instrumentation. Trained technicians would install the instrument before a workday begins and remove it after the workday ends. The process doesn't affect equipment performance in any way. And you or someone from your company are welcome to observe the installation.*

14. *A Do you have any questions about this phase of the study before I ask you just a few more questions?*

| | |
|---|---|
| *YES* | *01* |
| *NO* | *02* |
| *DK* | *08* |
| *RF* | *09* |

*PROGRAMMER NOTE:*

NEED A DISPOSITION AT THIS POINT TO MONITOR RESPONDENT BAIL OUT RATE.

OK= Continue with rest of the survey KB= Call back SC= Refused to continue, short complete

*14.B Is all of your equipment located at your company address <READ ADDRESS> or do you also have equipment located or in use at other work sites?*

| | | |
|---|---|---|
| *Equipment is all at company address* | *01* | *Skip to Q.17* |
| *Equipment is at other work sites* | *02* | |
| *DK* | *08* | |
| *RF* | *09* | |

*IF Q14 = DK/RF (98 or 99) ASK FOR MORE KNOWLEDGEABLE PERSON AND REPEAT 14-INTRO, PREFACED WITH THE FOLLOWING:*

*Hello. My name is ________ and I am calling on behalf of the Environmental Protection Agency. We are conducting a study with construction companies about the off-road diesel equipment and machinery used in their daily operations. <INSERT NAME OF PREVIOUS RESPONDENT> has been participating with us on this study and has referred me to you as the person more knowledgeable about the equipment and machinery used by your company. Let me tell you about it. CONTINUE WITH 14-INTRO.*

15. *At how many sites or facilities do you have equipment stored or in operation?*
    *ENTER NUMBER: ______*
    *Range= 2-97*
    *DK 98*
    *RF 99*

16. *Okay, we would like to scientifically select one of those sites, list the equipment at the site, and select at least one piece of equipment for instrumentation. So that we can select the site what is the name of up to five sites or facilities where you have equipment stored or in operation?*
    *Site #1: _*
    *Site #2: _______*
    *Site #3: _*
    *Site #4: _*
    *Site #5: _*

*INTERVIEWER AND PROGRAMMER: RANDOMLY SELECT ONE SITE AND TWO BACKUP SITES. READ TEXT BELOW AND THEN COLLECT ITEMS 17 – 22 ON EACH OF THE THREE SITES.*

*Thank you. We have selected one site and two back up locations. I need to collect information on each of these sites.*

17. *We would like to inventory equipment at the <SITE DESCRIPTION>site. Is there someone at the site that we should contact to schedule an appointment and let know that we have permission to visit the site and inventory the equipment?*
    *NO, I AM THE CONTACT 01 SKIP TO Q19.*
    *YES 02*

18. *What is the name and phone number of this person(s)?*
    *ENTER NAME1:_*
    *ENTER PHONE1:_______*

    *ENTER NAME2:_*
    *ENTER PHONE2:_______*

19. *What would be the best times to contact < you or that person/them>?*
    *ENTER TIME1:__*
    *ENTER TIME2:__*

20. *At this site, do you have equipment operating around the clock, in shifts?*
    *YES 01*
    *NO 02 TERMINATION 02*
    *DK/NOT CERTAIN 03 TERMINATION 02*

21. *Does the equipment operate more than one shift in a 24-hour period?*
    *YES 01*

| | | |
|---|---|---|
| *NO* | *02* | *TERMINATION 02* |
| *DK/NOT CERTAIN* | *03* | *TERMINATION 02* |

22. *Okay, what are the shifts that typically operate over a 24-hour period?*
*RECORD TIMES OF SHIFTS_____ TERMINATION 02*
*DK/NOT CERTAIN TERMINATION 02*

*TERMINATION TEXT:*

*TERMINATION 01 (RESPONDENT IS NOT QUALIFIED). Thank you. Those are all the questions I have. We appreciate your taking time to help with this study.*

*TERMINATION 02 (RESPONDENT IS QUALIFIED). Thank you. In the next few days, a technical specialist will call to schedule a time to perform the inventory at <name of site>. We appreciate your taking time to help with this study.*

# Appendix B:  Questionnaire for Onsite Equipment Inventory

[Derived from Questions 8-11 of Appendix A2 of Work Assignment 0-1]

APPENDIX B1-2

On-Site Equipment Inventory

A.2 On-Site Equipment Inventory

For respondents in the equipment sample, the step following the initial ownership interview is to obtain a listing of equipment that is eligible for instrumentation. This listing serves as a third-stage sample frame, and also will serve to describe the age and size distribution of equipment used by the respondent. The interviewer will continue with additional questions regarding the respondent's operation and use of equipment. For respondents who use equipment at multiple sites or on a continuous shift basis, additional sampling steps will be employed as appropriate to access equipment while retaining control of selection probabilities for individual pieces. We describe specific items below:

Item 1: *Respondent's work sites*. This question is intended to determine if a respondent has equipment stored or in operation at sites other than the home site listed in the establishment sample frame.

Item 2: *No. work sites with equipment*. This question determines the number of work sites at which the respondent stores or uses equipment. If the number is greater than 1, the technicians will select one site, using SRS, to reduce the number of sites to be visited. This step simplifies field operations and reduces respondent burden, as it may be impractical to schedule multiple appointments at different sites and times to inventory all pieces used by the respondent. Also for practical purposes, technicians may consider remote sites ineligible if they are beyond a pre-determined maximum distance from the respondent's home site.

Item 3: *Contact at remote site*. If a remote site is selected, the interviewer will ask whether an additional person, such as a site manager, should be contacted to obtain permission to visit the site. Responses to this item will be binary.

Item 4: *Additional Contact Information*. If the answer to Item 3 is 'YES,' the interviewer will request a name(s) and contact information for one or more contacts at the remote site.

Item 5: *Contact's Schedule*. The interviewer will request information on the contacts' work schedule(s), and good times to reach the contact(s).

Item 6: *Respondent's Shift Schedule*. This item determines whether the respondent operates equipment on a continuous shift basis, i.e., whether some portion of the respondent's equipment is in operation at any given time. Equipment in operation at the time of a site visit is unavailable for sampling or instrumentation. The response to this question is binary.

Item 7: *No. Shifts per 24-hour Period*. This binary item determines whether the respondent operates equipment over more than one shift in a 24-hour period. The object is to determine whether a site visit can be scheduled at any time when all equipment would be idle. If the number is greater than one, the technicians will select one shift, using SRS, and schedule a time to inventory the equipment when it is off-shift.

After selection of the home site or a remote site for piece selection, the technicians will complete an inventory of all equipment pieces on the site. They will obtain five items needed to uniquely identify individual pieces and their specifications. These items include:

- equipment type,

- equipment manufacturer,
- equipment model,
- equipment model year, and
- equipment serial number.

In addition, acquisition of these items allows the technicians to determine other equipment specifications directly without burdening the respondent with additional highly specific questions. For example, the equipment serial number allows determination of the equipment model year through commercially available serial number guides (EquipmentWatch, 2001a). Determination of manufacturer and model also allows determination of other specifications such as power and speed ratings from commercially available specification references or manufacturers' specifications (EquipmentWatch, 2001b). Again, the goal is to avoid the need to trouble respondents with detailed questions that are difficult to remember or that may require consultation of records.

*Equipment Piece Selection (Third-stage sampling)*. To select equipment pieces, interviewers will apply simple random sampling (SRS) through the use of random number tables (Cochran, 1977). After selection of an eligible equipment piece for either emissions or activity measurement, interviewers will continue with item 8.

Item 8: *Confirmation following Selection*: Following selection of a single piece for instrumentation, the technician(s) will confirm with the respondent that they have permission to instrument the selected piece. After receiving confirmation, they will proceed to instrument the piece.

Item 9: *Annual vs. Periodic Usage*: Regarding the piece selected for instrumentation, this item is designed to solicit information concerning whether the piece is used throughout the year, or periodically or seasonally during the year. This information may be particularly relevant to equipment in construction or agriculture where equipment use may follow consistent seasonal patterns.

Item 10: *Usage by Month*: In cases when the respondent indicates that the equipment piece is not used all through the year, this item asks the respondent to indicate during which months of the year they use the piece. This item gives a rough profile of the equipment piece's annual usage pattern, broadly indicating when during the year the selected piece or similar pieces might be available for instrumentation.

Item 11: *Use During Measurement Period*. This item attempts to determine whether the selected piece is likely to be used during the proposed measurement period, i.e., during the "next week" for emissions measurement, or during the "next 2-3 months" for activity measurement. If the answer is "NO," the selected piece will be considered ineligible for instrumentation. At that point, the technicians will select another equipment piece, and repeat items 8-11.

## Appendix C: Onsite Inventory Data Collection Forms and Random Selection Guidelines for Site, Shift of Equipment Piece Selection

[From Appendix A2 of Work Assignment 0-1]

**PAGE 1**

Establishment ID: ______________________ Apt date/time: ______________________ **Total # of Sites** [ ]

Site Number / Location: ______________________ Site name/contact info: ______________________

Note: Field ID resets to 1 by establishment, not site

| Field ID | Equipment Type | Manufacturer / Make | Model | Serial No. | Serial # Verified? | Hour Meter | Pipe OD (inches) | Ownership (if Known) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |
| | | | | | Y N N/A | | | Pr Sub Unk |

**PAGE 2**

Establishment ID: ____________

Site Number: ____________

Note: PEMS Testability Footprint = 4' x 3'. If in doubt on PEMS testability, indicate "Yes"
(actual base is 32" + 5" for weatherstation by 44" + 2" for external lines)

**Please provide general description of site operations:** ____________

**Which months (if any) does establishment suspend work?** ____________

| **Field ID** (from pg 1) | **Model** (from pg 1) | **Establishment Identifier** | **Field Observations / Comments** | **Oil Filter Hours/Date** | **PAMS Testable?** | **PEMS Testable?** | **Model Year** | **HP** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
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| | | | | | | | | |
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| | | | | | | | | |
| | | | | | | | | |

Date entered into CVS: ____________

# Appendix D:  Equipment Selection Spreadsheet

The equipment selection spreadsheet presented below is made up of a series of steps that allows for random selection of equipment to instrument based on a variety of factors. These steps are presented below.

- First, the user obtains the list of equipment for a given facility, and assigns the equipment to bins based on horsepower and hourly usage bins. For each bin, each piece of equipment is assigned a “high” or “low” value.

- Combining the two bins above yields a matrix of 5 composite HP/usage bins (columns A through C):
    - High HP – High Usage (HH)
    - High HP – Low Usage (HL)
    - Low HP – High Usage (LH)
    - Low HP – Low Usage (LL)
    - Other, Unclassified

- Per the random sampling design methodology, a weighting for each composite bin is assigned (column D)

- Letter depth for each bin is calculated in column E, based on the frequency of equipment in each composite bin multiplied by the assigned weighting factor. This total letter depth is divided by the intended number of equipment to instrument to arrive at the number of letters to use in column F.

- In column G, a letter sequence is assigned to each composite bin based on the associated letter depth. In this example, there are 15 letters in column G for bin HH, corresponding to the letter depth calculated in column E. The letters “wrap” at the eleventh letter of the alphabet, as calculated in column F.

- Having established a weighted letter sequence in Table 1, the user assigns a random value between 0 and 1 to each letter in Table 2, for each selection of interest (PEMS, PAMS, and associated backups). For each column, the user notes the letter corresponding to the largest random number – this is the selected letter.

- Next, to populate Table 3, the user assigns letters to each piece of equipment, equally distributing (in alphabetical order) the letters listed in column G of Table 1 over the selection number listed in column A of Table 1. The user then applies the letter randomly selected in table 2 to determine the selected piece of equipment for instrumentation.

Table 1

| Sel. No. | BIN | Freq | wtg | Total*Weighting Factor (determines letter depth) | No. Letters to Use for Assignment (Total from Column D/# of pieces of equipment desired to instrument) | |
|---|---|---|---|---|---|---|
| 2,4,6,8,9 | HH | 5 | 3 | 15 | | ABCDEFGHIJKABCD |
| | HL | 0 | 2 | 0 | | |
| 1,10 | LH | 2 | 2 | 4 | | EFGH |
| 3 | LL | 1 | 1 | 1 | | I |
| 5,7 | other | 2 | 1 | 2 | | JK |
| | | | | | | |
| | Total | 10 | | 22 | 11 | |

Table 2

| Random Selection | PEMS | PAMS | BACKUP PEMS#1 | BACKUP PAMS#1 | BACKUP PEMS#2 | BACKUP PEMS#3 | BACKUP PEMS#4 |
|---|---|---|---|---|---|---|---|
| A | 0.201811 | 0.146249 | 0.298636229 | 0.69851256 | 0.844387802 | 0.634902 | 0.336219 |
| B | 0.096008 | 0.441564 | 0.411690215 | 0.575815782 | 0.521009397 | 0.5176 | 0.507856 |
| C | 0.895035 | 0.687886 | 0.491319518 | 0.950765359 | 0.054609424 | 0.155629 | 0.738823 |
| D | 0.00878 | 0.785783 | 0.319540138 | 0.643402974 | 0.150657463 | 0.7398 | 0.102828 |
| E | 0.88382 | 0.227635 | 0.677964656 | 0.866680927 | 0.061540785 | 0.759889 | 0.684742 |
| F | 0.128361 | 0.617324 | 0.331917242 | 0.956118797 | 0.085137384 | 0.134607 | 0.312666 |
| G | 0.045328 | 0.513761 | 0.409310605 | 0.319438272 | 0.731236506 | 0.098346 | 0.400138 |
| H | 0.016053 | 0.110473 | 0.004007958 | 0.292767476 | 0.887208634 | 0.278232 | 0.098259 |
| I | 0.112497 | 0.267019 | 0.992324477 | 0.459703841 | 0.268231206 | 0.591281 | 0.084268 |
| J | 0.819821 | 0.568437 | 0.819043353 | 0.97927198 | 0.693526689 | 0.23279 | 0.903239 |
| K | 0.703438 | 0.422824 | 0.093420821 | 0.862101074 | 0.824485476 | 0.828995 | 0.478428 |
| | 0.895035 | 0.785783 | 0.992324477 | 0.97927198 | 0.887208634 | 0.828995 | 0.903239 |
| Select | C | D | I | J | H | K | J |

| Table 3 | | PEMS | PAMS | BACKUP PEMS#1 | BACKUP PAMS#1 | BACKUP PEMS#2 | BACKUP PEMS#3 | BACKUP PEMS#4 |
|---|---|---|---|---|---|---|---|---|
| 1 | EF | | | | | | | |
| 2 | ABC | X | | 3 | | 6 | 7 | 5 |
| 3 | I | | | | | | | |
| 4 | DEF | | X | | 5 | | | |
| 5 | J | | | | | | | |
| 6 | GHI | | | | | | | |
| 7 | K | | | | | | | |
| 8 | JKA | | | | | | | |
| 9 | BCD | X | X | 6 | 8 | 10 | 8 | 8 |
| 10 | GH | | | | | | | |

# Appendix E:  Equipment Instrumentation Data Collection Forms

[Derived from Appendix A3 of Work Assignment 0-1.]

| |
|---|
| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
| Test ID: __________ _ __________ |

## INSTALLATION DATA COLLECTION FORM COVER PAGE

**Test ID __ __ __ __ -- __ __ __ __** **(last 4 digits of Est ID – last 4 digits of serial #, i.e., 3424_4532)**

**Test Type (circle one): PEMS PAMS**

**Establishment Number: __ __ __ __ __ __ __**

**Site Number: __ __**

**Site Installation Location: ______________________________**
**______________________________**

**Installation Date:_____________________________________**

**Installation Technician:________________________________**

**Test Shift:_______________________________**

**Site Contact Name:__________________________________**
**Office Phone Number:__________________________**
**Cell Phone Number: ___________________________**
**Other:___________________________________**
**Type of Equipment:_________________________________**
**Equipment Model:__________________________________**
**Equipment Serial #:__________________________________**
**Contractor-specific Equipment ID:____________________**

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
| --- |
| Test ID:  __________ _ __________ |

**General Equipment Information (collect for both PEMS and PAMS)**

Check with site contact to confirm it's OK to instrument this piece of equipment.

Determine from site contact if this piece of equipment is used throughout the entire year, or only during some months:

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

If not year round, which months is it used?  (even if it's only used 1 time during the month)

_______________________________________________________________________

_______________________________________________________________________

Confirm total # of months (i.e., 8 months of use, 10 months of use, etc.)

Does contact expect this will be used during the test period (appox next month for PAMS or next day for PEMS)?

_______________________________________________________________________

_______________________________________________________________________

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
| --- |
| Test ID: ___________ _ ___________ |

**General Equipment Information (collect for both PEMS and PAMS)**

| EQUIPMENT DESCRIPTION | |
| --- | --- |
| Equipment Type: | |
| Equipment manufacturer: | Engine manufacturer: |
| Equipment model: | Engine model: |
| Equipment model year: | Engine model year: |
| Equipment serial no.:__ __ __ __ __ __ __ __ __ __ __ __. | Engine serial no.:_________________________________.<br>Engine Family: _________________________________. |
| Equipment Plate Code: ___ ___ (see codes below) | Engine Plate Code: ____ ____ (see codes below) |
| Equipment Comments: | Engine Comments: |
| Equipment Plate Codes:<br>01 = Not present<br>02 = Cannot locate<br>03 = Present but not specs not legible<br>04 = Present and legible<br>05 = Other | Engine Plate Codes:<br>11 = Not present<br>12 = Cannot locate<br>13 = Present but specs not legible<br>14 = Present and legible<br>15 = Other |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: ___________ _ ___________ |

## General Equipment Information (collect for both PEMS and PAMS)

| HOUR-METER | |
|---|---|
| Hour-meter function code 1: ___ ___ (see code 1 below) | Hour-meter function code 2: ___ ___ (see code 2 below) |
| Beginning date for current meter reading<br>(mm/dd/yyyy): __ __/__ __/__ __ __ __. | Engine hour-meter reading:__ __ __ __ ,__ __ __. |
| Hour-meter comments: | |
| Hour-meter Code 1:<br>21 = Meter not present<br>22 = Meter present but not functioning<br>23 = Original meter; reading can be presumed to represent hours since original purchase<br>24 = Original meter reset following maintenance or resale, can identify beginning date for current reading<br>25 = Original meter reset following maintenance or resale, CANNOT identify beginning date for current reading<br>26 = NOT original meter, can identify beginning date for current reading<br>27 = NOT original meter, CANNOT identify beginning date for current reading<br>28 = Other (DESCRIBE IN HOUR-METER COMMENTS)<br><br>Hour-meter Code 2:<br>30 = No reading available<br>31 = Current reading presumed accurate<br>31 = Current reading not accurate, reliable adjustment possible (DESCRIBE IN HOUR-METER COMMENTS)<br>33 = Current reading not accurate, reliable adjustment not possible (DESCRIBE IN HOUR-METER COMMENTS)<br>34 = Other (DESCRIBE IN HOUR-METER COMMENTS) | |

| VISUAL INSPECTION | |
|---|---|
| Are major exhaust leaks present? | Yes No (IF 'YES,' DO NOT INSTALL INSTRUMENT) |
| Is alternator speed signal reliable? | Yes No Unk (IF 'NO,' DO NOT INSTALL INSTRUMENT) |
| Are obvious modifications or mal-maintenance evident? | Y N (IF 'YES,' INSTALL INSTRUMENT AND DESCRIBE IN COMMENTS) |
| Comments: | |
| IF CANNOT INSTALL INSTRUMENT ON SELECTED PIECE, RECLASSIFY SELECTED PIECE AS 'INELIGIBLE,' SELECT BACKUP PIECE AND COMPLETE NEW DATA COLLECTION FORM | |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

### General Equipment Information (collect for both PEMS and PAMS)
### (Remember to take a legible "close-up" picture of all engine tag for future reference)

| ENGINE RATING | | | |
|---|---|---|---|
| Rated Power | | | |
| number:___ ___ ___ ___. | units code: ___ ___. | source code:___ ___. | method code:___ ___. |
| Rated Speed | | | |
| number:___ ___ ___ ___. | units: RPM . | source code:___ ___. | method code:___ ___. |
| Peak torque | | | |
| number:___ ___ ___ ___. | units code: ___ ___. | source code:___ ___. | method code:___ ___. |
| Peak Speed | | | |
| number:___ ___ ___ ___. | units: RPM . | source code:___ ___. | method code:___ ___. |
| Comments: | | | |

| Units codes | Source codes | Method Codes |
|---|---|---|
| 11 = horsepower (gross)<br>12 = horsepower (net)<br>13 = kilowatts (gross)<br>14 = kilowatts (net)<br>15 = foot-lbs(ft-lb)<br>16 = newton-meters (nm)<br>17 = Other (DESCRIBE) | 21 = Owner's/user's verbal report<br>22 = Engine plate<br>23 = Manufacturer'specifications<br>24 = Reference source<br>25 = Unavailable<br>26 = Other (DESCRIBE) | 31 = NETT SAE<br>32 = ISO<br>33 = Unknown<br>34 = Unavailable<br>35 = Other (DESCRIBE) |

### INSTALLATION PARAMETERS (collect for both PEMS and PAMS)

| Is exhaust after-treatment present? | Yes | No | Unknown |
|---|---|---|---|
| DESCRIBE AFTER-TREATMENT TECHNOLOGY: | | | |
| Tailpipe Dimensions: | | | |
| Outer diameter 1 (inches):_____________ | Outer diameter 2 (inches): ____________ (for elliptical pipes) | | |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

## PEMS AND PAMS RPM Calibration Data Collection Form

PAMS Manufacturer (please circle): Corsa Issac HEMDATA None (PEMS test)

RPM Sensor 1 Device (please circle): Capelec, Optical, Magnetic, tap

RPM Sensor 2 Device (please circle): Capelec, Optical, Magnetic, tap, None

"Confirmation" method: Onboard Tach, Hand held Tach, Sensor/Multimeter

## Pre-calibration Idle Measurement

"Confirmation" RPM =___________________

PAMS/PEMS Measured, Sensor 1 =________ Calibration Scaling Factor, Sensor 1 = _______

PAMS/PEMS Measured, Sensor 2 = _______ Calibration Scaling Factor, Sensor 2 = _______

***Pre-Test PEMS and PAMS Measurements***

**Conduct the following tests after calibrationss but before PEMS / PAMS testing**

| Test Type | "Confirmation" RPM | Sensor 1 | Sensor 2 | Exh Flow Rate (kg/hr) (PEMS only) |
|---|---|---|---|---|
| Pre-test Idle | | | | |
| Pre-test Mid-range (1000 – 1600 RPM) | | | | |
| Pre-test high-range (1600 – 2200 RPM) | | | | |

***Post-Test PEMS and PAMS Measurements***

**Conduct the following tests after PEMS /PAMS testing (before equipment removal)**

| Test Type | "Confirmation" RPM | Sensor 1 | Sensor 2 | Exh Flow Rate (kg/hr) (PEMS only) |
|---|---|---|---|---|
| Post-test Idle | | | | |
| Post-test Mid-range (1000 – 1600 RPM) | | | | |
| Post-test high-range (1600 – 2200 RPM) | | | | |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: ___________ _ ___________ |

# PEMS ONLY

| **PEMS** INSTALLATION DATE & TIME | |
|---|---|
| Date installed: ___ ___ / ___ ___ /___ ___ ___ ___. | Date tested: ___ ___ / ___ ___ /___ ___ ___ ___. |
| Independent Measurement of ambient temperature at test start time : _______________ Please indicate units: **F / C** | |
| Independent Measurement of humidity at test start time:________________ Please indicate units: RH AH Other______________ | |
| Comments: | |

| **PEMS** INSTRUMENT IDENTIFICATION | | | |
|---|---|---|---|
| SEMTECH ID.: ___________ | MPS ID: _____________ | Flowmeter ID.: __________ | FM box ID ______________ |
| Diameter of silicon hose used (inches): ___________ Length of silicon hose used (inches): _________ | | | |
| Note: all PEMS calibration info is recorded in electronic datafile | | | |

| **PEMS** VI ACQUISITION |
|---|
| VI Compliance: SAE J1708 SAE J1939 Unk None<br>VI Connector description:<br>Notes on VI Acquisition: |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

## PEMS ONLY

| **PEMS Gravimetric Filter Data Collection** | | |
|---|---|---|
| Date engine was last operated (prior to cold-start test): | | |
| Time engine was last operated (prior to cold-start test): | | |
| Hours since last engine operation (soak duration) | | |
| Filter ID | Filter Holder Location (circle) | Test Type (circle appropriate type)[1] |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |
| | 1 2 3 | CS HS WO FB DB |

1: CS = Cold Start, HS = Hot Start, WO = Warm Operation, FB = Field Blank DB = Dynamic Blank

NOTE: Field blanks and dynamic blanks should constitute 5% of all filters collected ***(each)***.

| **Other notes and comments regarding PEMS gravimetric filter testing:** |
|---|
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| |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
| --- |
| Test ID: __________ _ __________ |

## PEMS ONLY

**Record approximate times for each test segment created during PEMS testing**

Segment 1 time period:____________________________________________

Segment 2 time period:____________________________________________

Segment 3 time period:____________________________________________

Segment 4 time period:____________________________________________

**Other Installation Notes, Comments, etc.**

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

## PAMS ONLY

| **PAMS** INSTALLATION DATE & TIME **AND REMOVAL INSTRUCTIONS** | | |
|---|---|---|
| Date installed: ___ ___ / ___ ___ /___ ___ ___ ___. | Time installed: ___ ___: ___ ___ am pm | |
| Date removed: ___ ___ / ___ ___ /___ ___ ___ ___. | Time removed: ___ ___: ___ ___ am pm | |
| *In comments below, please note all equipment/engine modifications to restore to original during PAMS removal* | | |
| **Comments / modifications to restore equipment after PAMS removal:** | | |
| **PAMS** INSTRUMENT IDENTIFICATION | | |
| PAMS Manufacturer: Corsa Isaac HEMDATA | | |
| Serial #.: _______________ | RPM 1 Type: __________ (see types below) | RPM 2 Type: __________ (see below) |
| RPM 1 and 2 types may be optical, magnetic, Capelec (which is an A/C signal processor) or electrical tap into engine harness | | |
| Criteria used for logger auto shutdown: **switched dead / switched standby / voltage < cutoff / RPM < cutoff / Other** | | |
| If "other", please describe: | | |
| If voltage or RPM auto standby used, please list voltage or RPM set limit: _______________________________ | | |
| Describe method used to confirm auto shutdown: ________________________________________________ | | |
| Current drain while in standby: ________________ mA (not to exceed 200 mA) | | |
| **PAMS** VI ACQUISITION | | |
| VI Compliance: SAE J1708 SAE J1939 Unk None<br>VI Connector description:<br>Notes on VI Acquisition: | | |

Has date/time been set?___________ Has acquisition frequency been set to 1 Hz?_____________

Engine idle speed:__________________________

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

# PAMS ONLY

**Procedure for timing logger startup delay**

- Note equipment information and whether logger is on switched power or is always powered and begins logging based on an input signal
- Connect logger to computer, either by USB antenna or by cable
- Sync computer clock with logger then disconnect.
    - For Corsa, choose Set Data Logger Clock from the Setup menu
    - For Isaac, open Recording and Data Processing Parameters from the Tools menu. Click the Clock Icon. This will wipe all data from the logger.
- Disconnect logger and power off.
- Open Date and Time properties of computer
- Turn the key on (don't start engine), record the time shown on the computer (to the second) in the table below
- Wait for 10 seconds, then start the engine and record that time (to the second)
- Run engine for 15 seconds, turn all off and record time to the second
- Repeat the process at least one more time
- Pull data file and note the times when key on data stream began and when RPM data stream begin, and time when datastream ended.

Date:________________ Name of person who did test:_______________

Est ID:_________________ Equipment Serial No.:___________________

Equipment Make and Model:_________________ Logger Type:_____________

Logger ID / Serial #:_________________

Logger Power Condition (Circle one): Dead at key off / Standby at key off

Use HH:MM:SS format for on/off times.

| Test | Computer Time | | | Data Timestamp (from datafile) | | |
|---|---|---|---|---|---|---|
| | Key On | Engine Started | Key Off | Segment Start (key on) | RPM Start (engine started) | Segment End (key off) |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

# PAMS ONLY

## PAMS Operation Revisits / Reinspections

NOTE: Downloaded filename format should be "####AAAA_YYYY_MM_DD", where #### indicates last 4 digits of Establishment ID, AAA indicates last 4 digits of equipment serial #, and date follows.

| Date | File Downloaded? | Remaining Memory | Comments |
|---|---|---|---|
| | **Y N** | | |
| | **Y N** | | |
| | **Y N** | | |
| | **Y N** | | |
| | **Y N** | | |
| | **Y N** | | |
| | **Y N** | | |

| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

| Date | File Downloaded? | Remaining Memory | Comments |
|---|---|---|---|
| | Y N | | |
| | Y N | | |
| | Y N | | |
| | Y N | | |
| | Y N | | |
| | Y N | | |

# PAMS ONLY

**PAMS Revisit Calibration Checks**
**(check RPM calibration on all revisits)**

| Date | "Confirmation" RPM | Sensor 1 | Sensor 2 |
|---|---|---|---|
| | | | |
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| EQUIPMENT IDENTIFICATION, DESCRIPTION AND INSTALLATION PARAMETERS |
|---|
| Test ID: __________ _ __________ |

## PAMS

**Other Installation Notes, Revisit Comments, etc.**

## PAMS ONLY

**Current Location of Equipment (for PAMS revisits):**

| Date | Location |
|---|---|
| | |
| | |
| | |
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| | |
| | |
| | |
| | |

## Appendix F:  Emission Measurement Guidelines

[Including relevant SOPs for PEMS, QCM, Gravimetirc sampler, EFM, and MPS].

# Standard Operating Procedures for Gaseous and PM Emissions Measuring Equipment

# Prepared for ERG in support of Non-road Emissions Study

**Sensors, Inc**
**August 4, 2008**

# Overview of Standard Operating Procedures

This list defines the basic standard operating procedures for the non-road emissions program. Details are left out of this list so that it can be used as a quick reference guide for setting up and operating the emissions equipment in the ERG program. Detailed instructions are provided in this document (see table of contents) where needed.

**<u>A. Daily Equipment preparation PRIOR to Installation</u>**

2. Power up all equipment on rack; allow 1 hour for warmup on SEMTECH; MPS can be calibrated within 20 minutes
3. Confirm that flow tube diameter is correct for the engine to be tested (see instructions).
    a. If necessary, change flow tube to match engine exhaust/capacity.
    - If mounting new different flow tube, select the appropriate tube SN / diameter in the PPMD host software.

    b. Enter best estimate of "Maximum Exhaust" flow in Proportional Sampling screen (based on table provided).
4. Disconnect pressure lines and backpurge manifold at Flow Tube before or after each day of testing. **Do NOT backpurge tubing to MPS!**
5. Perform Daily MPS Setup
    a. Clean flow capillary with compressed air.
    b. Zero all pressure sensors
    c. Confirm / Adjust Major and Minor Block pressures
    d. Generate Lookup Tables
    e. Validate Lookup Tables
    f. Calibrate Sample Flow Capillary
    g. Set MPS to proportional flow and check major/minor/sample flows with no exhaust
6. Perform Daily Gravimetric Filter Setup
    a. Change filters
    b. Check N2 bottle pressure using SEMTECH; Install and turn on N2
    c. Check solenoid switching; leave in Bypass mode
    d. Set flow to 18 lpm, set MFC scale to 0.041, update E2
7. SEMTECH maintenance / setup
    a. Install new heated filter (if differential pressure sample and barometric is approaching 300 mBar)
    b. Install new FID fuel bottle if necessary (200 PSI / hour operation).
    c. Leak check sample path
    d. Check heated line operation
    e. Enable auto-zero at 1-hour intervals

**B. Install equipment on vehicle**

1. Install generator
2. Lift rack in place with crane (battery can power rack for ten minutes)
3. Secure with 2 large ratchet straps and resume power to rack
4. Install ground strap (from Rack to vehicle chassis)
5. Attach RPM probe or Vehicle Interface
6. Secure wires loosely with tie-wraps etc
7. Route exhaust from stack to EFM tube, avoid pinched hoses.

**C. Pre-test checkout on vehicle**

1. Launch SensorTech-PC host software and Data Viewer
2. In SEMTECH Test screen, verify all accessories are functioning and reporting data
    - Vehicle interface (if available)
    - GPS
    - Weather probe
    - RPM probe
    - Exhaust flowrate and temperature (from MPS)
3. Open Data Viewer
    - confirm all MPS and Gravimetric data is present
    - Verify 18 lpm flowrate for gravimetric system, and is set to Bypass
    - Verify MPS is in Mode 1 (proportional sampling)
    - Verify that MPS Sample flow < 2 sccm with engine off
4. Run target engine and verify MPS performance
    - Collect short data file while ramping engine speed
    - Check max exhaust flowrate; update value in PPMD host software if necessary
    - Confirm that Qminor decreases at least 2 LPM from idle to max exhaust. (If not, decrease Min Dilution ratio by one until this is achieved)
    - Confirm that Qminor does not go to zero prior to maximum exhaust conditions. (if it does, increase Min Dilution ratio by 1 until this is avoided)
    - Verify expected exhaust flowrate at idle conditions and maximum exhaust.
5. Shut down all equipment if waiting overnight. Turn off N2 bottle and FID bottle.

**D. Test Procedure**

1. Startup equipment and allow to warmup. Light FID when ready.
2. Using PPMD host software, zero all pressure sensors with compressor off.
3. Turn on MPS Air Compressor and Grav Filter Vacuum Pump. Turn on FID bottle and N2 bottle.
4. Verify Gravimetric filter flowrate and Bypass position
5. Verify Proportional Sampling mode
6. Perform Look-Up tables and verify
7. Switch to SensorTech-PC host software and repeat steps C1, C2, and C3
8. Utilize external antenna or Cantenna, as well as amplifier for remote operations
9. Start data collection
   - Open Session Manager
   - Perform Zero calibration on ambient air
   - Perform Span calibration (Quad and NO2)
   - Start Test recording
   - Set Filter to #1 (always lowest available filter number) just prior to engine start
   - Activate filter switching timer (10, 20, 30 minutes for filters 1, 2, and 3)
10. **Monitor data during test (see part F)**
11. After 3 hours:
    - Ask for access to equipment
    - Fill fuel tank on generator
    - Stop Data collection (leave session open)
    - Zero SEMTECH if necessary (AutoZero should be on)
    - Change gravimetric filters
    - Remove exhaust transport tubing to MPS and shut off compressor
    - Zero MPS pressures
    - Zero Block and Sample pressures
    - Verify Proportional mode, and switch back to SensorTech-PC software
12. When ready, Start new test recording

**E. End of Test Procedures**

- Stop Test
- Perform Zero and Span calibration on SEMTECH
- Stop Session Manager; download data
- Process and QA data using charting macro
- Remove all equipment
- Retrieve gravimetric filters (do not replace until ready for next test)

## F. Key Parameters to Monitor During Test

Gravimetric filter

- Grav Filter MFC flow: should be approx 18. If it is 30 or more, you will need to reset the flow using PPMD software)
- Grav Filter Number: verify that solenoids are switching
- Monitor temperatures: Cyclone, Manifold, and Filter

MPS:

- Major flowrate: typically 8 at idle, 10 – 11 at high exhaust flows.
- Minor flowrate: should be 2.5 – 3.5 at idle, 0 – 0.5 at max exhaust flow.
- Sample flowrate: 0 – 0.2 with no exhaust flow, 0.5 – 1 at idle, > 2 at high exhaust flows
- Exhaust flow rate: verify consistent values at idle conditions. Check if it is close to expected value for given engine size.

SEMTECH DS:

- Gaseous concentrations
- Sample pressure
- Temperatures

## H. Weekly MPS Maintenance

- Zero Pressure Transducers
- Perform lookup table separately for Major and Minor dilution systems.
- Check/adjust critical orifice flowrates
- Perform Dilution Flow calibrations: Major & Minor.

## I. Data Entry

- Process Data File (*.XML) into *.CSV data file
- Review *.CSV data file with Macro program
- Forward data to ERG FTP site and Carl Ensfield.

## Daily Equipment Preparation
### POWER UP ALL EQUIPMENT IN THE CABINET.

Confirm that ground straps are in place to prevent damage to the equipment. The cabinet should be attached to shore power when possible. The cabinet battery is for short-term use, similar in nature to an uninterruptible power supply battery. The SEMTECH DS gas analyzer takes one hour to warm-up at 13 VDC, and the MPS takes twenty minutes.

Connector : AC Line Power

Portable Power Generator


Air compressor toggle

Heated Line Controller

MPS Power/Air Filter

SEMTECH DS Power Switch


Vacuum Pump Switch

Power Strip/Breaker

## DAILY MPS SETUP

### Select flow tube to match engine size

- Choose the proper flow tube from the table below
- Install the flow tube and MPS securely on vehicle.

| Flow Tube O.D. | 2 inches | 2 - 1/2 inches | 3 Inches | 4 Inches | 5 Inches |
|---|---|---|---|---|---|
| **Diesel Engine with turbo (liters)** | less than 1.5 | 1.5 to 4.0 | 4 to 6 | 6 to 12 | 12 to 18 |
| **Gasoline engine (liters)** | less than 2 | 2 - 5 | 5 - 7 | | |

***NOTE: Changing a flow tube will require the following two changes in the PPMD host software.***

### Backpurge pressure lines.

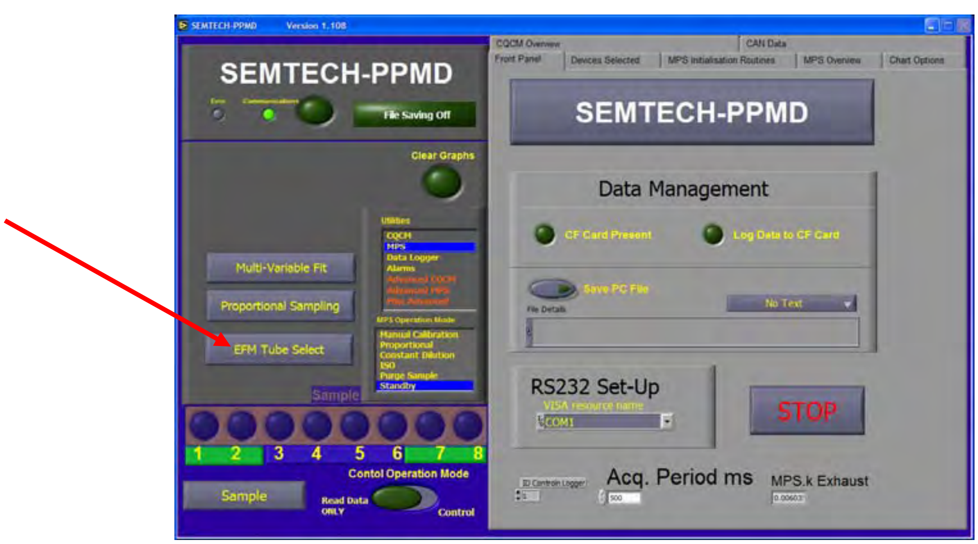
- Remove red, white, and blue pressure lines where they attach to manifold at Flow Tube
- Disconnect pressure lines at the MPS (VERY IMPORTANT!)
- Connect a source of dry, compressed air or N2 at the manifold going into the flow tube. Adjust pressure from 30 to 60 psig, and apply for at least 5 seconds for each line.
- Inspect the red, white, and blue pressure lines. If condensation or other contaminants are visible, backpurge these lines using the same procedure.

***CAUTION: Do not backpurge the colored pressure lines if they are still attached to the MPS. This would damage pressure sensors.***

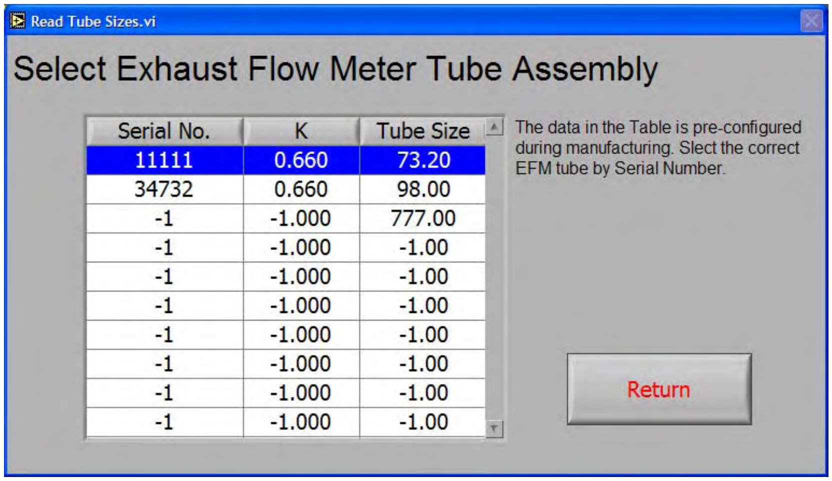
### Select flow tube in PPMD Host software.

If you have changed the flow tube, you must select the appropriate flow tube in the PPMD host software.

→ ***Go to Tab: Front Panel***
→ ***Utilities Menu: Select MPS***
→ ***Press button: EFM Tube Select***



Now, make your flow tube selection.

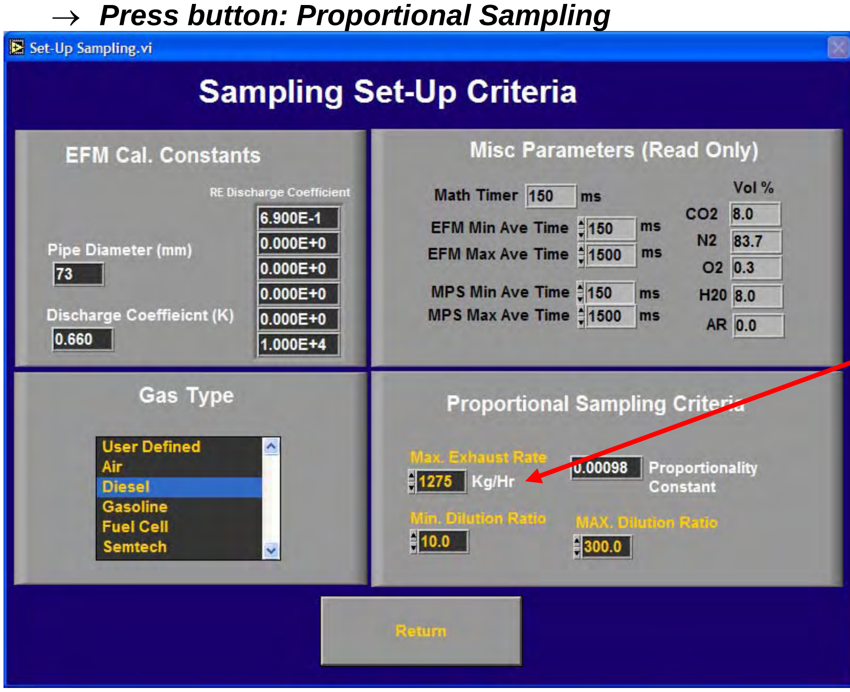



Note: If the flow tube you desire is not listed, please call for instructions on how to add a new flow tube and calibration coefficients to the menu.

## Change maximum exhaust flowrate in PPMD Host software.

If you have changed the flow tube, you must also change the maximum expected exhaust flowrate in the PPMD host software Proportionality setup screen.

→ ***Go to Tab: Front Panel***
→ ***Utilities Menu: Select MPS***
→ ***Press button: Proportional Sampling***



You will need to change the “Max Exhaust Flow” value for the vehicle that you are intending to test. The performance of the MPS device is optimized when this parameter is entered correctly. You can estimate the maximum exhaust flowrates from the following tables.

**Estimated maximum exhaust from diesel engines (Kg/hr)**

| Engine displacement, liters | Maximum engine speed, RPM | Max exhaust flowrate, non-turbo | Max exhaust flowrate, with turbo |
|---|---|---|---|
| 1 | 3000 | 86 | 171 |
| 1.5 | 3000 | 128 | 257 |
| 2 | 3000 | 171 | 343 |
| 4 | 3000 | 343 | 685 |
| 6 | 2500 | 428 | 857 |
| 8 | 2500 | 571 | 1142 |
| 10 | 2500 | 714 | 1428 |
| 12 | 2500 | 857 | 1713 |
| 15 | 2500 | 1071 | 2141 |

**Estimated maximum exhaust from spark-ignition engines (Kg/hr)**

| Engine displacement, liters | Maximum engine speed, RPM | Max exhaust flowrate, non-turbo | Max exhaust flowrate, with turbo |
|---|---|---|---|
| 1 | 5000 | 143 | 214 |
| 1.5 | 5000 | 214 | 321 |
| 2 | 5000 | 286 | 428 |
| 3 | 5000 | 428 | 642 |
| 4 | 5000 | 571 | 857 |
| 5 | 5000 | 714 | 1071 |
| 6 | 5000 | 857 | 1285 |

Note that the tables are approximations only. If the engine you are testing operates at a higher or lower maximum RPM than indicated, the estimates will be off accordingly. Also, if the application of the vehicle under test does not induce the maximum engine RPMs listed, then it is important to determine the actual engine speed during testing and estimate exhaust flow from that.

Another approach is to simply conduct a “practice” test on the vehicle, and measure the exhaust flowrates under its normal application. Just use the maximum exhaust flowrate observed. Before doing this however, make sure you complete the remaining daily equipment preparations in this section.

## Adjust Minimum Dilution Ratio in PPMD Host software.

Once the maximum exhaust flowrate is entered correctly, you may need to adjust the “minimum dilution ratio” in the Proportional Sampling screen. Normally you will not have to adjust this value, once it has been set up for a particular MPS. This parameter is used to ensure that the full range of Minor flowrate is used during a test (when operating at the maximum exhaust flowrate, the Minor flow should be close to zero).

Use the following table to determine what changes, if any, you should make to minimum dilution ratio. You will have to make this determination experimentally with the vehicle to be tested.

| Minor flowrate | Recommended adjustment |
|---|---|
| 0 – 500 sccm at Max Exhaust flowrate | None required |
| > 500 sccm at Max Exhaust flowrate | Decrease value |
| 0 at less than Max Exhaust flowrate | Increase value |

Adjust the Minimum Dilution Ratio until you have achieved 0 – 500 sccm Minor flowrate.

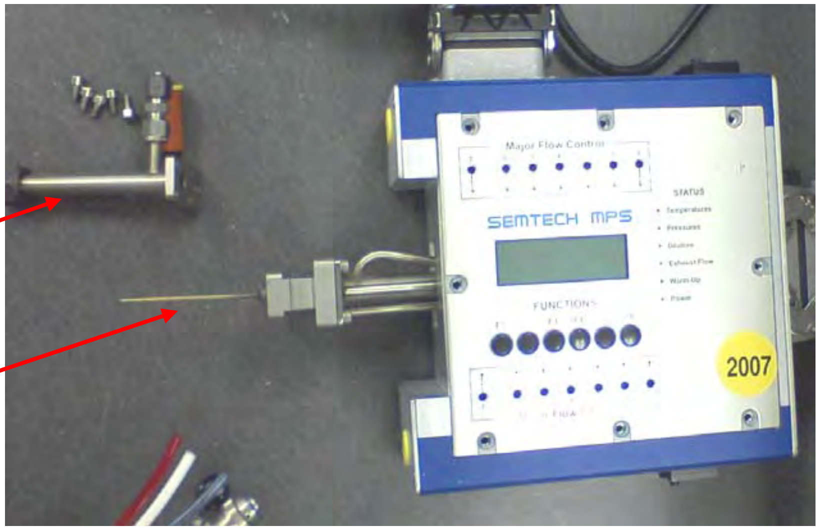
***NOTE: Before making an adjustment other than Minimum Dilution Ratio, make sure you complete the remaining daily equipment preparations in this section.***

## CLEAN FLOW CAPILLARY WITH COMPRESSED AIR.

- The Sample Capillary is shown to the left side in the drawing below.
- Remove capillary housing, being careful to retain o-rings.
- Remove capillary
- Back flush capillary with dry compressed air or $CO_2$.
- Replace capillary and housing, making sure to replace O-rings. If O-rings are worn or damaged, replace them.

**Removed capillary housing**

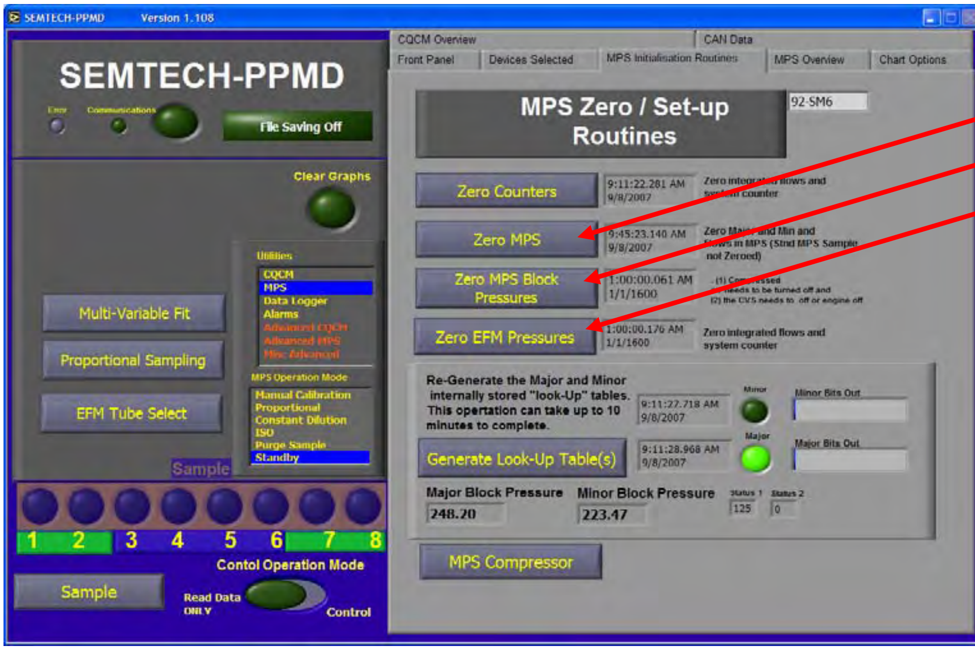
**Sample capillary**




## MPS INITIALIZATION AND ZEROING

- Turn on power at MPS air control box (minimum warm-up time is 20 minutes).
- Turn <u>off</u> compressed air supply to MPS
- Plug in RS232 Cable from CAN interface to your PC.
- Start up PPMD Host Software, and go to MPS Initialization Screens
- ***Important:*** **Before zeroing pressure sensors, Verify that there is no exhaust flow or residual major or minor block pressure (pressures should read approximately barometric)**

***Go to Tab: MPS Initialization Routines***




- Press "**Zero MPS" button**. This will zero the MPS major and minor flow sensors
- Press "**Zero EFM Pressures**". This will zero the EFM pressure sensors
- Press "**Zero Block & Sample Pressures**". This will zero the block pressure sensors and the Sample flow pressure sensors.

***NOTE:*** If during Zero Block & Sample Pressures, you receive the screen message: "Block Pressure is too High – Operation is cancelled", then there is probably residual pressure in the major and minor block manifold. Set MPS operation mode to "Manual" and let the pressure bleed down. Then, set the MPS operation mode back to "Standby".

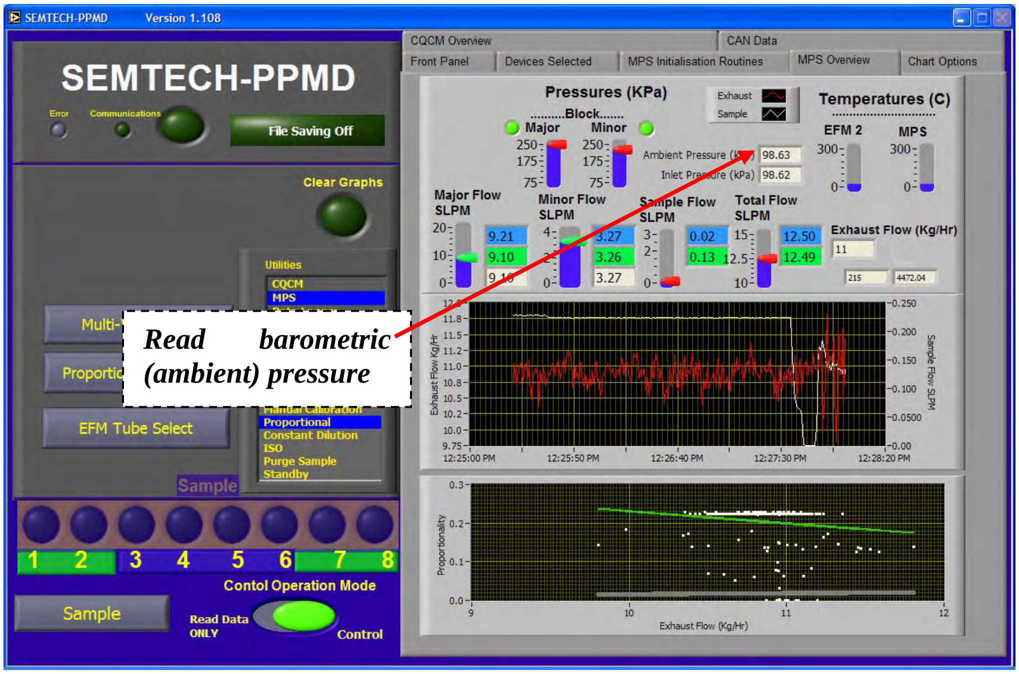
## Confirm / Adjust Major and Minor Block pressures

The major and minor manifold blocks must be controlled to a constant pressure. These pressures are now displayed on the MPS Zero / Setup screen at the bottom of the page. The recommended pressures are:

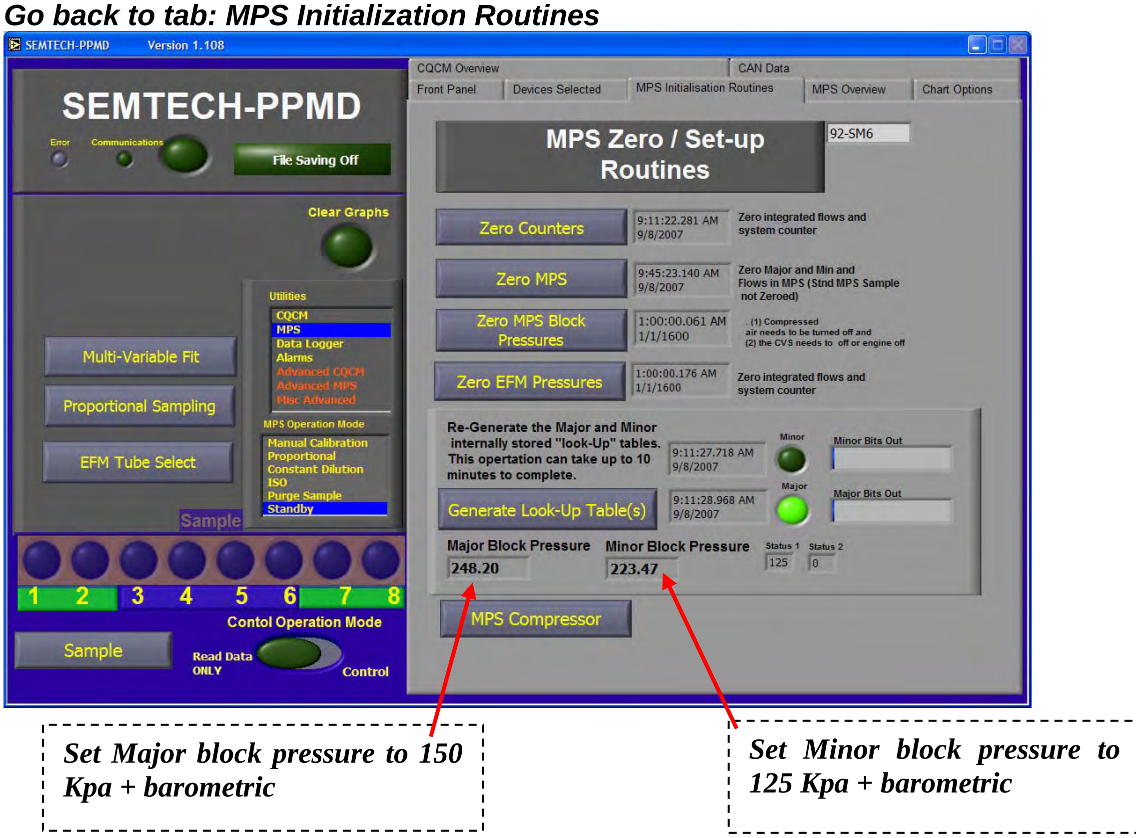
- Major block pressure = 150 Kpa + barometric
- Minor block pressure = 125 Kpa + barometric

Currently, the major and minor block pressures are displayed in units of absolute pressure, so you will have to add barometric pressure to the target values to determine the proper reading. You can read barometric pressure from the MPS Overview tab.

***Go to Tab: MPS Overview***



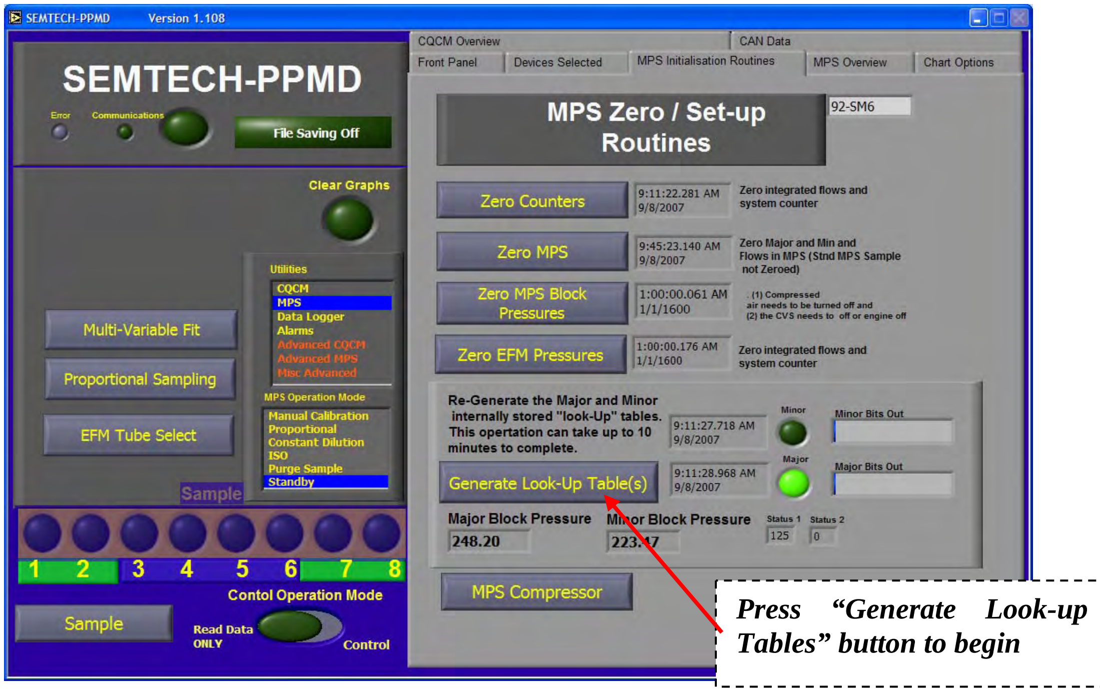

*Go back to tab: MPS Initialization Routines*




## Generate Lookup Tables

After the major and minor pressures are set, you must generate a Lookup Table for both the major and minor solenoid blocks. The PPMD host software will toggle through every combination of solenoids on the major or minor flow block, recording the measured major or minor flowrates for each combination. The MPS uses the Lookup Table on a 10 hz frequency to determine which combinations of solenoids to utilize to achieve the desired flow.

***Go to the tab: MPS Initialization Routines.***




Begin the process by pressing the "Generator Look-up Table" button on the MPS Initialization screen.

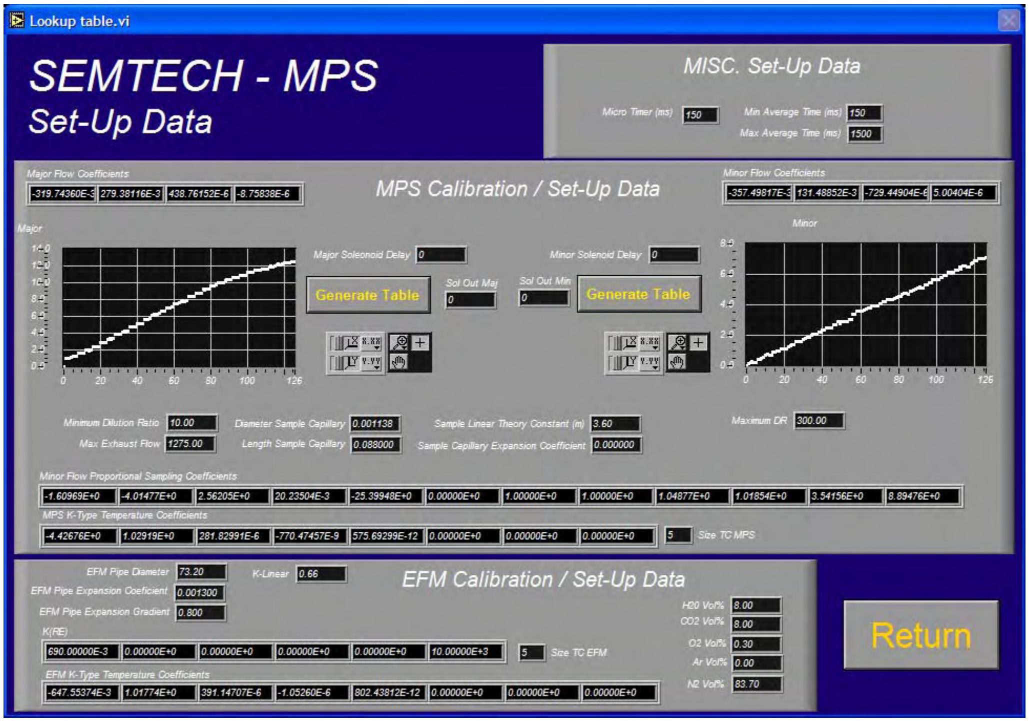
*NOTE: The software will allow you to perform the major and minor lookup tables simultaneously, but you should always perform the major and Minor lookup tables* *<u>separately.</u>*

Once the process begins, you will see the blue status bar indicating completion status. The process will take up to 10 minutes for both the major and minor solenoid blocks.

## Validate Lookup Tables

Once the major and minor lookup tables are complete, you should review the results. This is possible by pressing the "Read Parameters" button that is displayed when "Advanced MPS" is selected under the Utilities menu.

→ ***Utilities Menu: Select "Advanced MPS"***
→ ***Press button: "Read Parameters" to arrive at SEMTECH – MPS Set-Up Data***




It is common to see some small discontinuities in the flow vs solenoid combination chart. That is because the critical orifices are probably not set perfectly. If you see large irregularities with the Look-up Table, it may be necessary to re-set the critical orifices.

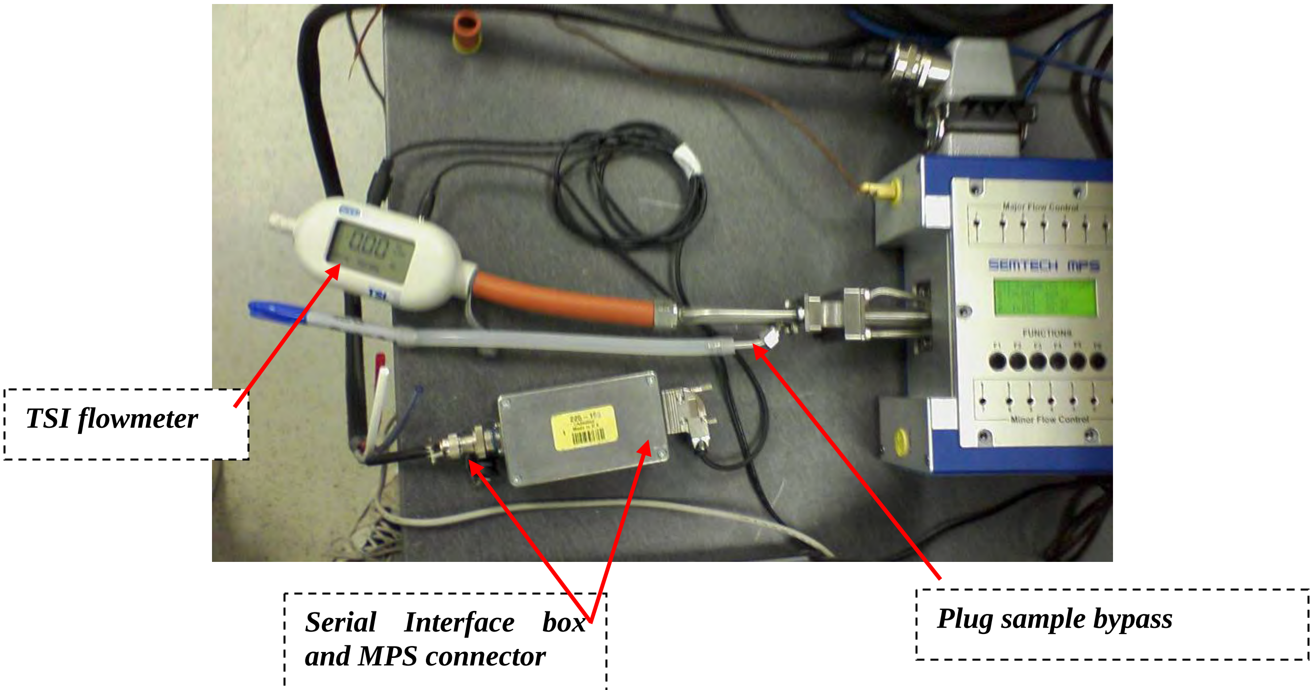
Note that in the above example, there is some flattening of the major flow at the higher solenoid combinations. That is common, and typically not a concern, as long as the major flowrate can achieve at least 80% of the total MPS flowrate setpoint.

## Calibrate Sample Flow Capillary

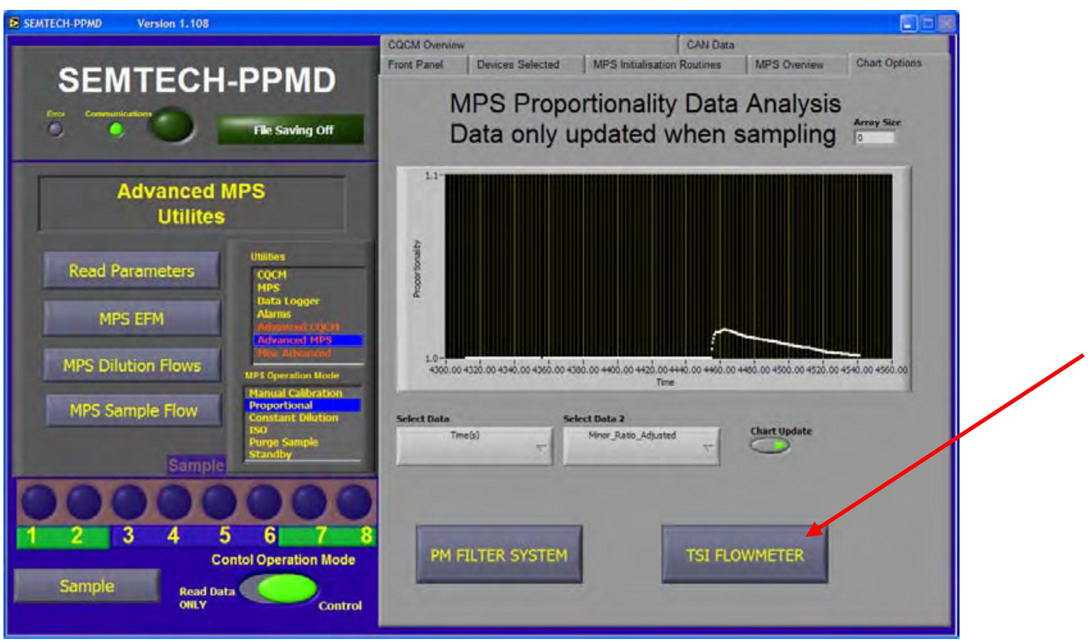
Once the sample flow capillary is cleaned, and all other steps listed above are complete, you can now calibrate the sample flow.

- Attach a TSI reference flow meter to the sample inlet of MPS Diluter as shown in the following photograph
- Ensure proper direction of flow for reference flow meter
- The TSI reference offers two connections:
    - Connect serial output to interface box and then to connector located at the end of the MPS pressure line harness.
    - Connect to 110 VAC source (required with this TSI model).

- Plug MPS sample bypass



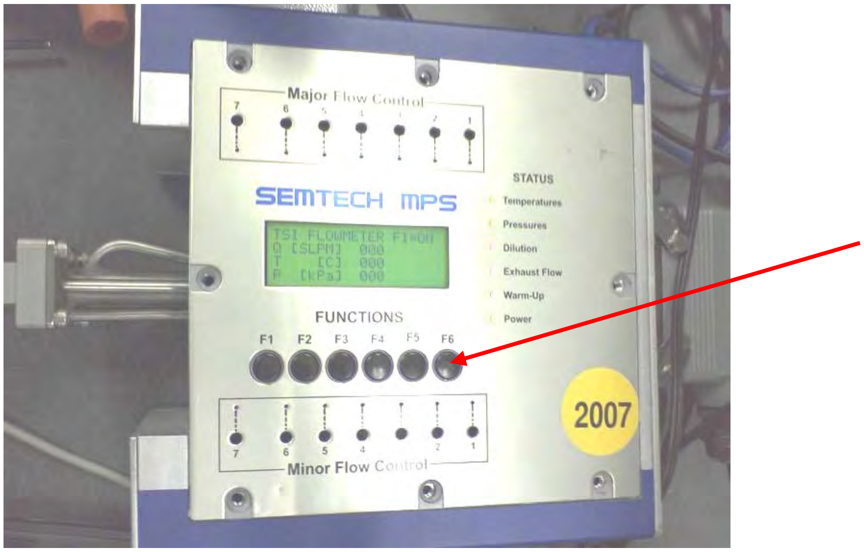

To enable the TSI flowmeter in the host software, select the “Chart Options” tab, and then press the “TSI Flowmeter” button at the bottom of the page.




If you have recently updated firmware on the MPS, you will need to enable the TSI flowmeter (once) using the front panel LCD display:

- From the MPS Display: Press F6 (21 times) until the “TSI flowmeter enable” screen is dislplayed

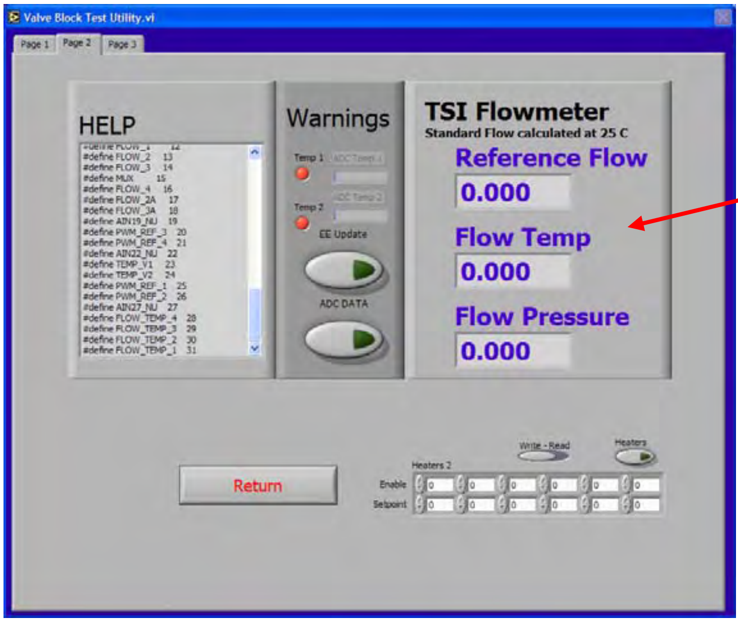
- Press F1 to enable the TSI reference meter
- Verify that the MPS Display now provides reference flow
- Access the Display Microprocessor and update the EEPROM (X17).




To check that the TSI reference is enabled within the PPMD host software, go to the MPS dilution flows screen under “Advanced MPS” utility. On page 2, view the reference flow meter data for Flow rate, temperature, and pressure.

From any screen,

→ ***Utilities Menu: Select “Advanced MPS”***
→ ***Press button: “MPS Dilution Flows”***
→ ***Select Page 2***

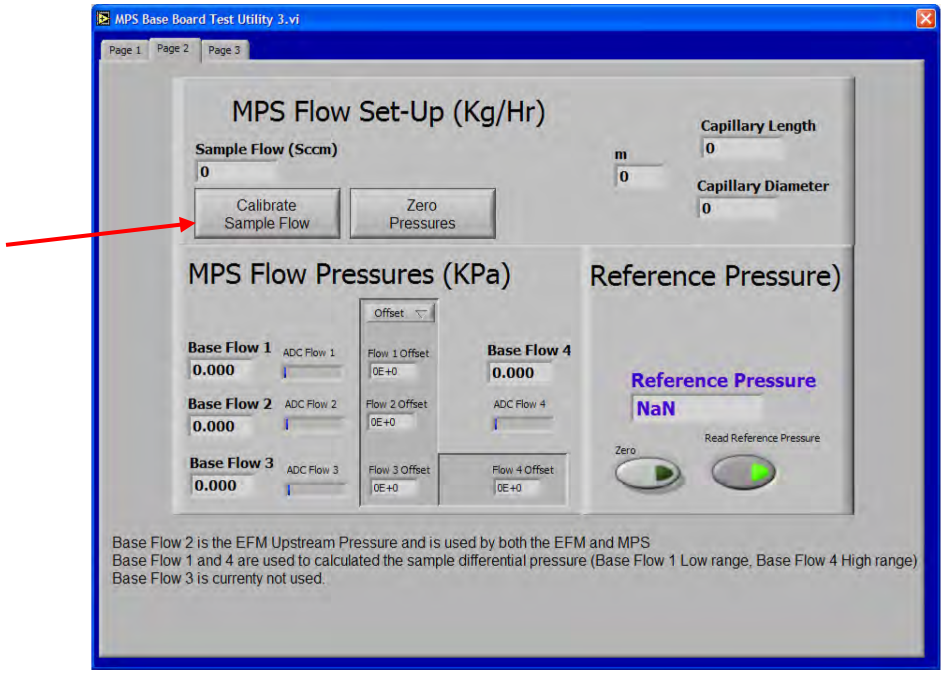



*Verify TSI flowmeter Readings are present*

If the values are unchanging, go to screen 1 and select a major dilution critical orifice, and confirm that reference flow INCREASES. Then, select a minor dilution critical orifice, and confirm that reference flow DECREASES. Turn off these critical orifices when finished.

- Having established communication with the TSI reference flowmeter, we can now proceed to the sample flow calibration screen:

  From any screen,
  → ***Utilities Menu: Select "Advanced MPS"***
  → ***Press button: "MPS Sample Flow"***
  → ***Select Page 2***




- Press button: Calibrate Sample Flow (a process screen will pop-up)
- Flow calibration sequence will begin automatically. You can view new data points from the Calibration Data Table.
- During data acquisition, note the status light for each point's Stability.

***Note: Sometimes the process will not be able to complete automatically if flow stability cannot be achieved at some conditions (typically after the 12 data point). If stability is not achieved after two minutes at a given data point, just press the "Continue" button at the bottom of the page to proceed.***

**IMPORTANT:** Before accepting the new data, confirm the following conditions:

1. The chart of pressure versus flow in the lower left corner of the screen. The data points need to be always increasing in an orderly fashion so that final flow fit is robust.
2. The Slope displayed in Micro Q vs. Reference Flow chart is 1.00 +/- 0.05
3. The Std. Diameter Capillary (mm) is +/- 5% of Diameter Capillary (mm) Micro.

***Caution: For deviations greater than these limits, always try to troubleshoot system before accepting new coefficients. For instance, confirm that your MPS inlet bypass is plugged so that all sample flows through your TSI reference flow meter.***

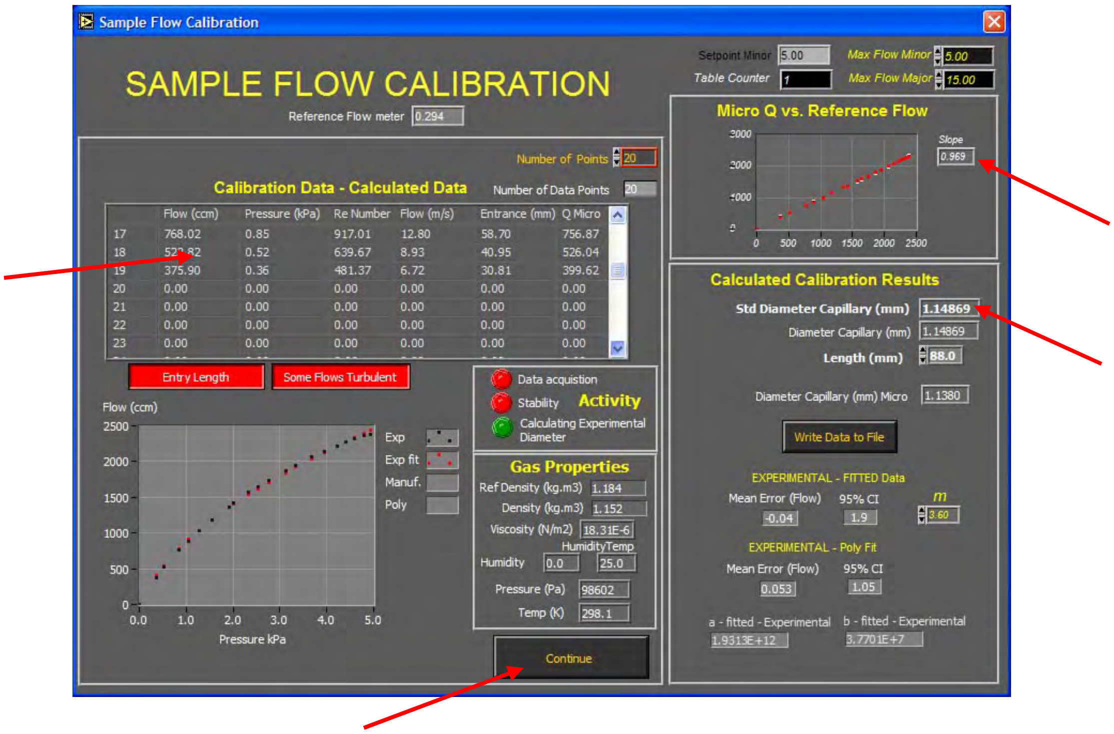



*Chart explanation: At each data of the 20 target data points, the process will look for stability and then save the data point. Near the 12th data point, the values will likely be unstable. After two minutes of non-stability, press the "Continue" button to proceed.*

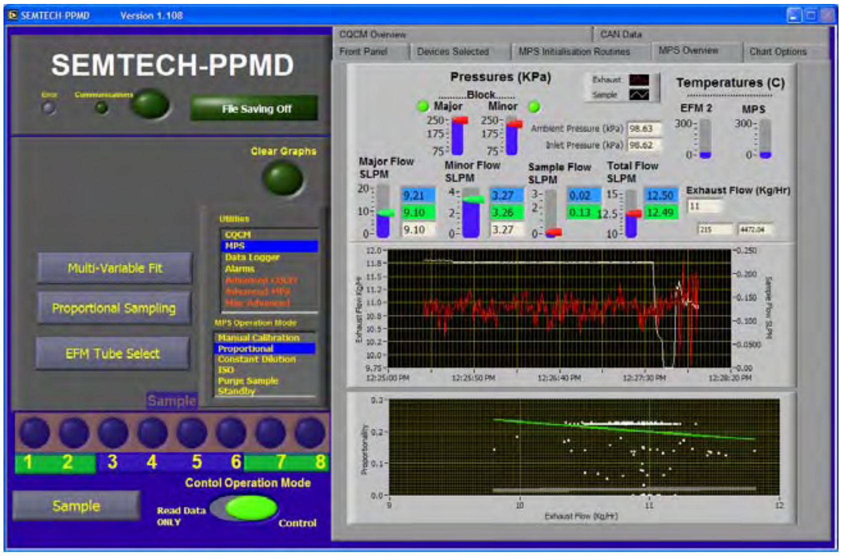
- When the process is complete, and the data looks acceptable, Exit screen by pressing the button: Continue,
- Choose to accept or decline the new coefficients.

## SET MPS TO PROPORTIONAL FLOW AND CHECK PERFORMANCE

When all of the above daily preparations are complete, you may now set the MPS to Proportional mode, ready for testing.

→ ***Utilities: select MPS***
→ ***Set Control Operation Mode: Control***
→ ***Select MPS Operational Mode: Proportional***

You may now want to clear the graphs if you want to view proportionality of live data, and proceed to the "MPS Overview" tab.




The following table is a guide to evaluate the MPS performance at various conditions. It is recommended to verify these criteria on each vehicle prior to conducting tests.

**Ideal MPS Performance Criteria**

| Engine condition | Q Minor | Q Sample |
|---|---|---|
| off | > 4 slpm | < 200 sccm |
| idle | > 2.5 slpm | na |
| Max exhaust flow ** | 0.2 to 0.5 slpm | Proportional over flow range |

** Note that if you are setting the engine speed without load to the engine, you will not be achieving nearly as high of exhaust flow as you would under load. If that is the case, make sure you have sufficient Q minor (at least 1 slpm) at maximum (unloaded) engine speed.

If the above criteria are met, then the MPS is ready for testing. If the MPS fails to meet one or more of the above criteria by a small amount, it is not necessarily a problem. It just means that it is likely that the proportionality parameters are not optimal for the vehicle you are testing, or the flow model could be improved. The proportionality parameters are easy to configure, and retest in this screen. The flow model is a bit more difficult to optimize (see next section). In any case, you can certainly proceed to test, as long as the sample flowrate is proportional over the flow range to be tested.

If there are significant deviations from the criteria listed above, then it would be advisable to investigate further before testing.

## DAILY GRAVIMETRIC FILTER SETUP

### Change Filters

Gravimetric filters must be changed prior to testing, or when they have reached their desired sample duration.

STEP 1: **Turn off** vacuum pump to gravimetric filter (and leave off until indicated)
STEP 2: Remove all filter holders

**47 mm filter cup, opened**

**47 mm filter cup assembly**

***Install with filter element facing <u>downward</u>***

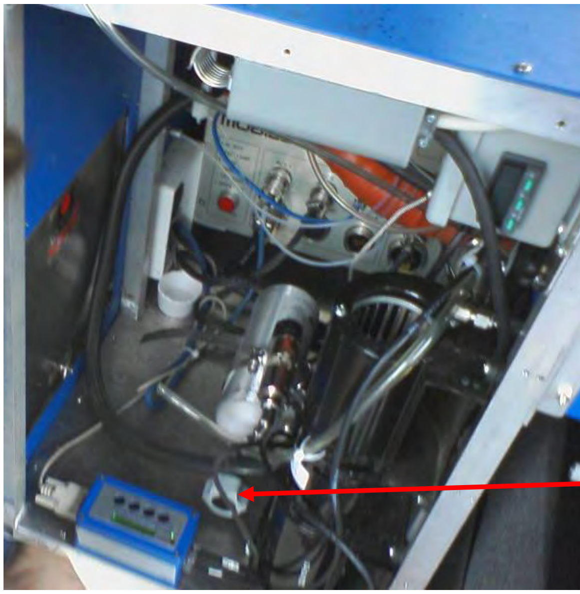
STEP 3: Carefully place the filters in the filter holders, with the filter element facing DOWNWARD (the sample flows upward). Replace the filter holders.

### Check / Open Nitrogen Cylinder

The gravimetric filter sampling system uses compressed nitrogen to operate pneumatic valves in order to switch between the three filter holders and bypass.

STEP 1: Check the remaining pressure of the N2 bottle by plugging into the SEMTECH FID fuel electronic pressure connector (will have to remove bottle).

STEP 2: Open the N2 cylinder when ready for testing, and verify that the pressure is set to 80 PSIG.



*Turn on N2 bottle*

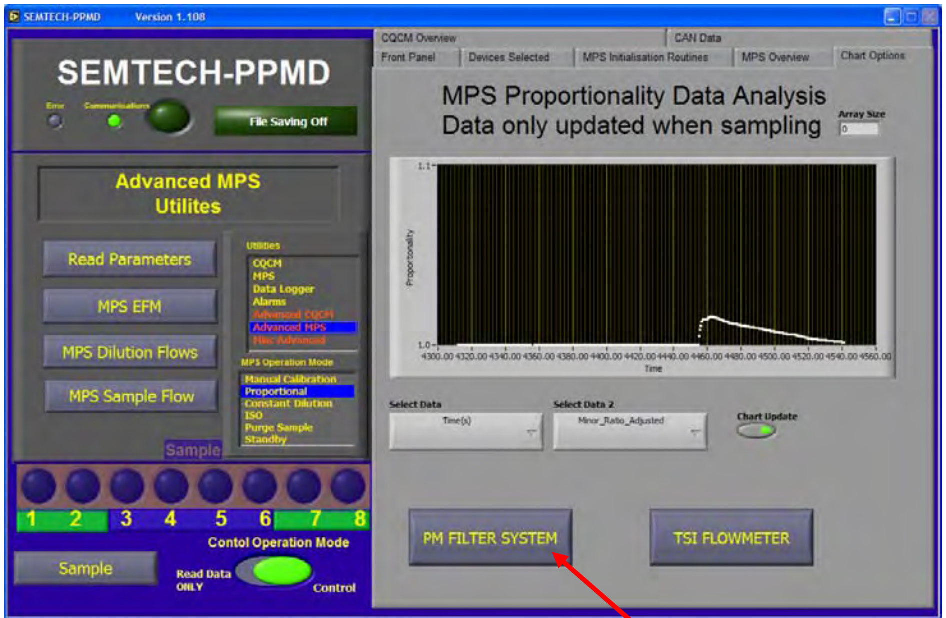
***Note:*** *Each time you replace the N2 cylinder (or if the usage rate seems excessive), you will need to* ***leak test*** *the N2 pneumatic connection. Open the cylinder valve, and then close again. Verify that the gage still reads 80 psig after 10 minutes.*

### Setup the Gravimetric Filter in PPMD software

You will need to access the Gravimetric Filter operating window in the PPMD host software in order to set the sample flowrate. Filter switching can be performed here, or in the SensorTech-PC software for the SEMTECH-DS.

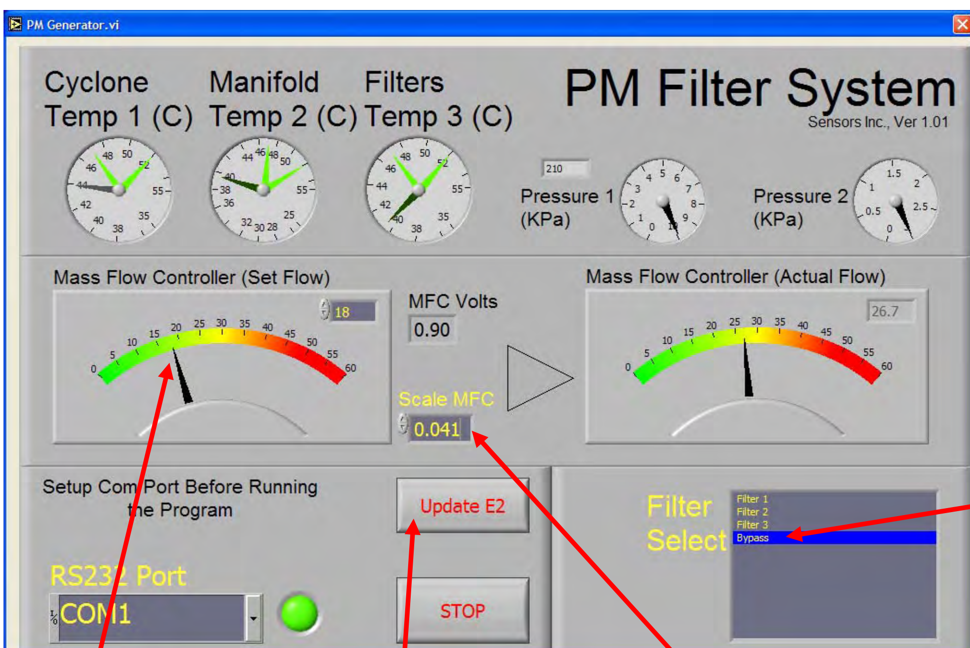
***IMPORTANT: Any Interruption of 120 VAC power will reset the flow setting and require you to repeat the following steps.***

→ ***Got to tab: "Chart Options"***
→ ***Press button: "PM Filter System"***




*Access Gravimetric Filter System*

***Gravimetric Filter System Operating Window***




***1. Verify you are in bypass mode***

***2. Set flowrate to 18 lpm by moving dial***

***3. Set scale factor to 0.041***

***4. Update E2***

Once in the Gravimetri ... low, perform the following steps:

STEP 1: With vacuum pump still off, toggle the solenoids that control the filter selection to ensure that they all work. Leave in BYPASS MODE.

STEP 2: Turn on vacuum pump

STEP 3: Set the flowrate to 18 liters per minute by moving the left hand dial with your mouse. After about 10 seconds, the actual flow (right-hand display) should move to match the target flow.

*Note: if flow control does not respond, reset the AC power to the gravimetric filter system and try again.*

STEP 4: Set the scale factor for the mass flow controller to 0.041

STEP 5: Update the E2

STEP 6: When these steps are complete, you may press the “STOP” button to exit

**NOTE: (DO NOT EXIT SCREEN BY PRESSING THE “x” IN THE UPPER RIGHT HAND CORNER OF WINDOW)**

## DAILY SEMTECH-DS MAINTENANCE

The following steps should be performed PRIOR to installation:

- Install new heated filter (if differential pressure sample and barometric is approaching 300 mBar)
- Install new FID fuel bottle if necessary ( 200 PSI / hour operation).
- Leak check FID fuel, and Close FID bottle
- Leak check sample path
- Check heated line operation (A/C line controlled through controller external to SEMTECH)

## INSTALL RPM PROBE

Install the RPM probe so that the optical signal may be read from reflective tape affixed to a rotating crankshaft pulley. The magnetically-secured RPM mounting base may typically be used to secure the optical sensor.

NOTE: Some software setup is required in the SensorTech-PC host software. See Section 2 for details.

## PREPARE ECU DATA COLLECTION EQUIPMENT

Install Collection of the ECU datastream should be investigated and attempted for all electronically-controlled equipment. For Caterpillar equipment, this will involve utilization of the Caterpillar Communication Adapter and CAT ET Software application operating on an additional laptop (as provided by EPA). This laptop should either be placed in the cab in a secure area, or in the PEMS rack. Remote control of the ECU data collection laptop may be required by way of a wi-fi or Internet-based network. For non-Caterpillar equipment, collection of ECU data should be attempted using appropriate-protocol communication adaptors in conjunction with either the SEMTECH or an external laptop, as needed.

# DATA ACQUISITION USING SEMTECH-DS WITH PPMD

Newer versions of SensorTech-PC host software for the SEMTECH-DS now support integrated data acquisition with the PPMD.

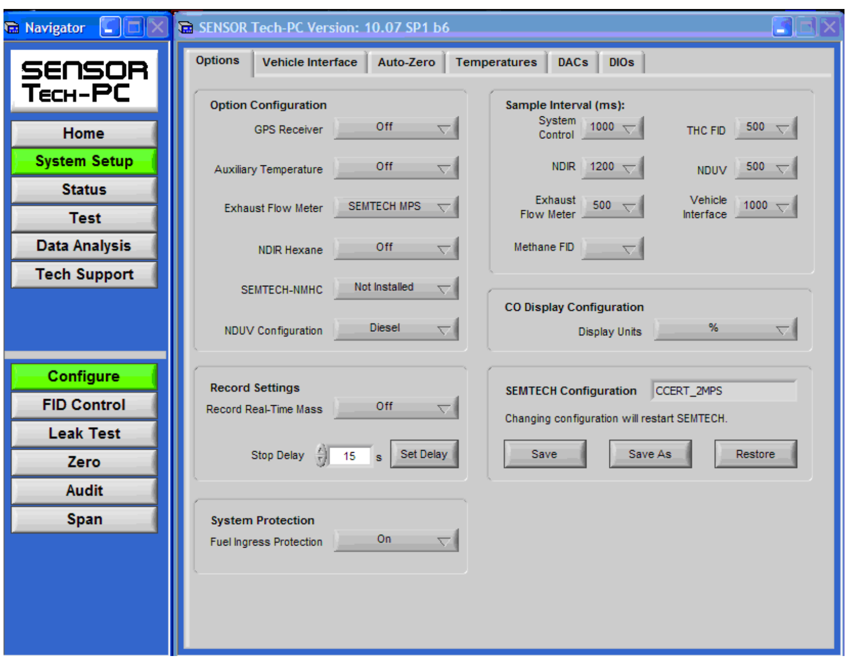
## CONNECT CAN NETWORK FROM PPMD SYSTEM TO SEMTECH

A special cable is required that connects the serial interface of the CAN module to the Aux-1 port on SEMTECH-DS. Please install this cable before proceeding.

## ENABLE MPS EXHAUST FLOW FROM SEMTECH DS

- Within SensorTech-PC Software, go to Set Up / System Configure
- Turn exhaust flow sensor choice to OFF, and then select MPS
- ***You are now prompted to select the appropriate PPMD.XML file which describes your PPMD configuration. Variables in the PPMD.XML file which are not present in the physical configuration of the PPMD equipment slows down the network.***
- ***Contact Sensors Service for assistance in identifying the appropriate file for your system.***
- Set the Exhaust Flow Meter update rate to 500 msec.

→ **Screens: System Setup, Configure.**
→ **Tab: Options.**

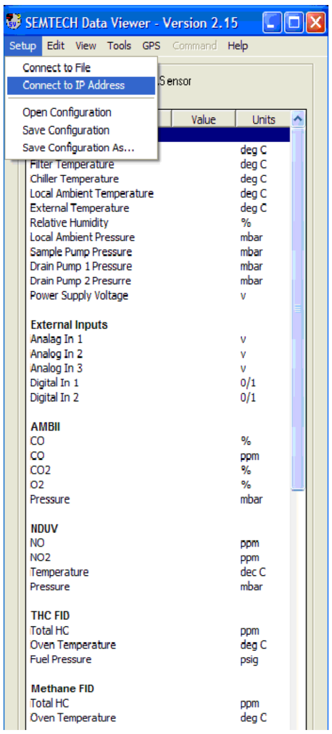


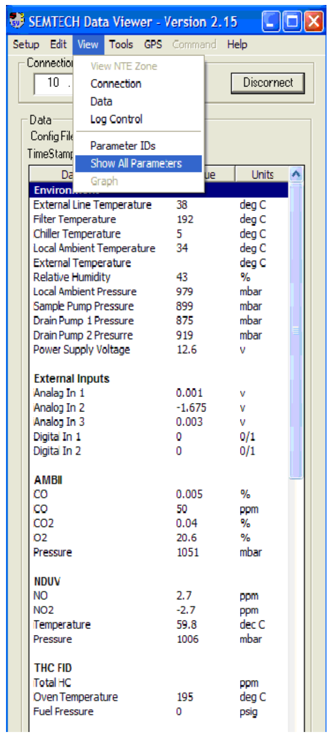

The SEMTECH-DS should now be communicating with the PPMD system. To verify, go to Road Test screen and verify that Exhaust Flow and Exhaust Temperature parameters are present.

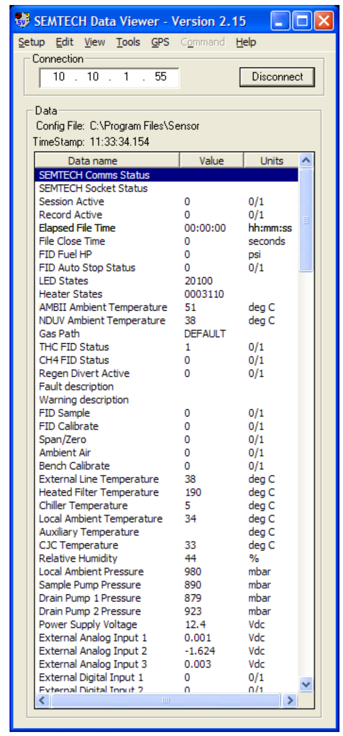
## LAUNCH "DATA VIEWER" TO VIEW PPMD DATA

Launch the Data Viewer utility found in the SensorTech-PC program group in the Start menu of Windows.

- Connect to IP Address,  (typically 10.10.1.55 for the Semtech DS)
- Press the  Connect button
- Press View tab, and select "Show all parameters"
- Scroll to the bottom, and you will find all PPMD related parameters.




You can use Data Viewer to check and monitor your PPMD parameters through the wireless (or wired) SEMTECH Ethernet connection to your laptop.  Furthermore, anytime you record a datafile, all PPMD parameters are recorded.

**IMPORTANT:  For the ERG project, make certain that the PPMD.XML file contains parameters for one MPS and the gravimetric system.**  Check that these parameters are present in Data Viewer.

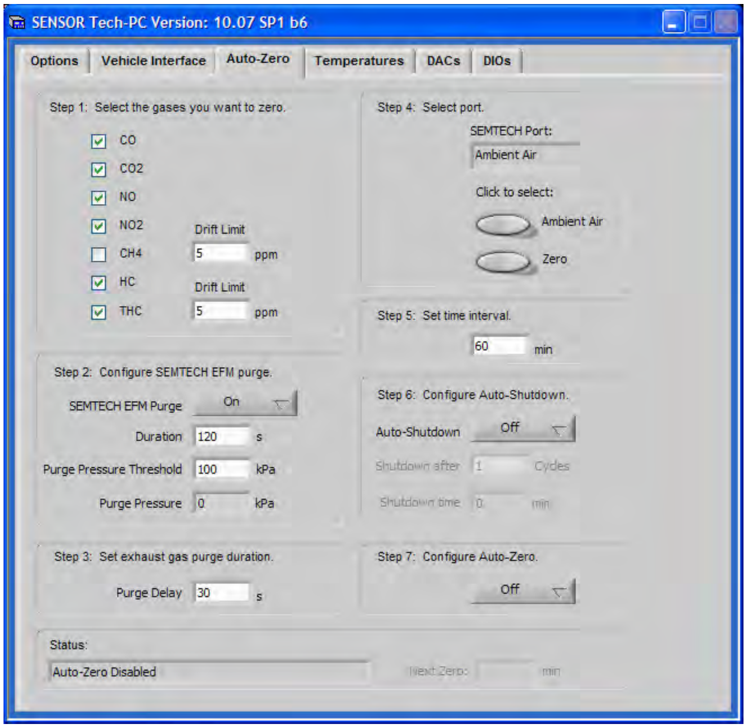
**IMPORTANT:  Check MPS Operation Mode:**  The MPS mode displayed in the Data Viewer is defined below.  It represents the mode that the MPS is set to.  In general, you want the MPS in proportional mode (mode 1).

| Value | MPS Operational Mode |
|---|---|
| 0 | Manual Calibration |
| ***1*** | ***Proportional (used for MPS #1)*** |
| 2 | DR  Constant Dilution  (used for MPS #2) |
| 3 | ISO |
| 4 | Purge Sample |
| 5 | Standby |

## SETUP AUTOZERO

Utilize this function to automatically zero Semtech DS analyzers each hour. You may also select to manually zero the SEMTECH DS  from this screen,
For instance after the completion of grav filter sampling.

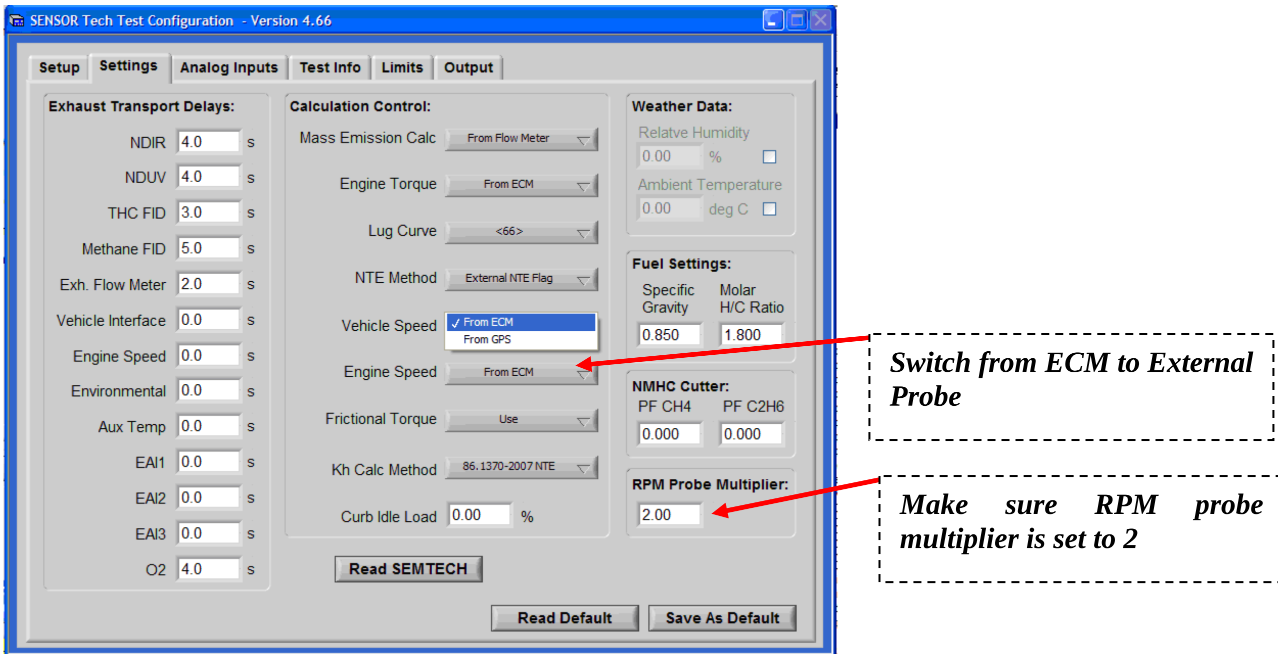
→ ***Screen: system setup, configure***
→ ***Tab: Auto-Zero***




## SETUP RPM PROBE

The RPM is setup in the Test / Configure menu.  Press the “Edit Test Configuration” button to access the screen shown below.  For Engine Speed, select “External Probe”.  Set RPM Probe Multiplier appropriate to allow actual RPM to be displayed and stored

→ ***Screen:  Test / Configure***
→ ***Press button: Edit Test Configuration***
→ ***Tab: Settings***



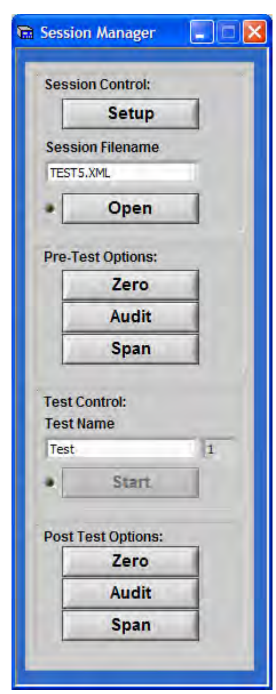

## RECORDING ECU DATA

Prior to the day's testing, attempt to establish communication with and acquire data (1 Hz) from the equipment's ECU. Use the appropriate data collection software to collect relevant data streams of interest, such as RPM, percent torque, load and throttle, and oil temperature (among other parameters) from the broadcast datastream.

## RECORDING TEST DATA

All test data for the ERG project will be recorded from the SEMTECH data logger. Typically, each day of testing will be recorded in a single Session, with multiple tests as needed.

STEP 1: Make sure all setup steps are completed
STEP 2: Open Session Manager Window
STEP 3: Name the Session, and press "OPEN"
STEP 4: Just before test is to begin, perform Zero and Span calibrations.
STEP 5: Under Test Control, press "START". You are now recording data.
STEP 6: Just before the engine starts, change filter control from Bypass to the desired filter number
STEP 7. Start the engine and monitor data.
STEP 8: Switch filters according to schedule.



## GRAVIMETRIC FILTERS -TIMED SWITCHING

The gravimetric filters can be switched automatically based on pre-set sampling intervals. This is performed using a Telnet window as described below.

***NOTE: Session Manager must be already be Open and Recording a test file.***

STEP 1: Go to PC's Run Command and type : "Telnet 10.10.1.55". You will see a log-on screen
STEP 2: Enter user name: "Sadmin" (***xadmin for Msn XP users***)
STEP 3: Enter password: "sem2002"
STEP 4: Type: ***Call GravFilter.scr.*** This starts the batch utility for timed filter switches.

***NOTE: Allow the Telnet screen to continue to operate during testing so that user can note Timer countdown and filter number selection.***

The filter switching batch utility will begin a timer countdown. The user can also over-ride the timers and perform actions as shown.

| PRESS | FUNCTION |
|---|---|
| SPACE BAR | to skip to next particulate filter cup. |
| ESCAPE | to abort the Filter sampling. |

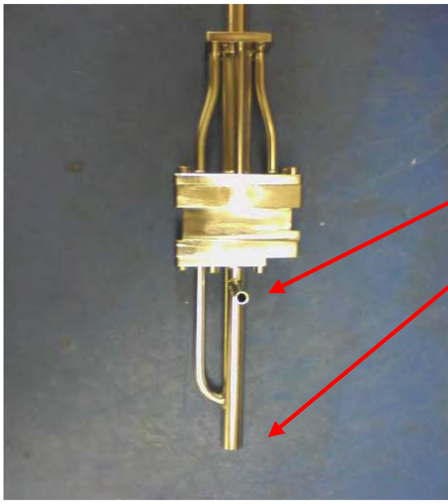
Filter Switching follows the Default setting below:

| Minutes | Description |
|---|---|
| 10 | cold start |
| 20 | warm operation |
| 30 | warm operation |

## Weekly MPS Maintenance

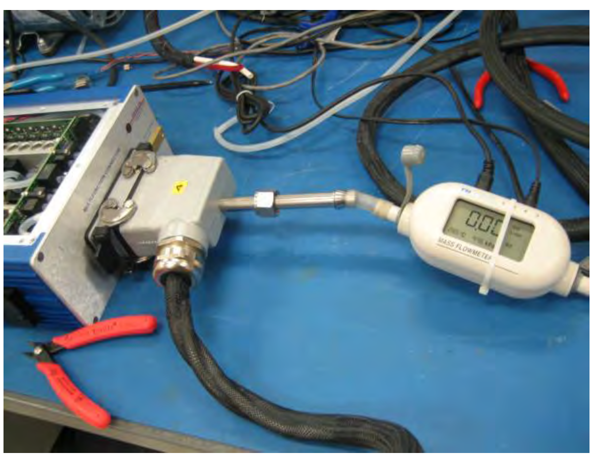
# CALIBRATE MAJOR AND MINOR DILUTION BLOCK FLOWS

- Zero Major and Minor flows
- Plug Sample Inlet and Sample Bypass (which eliminates sample flow to the reference flowmeter).

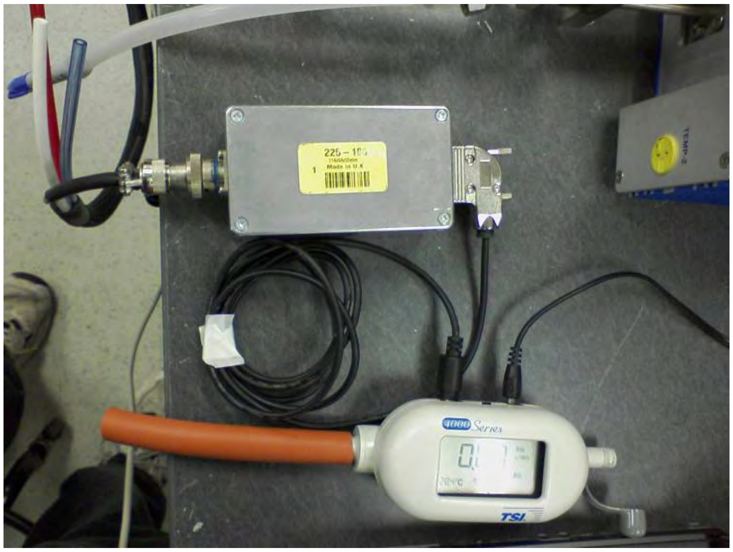


***Plug inlet and bypass***

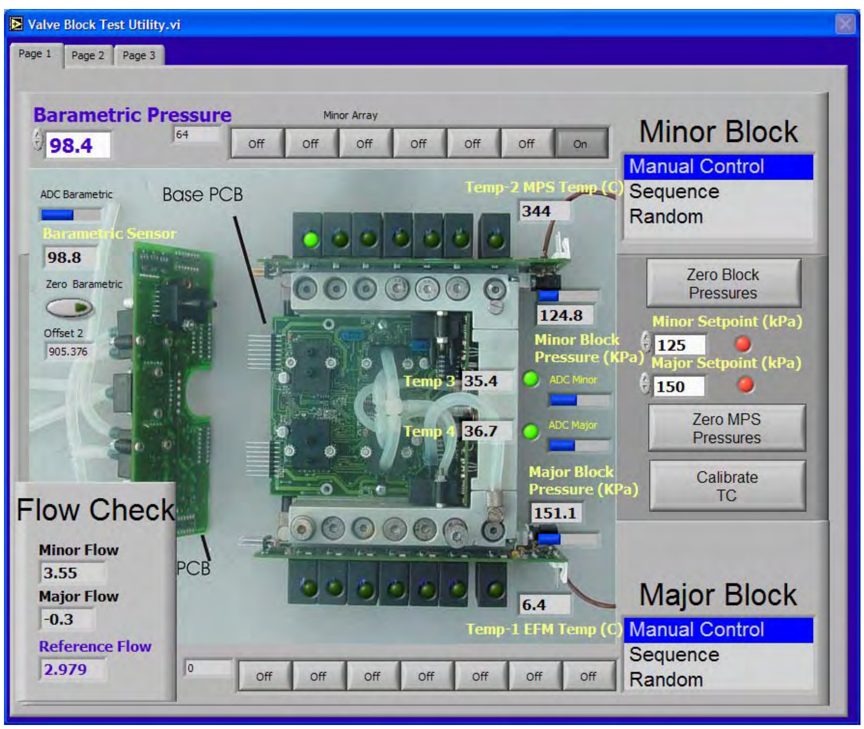
- Connect a reference flowmeter to outlet of MPS diluter.
- Ensure that direction of flow is correct (see backside of meter)



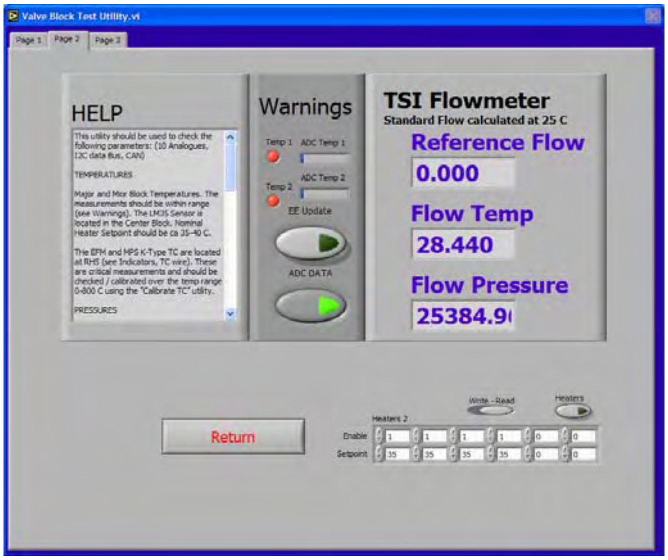
- Connect reference flow meter to flow box and flow box to MPS signal cable to provide signal to the CAN network.
- Connect power to flowmeter
- Flowmeter should display: MPS Dilution Flow, Temperature, and Pressure.



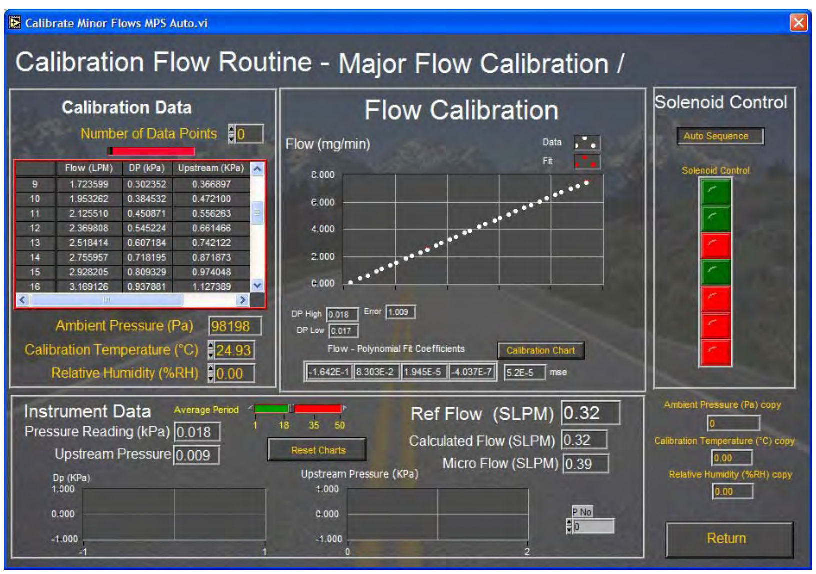
→ ***Utility Menu: Select “Advanced MPS”***
→ ***Press button: “MPS Dilution Flows”***




Note presence of Reference flow in lower left corner (blue text). Confirm reference temperature and pressure values by going to tab: Page 2




- Go to page 3.
- Press Button: Major Flow Calibration / Test
- Press button: Calibrate Flow to Generate Table for Major Flow.
- Cycle through the Major orifices until the Mean Standard Error < 5 x $10^{-3.}$
- Look for irregularities in the linearity charts for flow.
- User can accept new coefficients. (Message: Change calibration file & write coefficients to the Micro).




- Repeat the process and Choose Minor Flow Calibration / Test,
- Press Calibrate Flow to Generate Table for Minor Flow.
- Cycle through the minor orifices until the Mean Standard Error < 5 x $10^{-3.}$ then Press Return.
- As necessary, a user can accept new coefficients. (Message: Change calibration file & write coefficients to the Micro).

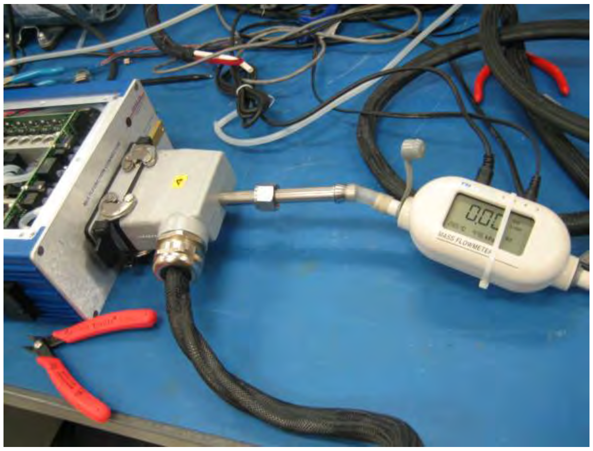
***If major and minor dilution flow values are linear and without significant outliers, you have successfully completed this section.***
***Go to page 2 and press RETURN.***

***If Major and Minor Dilution Flow values have significant outliers, recheck the setup. Make sure the sample and bypass are blocked. Repeat process.***

## CHECK / ADJUST CRITICAL ORIFICE FLOW RATES (AS NEEDED)

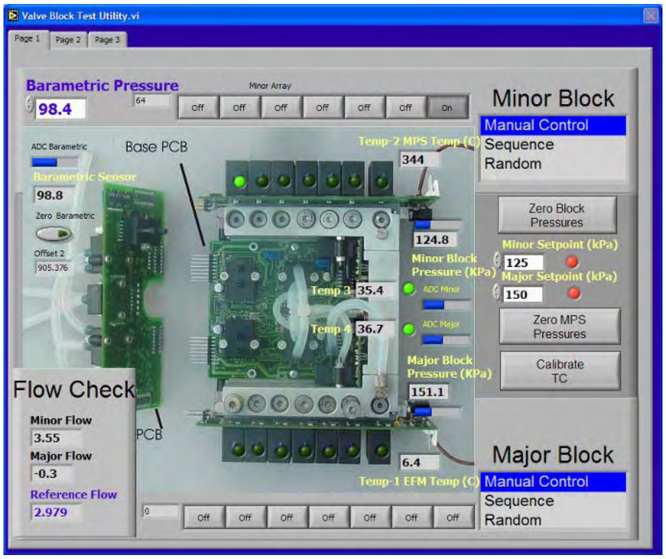
The critical orifices only need to be adjusted if the Lookup Table has significant discontinuities. If that is the case, then use the following procedure.

- Eliminate sample flow by plugging the MPS sample inlet and sample bypass.
- Connect reference flowmeter to outlet of MPS diluter.
- Ensure that direction of flow for reference flow meter is correct.



- Connect reference flow meter to flow box and then to MPS cable which provides power and signal.
- Enable the TSI flowmeter as described in section 1.

→ ***Utility Menu: Select "Advanced MPS"***
→ ***Press Button: "MPS Dilution Flows"***




- **Check / Set block pressures** as described in Section 1
- **Adjust major flow orifices**,

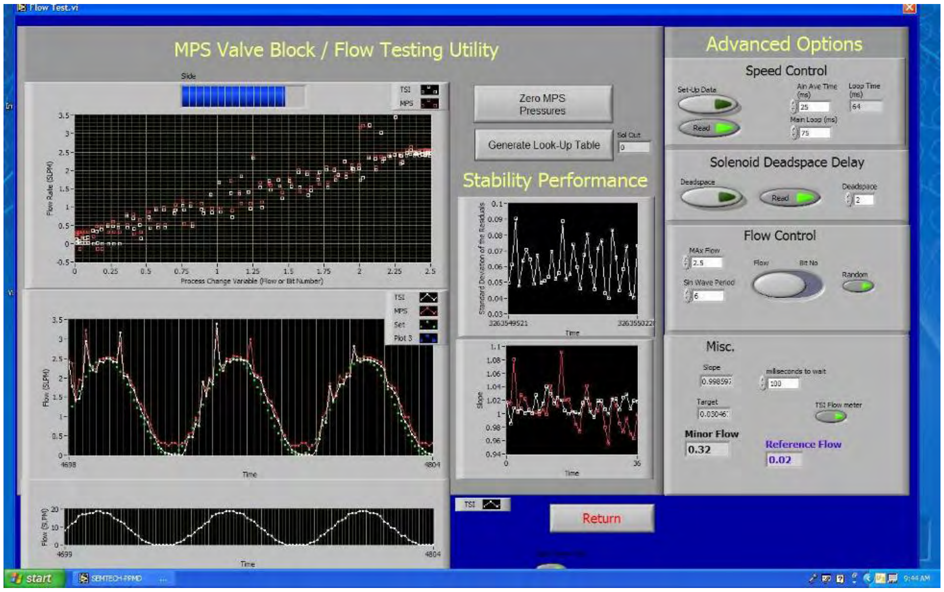
  Use PC valve block test utility .vi, and select an SOV.
  Utilize reference flow meter to read flow.
  ***Adjust largest SOV needle valve to 8.0 LPM dilution flow.***
  ***Step flow down in half for next SOV.***
  ***Settings: 8.0, 4.0, 2.0, 1.0, 0.5, 0.25, 0.125 LPM.***
  The critical orifice valves may be adjusted with an allen wrench while the MPS Display cover is in place. We recommend approaching flow set point from high while decreasing flow to minimize offset.
- **Adjust minor flow orifices**,

  Use PC valve block test utility .vi, and select an SOV.
  Utilize reference flow meter to read flow.
  ***Adjust largest SOV needle valve to 2.4 LPM dilution flow.***
  ***Step flow down in half for next SOV.***
  ***Settings: 2.4, 1.2, 0.6, 0.3, 0.15, 0.08, 0.04 LPM.***
  The critical orifice valves may be adjusted with an allen wrench while the MPS Display cover is in place. We recommend approaching flow set point from high while decreasing flow to minimize offset.
- **Update Lookup table** using procedure from Section 1. The reference flow meter is not required for the Look-Up Table, but can be used to confirm dilution flow readings (provided that the sample inlet and inlet bypass are plugged).

## FLOW TESTING UTILITY

Flow testing is required to confirm ability of MPS Valve Block to track requested flows. Modify Flow Control values to:

- 0 to 4.8 LPM for Minor Flow
- 0 to 16.0 LPM for Major Flow




This diagnostic reads expected versus actual dilution flow as measured by both internal MPS dilution flow meters and also by reference flow meter.

## GENERATE FLOW MODEL

The multi-variable model is pre-configured by Sensors.  This should only be adjusted based on detailed review of data.

# Data Quality Assurance

## EXHAUST FLOWRATE AT IDLE

If the exhaust flowmeter is working correctly, it should read within approximately 10% of the flowrates listed in the table below when idling at 600 RPM. If the idle speed is not 600 RPM, you can adjust the expected flow as follows:

Flow Expected @ Actual RPM = Flow at 600 RPM x (Actual RPM / 600)

**Expected Flowrates at Idle**

| Engine size, liters | Engine Speed, rpm | Exhaust Flow, kg/hr |
|---|---|---|
| 3 | 600 | 51 |
| 4 | 600 | 69 |
| 5 | 600 | 86 |
| 6 | 600 | 103 |
| 7 | 600 | 120 |
| 8 | 600 | 137 |
| 9 | 600 | 154 |
| 10 | 600 | 171 |
| 11 | 600 | 188 |
| 12 | 600 | 206 |
| 13 | 600 | 223 |
| 14 | 600 | 240 |
| 15 | 600 | 257 |

If the flowrate is significantly different from this value, do the following:

- Verify that the proper tube diameter is selected in the PPMD software.
- If the actual flowrate is significantly lower than expected, try backpurging the pressure lines at the manifold of the flow tube. Be certain not to backpurge the colored plastic pressure lines leading to the MPS, unless you disconnect them at the MPS.

## VERIFY MPS FLOWS

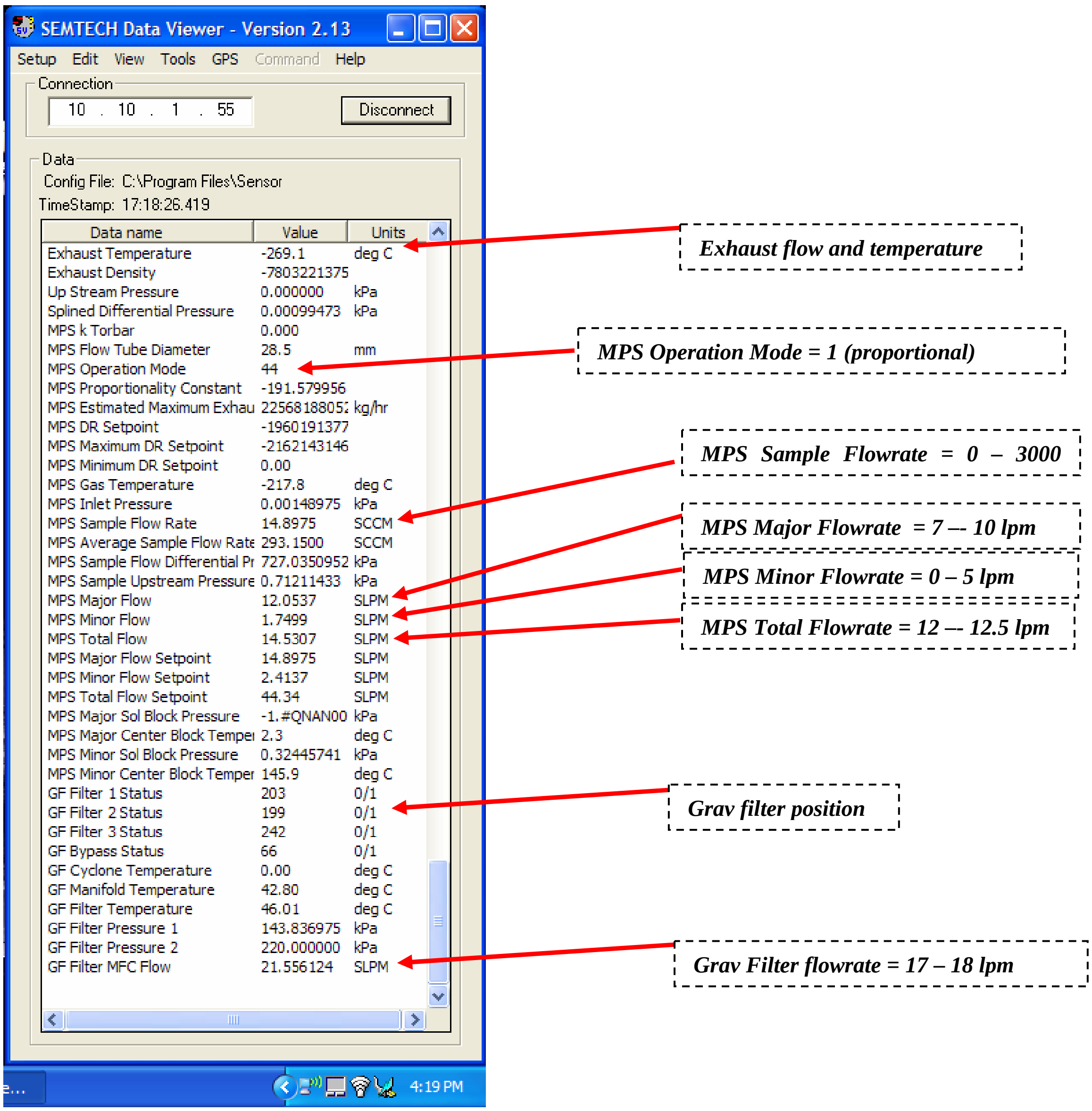
Perform the following MPS checks either with live data or from a recorded data file. Whenever the MPS is in proportional mode:

- Qtotal should be 12.5 lpm, +/- 0.5.
- At zero exhaust flow (engine off), Qsample should be less than 0.2 lpm
- At zero exhaust flow, Qminor should be > 4 lpm
- At max exhaust flow, Qminor should be slightly positive, or zero. If Qminor reaches zero at lower exhaust flowrates, or is greater than 0.5 lpm at max exhaust flow, perform adjustments as described in section 0.

## MONITOR KEY PARAMETERS DURING TESTS

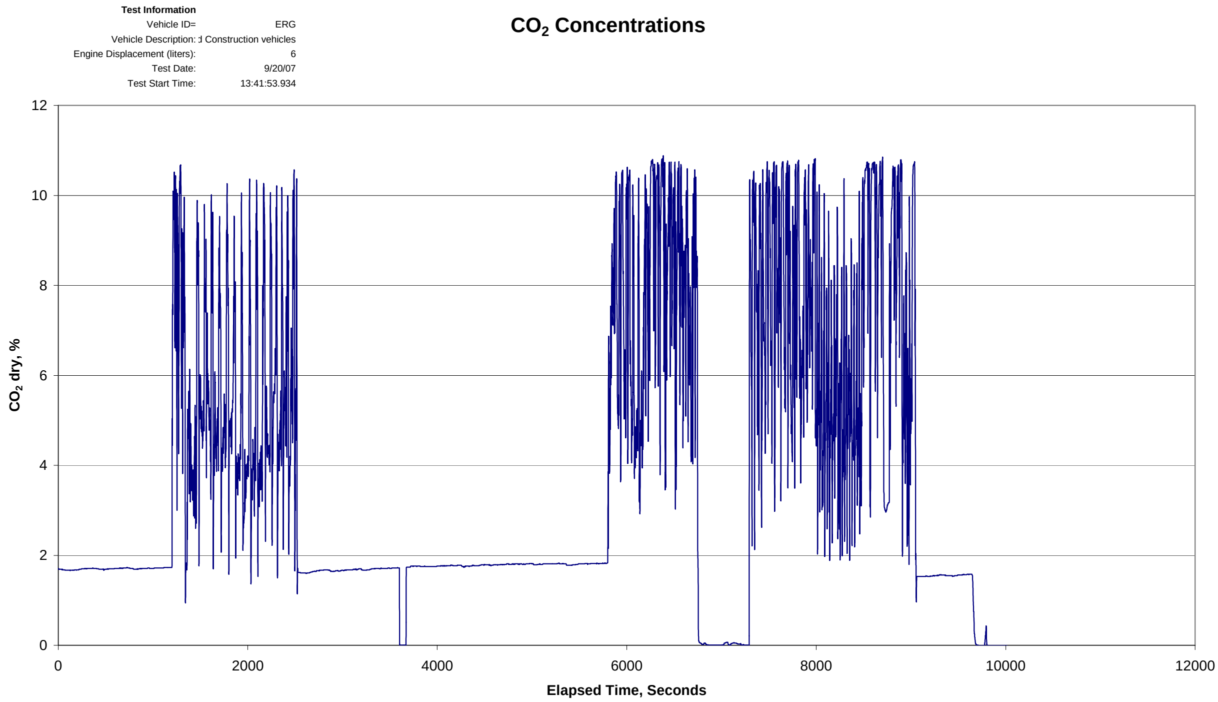
The Data Viewer utility allows us to monitor all key parameters during a test through the wireless Ethernet connection to the SEMTECH-DS. Here is a list of the most important parameters to monitor.

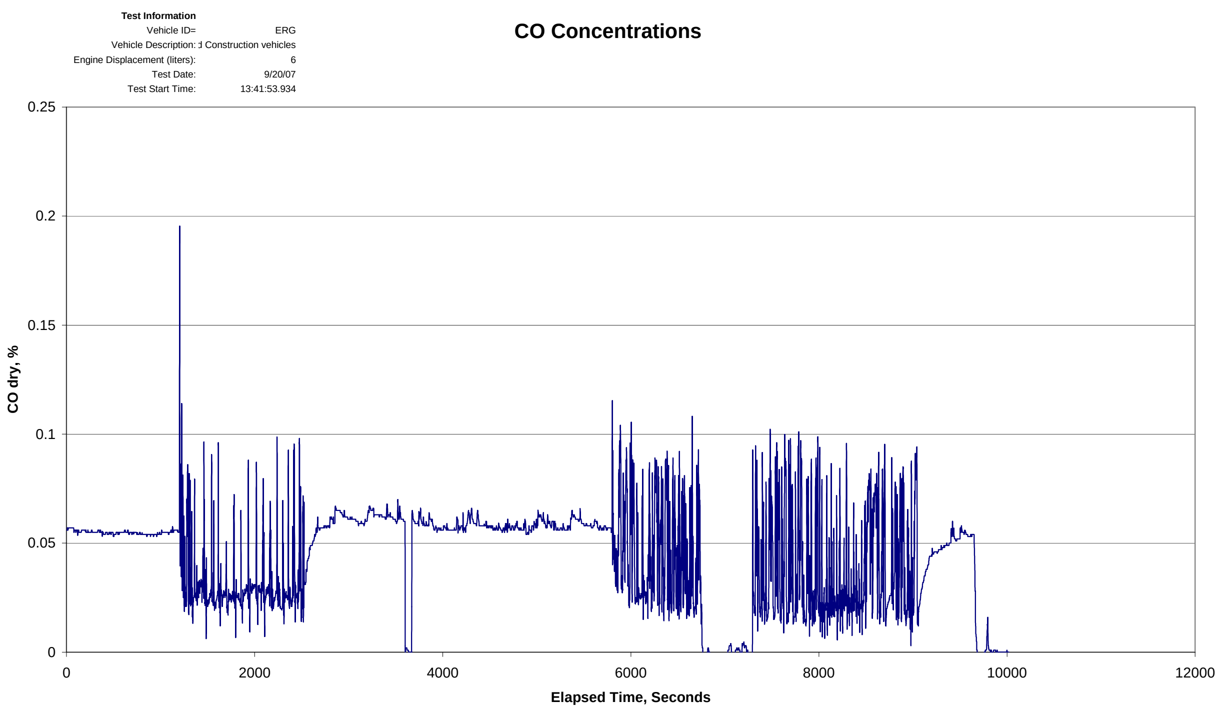
Note: The values in this screenshot are invalid and erratic. If this occurs, you must disable, and then re-enable the MPS in the System Setup / Configuration / Options screen of the SensorTech-PC software.

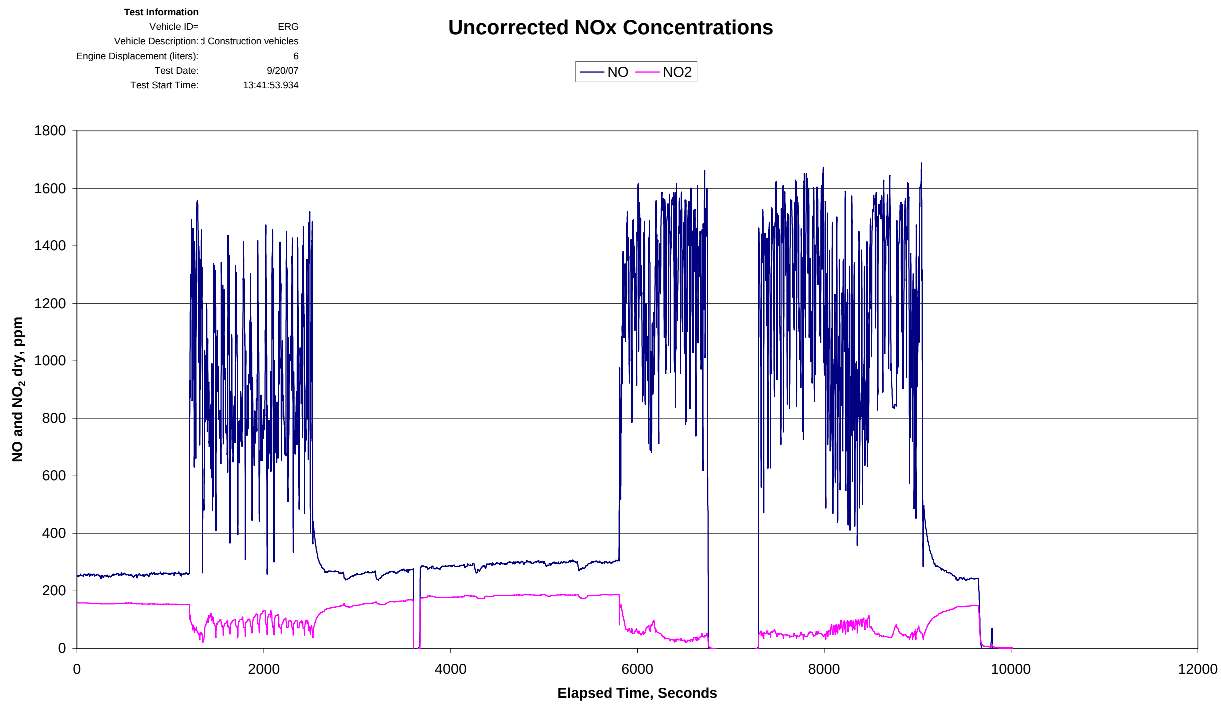


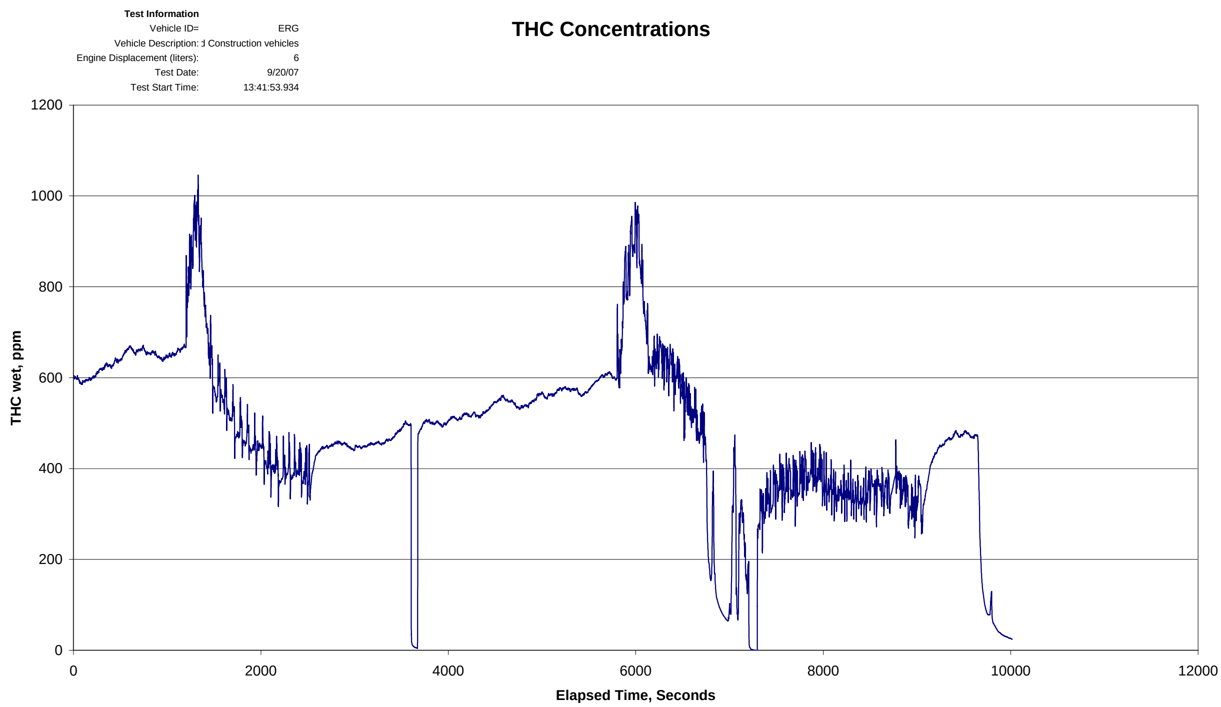
## DATA QUALITY ASSURANCE CHECK AFTER TESTS

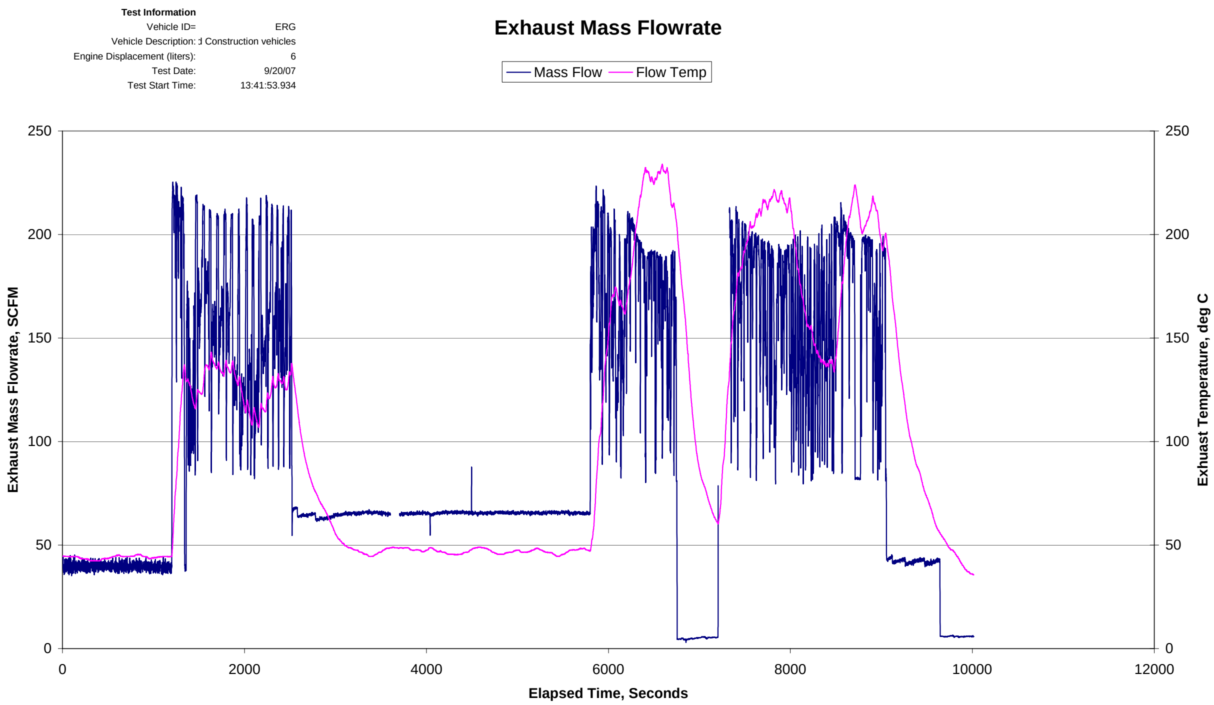
After testing, field technicians will chart the key parameters from the test for initial quality assurance verification. A charting macro has been developed, which will create the charts automatically. Below are examples of “good” data collected during a practice test.



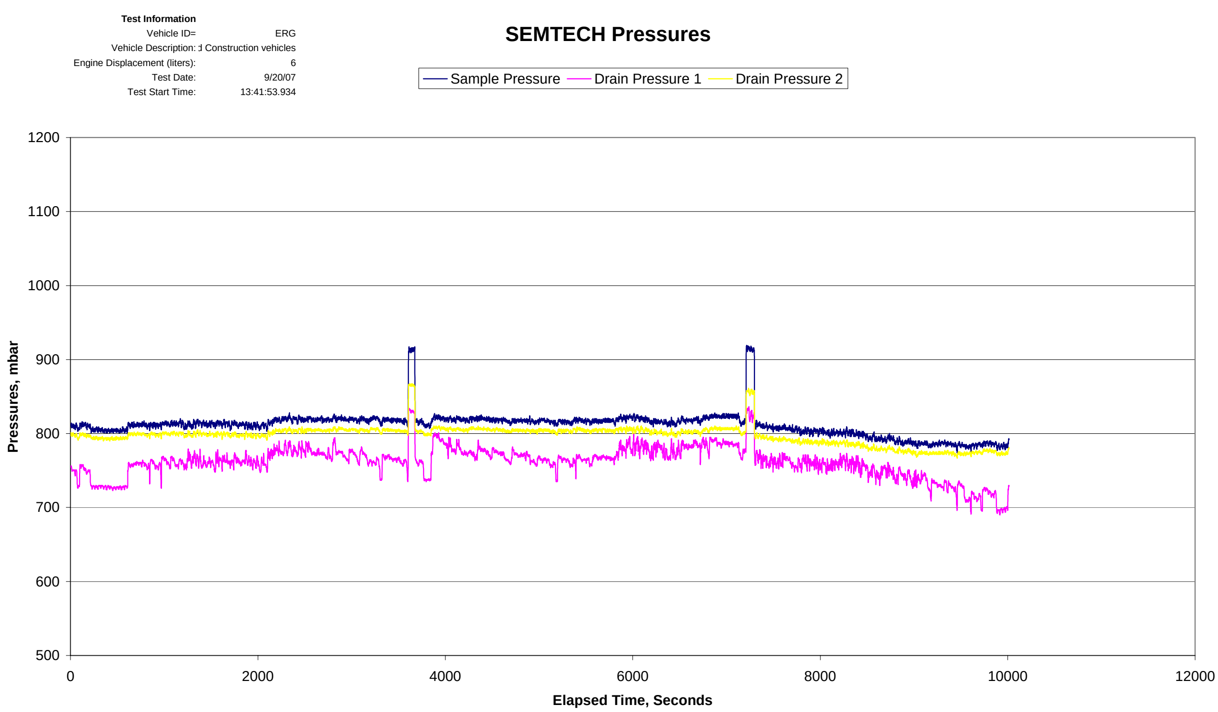




Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
Uncorrected NOx Concentrations
NO
NO2
NO and NO2 dry, ppm
Elapsed Time, Seconds

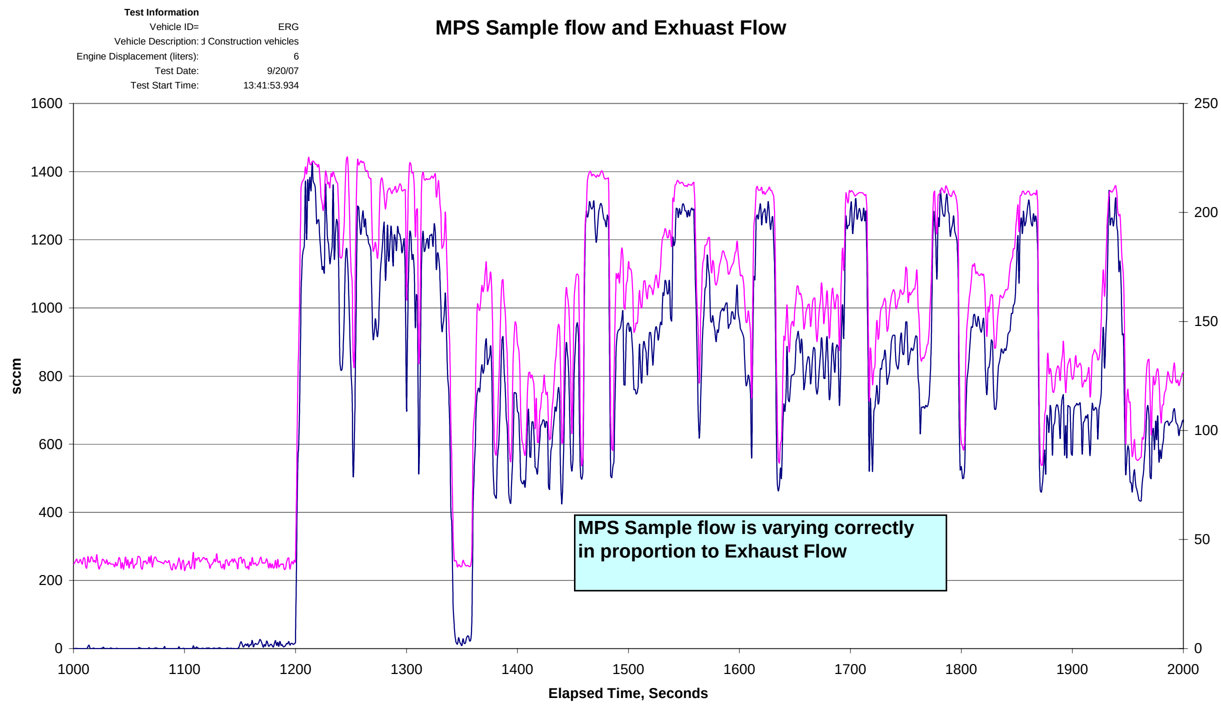

Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
THC Concentrations
THC wet, ppm
Elapsed Time, Seconds



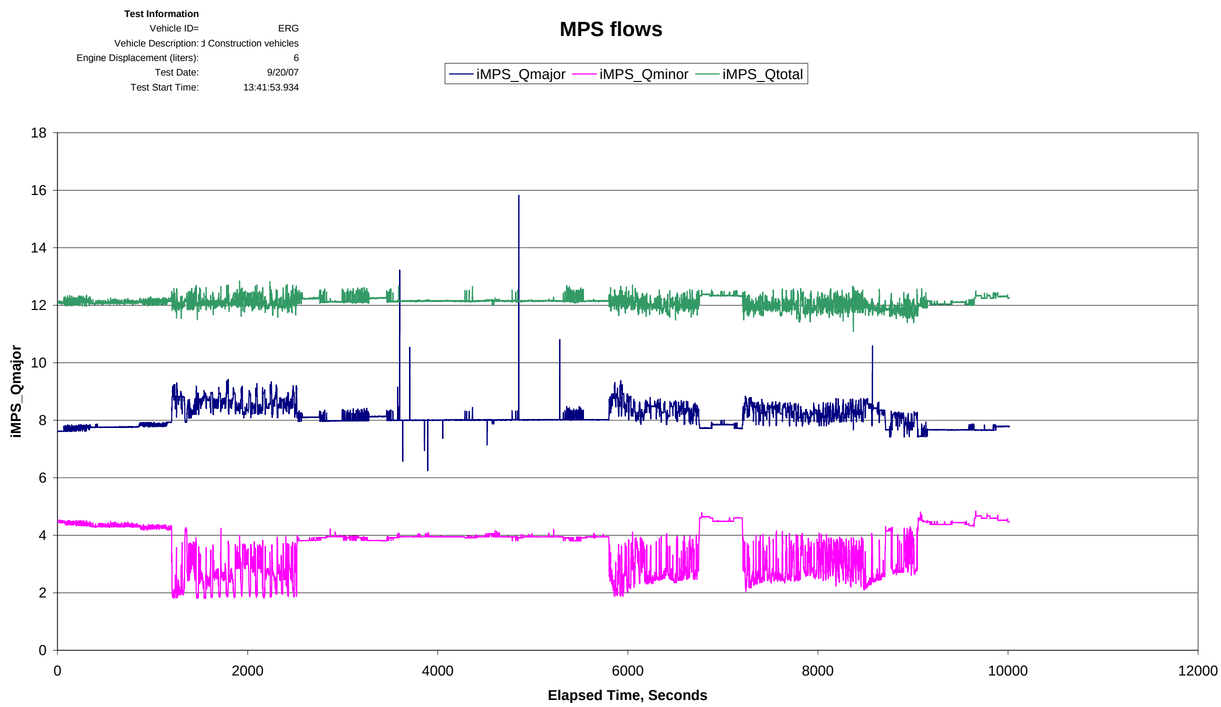
Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
Exhaust Mass Flowrate
Mass Flow
Flow Temp
Exhaust Mass Flowrate, SCFM
Exhaust Temperature, deg C
Elapsed Time, Seconds
0
50
100
150
200
250
0
2000
4000
6000
8000
10000
12000

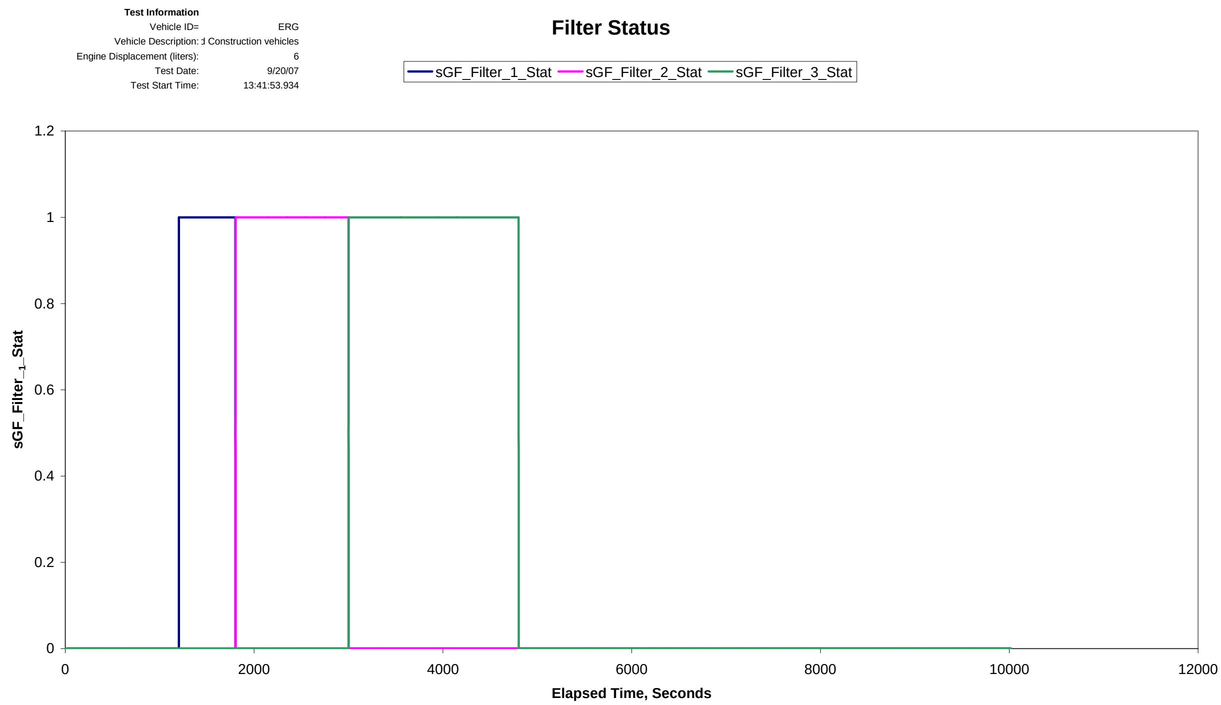
Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
SEMTECH Pressures
Sample Pressure
Drain Pressure 1
Drain Pressure 2
Pressures, mbar
Elapsed Time, Seconds
500
600
700
800
900
1000
1100
1200
0
2000
4000
6000
8000
10000
12000

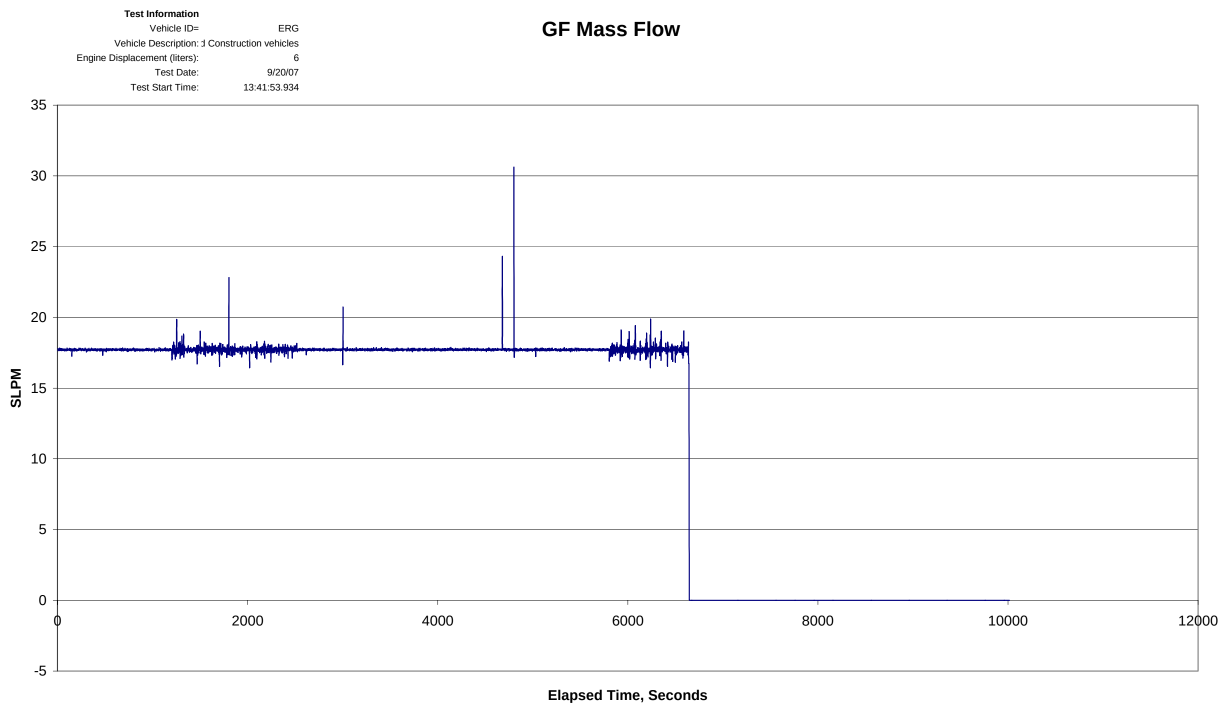


Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
MPS Sample flow and Exhuast Flow
sccm
Elapsed Time, Seconds
MPS Sample flow is varying correctly in proportion to Exhaust Flow

Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
MPS flows
iMPS_Qmajor
iMPS_Qminor
iMPS_Qtotal
iMPS_Qmajor
Elapsed Time, Seconds


Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
Filter Status
sGF_Filter_1_Stat
sGF_Filter_2_Stat
sGF_Filter_3_Stat
sGF_Filter_1_Stat
Elapsed Time, Seconds


Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
GF Mass Flow
SLPM
Elapsed Time, Seconds

# Appendix G: Activity Measurement Guidelines

[Including relevant PAMS SOPs].

# General Standard Installation Procedures for PAMS Installations

Find out how much time is available and plan accordingly.
Get a key and learn how to start the engine without moving the vehicle.
If you need to return the key, figure out how, when, who, etc.

Figure out where to put the logger and RPM sensors.
If equipment is 1999 or newer, locate and connect to CAN connector, if available.

**Determine power sources, for Corsas, install on switched power (Corsa is dead when key is off), for Isaacs, power should be steady (non-switched), but use switched power (key on) as input signal to start datalogger.**

**Ensure switched power (for Isaac input of Corsa main power) is constant and continuous during engine operation, not cycling (such as a relay) or intermittent**

**USE 24V to 12V power transformer for 24V systems!**

Route the wires. Don't obstruct any filler caps, access doors, etc.
Complete the instrumentation collection forms, including determining info about which months the equipment is used throughout the year.
**Take legible "close-up" picture of all engine tags**
Initiate the PAMS software on the configuration laptop
Mount and prepare the logger ensuring the datacard (or dataport) is accessible for future downloads
Ensure fuse is inline with logger for power on/power off.
**Ensure logger is mounted in correct orientation to prevent water incursion, and ensure the CF port is sealed with tape on the Corsa dataloggers**
**Ensure optical RPM sensor is mounted at slight/correct angle to reflective tape**
Power the logger and confirm communications with the computer (Ping).
Send the correct config file to the logger,
**Calibrate the RPM**
**Ensure acquisition frequency is 1 hz**
**Ensure the date and time stamps are correct, must be correct on laptop (and no DST for Corsas) (sync this twice for each datalogger)**
**Ensure datalogger shuts off during inactivity and turns on again during activity**

Check the real-time data to see if it looks good and is accurate (e.g., Sensor Check on Corsa).
Remove the installation data from the datalogger memory
Make sure everything is still working
Filename is ""XXXX_YYYY_PAMS", where XXXX is last 4 digits of estab ID, YYYY, is last 4 digits of serial #

**Perform dataogger startup delay testing according to data collection form instructions**

Seal and secure equipment appropriately, tighten up zip ties and wire bundles.
Zip tie bolts etc. that were removed for the install. Note them on data sheet.
ERG do final inspect of installation
Close it up.

**Verify all data collection is complete, and legible pictures have been taken**

*Regularly revisit all dataloggers to ensure they are secure, operating properly, and have sufficient unused memory. Download interim data, transmit it to FTP site and email Michael.Sabisch@erg.com*

***IMPORTANT SAFETY NOTES:***

***Safety note regarding use of optical RPM mounting magnets:***
*The RPM mounts use high-powered Neodymium magnets. They must be handled with care to avoid personal injury. Fingers can get severely pinched between magnets or a magnet and a metal surface. Magnetic attraction can slam a magnet against another magnet or metal surface, resulting in shattering of the magnet. Eye protection must be worn when handling these mounts, as shattering magnets can launch pieces at great speed. Never allow the magnets to be near computers, dataloggers, or electronic equipment of any type. If you have a pacemaker, metal stitches, or any metal objects in your body, do not work with or near the magnets.*
*Ensure the magnet is mounted in a location where it will not be heated abouve 175F.*
*Always tether the magnets with mount and zip ties.*

***Other general safety info:***
*Always follow all site safety guidelines.*
*Always tag out ignition when working on engines*
*When starting engines, always call out to verify nobody is working in the engine compartment or under equipment*
*Avoid moving and hot components when working on equipment*
*Always secure ladders and persons when climbing equipment*

## Guidelines for Corsa Datalogger software setup:

Set up an appropriate configuration file:

- Set up channels (tabs) for the two RPM inputs (see Images 1 and 2)
- Set up supply voltage tab, use 13 V as the auto start / auto stop settings (see Image 3)
- Do not set auto start/auto stop on any of the other tabs (RPMs) (see Image 3)
- RPM scale should be set at 1000, unless a decimal voltage is required for on/off, then set scale to 100 (See the "Other Installation Tips From Corsa" page)
- Ensure sample rate is 1 sample per second
- Do not set auto start/auto stop on any of the other tabs (RPMs) (see Image 3)
- RPM scale should be set at 1000, unless a decimal voltage is required for on/off, then set scale to 100 (See the "Other Installation Tips From Corsa" page)

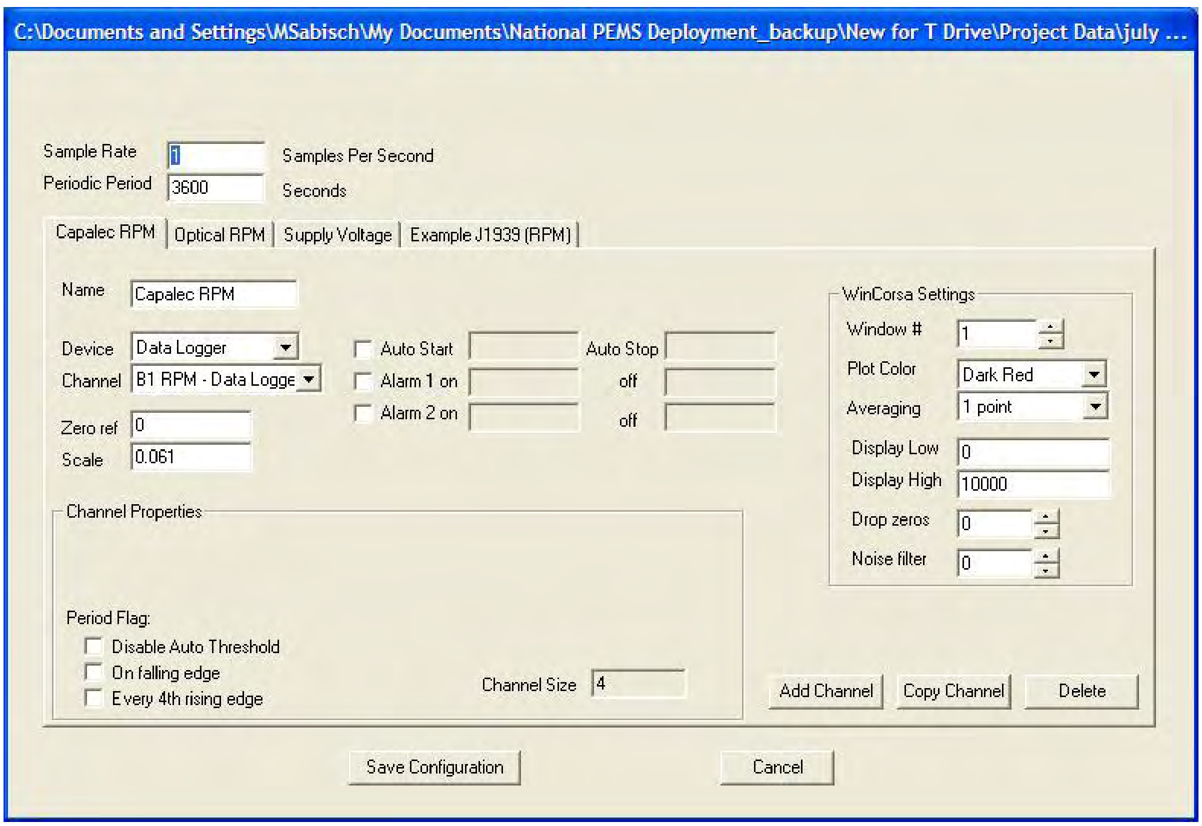



**Image 1 Optical Sensor Configuration Channel Tab**

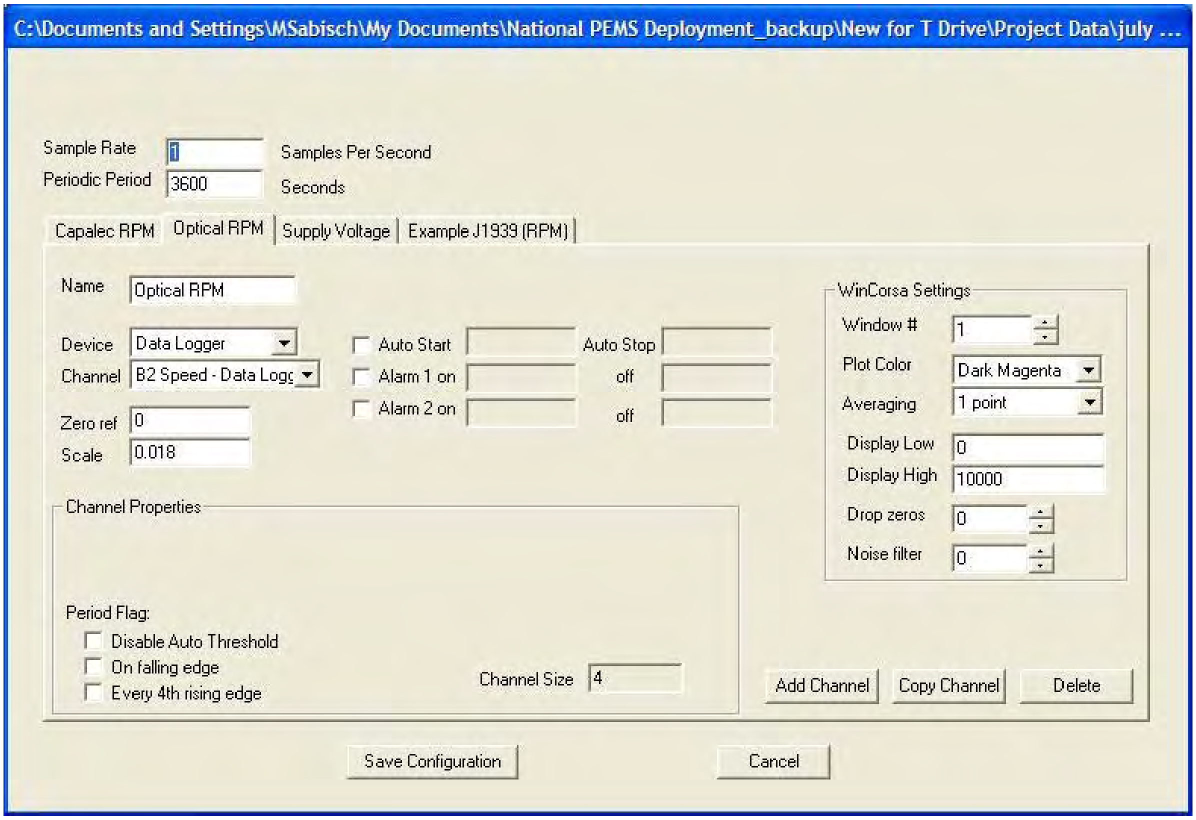



**Image 2: Capelec RPM Configuration Channel Tab**

• Under the "Datalogger" drop-down menu, select "send config file to datalogger"

• Disregard the unable to restart datalogger pop up error message, it's erroneous

• Start vehicle/equipment, and under the "Datalogger" menu, select "Sensor Check" to see real-time values

• In Sensor Check screen, ensure datalogger is acquiring reasonable data.

• Verify/calibrate two recorded RPMs (optical/capelec) with tach on equipment or handheld tach, record values on datasheet after calibration. To do this, cycle the Capelec thru all 9 settings (1, 2, 3, 4, 5, 6, 8, 10, 12) at idle, 1500, and 2000 RPM (confirmed via onboard, handheld, or optical tach) to find setting where Capelec gives proper RPM. It may be easier doing this by creating and reviewing after running this "cycle".

• After a few minutes of engine operation, turn off engine, and watch datalogger. Ensure "Run" LED shuts off (or flashes).

• Select "Save Data File from Datalogger" under the "Datalogger" drop down menu.

• Under the "File" drop-down menu, open the file you just saved using the "Open Data File" menu selection.

• Once the data is shown (as the strip chart), select the "view" drop-down menu, and select the "Data values" option.

• Review the data values to ensure that data is recorded when it should be (when the engine is started), and that acquisition quits when the engine is shut off (i.e., verify that voltage rises above 13V and data recording begins when vehicle is started and that voltage drops below 13V and acquisition stops when vehicle is shut off).

• Verify RPMs and all other recorded data in the datafile are reasonable.

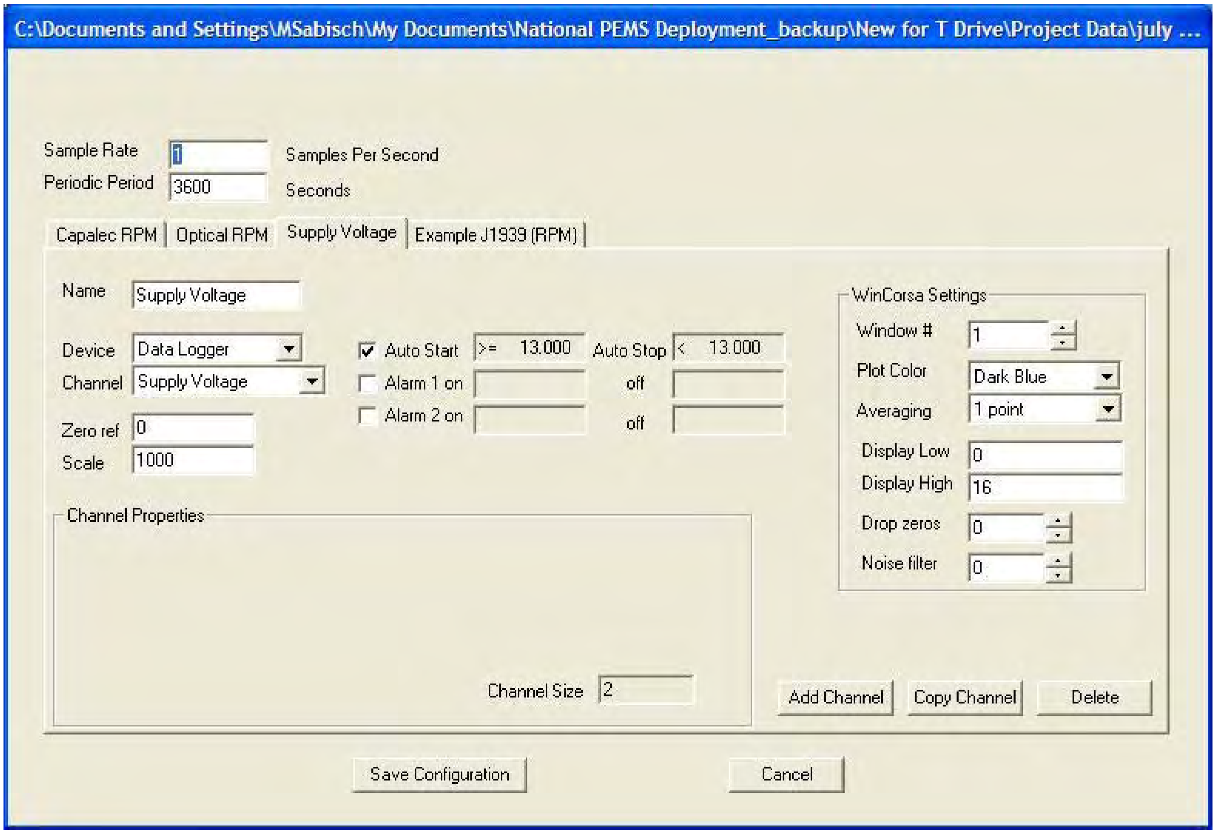



**Image 3: Supply Voltage Configuration Channel Tab**

## Guidelines for retrieval of files from Corsa Dataloggers:

When retrieving Corsa PAMS datafiles from the Corsa dataloggers, follow the following steps:

- Attempt to communicate remotely with system (ping), note result on data collection form
- Remove equipment from protective case/bags
- Remove inline fuse to power down datalogger
- On your laptop, create directory for download named with last four digits of establishment #, last four digits of Equip Serial #, and date in the format of "XXXX_XXXX_2008MMDD".
- Using flash card reader, copy all *.EZD files from the card into the directory on your laptop
- Reinstall card in datalogger, reseal unit, power up.
- When done with all your file retrievals (once back in your hotel), upload all new data directories onto the secure project FTP site under the "PSU1 PAMS Data" main directory into the "Incoming from field" subdirectory.
- Update the Update "PAMS Tracking Master.xls" on CVS with all of the download visits
- Email Michael.Sabisch@erg.com to advise that new files are in the "incoming folder"
- Archive all data on EPA laptop
- NOTE: DO NOT DOWNLOAD VIA RF RADIO, AS THIS FILE TYPE WILL NOT CONTAIN EMBEDDED DATE/TIME STAMPS. DATA MUST BE COPIED DIRECTLY FROM CF CARD REMOVED FROM DATALOGGER.

## Guidelines for office processing of Corsa datafiles (to be done in Austin)

- Move new *.ezd files from "incoming" folder to proper folder, and download from FTP site into proper location on T drive
- Open Corsa software, select the "CF Card" drop down menu, then "Save Data file from CF", then select "As Comma Separated Values (.csv). A popup should be displayed that asks if you want to export (or save, or something), your events, please select "yes" (this will save the file with embedded date/time stamps for each record).
- Import into SAS, append as needed, process and analyze. Archive the original processed files (*.csv) and the original unprocessed files (*.ezd).

**Additional Corsa system installation suggestions**
6/5/06, Erik Kaupa, Corsa Instruments

**ESD precautions** (quick summary)

- Connect ground and bus cables, and black "drain" ground wire first.
- Ground yourself to chassis frequently as you work.
- Drain any charge off thermocouple leads before plugging them in.

**Connectors**

- The 11-pin connectors on the EZ-CF unit are fragile.
- Inspect both ends before connecting, check for bent pins.
- Orient the two ends with the notches lined up before you push them together
- Do not use excessive torque on the lock ring
- Sockets not at exactly the same depth are a manufacturing tolerance issue, not necessarily a cause for concern.

**Power wiring**

- Corsa recommended practice is to ground the datalogger (black and brown wires) to the chassis.
- Grounding the datalogger to the negative battery terminal is acceptable if the battery terminal is connected directly to the chassis.
- DO NOT ground the datalogger to the negative battery terminal if there is a disconnect switch in the negative power lead from battery to chassis. Use the chassis side of the disconnect switch instead.
- Corsa recommended practice is to connect the red power wire to the vehicle side of the master disconnect switch.
- Connecting red power wire directly to the battery is acceptable. Consider safety and service issues.
- On 24 volt trucks, connect the red power wire to +12, not to +24 volts.
- Corsa system can also be powered through the J1939 module, in this case 12 or 24 volts is OK.
- If system is powered through CAN module it is still important to connect the black and brown ground wires from the "veh" connector to the chassis.

**Cables**

- If a cable is constrained so that all the flexing happens at one point, it will fail.
- Cable failures are most common right at the connector.
- Cables must not be over-constrained
- There must be some room for flex at the connector
- Cable installation problems (too tight, too heavy, too loose, no room to flex) can also cause the connectors to fail or go intermittent.

## Other Installation Tips From Corsa:

To be able to set the Voltage threshold to the 10th of a volt:
- Modify the config file as follows:
- Change the scale factor for the Box Voltage from 1000 to 100. That will cause the box voltage to be recorded as VoltsX10 (i.e., 12.5 V will be recorded as 125).
- Change the name of the tab from Box Voltage to Box Voltage X 10. That will remind the post processors when they get the data.

You should now be able to enter a record start/stop threshold of 13.3, or whatever is appropriate.

Each time you go check a logger that doesn't have a fuse on the hot leg of the power circuit (i.e., the red wire attached to the solenoid or battery), put a fuse on it. That way the next time we power down the loggers we will be able to conveniently do it by removing the fuse instead of the risky practice of unplugging the power circuit plug.

Whenever you check a Corsa logger and have trouble communicating or need to power it down:
- Note the LEDs. See if the Error light is on, etc.
- Watch the LEDs as it powers down. The CF LED should blink as the logger releases the empty space of the CF from itself.
- Record the file names and sizes if you find the CF is full with a corrupted file. That means the logger never released the empty space for some reason.

Corsa has only seen this when a CF is removed before powering down the logger or when a logger's internal battery gets too weak to support the normal power-down sequence. We have seen it under circumstances they have never seen, so we should help them figure out what is happening by using the above steps.

**Additional Suggestions for maximizing error-free data retrieval**
7/21/2006 ver 1.0

This document will outline some practices and procedures for successful operation of the Corsa CF Data Logger. Following these procedures will maximize the rate of error-free data retrieval.

**Installation and setup:**

- Wire so power is always on -- not turned off with truck
- Make sure truck provides steady 12v or more
- Install a switch for power down when removing cards
- Don't plug and unplug fragile 11-pin connectors

**Startup and checkout prior to logging session:**

- With power off install "ready" CF media (see below for media prep)
- Turn power on
- See LED's -- green PWR, amber ERR, green CF.
- CF will blink and go on steady, ERR will turn off, RUN will blink at sampling rate (1hz)

If LED's are OK as above, if there is no time or personnel to do a more thorough test, send the truck out now.

- Only if needed, send new config. Best to leave the config alone if it's OK.
- Check clock, set if needed
- Check status
- Optional, sensor check.
- Download the short recording via radio and verify all channels OK, etc.
- Verify that RUN LED is blinking, ERR is off, CF is on steady, may have short flashes.

Now ready to go.

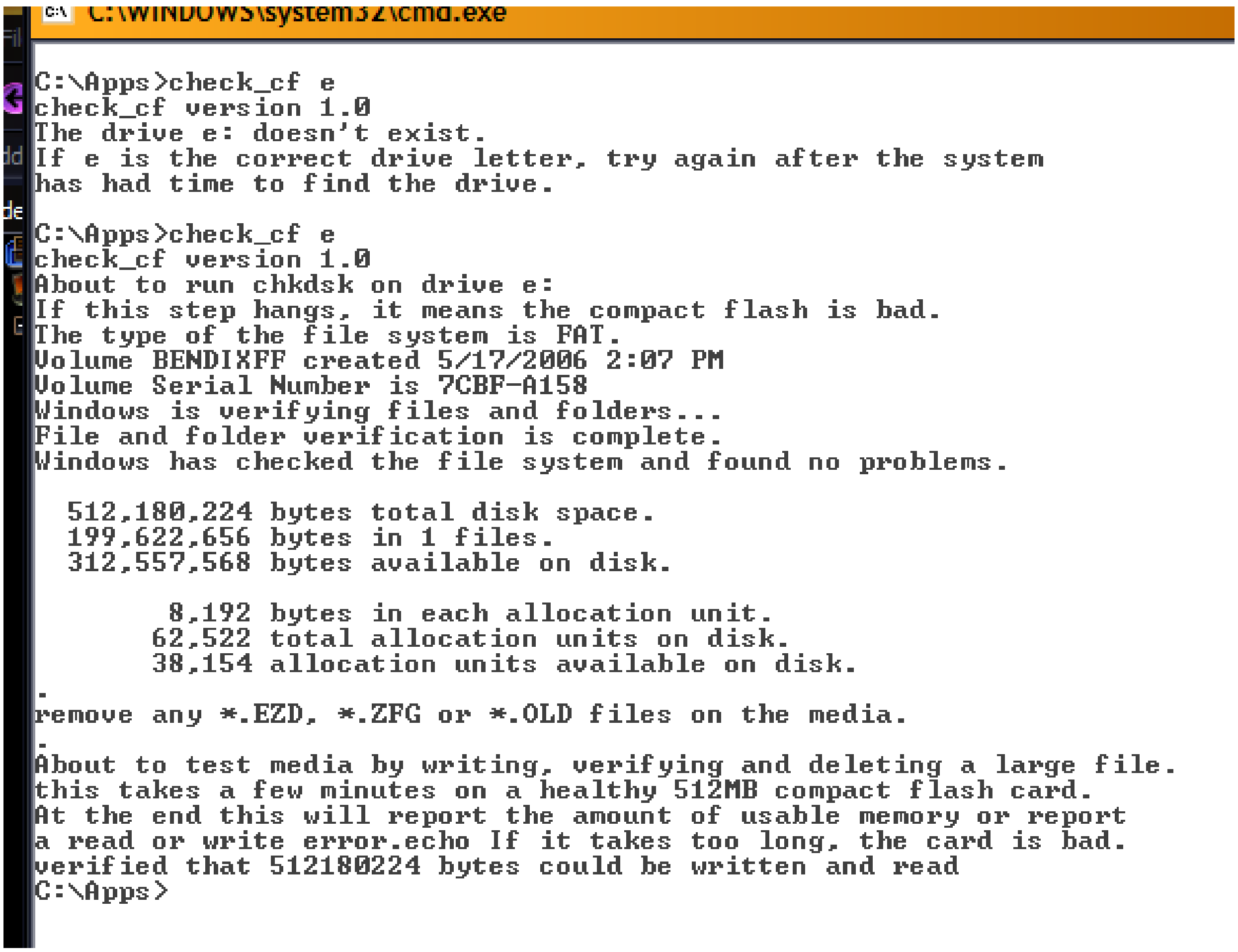
**CF media preparation**

- If there are any non-Corsa files on the CF card, delete them.
- run Check_CF
- from the Windows XP start menu, select run, and fill in CMD in the box.
- in the black command window, go to the directory where the program files are. for instance d: (enter) then cd \apps (enter)
- type check_cf and the drive letter for your CF card, for instance check_cf f
- Verify that check_cf reports media type FAT
- Check the amount of space reported on the last line of check_cf versus the chkdsk report higher on the screen and versus the card size.
- If no errors and Check_CF does not hang, card is OK to use.
- If CF check reports errors or hangs, send the card to Corsa for evaluation or throw it away.

Explanation of CF Check:

- consists of files cf_check.bat and cf_rw.exe
- Checks type of file system
- deletes files a*.ezd, *.old, *.zfg
- runs chkdsk
- Writes and reads a special pattern to the entire card to verify function.
- Leaves this special pattern on the card so that Corsa data blocks beyond the file pointers will be obvious.  This will make retrieval of damaged files easier.

Example screen shot from good CF card:


C:\WINDOWS\system32\cmd.exe

```
C:\Apps>check_cf e
check_cf version 1.0
The drive e: doesn't exist.
If e is the correct drive letter, try again after the system
has had time to find the drive.

C:\Apps>check_cf e
check_cf version 1.0
About to run chkdsk on drive e:
If this step hangs, it means the compact flash is bad.
The type of the file system is FAT.
Volume BENDIXFF created 5/17/2006 2:07 PM
Volume Serial Number is 7CBF-A158
Windows is verifying files and folders...
File and folder verification is complete.
Windows has checked the file system and found no problems.

  512,180,224 bytes total disk space.
  199,622,656 bytes in 1 files.
  312,557,568 bytes available on disk.

        8,192 bytes in each allocation unit.
       62,522 total allocation units on disk.
       38,154 allocation units available on disk.
.
remove any *.EZD, *.ZFG or *.OLD files on the media.
.
About to test media by writing, verifying and deleting a large file.
this takes a few minutes on a healthy 512MB compact flash card.
At the end this will report the amount of usable memory or report
a read or write error.echo If it takes too long, the card is bad.
verified that 512180224 bytes could be written and read
C:\Apps>
```

# Installation and Setup – Isaac Logger

## Initial Setup of Logger

- Make sure software is installed on laptop and that the Isaac driver has also been installed.
- Connect to logger using USB cable and power on the logger
- Start the Isaac Analyzer software. If it is the first time it has been run on your computer, run the License Manager from the Help menu. Fill out using the information in the CD holder.
- From the Tools menu, select Communication Parameters and open the advanced window.
- Choose Test Connection, which should display the connected logger. Select Ok.

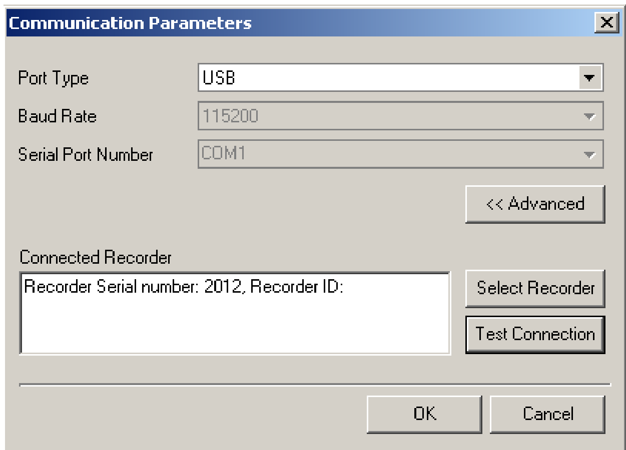



Image 4. Isaac Communications Parameters

## Configuring Channels and Recording Conditions (Autostart)

- From the Tools menu, select Recording and data processing parameters

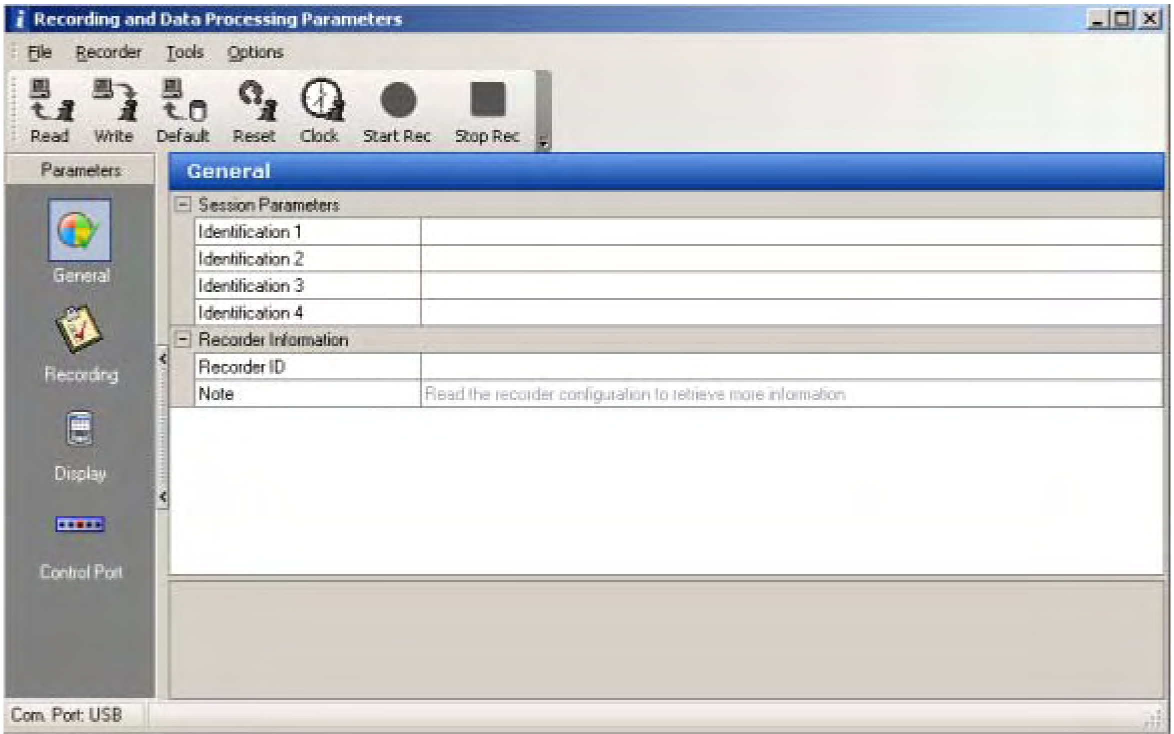



Image 5. Isaac Recording and Data Processing Parameters Window

- Select “Read” to read the current configuration from the logger
- The 4 buttons on the left of the screen indicate the parameters for recording and displaying data. Select General.
- The general parameters allow notes and labels and are primarily for organization.
- Select Recording Parameters.
- Set up the 2 RPM channels under Detectors including the names and pulses per revolution.
- The column to the right of Channel indicates whether a channel is recorded, and the column header is the number of samples per second. Be sure the 2 RPM signals and the voltage are checked and the column heading is 1 Hz
- The D column is for display options. Check the same rows as the sampling column.
- The RC column is for recording conditions. Clicking anywhere in this column brings up the recording conditions window.

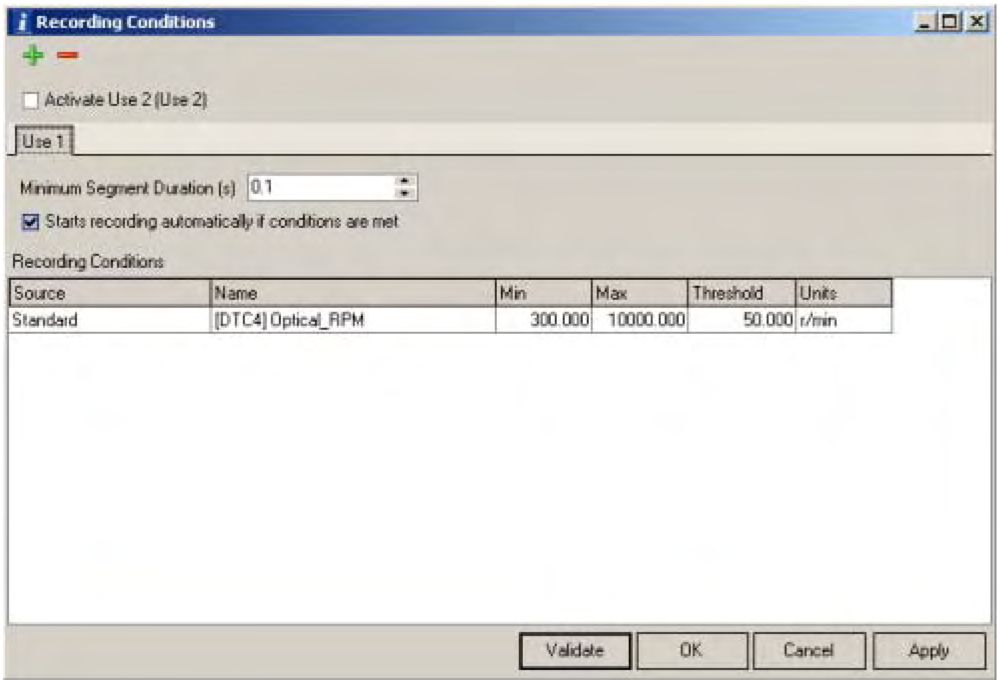


Image 6. Isaac Recording Conditions Window

- Make sure to check "Starts recording automatically if conditions are met." Click the name of the channel to select the input used to start and stop recording. Enter the range of measured values within which recording is desired. The threshold refers to the deadband that prevents recording from cycling on and off near the ends of the range. Click Ok when the Recording Conditions are set up satisfactorily.
- If switched power is used to start recording, its input will need to be added under Detectors with the RPM signals.
- The Display parameter indicates how the information will be displayed by the Isaac software. The desired channels must be turned on and set to some type of meter type to be shown when monitoring signals.
- Save the configuration for the Recording and Data Processing Parameters from the file menu.
- Click Write to write the configuration to the Isaac recorder.

**Recovering Data from Logger**

- Make sure logger is powered and connect to computer. Start Isaac Analyzer software.
- From the File menu, choose New. Create a directory for download named with last four digits of establishment #, last four digits of Equip Serial #, and date in the format of "XXXX_XXXX_2007MMDD". Name the file similarly and click Save.
- Look over the check boxes and then click the right arrow to begin the file transfer.
- Revisit Channels and recording parameters to verify that the logger is still configured properly. If any changes are needed, be sure to write them back to the logger.
- It is likely that the Red LED will be on to indicate that the system is stopped after data transfer. Either turn the box off and on or press reset from the Recording and Data Processing Parameters window to make the system ready to record again. Ensure the green or yellow LEDs are flashing, indicating that it is ready. A flashing yellow LED indicates that the memory is greater than 50% full.

- When back from the field, the data must be exported to a CSV file in order to be read by a program other than Isaac Analyzer V8. Select File, Export while the Data File window is open. Choose CSV file and select a filename and location.
- Note: If you encounter an error during file retrieval (or the associated data processing step), shut down and restart the Isaac datalogger and retry to download the file. Be sure to collect the raw datafile, even if a restart doesn't correct the processing error.
- **Always save all data before resetting the datalogger.**

## Collecting CAN Data from Isaac DataLogger

Per “Jaques” at Isaac:

The big circle Deutsch connectors will give a indication whether it is 1708 or J1939. If you have 6 pins it is 1708, if you have 9 pins it can be either. But the triangle connector with the triangle center with the pin inside is J1939 and if you see that in the future it is a solid confirmation of J1939. He said we can use the triangle connector that fits our data logger connector. Now how to configure our config file for J1939 communication. Once you are connected to the logger click the tools Icon or go from the drop down menu and click recording and data processing parameters. Click the recording Icon, this will bring up your config file. Choose CAN1 from the channels column. In the CAN1 right hand window choose J1939 under the none drop down window. Under the messages column click the click here to add messages link. This will bring up a CAN message selection window. In this window there are 3 icons in the upper left hand corner. Click the one that isn't the plus or minus, it will be the Import DBC Database icon. This will bring up a open window. Select SAE_j1939 and open it. This will bring up a long list of message definitions. Your will need to add which definitions you think you will need to get a good RPM signal to the selected messages and click import. Now you will have the definitions under the CAN1 channel and you can set them to any special parameters you wish.

For additional guidance, please call Jaques at 450-658-7520.

## Installation of CarDAQ-AVIT with DAWN Software

### Setup of CarDAQ-AVIT

- Power up logger using either the DB25 (parallel) or the vehicle (J1939) connections
  - For the DB25, pins 22,23, and 25 are ground while pin 24 is +12V
- Using a crossover network cable, connect the AVIT to your computer
- Set up a network to autodetect network settings, then enable. The upper right LED above “Status” should light, along with the upper right LED on the Ethernet plug. You can also fix the address at 192.168.0.102.
- Start an internet program and find the address 192.168.0.101. This should bring up the logger web page.


Image XX. The CarDAQ-AVIT web page

- Click and open the link for the Installer to get the AVIT to be a J2534 passthru device. Install the AVIT drivers. Some links require a username and password:
  - Username: root
  - Password: powerful

## Appendix H:  Work Assignment Data Tables

[From App B of original Work Assignment]

Populations, Usage and Emissions of Diesel Nonroad Equipment in EPA Region 7

Statement of Work

# APPENDIX B

## Proposed Data Tables and Formats

This Appendix contains proposed data formats for the tables listed in Table 9 of the Statement of Work, which is also reproduced here. The formats include Field Descriptors, suggested field names, and suggested formats. Several translation tables follow the data tables. The translation tables define the values of coded variables used in the data tables.

Table 9 Tentative Data Structure for the Nonroad Pilot Data Collection

| Table Description | Table Name | Primary Key(s) | Unique Records | Records/ respondent | Parent Table |
|---|---|---|---|---|---|
| Equipment Ownership Interview Results | eqtOwnIview | respondent ID | 2,080 | 1 | --- |
| On-site Equipment Inventory, Interview Portion | eqtInvIview | respondent ID | 2,080 | 1 | eqtOwnIview |
| On-site Equipment Inventory, Site-list Portion | eqtInvSiteList | respondent ID, siteNum | 540 | 1 to many | eqtInvIview |
| On-site Equipment Inventory, Equipment List Portion | eqtInvEqtList | respID, siteNum, pieceNum | 540 | 1 to many | eqtInvSiteList |
| Equipment Identification, Description and Instrumentation Parameters | eqtInstParam | pieceID | 540 | 1 | eqtInvEqtList |
| Output file containing activity data collected by PAMS | eqtActivity | respID pieceID (vehicle SSN) | 540 | 1 to many | eqtInstParam |
| Output files containing emissions data collected by PEMS | e<*respid*>_<*pieceID*>.<*extension*> | respID pieceID | thousands | 1 to many | eqtInstParam |

| Data Table Description: Results from the Equipment Ownership Interview (eqtOwnIview) | | |
|---|---|---|
| Field Description | Field Name | Field format |
| Respondent’s ID Code (Primary Key) | respID | character(10) |
| Sample Identifier (Establishment or Equipment sample) | sample | numeric(2.0) |
| Respondent’s selection probability (2nd stage) | pSSU | numeric(10.8) |
| Date interview completed | dateCompleted | character(8), mmddyyyy |
| Interviewer ID Code | iwerID | character(10) |
| Respondent’s 3-4 digit NAICS Code | respNAICS | numeric(4.0) (integer) |
| Respondent’s PSU (County FIPS) | respFIPS | numeric(5.0) (integer) |
| Respondent’s Incentive Group | respIncentiveGrp | numeric(2.0) |
| Interview Mode | iviewMode | numeric(2.0) |
| Interview Final Result Code | iwFinal | numeric(3.0) |
| Establishment measure of size (MOS) from sample frame | frameMOS | numeric(10.) |
| Beginning time for interview | timebeg | time(00:00) |
| Q2: verify respondents business activity (NAICS category) | Q2isNAICSAccurate | numeric(2.0) |
| Q3: Respondent’s self-reported business activity | Q3businAct | character(250) |
| Q4: Respondent’s self-reported employer status (GPI) | Q4isEmployer | numeric(2.0) |
| Q4: Respondent’s self-reported farm status (Agriculture) | Q4isFarm | numeric(2.0) |
| Q5: Respondent’s self-reported number of employees | Q5numEmpl | numeric(8.0) |
| Q5: Respondent’s self-reported farm acreage | Q5farmAcres | numeric(8.0) |
| Q6: Respondent’s self-reported MOS Class (no. employees, GPI) | Q6numEmplCls | numeric(2.0) |

| | | |
|---|---|---|
| Q6: Respondent’s self-reported MOS Class (farm acreage, Agriculture) | Q6acresCls | numeric(2.0) |
| Q7: Respondent’s diesel equipment usage | Q7useDslEqt | numeric(2.0) |
| Q8: No. Equipment pieces used | Q8numEqt | numeric(8.0) |
| Q9: Respondent’s self-classification: no. equipment pieces | Q9numEqtCls | |
| Q10: Eligibility for Emissions Measurement | Q10eligibilityPEMS | numeric(2.0) |
| Ending time for interview | timeend | time(00:00) |

Data Table Description: Interview Portion of the On-site Equipment Inventory (eqtInvInterview)

| Field Description | Field Name | Field format |
|---|---|---|
| Respondent’s ID Code (Primary Key) | respID | character(10) |
| Date Inventory Completed | dateCompleted | character(8), mmddyyyy |
| Inventory Final Outcome Code | invFinal | numeric(8) |
| Beginning time for inventory | timebeg | time(xx:xx) |
| Q1: Respondent’s work sites (binary) | Q1hasMultSites | numeric(4) |
| Q2: No. work sites with nonroad equipment | Q2numSites | numeric(4) |
| Q3: contact at remote site (binary) | Q3hasSiteContact | numeric(4) |
| Q6: Respondent’s shift schedule (binary) | Q6hasShifts | numeric(4) |
| Q7: Number of shifts per 24-hour period | Q7shiftsPer24 | numeric(4) |
| Q8: Respondent’s consent to instrument selected piece | Q8respOK | numeric(4) |
| Q9: Annual vs. Periodic Usage? | Q9annualPerUsage | numeric(4) |
| Q10: Usage by Month | Q10_1 | numeric(4) |
| | Q10_2 | numeric(4) |
| | Q10_3 | numeric(4) |
| | Q10_4 | numeric(4) |

| | | |
|---|---|---|
| | Q10_5 | numeric(4) |
| | Q10_6 | numeric(4) |
| | Q10_7 | numeric(4) |
| | Q10_8 | numeric(4) |
| | Q10_9 | numeric(4) |
| | Q10_10 | numeric(4) |
| | Q10_11 | numeric(4) |
| | Q10_12 | numeric(4) |
| Q11: Use during measurement period | Q11useMeasPer | numeric(4) |
| Ending time for Inventory | timeend | time(xx:xx) |

| Data Table Description: Site List Portion of the On-site Equipment Inventory (eqtInvSiteList) | | |
|---|---|---|
| **Field Description** | **Field Name** | **Field format** |
| Respondent’s ID Code (Primary Key) | respID | character(10) |
| Site Number | siteNum | numeric(4) |
| Site code | siteCode | numeric(2) |
| Distance Code | distCode | numeric(2) |
| Equipment shift code | eqtShiftCode | numeric(2) |
| Shift Selection Code | shiftSelectCode | numeric(2) |
| Site Description | siteDesc | character(250) |
| Was site selected? | wasSiteSelected | numeric(2) |
| Site Selection Probability (SRS) | pSite (=1/Q2numSites) | numeric(10.8) (real) |

| Data Table Description: Equipment-List Portion of the On-site Equipment Inventory (eqtInvEqtList) | | |
|---|---|---|
| **Field Description** | **Field Name** | **Field format** |
| Respondent’s ID Code (Primary Key) | respID | character(10) |
| Site Number (Primary Key) | siteNum | numeric(4) |
| Shift Selection Code | shiftSelectCode | numeric(2) |
| Piece number | eqtPcNum | numeric(8) |
| Equipment type code | eqtType | numeric(4) |
| Equipment type description | eqtTypeDesc | character(50) |
| Equipment manufacturer | eqtMfr | character(25) |
| Equipment model | eqtModel | character(25) |
| Equipment model year | eqtModelYr | numeric(4) |
| Equipment serial number | eqtSerialNum | character(20) |

| | | |
|---|---|---|
| Is piece eligible for emissions measurement? | isEligible | numeric(2) |
| Was piece selected for measurement? | isSelected | numeric(2) |
| Piece's selection probability (SRS) | pPiece | numeric(10.8) (real) |
| Comments | comments | character(250) |

Data Table Description: Equipment Identification, Description and Instrumentation Parameters
(eqtInstParam)

| Field Description | Field Name | Field format |
|---|---|---|
| Respondent's ID Code (Primary Key) | respID | character(10) |
| Piece number | eqtPcNum | numeric(8) |
| Equipment serial number | eqtSerialNum | character(20) |
| Number of respondent's sites | numSites | numeric(4) |
| Number of work shifts | numShifts | numeric(4) |
| Number of eligible pieces on selected site | numPieces | numeric(8) |
| Equipment type code | eqtType | numeric(4) |
| Equipment type description | eqtTypeDesc | character(50) |
| Equipment manufacturer | eqtMfr | character(25) |
| Equipment model | eqtModel | character(25) |
| Equipment model year | eqtModelYr | numeric(4) |
| Equipment plate code | eqtPlateCode | numeric(2) |
| Equipment comments | eqtComments | character(250) |
| Engine manufacturer | engMfr | character(20) |
| Engine model | engModel | character(20) |
| Engine model year | engModelYr | numeric(4) |
| Engine serial number | engSerialNum | character(20) |

| | | |
|---|---|---|
| Engine family | engFamily | character(20) |
| Engine plate code | engPlateCode | numeric(2) |
| Engine comments | engComments | character(250) |
| Hour-meter function code 1 | hrMeterCode1 | numeric(2) |
| Hour-meter function code 2 | hrMeterCode2 | numeric(2) |
| Beginning date for current hour-meter reading | hrMeterBegDate | character(8)(mmddyy yy) |
| Hour-meter reading | hrMeterReading | numeric(10.8) |
| Hour-meter comments | hrMeterComments | character(250) |
| Are major exhaust leaks present? | isExhLeak | numeric(2) |
| Is alternator speed signal reliable? | isAltSignal | numeric(2) |
| Are modifications or malmaintenance evident? | isModMal | numeric(2) |
| Visual Inspection Comments | visInspectComm | character(250) |
| Installation date | installDate | character(8) mmddyyyy |
| Removal date | removeDate | |
| Installation time | installTime | time(hh:mm) |
| Removal time | removeTime | time(hh:mm) |
| Installation Comments | installComments | character(250) |
| Removal Comments | removeComments | character(250) |
| Engine rated power: value | engRatePwr | numeric(10.8) |
| Engine rated power: units | engRatePwrUnits | numeric(2) |
| Engine rated power: source code | engRatePwrSrce | numeric(2) |
| Engine rated power: method code | engRatePwrMeth | numeric(2) |
| Engine rated speed: value | engRateSpd | numeric(10.8) |
| Engine rated speed: source code | engRateSpdSrce | numeric(2) |
| Engine rated speed: method code | engRateSpdMeth | numeric(2) |
| Engine peak torque: value | engPeakTorq | numeric(10.8) |

| | | |
|---|---|---|
| Engine peak torque: units | engPeakTorqUnits | numeric(2) |
| Engine peak torque: source code | engPeakTorqSrce | numeric(2) |
| Engine peak torque: method code | engPeakTorqMeth | numeric(2) |
| Engine peak speed: value | engPeakSpd | numeric(10.8) |
| Engine peak speed: units | engPeakSpdUnits | numeric(2) |
| Engine peak speed: source code | engPeakSpdSrce | numeric(2) |
| Engine peak speed: method code | engPeakSpdMeth | numeric(2) |
| Engine rating: Comments | engRateComm | character(250) |
| Is after-treatment present? | isAfterTreat | numeric(2) |
| Description of after-treatment technology | afterTreatDesc | character(250) |
| Unit power (volts) | unitPower | numeric(10.8) |
| Tailpipe outer diameter (inches) | tailpipeOD | numeric(10.8) |
| Tailpipe wall thickness (inches) | tailpipeID | numeric(10.8) |
| Instrument Code | instCode | numeric(2) |
| Box Number | spotBoxNum | character(8) |
| Datalogger ID | spotDataLoggerID | character(8) |
| Flowmeter ID | spotFlowMeterID | character(8) |
| Nox/O2 sensor ID | spotNOxO2SensorID | character(15) |
| Cell number | spotCellNum | character(12) |
| Precalibration: calibration ID number | preCalID | character(8) |
| Precalibration: calibration date | preCalDate | character(8) mmddyyyy |
| Precalibration: flow-meter, 0th order term | preCalFlow_0 | numeric(10.8) |
| Precalibration: flow-meter, 1st order term | preCalFlow_1 | numeric(10.8) |
| Precalibration: flow-meter, 2nd order term | preCalFlow_2 | numeric(10.8) |
| Precalibration: flow-meter, 3rd order term | preCalFlow_3 | numeric(10.8) |
| Precalibration: NOx conc., 0th order term | preCalNOx_0 | numeric(10.8) |
| Precalibration: NOx conc., 1st order term | preCalNOx_1 | numeric(10.8) |

| | | |
|---|---|---|
| Precalibration: NOx conc., 2nd order term | preCalNOx_2 | numeric(10.8) |
| Precalibration: NOx conc., 3rd order term | preCalNOx_3 | numeric(10.8) |
| Precalibration: $O_2$ conc., 0th order term | preCalO2_0 | numeric(10.8) |
| Precalibration: $O_2$ conc., 1st order term | preCalO2_1 | numeric(10.8) |
| Precalibration: $O_2$ conc., 2nd order term | preCalO2_2 | numeric(10.8) |
| Precalibration: $O_2$ conc., 3rd order term | preCalO2_3 | numeric(10.8) |
| Precalibration: COconc., 0th order term | preCalCO_0 | numeric(10.8) |
| Precalibration: COconc., 1st order term | preCalCO_1 | numeric(10.8) |
| Precalibration: COconc., 2nd order term | preCalCO_2 | numeric(10.8) |
| Precalibration: COconc., 3rd order term | preCalCO_3 | numeric(10.8) |
| Precalibration: THCconc., 0th order term | preCalTHC_0 | numeric(10.8) |
| Precalibration: THCconc., 1st order term | preCalTHC_1 | numeric(10.8) |
| Precalibration: THCconc., 2nd order term | preCalTHC_2 | numeric(10.8) |
| Precalibration: THCconc., 3rd order term | preCalTHC_3 | numeric(10.8) |
| Poscalibration: calibration ID number | postCalID | character(8) |
| Poscalibration: calibration date | postCalDate | character(8) mmddyyyy |
| Postcalibration: flow-meter, 0th order term | postCalFlow_0 | numeric(10.8) |
| Postcalibration: flow-meter, 1st order term | postCalFlow_1 | numeric(10.8) |
| Postcalibration: flow-meter, 2nd order term | postCalFlow_2 | numeric(10.8) |
| Postcalibration: flow-meter, 3rd order term | postCalFlow_3 | numeric(10.8) |
| Postcalibration: NOx conc., 0th order term | postCalNOx_0 | numeric(10.8) |
| Postcalibration: NOx conc., 1st order term | postCalNOx_1 | numeric(10.8) |
| Postcalibration: NOx conc., 2nd order term | postCalNOx_2 | numeric(10.8) |
| Postcalibration: NOx conc., 3rd order term | postCalNOx_3 | numeric(10.8) |
| Postcalibration: $O_2$ conc., 0th order term | preCalO2_0 | numeric(10.8) |
| Postcalibration: $O_2$ conc., 1st order term | postCalO2_1 | numeric(10.8) |
| Postecalibration: $O_2$ conc., 2nd order term | postCalO2_2 | numeric(10.8) |
| Postcalibration: $O_2$ conc., 3rd order term | postCalO2_3 | numeric(10.8) |

| | | |
|---|---|---|
| Postcalibration: COconc., $0^{th}$ order term | postCalCO_0 | numeric(10.8) |
| Postcalibration: COconc., $1^{st}$ order term | postCalCO_1 | numeric(10.8) |
| Postecalibration: COconc., $2^{nd}$ order term | postCalCO_2 | numeric(10.8) |
| Postcalibration: COconc., $3^{rd}$ order term | postCalCO_3 | numeric(10.8) |
| Postcalibration: THCconc., $0^{th}$ order term | postCalTHC_0 | numeric(10.8) |
| Postcalibration: THC conc., $1^{st}$ order term | postCalTHC_1 | numeric(10.8) |
| Postcalibration: THC conc., $2^{nd}$ order term | postCalTHC_2 | numeric(10.8) |
| Postcalibration: THC conc., $3^{rd}$ order term | postCalTHC_3 | numeric(10.8) |
| Date of site-visit (for maintenance during use) | visitDate | character(10) mmddyyyy |
| Time of site visit (for maintenance during use) | visitTime | time (hh:mm) |
| Reason for site visit | visitReason | character(250) |
| Actions taken during site visit | visitActions | character(250) |
| Outcome code for site visit | visitOutcome | numeric(2) |

Translation Table: Final Interview Result Codes for the Equipment Ownership Interview
(resultEqtOwnIview)

| Field Outcome Description | Code |
|---|---|
| Interview completed successfully | 40 |
| Refusal | 41 |
| Break off (partial interview) | 42 |
| Knowledgeable respondent unavailable after repeated callbacks | 43 |
| Intended respondent not at listed phone number | 44 |
| Language barrier | 45 |
| Other (specify in comments | 46 |

Translation Table: Final Result Codes for the On-site Equipment Inventory
(resultEqtInv)

| Field Outcome Description | Code |
|---|---|
| Inventory complete (home site) | 80 |
| Inventory complete (remote site) | 81 |
| Break off (partial inventory) | 82 |
| Knowledgeable respondent unavailable after repeated visits | 83 |
| Intended respondent not at listed address | 84 |
| Refusal | 85 |
| Language barrier | 86 |
| Other (specify in comments) | 87 |

| Translation Table: Final Result Codes for the On-site Equipment Inventory SiteList and Description (resultSiteList) | |
|---|---|
| Field Outcome Description | Code |
| <u>Site Codes</u> | |
| Primary Site | 01 |
| Secondary Site (Remote) | 02 |
| <u>Distance Codes</u> | |
| ≤ *travelDistance* | 10 |
| > *travelDistance* | 11 |
| <u>Equipment Shift Codes</u> | |
| One shift per 24-hour period (1/24-hr) | 20 |
| Two shifts per 24-hour period (2/24-hr) | 21 |
| Three shifts per 24-hour period (3/24-hr) | 22 |
| Other (Describe in comments) | 23 |
| <u>Shift Selection Codes</u> | |
| Day shift | 30 |
| Swing shift | 31 |
| Graveyard or night shift | 32 |
| Other (Describe in comments) | 33 |

| Translation Table: Codes for the Identification, Description and Installation Parameters (resultEqtInst) | |
|---|---|
| Field Outcome Description | Code |
| <u>Equipment Plate Codes</u> | |
| Not present | 01 |
| Cannot Locate | 02 |

| | |
|---|---|
| Present but specs not legible | 03 |
| Present and legible | 04 |
| Other | 05 |

<u>Engine Plate Codes</u>

| | |
|---|---|
| Not present | 01 |
| Cannot Locate | 02 |
| Present but specs not legible | 03 |
| Present and legible | 04 |
| Other | 05 |

<u>Hour-meter function Code 1</u>

| | |
|---|---|
| Meter not present | 21 |
| Meter present but not functioning | 22 |
| Original meter, reading presumed to represent hours since original purchase | 23 |
| Original meter reset following maintenance or resale, can identify beginning date for current reading | 24 |
| Original meter reset following maintenance or resale, CANNOT identify beginning date for current reading | 25 |
| NOT original meter, can identify beginning date for current reading | 26 |
| NOT original meter, CANNOT identify beginning date for current reading | 27 |
| Other: (describe in hour-meter comments) | 28 |

<u>Hour-meter function code 2</u>

| | |
|---|---|
| No reading available | 30 |
| Current reading presumed accurate | 31 |
| Current reading not accurate, reliable adjustment possible (describe in hour-meter comments) | 32 |
| Current reading not accurate, reliable adjustment NOT possible (describe in hour-meter comments) | 33 |
| Other (describe in hour-meter comments) | 34 |

<u>Engine Rating Units Codes</u>

| | |
|---|---|
| Horsepower (gross) | 11 |

| | |
|---|---|
| Horsepower (net) | 12 |
| Kilowatts (gross) | 13 |
| Kilowatts (net) | 14 |
| Foot-lbs (ft-lb) | 15 |
| Newton-meters (nm) | 16 |
| Other (describe) | 17 |

Engine Rating Source Codes

| | |
|---|---|
| Owner's/User's verbal report | 21 |
| Engine plate | 22 |
| Manufacturer's specification | 23 |
| Reference source | 24 |
| Unavailable | 25 |
| Other (describe) | 26 |

Engine Rating Method Codes

| | |
|---|---|
| NETT SAE | 31 |
| ISO | 32 |
| Unknown | 33 |
| Unavailable | 34 |
| Other (describe) | 35 |

Portable Instrument Codes

| | |
|---|---|
| Portable Activity Measurement System (PAMS) | 01 |
| Simple Portable On-vehicle Measurement (SPOT) | 02 |
| Sensors Emission Technology - Diesel (SEMTECH-D) | 03 |
| Other | 04 |

Site-visit/Maintenance Outcome Codes

| | |
|---|---|
| Instrument retained, data prior to visit invalid | 10 |
| Instrument retained, data prior to visit valid | 11 |
| Instrument replaced, data prior to visit invalid | 20 |

| | |
|---|---|
| Instrument replaced, data prior to visit valid | 21 |
| Instrument not replaced, data prior to visit invalid | 30 |
| Instrument not replaced, data prior to visit valid | 31 |

# Appendix I: Offsite Emissions Measurement QC and Analysis

## PEMS Data Quality Assurance

Note: the following QC steps are provided in the PEMS SOPs, as they may be applied in the field. They are repeated here as they will be reviewed in the office as part of the QC process.

### EXHAUST FLOWRATE AT IDLE

If the exhaust flowmeter is working correctly, it should read within approximately 10% of the flowrates listed in the table below when idling at 600 RPM. If the idle speed is not 600 RPM, you can adjust the expected flow as follows:

Flow Expected @ Actual RPM = Flow at 600 RPM x (Actual RPM / 600)

**Expected Flowrates at Idle**

| Engine size, liters | Engine Speed, rpm | Exhaust Flow, kg/hr |
|---|---|---|
| 3 | 600 | 51 |
| 4 | 600 | 69 |
| 5 | 600 | 86 |
| 6 | 600 | 103 |
| 7 | 600 | 120 |
| 8 | 600 | 137 |
| 9 | 600 | 154 |
| 10 | 600 | 171 |
| 11 | 600 | 188 |
| 12 | 600 | 206 |
| 13 | 600 | 223 |
| 14 | 600 | 240 |
| 15 | 600 | 257 |

If the flowrate is significantly different from this value, do the following:

- Verify that the proper tube diameter is selected in the PPMD software.
- If the actual flowrate is significantly lower than expected, try backpurging the pressure lines at the manifold of the flow tube. Be certain not to backpurge the colored plastic pressure lines leading to the MPS, unless you disconnect them at the MPS.

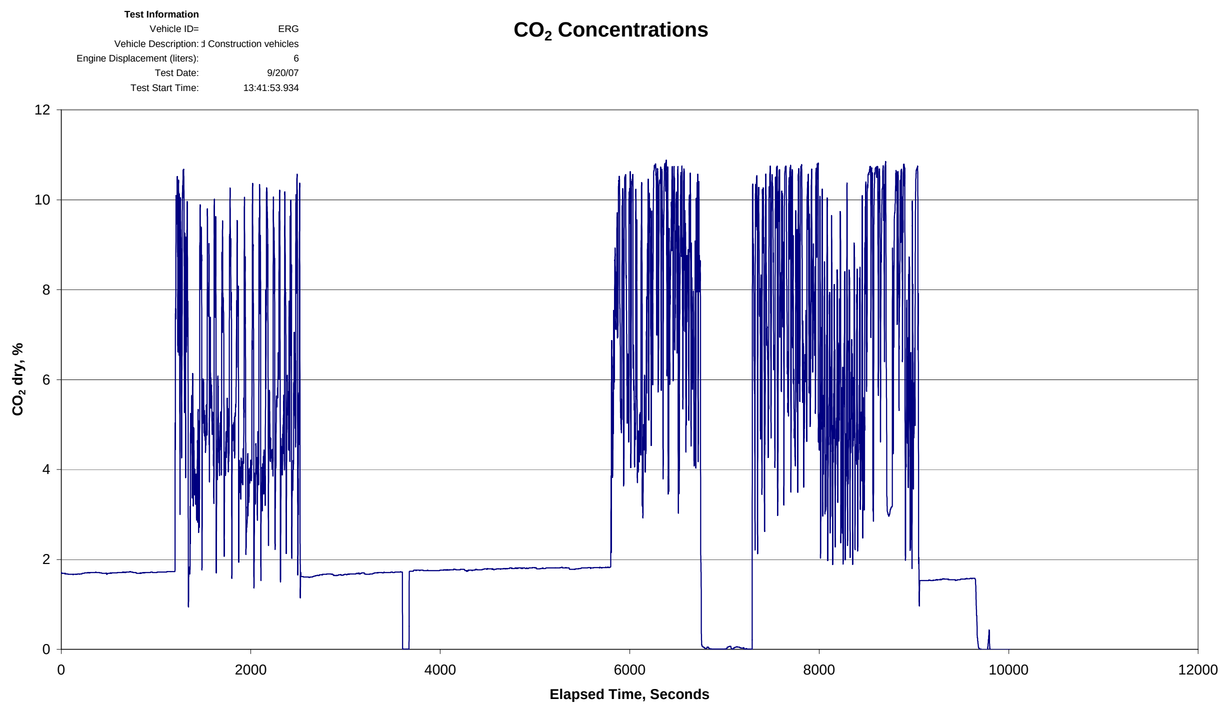
### VERIFY MPS FLOWS

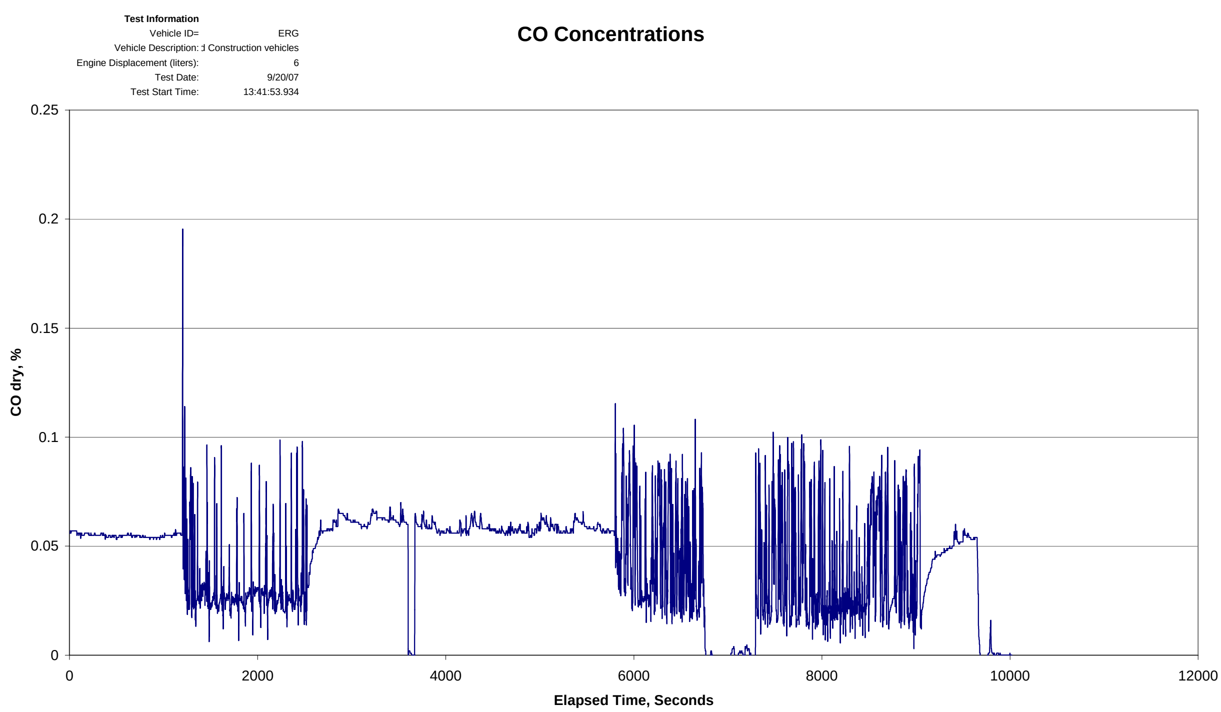
Perform the following MPS checks either with live data or from a recorded data file. Whenever the MPS is in proportional mode:

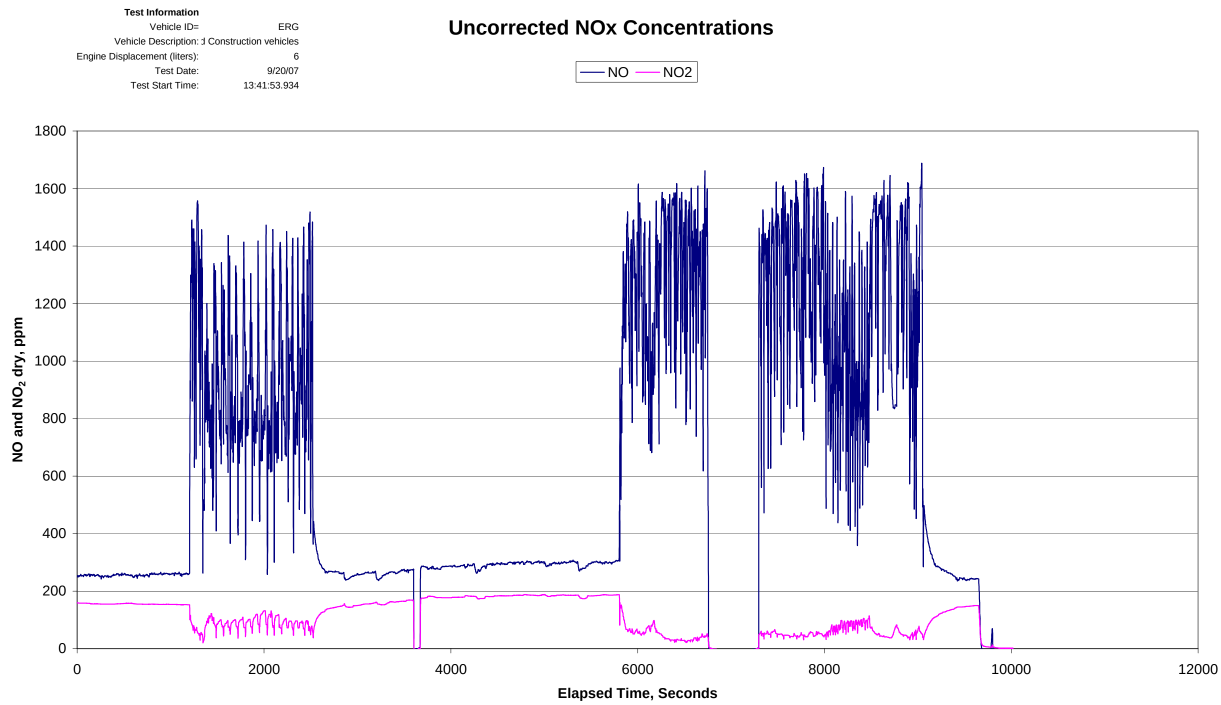
- Qtotal should be 12.5 lpm, +/- 0.5.
- At zero exhaust flow (engine off), Qsample should be less than 0.2 lpm
- At zero exhaust flow, Qminor should be > 4 lpm
- At max exhaust flow, Qminor should be slightly positive, or zero. If Qminor reaches zero at lower exhaust flowrates, or is greater than 0.5 lpm at max exhaust flow, perform adjustments as described in section 0.

## DATA QUALITY ASSURANCE CHECK AFTER TESTS

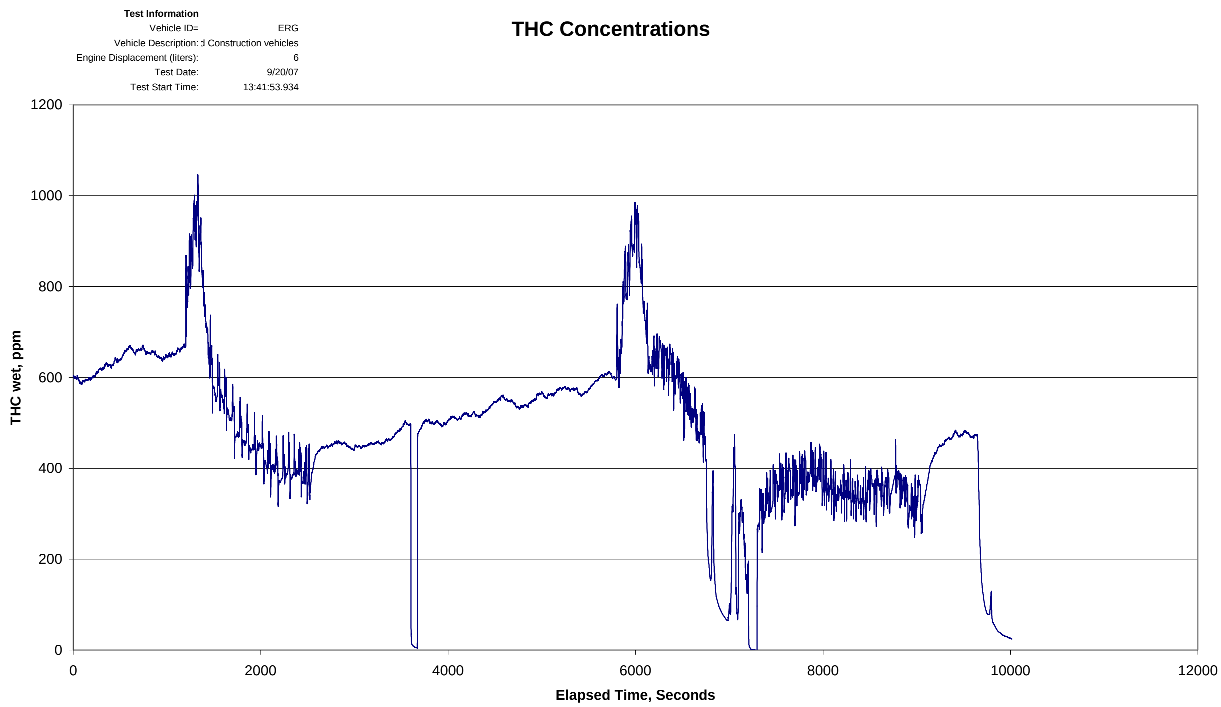
After testing, field technicians will chart the key parameters from the test for initial quality assurance verification. A charting macro has been developed, which will create the charts automatically. Below are examples of “good” data collected during a practice test.



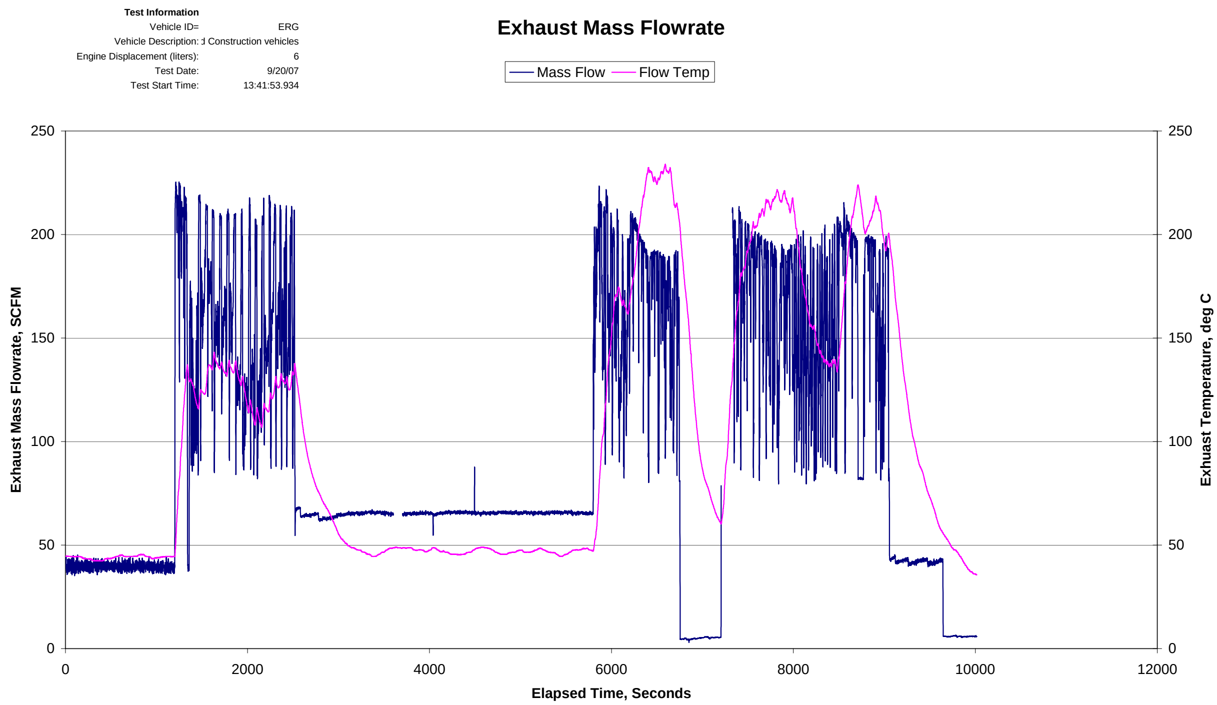



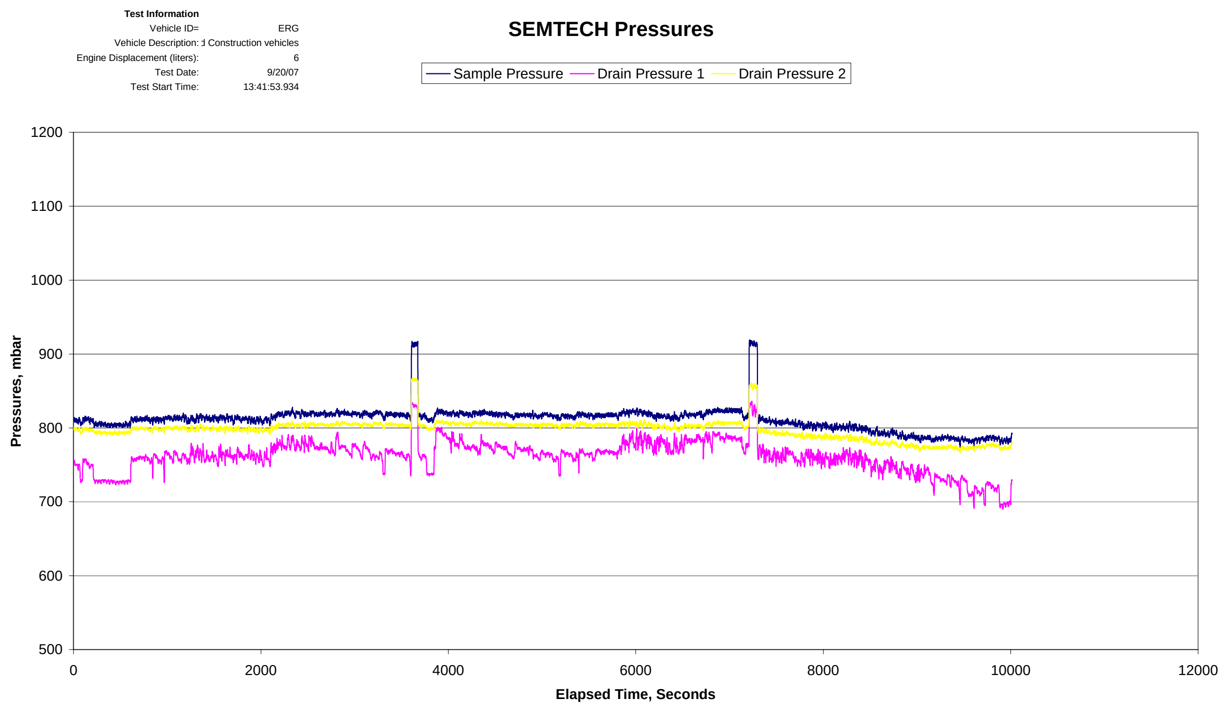


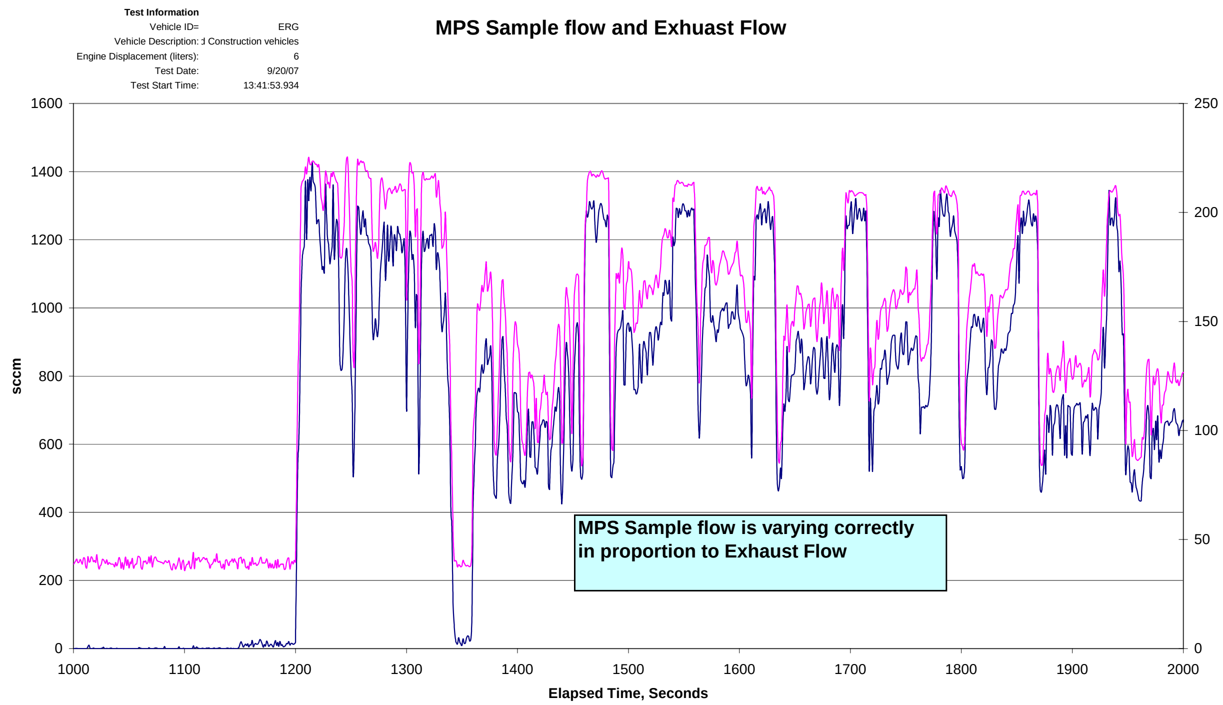
Test Information
Vehicle ID=
ERG
Vehicle Description:
Construction vehicles
Engine Displacement (liters):
6
Test Date:
9/20/07
Test Start Time:
13:41:53.934
Uncorrected NOx Concentrations
NO
NO2
NO and NO2 dry, ppm
Elapsed Time, Seconds

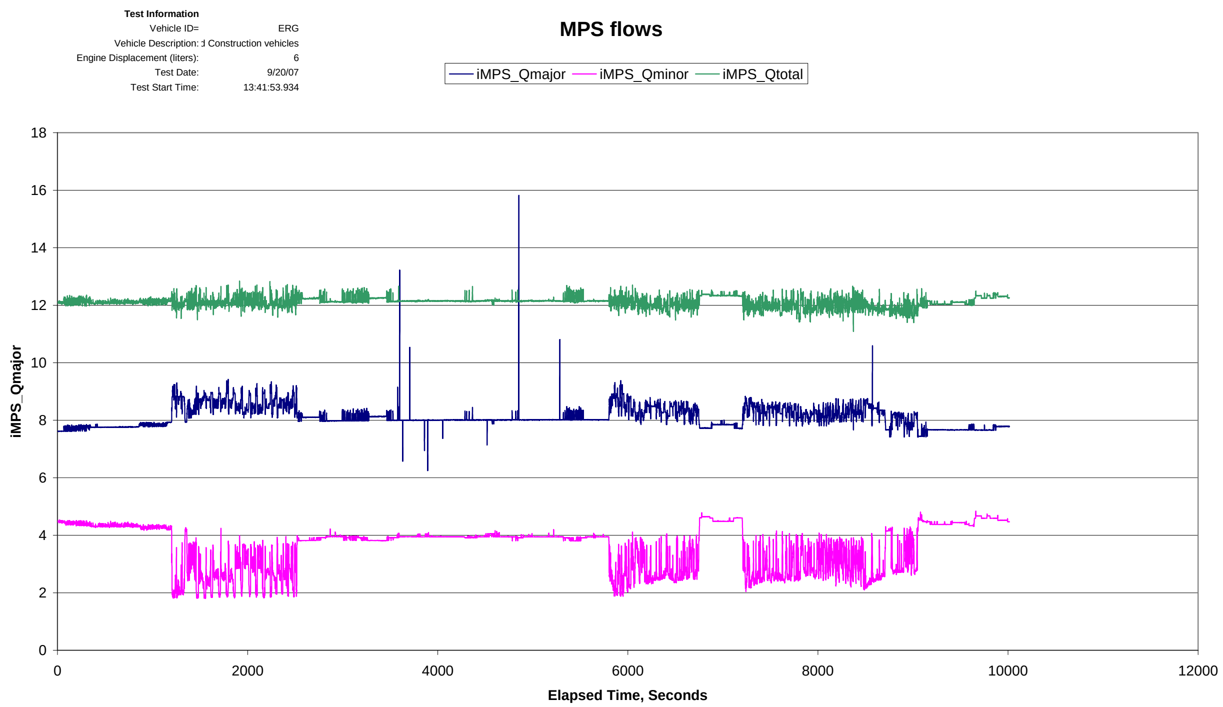
Test Information
Vehicle ID=
ERG
Vehicle Description:
Construction vehicles
Engine Displacement (liters):
6
Test Date:
9/20/07
Test Start Time:
13:41:53.934
THC Concentrations
THC wet, ppm
Elapsed Time, Seconds


Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
Exhaust Mass Flowrate
Mass Flow
Flow Temp
Exhaust Mass Flowrate, SCFM
Exhaust Temperature, deg C
Elapsed Time, Seconds

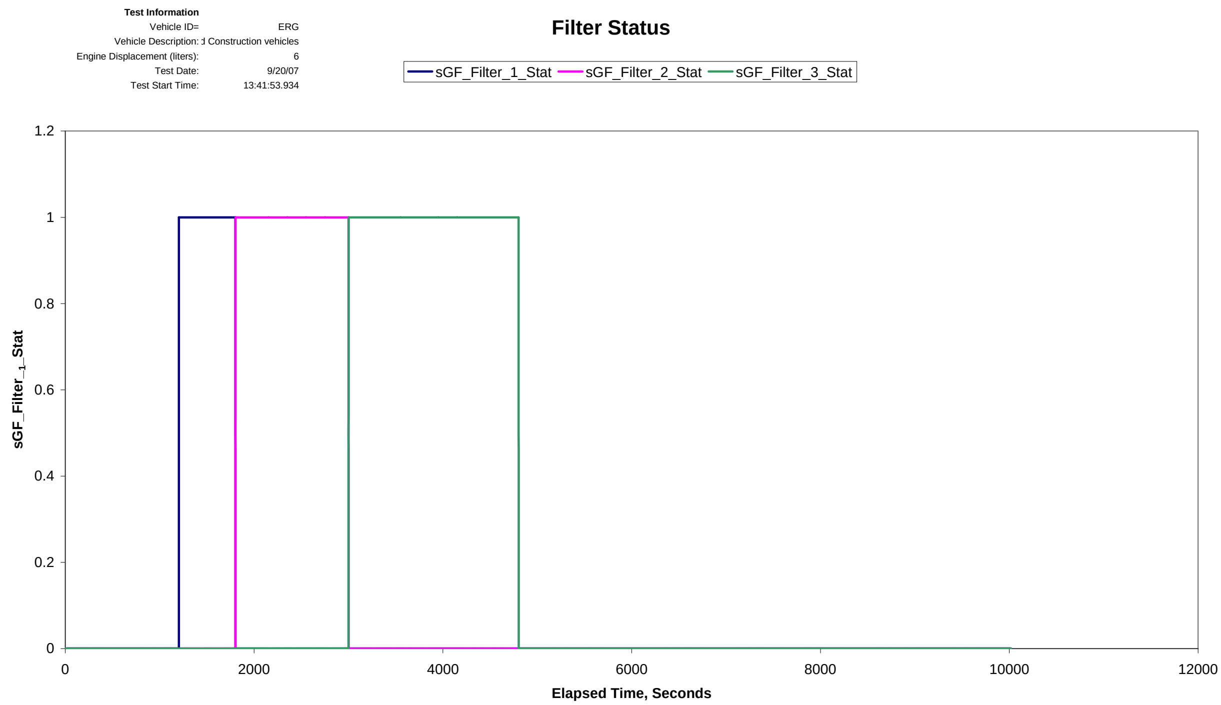

Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
SEMTECH Pressures
Sample Pressure
Drain Pressure 1
Drain Pressure 2
Pressures, mbar
Elapsed Time, Seconds

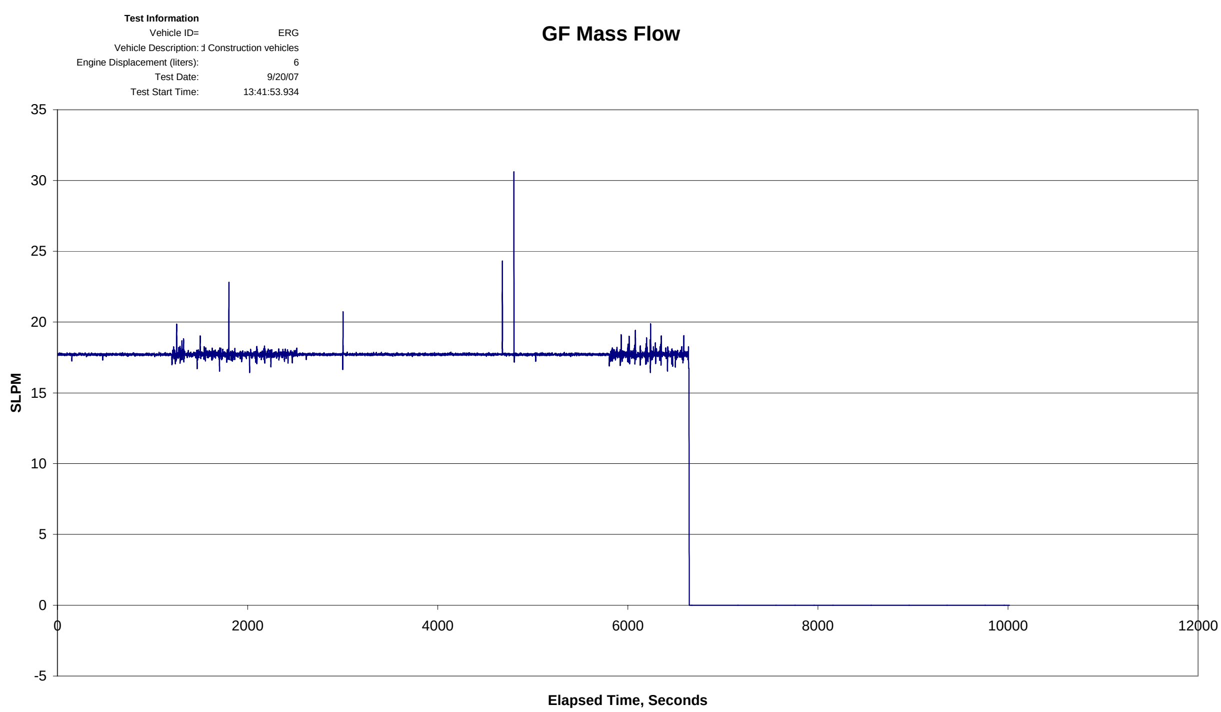


Test Information
Vehicle ID=
ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters):
6
Test Date:
9/20/07
Test Start Time:
13:41:53.934
MPS Sample flow and Exhuast Flow
sccm
Elapsed Time, Seconds
MPS Sample flow is varying correctly in proportion to Exhaust Flow

Test Information
Vehicle ID=
ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters):
6
Test Date:
9/20/07
Test Start Time:
13:41:53.934
MPS flows
iMPS_Qmajor
iMPS_Qminor
iMPS_Qtotal
iMPS_Qmajor
Elapsed Time, Seconds


Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
Filter Status
sGF_Filter_1_Stat
sGF_Filter_2_Stat
sGF_Filter_3_Stat
sGF_Filter_1_Stat
Elapsed Time, Seconds


Test Information
Vehicle ID= ERG
Vehicle Description: Construction vehicles
Engine Displacement (liters): 6
Test Date: 9/20/07
Test Start Time: 13:41:53.934
GF Mass Flow
SLPM
Elapsed Time, Seconds

## PAMS Data Quality Assurance

A number of steps will be taken in processing the PAMS data in order to identify and flag any potentially suspect or erroneous data. The type of PAMS analysis will depend on specifics for the type of installation and the data collected. Some variabilities include:

How many different RPM signals are being collected

Was interim data collected during the collection period? Might duplicate records exist?

Is any portion of the data due to ERG personnel revisiting the datalogger?

Were any calibration issues noted during the installations, revisits, or removals?

What type of datalogger was used to collect the data?

What type of RPM collection devices were used?

Is any RPM sensor "noise" evident when the equipment is inactive?

Was RPM outside (above or below) expected ranges during operation?

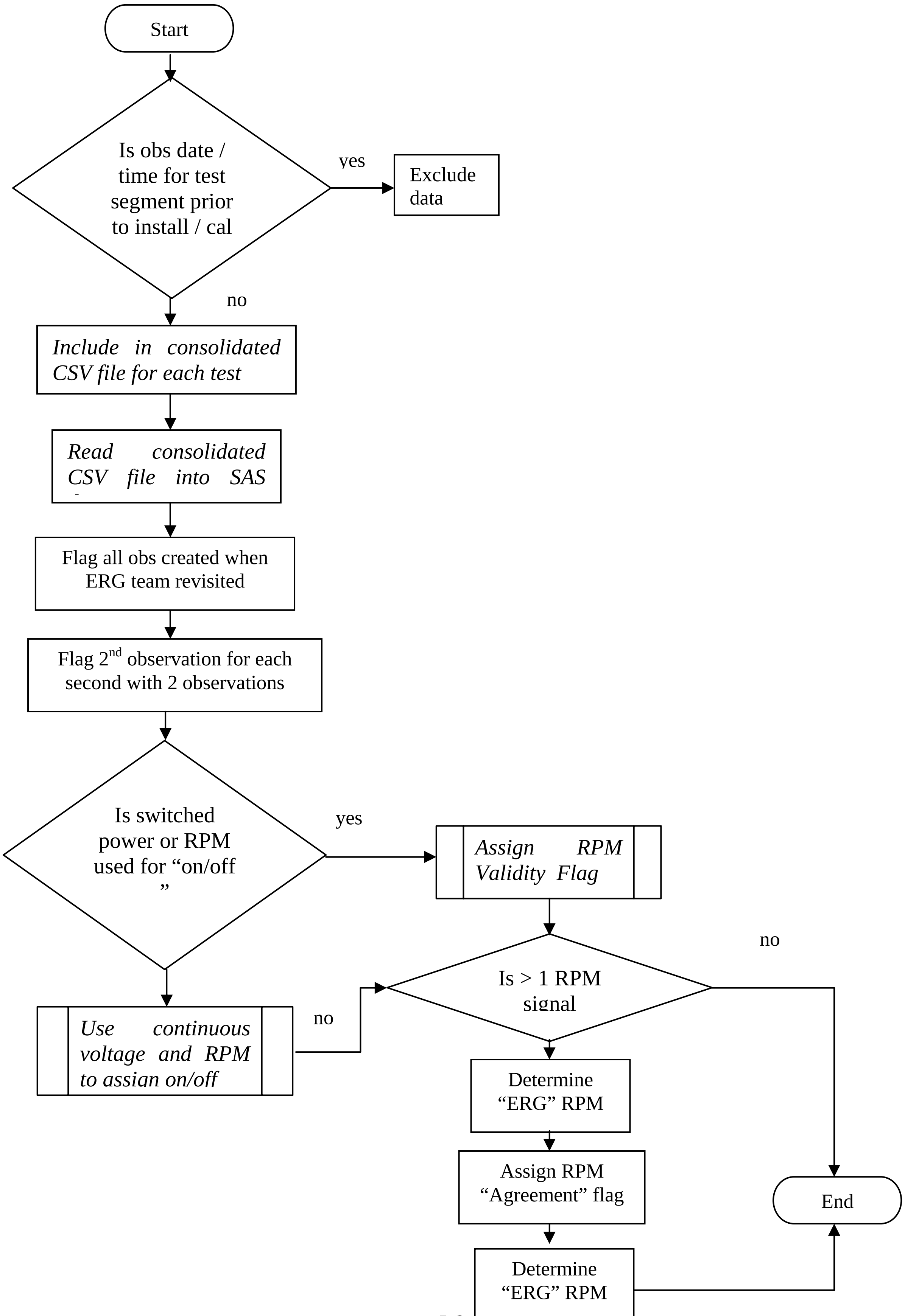
Was any RPM data null during testing?

Was the datalogger installed to go to standby or shut off based on key position?

Was switched voltage, RPM minimum, or some other criteria used for standby?

Was switched voltage recorded?

A general flowchart for logic to be used to analyze PAMS data is provide on the next page. Following that analysis logic flowchart are programming subroutines to be used for determining whether collected RPM is valid and whether the equipment is "active" (turned on and operating).


Start
Is obs date / time for test segment prior to install / cal
yes
Exclude data
no
Include in consolidated CSV file for each test
Read consolidated CSV file into SAS
Flag all obs created when ERG team revisited
Flag 2nd observation for each second with 2 observations
Is switched power or RPM used for "on/off"
yes
Assign RPM Validity Flag
Is > 1 RPM signal
no
no
Use continuous voltage and RPM to assign on/off
Determine "ERG" RPM
Assign RPM "Agreement" flag
Determine "ERG" RPM
End

**RPM Validity subroutine, Phase I**

## Step $RPM_1$: Assign initial RPM validity status

If installation used " Capelec" (inductive) and optical RPM pickup devices (1688-1462, 2208_1918, 1437_0399, 1437_1396, 1688_0216)
Capelec RPM = invalid
If Optical < 250 and equipment active = Y, then RPM = invalid
If Equipment = inactive and Optical NE 0, the RPM = invalid

If installation used "Equipment RPM" (tap into wiring harness) and optical RPM pickup devices (1911-9540)
equipment RPM = valid RPM = ERG RPM
If RPM > 50, equipment = active
If RPM < 50, equipment = inactive

**Step $RPM_2$: Check RPM validity status when equipment is "off".**
For all installations, If RPM1 = RPM2 = 0 and equipment = inactive, then both rpms = valid

## Step $RPM_3$: Identify and flag RPM "noise orphans" when equipment is "off"

For both RPM measurements for each installation, if equipment = inactive and RPM NE 0, but average of 5 preceding RPMs < 50 and average of following 5 RPMs < 50, then the nonzero RPM is invalid (this occurs frequently because random non-zero data is recorded for the optical sensor by the Corsa dataloggers when the equipment is not operating)

**Step $RPM_4$: Identify and flag invalid RPM (zero) when equipment is "on"**
If equipment is active, and RPM 2 (optical) is 0, RPM 2 is invalid
If equipment is active, and RPM 1 (Capelec) is 0, RPM 1 is (remains) invalid

**Step $RPM_5$: Reassess Capelec RPM for possible valid data when equipment is "on"**
If equipment = active and RPM 1 (Capelec) is < 6000 and averages of 5 before and after are > 250 then $RPM_{capelec}$ = valid

**Step $RPM_6$: Assign RPM "agreement" when 2 RPM signals are present**
If both RPM measurement readings disagree by over 10% for any one observation then RPM agree = N

**Step $RPM_7$: Define a new variable which is the "true" RPM**
$RPM_{ERG}$ = $RPM_{valid}$ or null (".") if neither are valid

**Equipment Active Subroutine**

### Step $Active_1$: Plot and review data to determine equipment on/off voltages

Make and review plots of voltage and RPM (both vertical axes) vs time (horizontal axis) to determine recorded system voltages when the equipment is on vs. when the equipment is off. Review data to obtain specific numbers.

### Step $Active_2$: Assign initial equipment on/off status based on voltage cutpoint

Two methods were used to tailor the equipment “active status. For this step, we “tweaked” the voltage on/off limit in an effort to accurately capture “active” vs. “inactive” status. However, although lowering the voltage cutoff limit reduced the amount of data lost at the beginning of a datafile, this also resulted in more data collected when the equipment was not running but the equipment was incorrectly classified as active (such as when the equipment is shut off but the battery voltage has not yet decayed to the cutoff limit, or when voltage is hovering near the cutoff and simply drifts over the cutoff, resulting in “active” orphan observations).

Conversely, increasing the voltage cutoff limit would eliminate the incorrect classification of null (non-running) data as “active”, but this would also result in lost data at the very beginning of a run episode when the equipment is initially started (and the battery voltage hasn’t yet risen to the cutoff limit).

Consequently, in addition to tailoring the voltage cutoff limit, RPM characteristics were used to tailor the equipment “active” vs. “inactive” classification. The first step in this process was to identify activity vs. RPM discrepancies, as described in Steps 3 and 4 below:

**Step $Active_3$: Flag observations in which RPM > 500 but equipment is inactive** – This can happen because of voltage fluctuations above or below the on/off voltage cutpoint when the equipment is in use, but also may be due to RPM “noise” (non-zero data) recorded when the equipment is turned off (this phenomenon was commonly seen with optical RPM sensors installed with Corsa dataloggers).

**Step $Active_4$: Flag observations in which RPM = 0 but equipment is active**.
Three different scenarios were seen to cause this:
**Active4a)** Equipment has been turned off, but battery voltage is still above “active’ cutpoint
**$Active_{4b}$)** RPM signal is intermittent or unreliable (1688-1462)
**$Active_{4c}$)** Another phenomenon was seen with several optical RPM sensor/Corsa datalogger installations. These datasets (1688-0216, 2208-1918, 1437-0399, and 1437-1396) each contain data where the equipment appears to be running, but RPM drops to zero. After 1 or more time-consecutive (1-second) observations with zero RPM, the data has a jump in time, where several seconds up to several minutes of data are not present (time jump). After the jump, the data has several more time-consecutive 1-second observations, still with zero RPM. Throughout this episode, RPM is recorded as zero but equipment is classified as “active”. We don’t know what happens with the equipment during the time no data was collected (if indeed this is a true jump in time).

### Step $Active_5$: With consideration of results identified in Steps 2 and 3, tailor equipment “active” status based on RPM data

For all tests where we had a reliable (non-zero) RPM signal when the equipment was running, we used RPM as a secondary check for “active”. Test data 1688-1462 was found to have an unreliable RPM signal (described in Step 4b above), so for this dataset we could only use voltage as a criteria for active vs. inactive.

For the remainder of the tests, we used the following logic to use RPM to tailor the equipment “active” vs. “inactive” status:

**Active$_{5a}$)** If RPM < 50, and the average of the following (later in time) 5 time consecutive observations is <50, then equipment is inactive.
**Active$_{5b}$)** If RPM < 50, and the average of the previous (earlier in time) 5 time consecutive observations is < 50, then equipment = inactive

Note for steps 5a and 5b, the logic only applies to time consecutive observations. As described in 4c, we have a number of files where the equipment appears to be running, then RPM goes to zero, several observations are collected with RPM at zero but voltage above the cutpoint. These groups of observations also have a jump in time, so steps 5a and 5b are not applied here because we don't know what is happening during the time the data is not recorded. In these scenarios, these "zero RPM" but "active" observations are held as "active".

Note also that the observations with a jump in time will affect our "trip" counts (number of on/off events), since we don't have information about what is happening during the missing time periods.

**Step Active$_6$: Eliminate trip "orphans"**
A final pass is made through each dataset to find any trips with only 1 or 2 "active" observations (they are surrounded by zero RPM data). If these are found, they are reclassified as "inactive".

# Appendix J:  Onsite Inventory Team Leader Duties

## Responsibilities for ERG Onsite Inventory Personnel

• The prior evening, check appointments for the following day (listed on "Establishment Master" on CVS). Contact Lori Snook (913-649-2225, ext 0, LSnook@fal.com) for any needed clarification or to resolve any coordination issues

• Each evening, talk with the onsite manager about vacancies in the PAMS / PEMS installation / test schedule. During the next day's inventories, try to schedule appointments to fill these vacancies.

• Ensure locations and contacts are known for each upcoming inventory appointment

• Perform day's inventories (diesel, nonroad equipment at least 25 hp)

• You are the first face-to-face contact for each establishment contact. Briefly describe what happens from here (PAMS/PEMS dependent upon participant agreement), and either try to schedule a PEMS/PAMS appointment, or ask the contact if we'll can be in touch to coordinate a convenient time for instrumentation (feel out the contact's demeanor and schedule feasibility).

• When the inventory is conducted, ask the site contact how many sites are currently active (that day) for the establishment. Record on top right of inventory form.

• Ask site contact in general which months operations are typically conducted / not conducted.

• For establishments with more than 1 site, we can inventory 2 sites per establishment. Once the # (1 or 2) and locations of the sites are determined, those are the sites which must be inventoried. If establishment has more than 2 sites, use an Excel random number generator to determine which 1 or 2 sites to inventory (always do 2 sites, if schedule and logistics permit).

• During inventory, complete the inventory data collection form for each piece of equipment, and take pictures of the equipment (including "close-up" shot of serial # tag and any other identifying info). Ensure the "close-up" camera setting is used so the detail is clear. Also, take overall shots of equipment for future reference.

• After inventory, back at hotel, download photos and rename / categorize photos, post photos to FTP site in correct directory / subdirectory. The naming convention is:

####_AXAXA__XXX_#.JPG
#### = Last 4 digits of Establishment Number
AXAXA = Equipment Model
XXX = Last 3 digits of Equipment Serial #
# = sequential photo number

• Update "Establishment Master" (on CVS) from day's inventories, indicate on "Establishment Tracking" all new appointments and which sites still need appointments, which sites are complete, etc. Let Lori know if any sites need reschedules.

• Update "Equipment Detail Master" on CVS with all equipment inventoried each day. Use photos to confirm serial numbers, model #s, etc. Email Michael.Sabisch@erg.com, Sandeep.Kishan@erg.com after "recommitting" to CVS, so equipment selections for instrumentation may be made in Austin.

• Discuss with onsite manager all new appointments, and also what installation / test vacancies the test team still has

• Email brief diary to Michael.Sabisch@erg.com, sandeep.Kishan@erg.com

# Appendix K:  Onsite Installation Manager Duties

## ERG Onsite Installation Manager Duties
## National PEMS Deployment

### PAMS Testing

- Schedule and perform ***PAMS installations*** at start of each phase (SRI assists with PAMS)

♦ IMPORTANT: Make installation appointments for several days in advance, one to two installations per day. Work with inventory person to assist in scheduling (during inventories), and note that Lori Snook / Mike Sabisch can assist with scheduling installs, as needed. It can take some time to get appointments in place, so please prioritize this.

♦ The project is hectic during PAMS installations. Ensure you take the time to charge batteries (drill/camera/etc), organize equipment, make list of anything that's needed, do any other equip preparations necessary for next day's installs. Go shopping for any field testing materials, if necessary (delegate to other ERG folks and SRI folks as needed).

♦ Collect ALL PAMS installation information on "Installation Data Collection Forms"
Note all installation anomalies and details on instrumentation form.

♦ Ensure you obtain answer to questions pertaining to annual usage of each piece of equipment. These questions are on the installation data collection forms.

♦ Take pictures of PAMS installs and post to FTP site using appropriate naming convention. Take "close-up" pictures of engine and serial # tags with appropriate "close-up" setting of camera. Ensure settings are correct so images are clear.

♦ Update all appropriate CVS lists (Establishment Master, Equipment Detail Master, and PAMS Tracking Master)

♦ Either copy/fed-ex installation forms to Mike S, or fax them to Mike S, weekly. If writing is small, fax may not be legible and they'll need to be copied and fed-exed.

- Schedule and perform ***PAMS revisits*** at least weekly for each install throughout phase

♦ Collect all revisit info on the PAMS' "Installation Data Collection Form"
Note all installation anomalies and details on instrumentation form.

♦ Perform and record RPM check during revisit

♦ Verify and record remaining PAMS memory during revisit

♦ Update all appropriate CVS lists (only the PAMS Tracking Master)

♦ Correct any malfunctions identified during revisit, contact Mike S if anything is wrong that cannot be corrected or if any data has not been collected for any reason

♦ Post downloaded data to FTP site, advise Mike S that new data has been posted. Also, archive all PAMS data on your computer for future backup.

### PEMS Testing

- Schedule PEMS instrumentation appointments for at least one week in advance (Update the Establishment master spreadsheet with on CVS with the schedule info). Work with inventory person to assist with PEMS scheduling.
- Assist Sensors / SRI with PEMS installation

♦ Ensure you obtain answer to questions pertaining to annual usage of each piece of equipment. These questions are on the installation data collection forms.

- Ensure a pre-test RPM calibration and a post-test RPM check are performed and recorded on the instrumentation form for each PEMS test.
- Collect ALL PEMS and PAMS installation information on "Installation Data Collection Forms".
- Note all installation anomalies and details on instrumentation form

- Take photos of all installations. Also, Take "close-up" pictures of engine and serial # tags with appropriate "close-up" setting of camera. Ensure settings are correct so images are clear. For PEMS testing, TAKE PHOTO OF SURFACE WHERE PEMS WILL BE MOUNTED PRIOR TO MOUNTING, DESCRIBE ALL EXISTING DAMAGE ON INSTRUMENTATION FORM. Post all photos to FTP site using appropriate naming convention.
- Determine how many unused filters we have to ensure sufficient gravimetric filters are available for at least a week's worth of PEMS testing, and email Michael.Sabisch@erg.com if more are needed
- Ensure 5% of gravimetric filters are sampled as field blanks, and 5% are sampled as dynamic blanks
- After PEMS testing, refrigerate gravimetric filters and ship weekly to EPA per gravimetric filter SOPs (ship cold, on frozen "Blue Ice", no later than Wednesday). ENSURE FILTER LOG IS CURRENT BEFORE SHIPPING.
- Email michael.sabisch@erg.com to advise # of filters you're shipping to EPA
- Copy and ship all PEMS install forms to Michael Sabisch weekly at: 5608 Parkcrest Drive, Suite 100, Austin, Tx 78749, 512-791-7739. Use same fed-ex # and charge # as filters for shipping the forms.
- Schedule and track field and dynamic blanks (record in filter log and on installation forms)
- Update all appropriate CVS lists with PEMS test info (Establishment Master, Equipment Detail Master, and Filter Log)
- As it comes available, post all PEMS data to FTP site, archive on ERG computer, email MS

## Other

- Review and map out locations of appointments (listed in the "Establishment Master") each night for the following day. It may be helpful to enter the locations into your vehicle's GPS system.
- After you've successfully posted photos for anything, ERASE ALL DOWNLOADED PHOTOS FROM CAMERA CARD!
- Record any notable issues that arise during the day for ERG diary or discuss with Mike

# Appendix L:  Grav Filter Handling SOPs

**Filter Field Handling SOPs for National PEMS Deployment**

This standard operating procedure (SOP) presents the procedures to follow when testing using $PM_{2.5}$ gravimetric filters received from EPA.

This SOP should be used in conjunction with the SOPs developed for other field sampling tasks associated with the Populations, Activity and Emissions of Diesel Nonroad Equipment in EPA Region 7 project.

The filters will be provided by USEPA, either shipped to the hotel or sent in the Sensors trailer. When these are received, check to see if they have a unique, new filter ID number. If not, contact Michael.Sabisch@erg.com (512-791-7739) to obtain a filter ID number. Record the filter ID numbers in the filter log. This number will be used for all filter tracking (including the installation forms and post-weight measurements).

Each shipping container (plastic container) contains a pre-weighed Teflon filter loaded into a cassette (white holder). The cassette in which the filter is loaded has a support grid with an imprinted number on it. This number can be seen only from the bottom of the cassette. There are two codes on the dish: the filter identification bar-code label (as described above) and the screen ID label containing the last three digits of the filter cassette screen ID.

When handling the filter, handle the cassette by the white holder only, so as not to touch or contaminate the filter. NEVER TOUCH THE FILTER. If the filter is inadvertently touched, please note on the data collection form.

Sensors will install the filters in the sample holders in their test equipment. Record the filter ID and sample holder number in the appropriate location on the instrumentation data collection form. Also, note the type of gravimetric sample (whenever available) on the instrumentation data collection form. Types of gravimetric samples are cold start, warm operation, and hot start. Sensors will conduct all gravimetric filter testing.

After the sample has been collected and the filter removed from the sample holder, replace the filter in its original container (with appropriate ID). Put this container in an individual sandwich-sized ziplock bag, as described in Item 1. b. below. Place all the bagged, used filters in a cooler with frozen blue ice immediately after sampling, return to the hotel room (or ship immediately) and keep refrigerated (near freezing) and keep the blue ice frozen until ready to ship to EPA.

When returning filters to the USEPA:

1. Keep all filters cold before shipping:
    a. Place blue ice in a freezer for at least 24 hours prior to shipping;
    b. individually seal each filter in a small (sandwich-sized) ziplock bag, then place all ziplocked filters into a large ziplock bag.
2. Pack the cooler carefully:
    a. Cover the bottom of the cooler with frozen blue ice;
    b. If there is room, place frozen blue ice around the sides of the cooler;
    c. Bubble wrap sealed bags containing the filters/cassettes to minimize movement of filter cassettes during shipping,

d. Place the bubble wrapped sealed bags directly on top of the blue ice on the bottom of the cooler;

e. Make sure that the bags are packed in closely to avoid empty spaces;

g. Immediately cover the bags completely with a layer of blue ice;

    i. Blue ice on top of the filters is an important step to keep the filters cold,

h. If necessary, use plastic filler on top of the blue ice to keep cooler contents from moving around during shipment;

h. Never place plastic or other filler between the blue ice and the filter bags

i. Close the cooler lid securely and tape shut.

3. Ship smart:

    a. Ship weekly by Wednesday and never on a Thursday or Friday;

        i. If you miss a Wednesday shipment, wait until Monday to ship,

        ii. Notify Michael Sabisch by e-mail (Michael.Sabisch@erg.com) to advise # of filters to come, and record details on "filter Log" (on CVS)

    b. Make sure that FedEx can pick the shipment up the day you want;

        i. If there is a problem on pickup, unload the cooler contents and keep them cold (described in Item 1 above),

        ii. Repeat packing for day of next shipping,

    c. Ship FedEx (priority overnight) express service,

Ship to:

Carl Fulper

US EPA

2000 Traverwood Drive

Ann Arbor, Mi  48105

734-214-4400

Please always indicate the shipment is from ERG.

ERG's fed-ex # is 2445-0833-2

ERG's internal reference # is 0218.01.001.009

# Appendix M:  Onsite Oil andFuel Sampling SOPs

**Fuel and oil sampling procedures for Nonroad PEMS Study**

## Fuel sampling

- Locate diesel fuel tank on equipment, and using the electric fuel pump, draw some diesel fuel through the pump and tubing, routing the outlet hose back into tank. This will flush the fuel sampling system. Then, insert the outlet hose into the 1 L glass jar (located in bottom cabinet in front of Sensor's SEMTECH trailer). Fill the jar, leaving a small empty space near the top for liquid expansion.

- Once the jar is nearly full, put the outlet end of the fuel line into the fuel tank, remove the inlet from the fluid, and run the pump so the residual fuel in the sampling system is drained back into the equipment fuel tank.

- Secure the sample jar lid tightly. Using a permanent, indelible marker, write the sample # on one of the label cards with a metal tie band. The sample number should be the last 4 digits of establishment #-last 4 digits of equipment serial #-YYYY/MM/DD (i.e., 1456-5675-20070710 for a fuel sample taken July 10, 2007 from the piece of equipment with last 4 digits of serial # 5675 at establishment 1456). Tightly secure the tie band around the neck of the bottle.

- Using a permanent, indelible marker, mark the fuel level around the entire outside of the jar.

- Using a permanent, indelible marker, also write the sample # on a sticky label and affix to the side of the sample jar (placing the top of the sample label adjacent with the fuel level).

- Place the sample in the sample cooler in the lower cabinet at the front of the trailer, surrounded with overpack to protect it during transport.

## Oil sampling

- Using the Polaris oil sampling supplies, draw an oil sample (see guidelines on next page). Pour the sample from the plastic Polaris jar into the glass oil sample jar located at the front of the Sensor's SEMTECH trailer. Draw additional sample as needed to fill the glass jar completely (with small air space near the top).

- Secure the lid tightly, and affix a tie-on label with sample # as described above.

- Make an indelible mark at the oil level around the entire perimeter of the glass jar with a marker, and affix the identifying sticky label according to the oil level as described above.

- Place the sample in the sample cooler in the lower cabinet at the front of the trailer, surrounding with overpack to protect it during transport.

Use of Polaris oil sampling equipment, taken from: http://www.polarislabs1.com/oil-sample.htm

**Using a Vacuum Pump**

The vacuum pump is used to extract samples from a dipstick or non-pressurized system. When extracting the sample, it is important to use a new piece of tubing in order to avoid sample contamination. It is also important to have an appropriate container and follow all the directions thoroughly to ensure that the oil sample is representative of all the oil in the machine.

POLARIS has developed oil analysis kits in order to make oil analysis convenient, easy and simple. These kits include pump, tubing, jars and preaddressed mailers.

**Step 1-** Carefully unpack the POLARIS Sample Kit, place material on a clean surface and fill out sample jar label. Measure tube to the length of reservoir tank or dipstick, add 6 inches to the measurement and place a mark on the tube.

**Step 2-** Insert the tube through the head of the vacuum pump and tighten lock ring. The tube should extend about 1 inch beyond the base of the vacuum pump head.

**Step 3-** Screw in the white sample jar to the bottom of the vacuum pump and tighten securely. Place tube into the oil, retaining tube up to the mark on the tube.

**Step 4-** Push and pull the vacuum pump plunger a few times to start the suction. Continue pumping until sample jar is ¾ full. Hold the pump upright in order to avoid contamination.

**Step 5-** Unscrew the sample jar from the vacuum pump and place the lid back on the sample jar and tighten securely. Drain remaining fluid out of tube into tank and remove tube from fill port. Unscrew locking ring on vacuum pump, remove and properly dispose used tube. Place the sample jar label on sample jar and the appropriate return-mailing label on black return mailer. Send the sample to the lab immediately