Quality Assurance Project Plan Addendum

Discoverer $PM_{2.5}$ Speciation Monitoring Program

Shell Offshore, Inc.

Anchorage, Alaska

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Quality Assurance Project Plan Addendum

for the

Discoverer $PM_{2.5}$ Speciation Monitoring Program

Anchorage, Alaska

Prepared for

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A. PROJECT MANAGEMENT ELEMENTS

A1 APPROVALS

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1/11/2012

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1/11/2012

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SLR Air Measurements Group Manager

Date

1/11/2012

Brad Broker
SLR Project Manager

Date

1-11-2012

Gregg Malinky
Quality Assurance Officer

Date

Christopher Hall
Air Data Analyst/Air QA Coordinator
US EPA Region 10 Office of Environmental Assessment

Date

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A3 DISTRIBUTION LIST

Table A-1 provides the names, professional titles, organizations, and contact information of the individuals involved in the development of this Quality Assurance Project Plan (QAPP). This list will be used to distribute this QAPP and any significant revisions.

Table A-1: QAPP Distribution List

Name of Individual/Title	Organization	Contact Information
Susan Childs Alaska Venture Support Integrator	Shell Offshore, Inc.	3601 C Street, Suite 1000 Anchorage, AK 99503 (907) 646-7112 Susan.Childs@shell.com
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A4 PROJECT/TASK ORGANIZATION

In 2011, Shell Offshore, Inc. (SOI) contracted the services of SLR International Corporation (SLR) to provide $PM_{2.5}$ speciation monitoring required to support offshore exploration drilling in the Beaufort and Chukchi Seas. Figure A-1 provides the organization plan for this project. The key personnel involved with this project and their respective responsibilities are summarized in Table A-2. SLR will be responsible for all aspects of air monitoring, database management, and reporting.

Table A-2: Key Individuals and Responsibilities

Key individuals	Responsibilities
Alaska Venture Support Integrator	Susan Childs has the overall responsibility for coordination and implementation of the $PM_{2.5}$ Speciation Monitoring Project.
SLR Alaska Air Quality Group Manager	Al Trbovich will advise project manager and auditor on data quality assurance and quality control requirements.
SLR Air Measurements Group Leader	Steve Mackey is responsible for the SLR Air Measurements Group organization and leadership. Mr. Mackey will ensure that SLR assets and resources are available to the Project Manager to ensure successful completion of the project objectives.
SLR Project Manager	Brad Broker is responsible for management of the technical staff conducting the $PM_{2.5}$ Speciation Monitoring Program and ensuring that the project is completed within established schedules and budgets.
SLR Quality Assurance Officer	Gregg Malinky is responsible for monitoring the implementation of QA/QC procedures and programs to maintain high quality data. Gregg remains organizationally independent of the analysis and distribution processes.
Station Lead Operator	Dale Crow is responsible for overseeing the installation and operation of the $PM_{2.5}$ Speciation samplers.
Data Manager	Rebecca Van Wyck is responsible for maintaining the project databases for all field data and for preparing data reports.

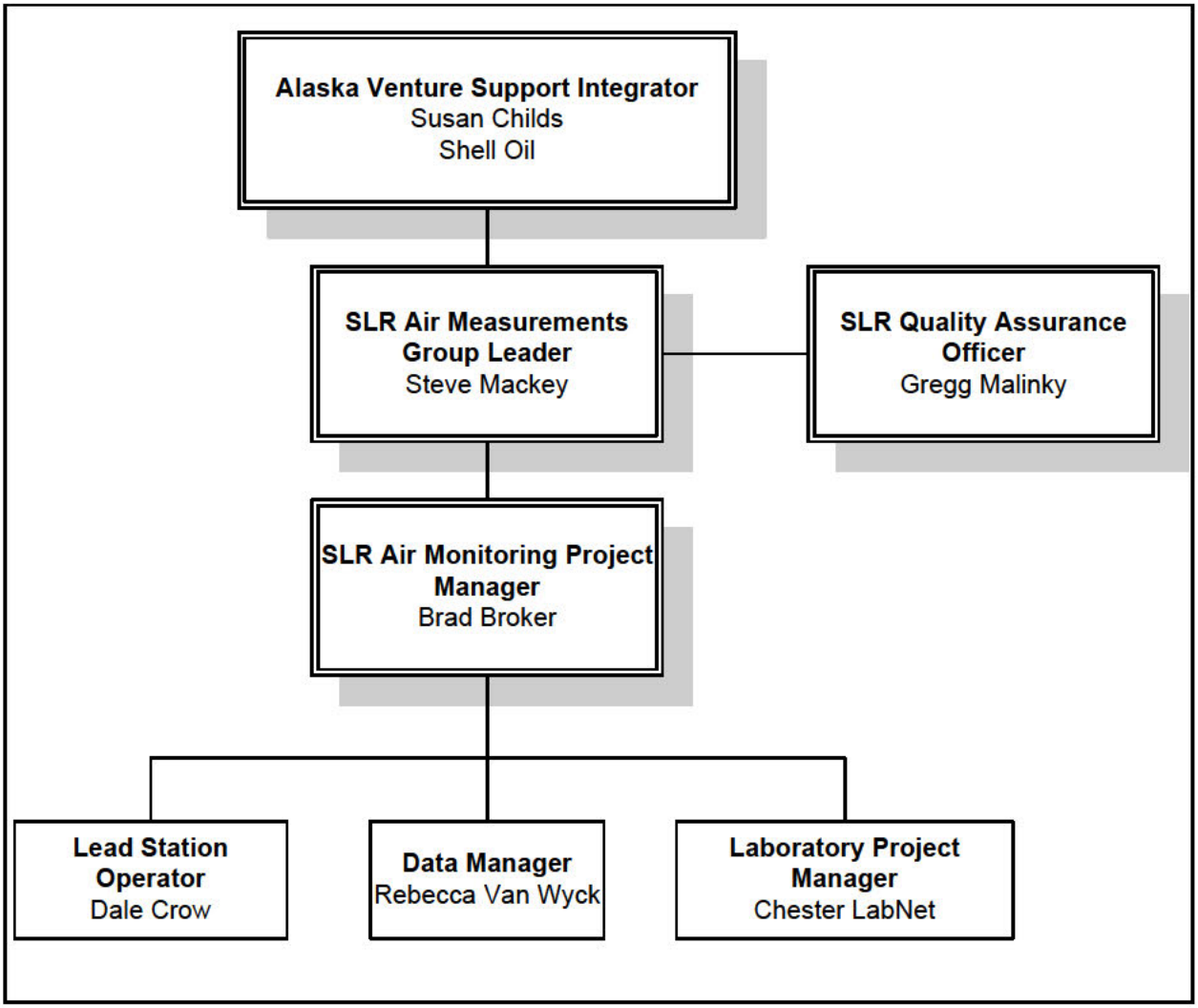


Figure A-1: Monitoring Program Organizational Chart

A5 PROBLEM DEFINITION/BACKGROUND AND PROJECT OBJECTIVE

SOI applied for an outer continental shelf (OCS) / prevention of significant deterioration (PSD) air quality permit from the United States Environmental Protection Agency (EPA) in January 2010. The air quality permit is required for the operation of an oil exploratory vessel in the seas north of the Alaska coastline. On September 19, 2011 EPA issued air quality permit R10OCS/PSD-AK-2010-01 to SOI to operate the Noble Discoverer (Discoverer) drillship in the Beaufort Sea and air quality permit R10OCS/PSD-AK-09-01 to operate in the Chukchi Sea.

Conditions specified within each of these air quality permits require SOI to conduct post-construction ambient air quality and meteorological monitoring. The air quality permit conditions specify that $PM_{2.5}$ mass, $PM_{2.5}$ chemical speciation, horizontal wind direction and speed, temperature, solar radiation, and temperature difference measurements are to be collected.

SLR International Corp (SLR) operates ambient air and meteorological monitoring stations on behalf of SOI at Kaktovik, Alaska (Barter Island) and Point Lay, Alaska. Additionally, SLR operates an ambient air and meteorological monitoring station at Wainwright, Alaska and Deadhorse, Alaska as part of a Shell / ConocoPhillips joint monitoring venture. EPA approved the Quality Assurance Project Plans (QAPP) for Point Lay, Wainwright, and Deadhorse ambient air quality and meteorological monitoring programs on October 14, 2011. The QAPP for the Kaktovik ambient air quality and meteorological monitoring program was approved by EPA on November 16, 2011.

Point Lay and Wainwright ambient air quality and meteorological monitoring stations are located along the Chukchi Sea while the Deadhorse and Kaktovik monitoring stations are located along the Beaufort Sea. Accordingly, data collected at these sites provides the required ambient air quality and meteorological monitoring specified in the SOI permits with the exception of the $PM_{2.5}$ chemical speciation monitoring. Refer to the approved project QAPPs for specifics on the ambient air quality and meteorological monitoring programs operated at each station.

Permit condition R1.2 (Chukchi permit R10OCS/PSD-AK-09-01) and S1.2 (Beaufort permit R10OCS/PSD-AK-2010-01) each specify: *"The Permittee shall use a continuous sampler and a manual sampler to measure $PM_{2.5}$. In addition, filters from the manual sampler shall be analyzed as provided for in the EPA-approved ambient air quality and meteorological plan required pursuant to Condition R.3 to allow for the chemical speciation of $PM_{2.5}$ constituents, including but not limited to sulfates, nitrates, organics, metals, sea salt, and crustal matter."*

To satisfy these permit conditions, samples collected from the manual samplers operated at Deadhorse were considered. However, these samplers collect samples on a single, Teflon® sample media as part of the $PM_{2.5}$ mass monitoring program. This Teflon® sample media is only appropriate for a portion of the analyses typically performed to collect $PM_{2.5}$ chemical speciation data.

Supplemental filter-based samplers capable of collecting samples on multiple filter media are required in order to successfully analyze for all the desired $PM_{2.5}$ constituents. Supplemental samplers will be installed at Deadhorse and Wainwright monitoring stations to collect $PM_{2.5}$ speciation samples. Deadhorse sampling will satisfy the $PM_{2.5}$ speciation monitoring requirements in the Beaufort Sea and Wainwright sampling will satisfy the $PM_{2.5}$ speciation monitoring requirements in the Chukchi Sea.

This QAPP describes the $PM_{2.5}$ chemical speciation monitoring plan and is considered a supplement to the ambient air quality and meteorological monitoring QAPPs already approved for Point Lay, Wainwright, Deadhorse and Kaktovik air monitoring programs. When used in combination, these QAPPs represent the monitoring plan required in permit condition R.3. (Chukchi permit R10OCS/PSD-AK-09-01) and S.3 (Beaufort permit R10OCS/PSD-AK-2010-01).

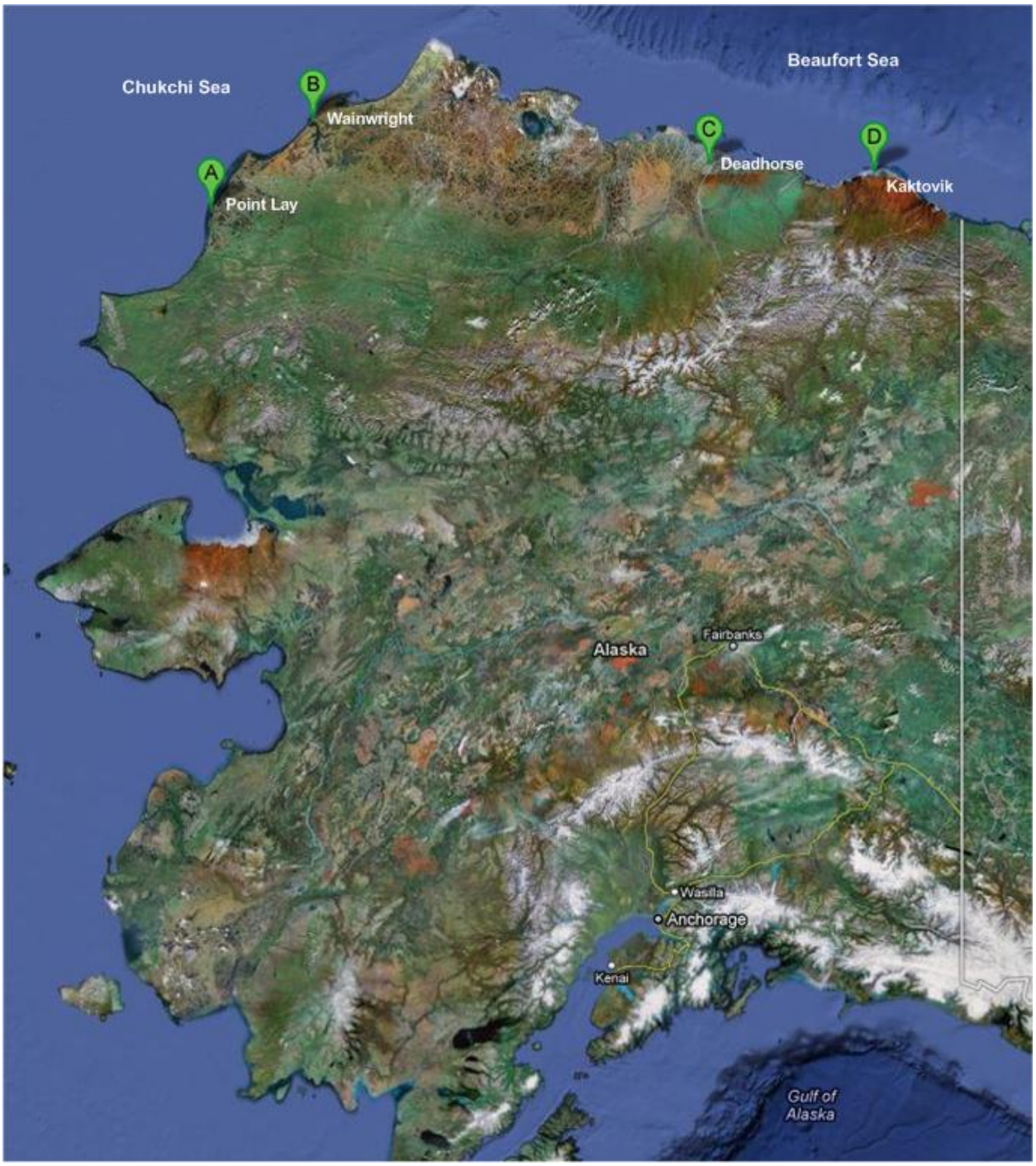


Figure A-2: Project Location Map.

A6 PROJECT/TASK DESCRIPTION

Quality Assurance requirements for $PM_{2.5}$ Chemical Speciation monitoring are not addressed in any of the published EPA guidance that typically directs PSD ambient air and meteorological monitoring. Absent specific requirements, the SOI $PM_{2.5}$ speciation monitoring program is based in part on the EPA Speciation Trends Network (STN) $PM_{2.5}$ speciation monitoring program and the Interagency Monitoring of Protected Visual Environments (IMPROVE) program.

$PM_{2.5}$ chemical speciation monitoring is required by permit condition R1.2 (Permit R10OCS/PSD-AK-09-01) and S1.2 (R10OCS/PSD-AK-2010-01). Accordingly, $PM_{2.5}$ chemical speciation monitoring will continue in both the Chukchi and Beaufort Seas for a minimum of 1 year after commencement of initial operation of the Discoverer as an OCS source.

In 2012, $PM_{2.5}$ speciation sampling will occur at Wainwright to satisfy Chukchi Sea monitoring requirements and at Deadhorse to satisfy Beaufort Sea monitoring requirements. Chukchi Sea monitoring may be performed at Point Lay and Beaufort Sea monitoring may be performed at Kaktovik in future years.

A6.1 FIELD MEASUREMENTS

A6.1.1 $PM_{2.5}$ Chemical Speciation

$PM_{2.5}$ Chemical Speciation monitoring equipment will be operated using Prevention of Significant Deterioration (PSD) quality assurance practices as a guide. Samplers will be installed, calibrated, and operated according to manufacturer recommended procedures. Calibration and periodic flow-rate verifications will be documented throughout the monitoring program. Field blanks and laboratory quality assurance procedures are described in section B5. Table A-3 lists the parameters that will be measured.

Table A-3: Chemical Speciation Parameters

Parameter / Species	Symbol	Analysis Method	AQS Parameter
Mass	$PM_{2.5}$	Gravimetry	88502
Sulfate	$SO_4^{=}$	Ion Chromatography[1]	88403
Nitrate	NO_3^-	Ion Chromatography[1]	88306/88310
Chloride	Cl^-	Ion Chromatography[1]	88203
Organic Carbon	OCR	Thermal/Optical Reflectance[2]	88370
Organic Carbon (TOR)	OCT	Thermal/Optical Transmission[2]	88355
OC-Peak 1	OC1	Thermal/Optical Reflectance[2]	88374
OC-Peak 2	OC2	Thermal/Optical Reflectance[2]	88375
OC-Peak 3	OC3	Thermal/Optical Reflectance[2]	88376
OC-Peak 4	OC4	Thermal/Optical Reflectance[2]	88377
Pyrolized Carbon (TOR)	OPR	Thermal/Optical Reflectance[2]	88378
Pyrolized Carbon (TOT)	OPT	Thermal/Optical Transmission[2]	88388
Elemental Carbon (TOR)	ECR	Thermal/Optical Reflectance[2]	88380
Elemental Carbon (TOT)	ECT	Thermal/Optical Transmission[2]	88357
EC-Peak 1	EC1	Thermal/Optical Reflectance[2]	88383
EC-Peak 2	EC2	Thermal/Optical Reflectance[2]	88384
EC-Peak 3	EC3	Thermal/Optical Reflectance[2]	88385
Total Carbon	TC	Thermal/Optical Reflectance[2]	

[1] Analytical measurement determined by NIOSH 7903 Ion chromatography method

[2] Analytical measurement determined by IMPROVE-A carbon analysis method.

Table A-4: Chemical Speciation Elemental Parameters

Element [1]	Symbol	Element [1]	Symbol
Sodium	Na	Zirconium	Zr
Magnesium	Mg	Niobium	Nb
Aluminum	Al	Molybdenum	Mo
Silicon	Si	Palladium	Pd
Phosphorous	P	Silver	Ag
Sulfur	S	Cadmium	Cd
Chlorine	Cl	Indium	In
Potassium	K	Tin	Sn
Calcium	Ca	Antimony	Sb
Scandium	Sc	Cesium	Cs
Titanium	Ti	Barium	Ba
Vanadium	V	Lanthanum	La
Chromium	Cr	Cerium	Ce
Manganese	Mn	Samarium	Sm
Iron	Fe	Europium	Eu
Cobalt	Co	Terbium	Tb
Nickel	Ni	Hafnium	Hf
Copper	Cu	Tantalum	Ta
Zinc	Zn	Wolfram	W
Gallium	Ga	Iridium	Ir
Arsenic	As	Gold	Au
Selenium	Se	Mercury	Hg
Bromine	Br	Thallium	Tl
Rubidium	Rb	Lead	Pb
Strontium	Sr	Uranium	U
Yttrium	Y		

[1] Analytical measurement determined by X-ray Fluorescence Analysis (XRF) EPA Method IO-3.3

A6.2 SITE LOCATION

The selected monitoring sites for the $PM_{2.5}$ speciation monitoring are described in the various QAPPs approved by the EPA (Point Lay, version 1.4, Wainwright version 2.0, Deadhorse version 2.0, and Kaktovik version 1.1). Point Lay and Wainwright monitoring locations are expected to be representative of $PM_{2.5}$ chemical speciation concentrations observed in and near the Chukchi Sea. Deadhorse and Kaktovik monitoring locations are expected to be representative of the Beaufort Sea.

A6.3 WORK SCHEDULE/PROJECT TASKS

Personnel working on the monitoring project will be selected by the SLR project manager and deemed fully qualified, trained, and capable of assigned tasks. Work schedules shall be determined by the SLR project manager and will include:

- Field or laboratory data review,
- Data quality assurance and quality control (QA/QC),
- Start-up calibrations,
- Field operation of samplers,
- Data summary reports (quarterly and annual),
- Preventive maintenance, and
- Corrective actions and reactive maintenance of unplanned system failures.

The monitoring period for the $PM_{2.5}$ speciation monitoring is anticipated to begin by January 17, 2012 but collection of $PM_{2.5}$ chemical speciation samples are expected to begin January 28, 2012 due to delays in sampler manufacturing. Sampling is expected to continue for a minimum of one year after initial commencement of exploration drilling which is scheduled to begin in July 2012. Monitoring beyond July 2013 will be determined by future air quality permit conditions. Table A-5 provides the work schedule for this monitoring project.

Table A-5: Work Schedule for $PM_{2.5}$ Speciation Monitoring

Monitoring Event	Date
QAPP Preparation, Equipment Procurement	December 2011 – January 2012
Submit QAPP for EPA approval	On or before January 17, 2012
Sampler installation and calibration [1]	January 25, 2012
First Sample Collected [2]	January 28, 2012
Quarterly and annual reports prepared and issued within 45 days of completion of the monitoring period [3]	Varies

[1] Monitoring is expected to occur at Deadhorse and Wainwright in 2012.

[2] Permit condition 1.3 under Post-Construction Ambient Air Quality Monitoring for each permit indicates that the sampling period shall commence within 120 days of when the final permit is issued. January 17, 2012 is the 120th day since the permit was issued however the first scheduled "run-date" according to the EPA 6 day sampling schedule is January 22, 2012.

[3] Although monitoring begins in January, 2012, monitoring periods will be adjusted to nearest full calendar month to simplify reporting. January sampling performed in 2012 will be included with February 2012 data for the purposes of reporting.

Monitoring Year Quarters

Monitoring Quarter A	February 1, 2012 – April 30, 2012
Monitoring Quarter B	May 1, 2012 – July 31, 2012
Monitoring Quarter C	August 1, 2012 – October 31, 2012
Monitoring Quarter D	November 1, 2012 – January 31, 2013
Monitoring Quarter E	February 1, 2013 – April 30, 2013
Monitoring Quarter F	May 1, 2013 – July 31, 2013 [1]

[1] Schedule will be extended in similar fashion if monitoring is extended beyond July 2013.

A6.4 PROJECT RECORDS/REPORTS

Table A-6 lists the project records and reports that will be included in the monitoring project. Project records and reports will include calibration documentation, quality control verification documentation, and annual monitoring data summary reports. If needed, corrective action reports and plans may be included in project documentation. Annual data summary reports will include supporting field and laboratory QC documentation.

Table A-6: Summary of Project Records and Reports

Records / Reports	Frequency	Content	Individual Responsible	Distribution
Calibration	Initial Setup	Accuracy Assessment	Field Operator	SLR Project Manager
Sampling Period QC Verifications	Before and after each monthly sampling period	Accuracy Assessment Summary	Field Operator	SLR Project Manager
Lab Data Summary	After each batch analysis	Analytical Data	Laboratory Project Manager	SLR Project Manager
Quarterly Summary Report	Quarterly	Summarize data	Data Manager	SLR Project Manager, SOI, EPA
Annual Summary Report	Annually	Summarize data	Data Manager	SLR Project Manager, SOI, EPA
Corrective Action Reports and responses	As Needed	Summarizes corrective actions taken to restore station to compliant status	SLR Project Manager	Field Operator, included in Annual Summary Report if needed

A7 QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT

Measurement Quality Objectives (MQOs) are designed to evaluate and control various phases (sampling, preparation, and analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the data quality objectives (DQOs).

MQOs can be defined in terms of precision, accuracy, representativeness, detectability, completeness, and comparability.

Precision is an assessment of the mutual agreement among multiple independent measurements under similar conditions. EPA STN sampling does not require the operation of field precision samplers. Precision assessments are generally performed at the laboratory during the analytical process by repeated measurement of the same sample to assess analytical method reproducibility. Consistent with EPA STN sampling, precision will be assessed by methods specific to each analytical method. Table A-7 provides a summary of the methods used to determine analytical precision

Table A-7: Methods for Determining Analytical Precision

Analytical Method	Precision Method
Gravimetric / Mass	Standard Deviation of control filters
X-ray Fluorescence (XRF)	Replicate sample analysis
Ion Chromatography (IC)	Standard Deviation of QA standards
Thermal / Optical Reflectance or Transmission (TOR/TOT)	Replicate sample analysis

Accuracy is a measure of the proximity of a given measurements and the true value. Accuracy includes components of both random error and systematic error associated with instrumental bias. Accuracy will be assessed for field operations during sampler quality control flow calibration verifications. Additionally, during laboratory analysis, accuracy will be assessed by the analysis of samples containing known amounts of target species and elements.

Data completeness is a measure of the amount of data actually collected compared with the amount of data that could have been collected during the defined monitoring period, expressed as a percentage. Data completeness is calculated by dividing the number of valid samples by the total number of possible samples that were planned for collection during the monitoring period. The EPA STN QAPP does not clearly provide specific criteria or guidance for $PM_{2.5}$ speciation data completeness goals. The EPA STN QAPP adopts 40 CFR Part 50 data completeness requirements which only address priority pollutants. $PM_{2.5}$ mass is the only priority pollutant measured in the Beaufort and Chukchi Sea $PM_{2.5}$ speciation program. Both the STN and Interagency Monitoring of Protected Visual Environments (IMPROVE) indicate that a differentiation is made between recovery rate and data completeness. Recovery rate refers to the data completeness of the $PM_{2.5}$ mass measurement while completeness refers to the validity of the entire sample. Entire sample validity requires valid sample concentrations be obtained for $PM_{2.5}$, sulfate, organic carbon, elemental carbon, and nitrate. Consistent with 40 CFR Part 50 priority pollutant data completeness requirements, the MQO goal for overall data completeness during the monitoring project is defined as 80 percent data capture for entire sample validity as defined by valid concentrations for $PM_{2.5}$ mass, sulfate, organic carbon, elemental carbon, and nitrate for an individual sample.

The MQOs for detection capabilities of the project are defined in terms of measurement resolution. Due to the complex nature of the sample collection and measurement procedures in the lab, species and element detection limits are not provided in this QAPP. However, refer to appendix D for descriptions of the analytical methods and expected project detection limits.

Detectability, method comparability, and representativeness are determined by the siting and exposure of the $PM_{2.5}$ speciation sampler and the use of approved analytical methods. The space-time domain and aspects for this specific application have been considered for each measurement parameter as prescribed in *Meteorological Monitoring Guidance for Regulatory Modeling Applications*, Section 3.1.1 Objective for Siting (EPA-454/R-99-005). $PM_{2.5}$ criteria were applied to assess the siting for this project. Additionally, the selected analytical laboratory and methodology selected for the project is consistent and comparable to those used for the EPA STN.

Table A-8: Summary of MQOs for the $PM_{2.5}$ Chemical Speciation Monitoring Program

Quality Objective	Assessment Method	Acceptance Criteria[1]	Corrective Actions
Accuracy	Sampler Flow Verifications	± 10%	Re-calibrate sampler flow
	Laboratory Quality Control Samples	Gravimetric / Mass - ± 5 µg X-ray Fluorescence (XRF) / Elements - ± 10% Ion Chromatography (IC) / Ions - ± 10% Elemental / Total Carbon (TOR / TOT) - ± 10%	Re-calibrate, re-analyze QC and field samples
Precision[2]	Laboratory Replicates	Gravimetric / Mass - ± 5 µg X-ray Fluorescence (XRF) / Elements - ± 7% or 5% Ion Chromatography (IC) / Ions - ± 10% Elemental Carbon (TOR / TOT) - ± 10% Total Carbon (TOR / TOT) - ± 10%	Re-calibrate, re-analyze QC and field samples
Data Completeness	Calculated	≥ 80% per monitoring quarter (valid samples defined by combined $PM_{2.5}$, Sulfate, OC, EC, Nitrate valid measurements for the sampling event)	Collect additional samples; Re-analysis of samples by laboratory
Representativeness	Sampler siting	Meets $PM_{2.5}$ requirements	N/A
Detectability[3]	Laboratory determined detection limits	Gravimetric / Mass – 0.3 µg/m^3 X-ray Fluorescence (XRF) / Elements – 0.05 – 20 ng/m^3 Ion Chromatography (IC) / Ions - 10 – 100 ng/m^3 Elemental Carbon (TOR / TOT) - 100 ng/m^3 Total Carbon (TOR / TOT) - 250 ng/m^3	N/A
Comparability	Analytical methodology	Analytical laboratory experienced with STN/IMPROVE Measurement methods consistent with STN/IMPROVE	N/A

[1] Laboratory acceptance criteria defined from IMPROVE MQO goals.
[2] Precision objectives for measurements that are significantly above instrument detection limits. Assessment of measurements near or below detection limits exaggerates statistical uncertainty. XRF precision criteria depends upon the number of fluorescers for a particular element.
[3] Detection limits vary for each analytical parameter.

A8 SPECIAL TRAINING/CERTIFICATIONS

Field personnel working on this project will have their qualifications reviewed and will be determined by the project manager to have sufficient experience and knowledge in $PM_{2.5}$ monitoring. Laboratory personnel will have their qualifications reviewed by the laboratory manager and will be determined to have sufficient experience and knowledge in analytical procedures.

Training on the proper setup, calibration, and operation of the $PM_{2.5}$ chemical speciation samplers will be provided by the instrument manufacturer. All SLR field personnel will be trained in site-specific safety and logistics. Training will be conducted by the SLR project manager or his designees. Site-specific training checklists will document the specific training received by each field technician (Appendix C). Training in laboratory procedures will be provided by the laboratory manager. Sample laboratory procedures are provided in Appendix D.

A9 DOCUMENTS AND RECORDS

Table A-9 provides a list of the documents and records that will be generated as part of the project and included in the applicable data reports. Copies of all field documentation will be maintained on-site and at the SLR office. All electronic data will be stored on a server at the SLR office and will be backed up periodically to alternate storage locations to prevent data loss. Laboratory records will be stored at the laboratory facility and backed up according to laboratory data management procedures.

Sample project forms are included in Appendix C. Data report submittal and content requirements are provided in section C2.

Table A-9: Summary of Documents and Records

Document Type	Frequency	Preparer
Calibration Sheets	Monthly	Station Operator
Maintenance Log	As needed	Station Operator
Sample Chain of Custody Forms	Each batch shipment	Station Operator
Laboratory Analytical Summary Reports	Each filter batch	Laboratory Manager
Quarterly Data Report	Quarterly	Data Manager
Annual Data Report	Annually	Data Manager
QAPP Revisions	As needed	Project Manager

B. MEASUREMENT AND DATA ACQUISITION

B1 SAMPLING PROCESS DESIGN

The primary objective of the $PM_{2.5}$ Speciation Monitoring Program is to collect $PM_{2.5}$ chemical speciation data and comply with post construction monitoring requirements specified in permit number R10OCS/PSD-AK-09-01 (Noble Discoverer Drillship - Chukchi Sea Exploration Drilling Program) and R10OCS/PSD-AK-2010-01 (Noble Discoverer Drillship - Beaufort Sea Exploration Drilling Program).

To accomplish this objective, $PM_{2.5}$ chemical speciation data, including sulfates, nitrates, organics, metals, sea salt and crustal matter will be collected at a location representative of the Beaufort and Chukchi Seas. Point Lay and Wainwright monitoring locations are expected to be representative of concentrations observed in and near the Chukchi Sea. Deadhorse and Kaktovik monitoring locations are expected to be representative of the Beaufort Sea.

Chukchi Permit (R10OCS/PSD-AK-09-01) condition R.1.3 and Beaufort Permit (R10OCS/PSD-AK-2010-01) condition S.1.3 specify the monitoring period shall commence within 120 days after the final permit is issued and continue for a minimum of 1 year after commencement of initial operation of the Discoverer as an OCS Source. This suggests a sampling program from January 17, 2012 until at least July, 2013.

EPA STN samples are collected on a once every three day or once every six day schedule all year-round to assess national trends in background pollutant concentrations. Higher frequency sampling schedule is generally followed by locations where $PM_{2.5}$ concentrations tend to be relatively high or pose a health concern. Because observed $PM_{2.5}$ mass concentrations along the Chukchi and Beaufort Seas have historically been very low, the project adopts a one sample every six day frequency and schedule. The first scheduled sampling day for a monitoring period beginning January 17, 2012 is January 22, 2012. The sampling schedule is provided in Appendix B.

$PM_{2.5}$ chemical speciation samplers will supplement existing ambient air quality and meteorological monitoring equipment already in operation at the representative location. Met One SuperSASS™ samplers capable of collecting samples on multiple sample media (Teflon, Nylasorb, and quartz) will be used to ensure proper sample collection and handling. Met One SuperSASS™ samplers were selected after careful consideration of site characteristics and after consideration of site operator survey results provided in *Evaluation of $PM_{2.5}$ Chemical Speciation Samplers for Use in the EPA National $PM_{2.5}$ Chemical Speciation Network*, Table II-15 (EPA-454-R-01-005). Critical sampler characteristics include single person field installation ability, quick installation time, sampler ease of use for both sample collection and audit and calibration, and sampler operation reliability. SuperSASS™ samplers are currently used in the EPA STN sampling network in combination with another sampler specific to carbon sample collection.

EPA STN samples are collected and analyzed by EPA's contract laboratory in North Carolina. Since the EPA STN program and contract lab are geared toward state and local agency participation, the laboratory generally does not solicit work from other entities. Instead, an alternate, non-EPA contract lab (Chester LabNet) on the west coast will be used. This lab has experience performing $PM_{2.5}$ speciation analysis and is located on the west coast making sample shipment more convenient and reliable. The lab will use similar laboratory testing methodology as that used by the EPA STN contract laboratory. Tables A-3 and A-4 provide a list of the project target constituents and analytical procedures used for each.

Figure B-1 provides a map depicting the general project area. The Beaufort and Chukchi Seas combined represent approximately 1,000 miles of north Alaska coastline. Ambient air quality and meteorological monitoring is already taking place at Wainwright, Point Lay, Deadhorse, and Kaktovik communities. These monitoring stations will be expanded to include $PM_{2.5}$ speciation monitoring as described in this QAPP.

The Point Lay (A on Figure B-1) ambient air and meteorological monitoring site is located at the northeast corner (off of Tuttunniagvik Street just north of Sisrik Avenue) of the Point Lay Village, Alaska. The community of Point Lay is located on the Chukchi Sea coast approximately 180 miles southwest of Barrow and 2 miles southwest of the Kokolik River. Figure B-2 provides a view of the Point Lay station. For more specifics regarding the Point Lay monitoring program, refer to the approved Point Lay ambient air and meteorological monitoring QAPP.

The Wainwright (B on Figure B-1) ambient air quality and meteorological monitoring site is located on the east side of the community of Wainwright. The community of Wainwright is located on the Chukchi Sea coast approximately 90 miles southwest of Barrow and 3 miles northeast of the Kuk River estuary (also known as the Wainwright Inlet or Lagoon). The monitoring site is located on a broad flat coastal plain that is dotted with several small lakes and ponds at an elevation of approximately 26 feet above sea level. Figure B-3 provides a view of the Wainwright station. For more specifics regarding the Wainwright monitoring program, refer to the approved Wainwright ambient air and meteorological monitoring QAPP.

The Deadhorse (C on Figure B-1) ambient air monitoring site is located in the town of Deadhorse, Alaska along the arctic coastal plain approximately 12 kilometers (km) south of the shoreline and approximately 160 km north of the Brooks Range. The station is located approximately 61 feet above sea level and is surrounded by light industrial facilities within the town of Deadhorse. Figure B-4 provides a view of the Deadhorse station. Form more specifics regarding the Deadhorse monitoring program, refer to the approved Deadhorse ambient air and meteorological monitoring QAPP.

The Kaktovik (D on Figure B-1) ambient air and meteorological monitoring site is located along the landfill access road southeast of the Kaktovik Village on Barter Island on the Beaufort Sea. The station is located at approximately 35 feet above sea level and is surrounded by tundra vegetation consisting of low shrubs, sedges, and mosses. Figure B-5 provides a view of the Kaktovik station. For more specifics regarding the Kaktovik monitoring program, refer to the approved Kaktovik ambient air and meteorological monitoring QAPP.

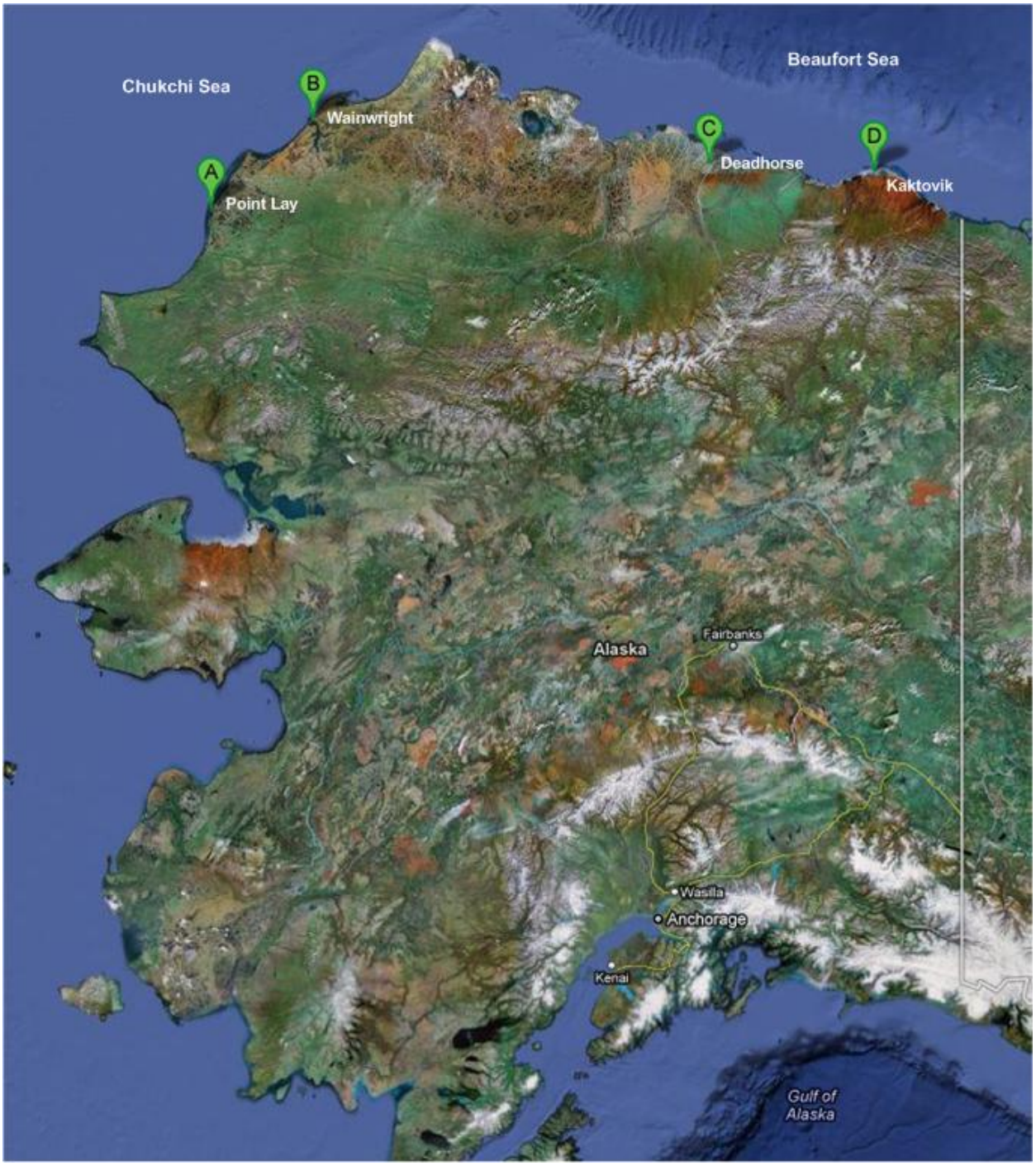
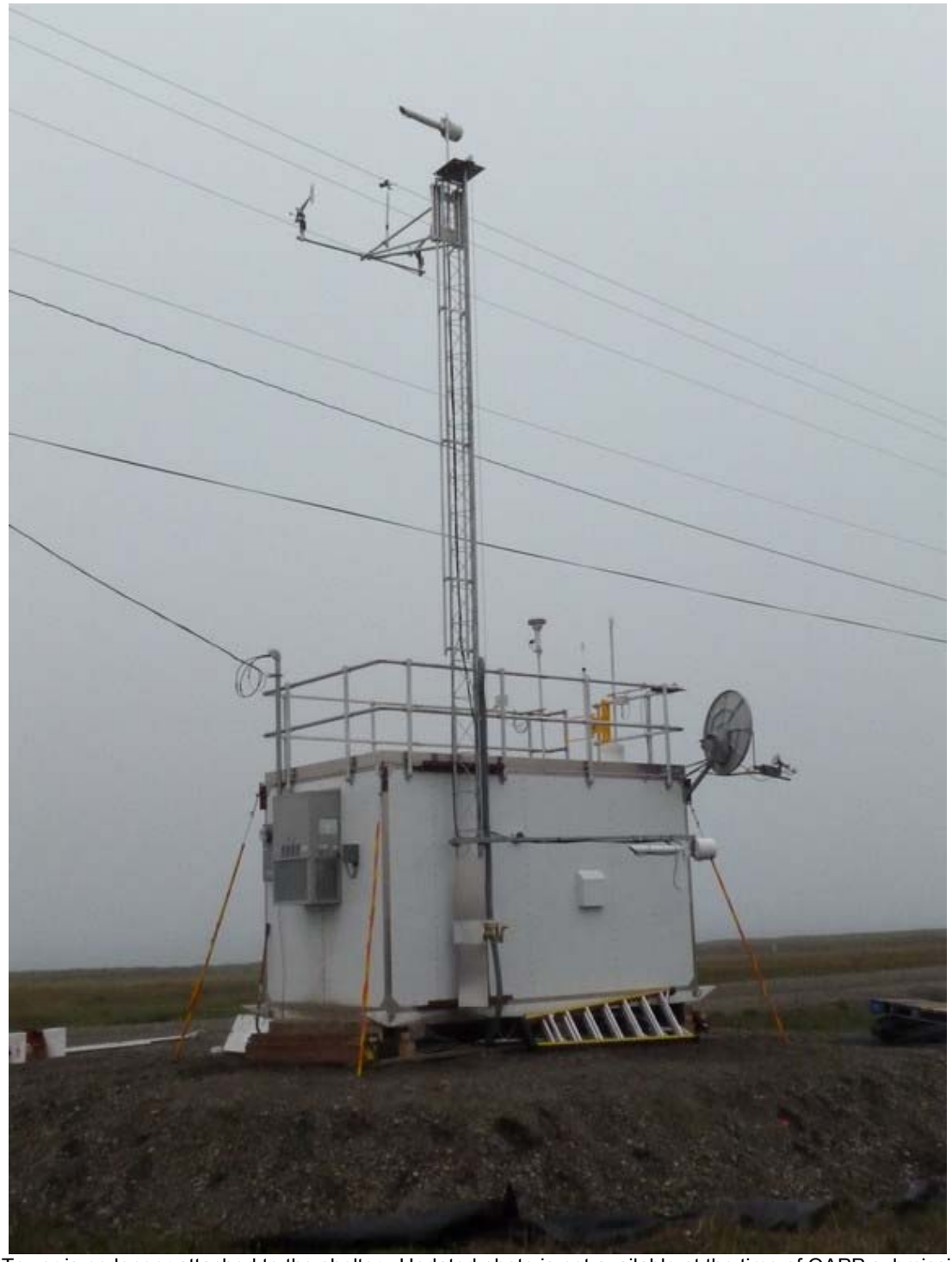


Figure B-1: $PM_{2.5}$ Speciation Monitoring Program Site Map

Figure B-2: Point Lay Monitoring Station

Figure B-3: Wainwright Monitoring Station

Figure B-4: Deadhorse Monitoring Station



* - Tower is no longer attached to the shelter. Updated photo is not available at the time of QAPP submission.

Figure B-5: Kaktovik Monitoring Station

B2 SAMPLING METHODS

Met One Spiral Aerosol Speciation Samplers SuperSASS™ $PM_{2.5}$ Speciation samplers will be used. This sampler provides multiple parallel sample cassettes. Each cassette has its own cyclone size-selective $PM_{2.5}$ inlet, denuder (if applicable), and tandem filter holder. The cassettes are mounted in an aspirated solar shield that maintains the eight independent sampling cassettes at the same temperature within 3°C during and after a sample event. The cassette inlets point downward. Each channel is independently flow-controlled to 6.7 liters per minute (LPM) and volumetric flow and volume are logged each five minutes. Ambient barometric pressure and temperature are also measured and logged. The sampler incorporates a $PM_{2.5}$ Sharp Cut Cyclone aerosol separator which requires no grease or oil. The $PM_{2.5}$ cyclone inlet is designed to be removable from the cassette which allows either field or laboratory maintenance. The filter samples are transported to the laboratory for analysis in their filter cassettes. Sample recovery and cleaning in the laboratory insures the inlet and sampling cassette is free from contamination each sample event. The sampler is designed without a plenum or sample tube which require frequent field maintenance. The Fine Particle sample exits the cyclone and is immediately captured on the filter cassette. The sample cassettes are designed to use one or two stacked 46.2-mm filters. Any cassette can be configured with one or two filters or a denuder followed by one or two filters. Figures B-6 and B-7 provide views of sampler schematic.

Monitoring equipment will be operated using Prevention of Significant Deterioration (PSD) quality assurance practices as a guide. In general, samplers will be calibrated and operated according to manufacturer recommendations and consistent with EPA STN quality assurance procedures. Calibrations and periodic flow-rate verifications will be documented and provided as quality assurance documentation for the monitoring. Independent audits will be performed on the samplers. Collocated sampler operation for $PM_{2.5}$ speciation monitoring is not planned. Section B5 describes the project Quality Control procedures.

Section B4 provides a description of the different sampling media used for the project. The sampling schedule is provided in Appendix B. Sampling is expected to occur on a once every six day schedule and sample collection time is expected to be for 24 hours.[1]

[1] 40 CFR Part 50, Appendix L indicates that a sampling period of 1,380 to 1,500 minutes (23 hours to 25 hours) for $PM_{2.5}$ is acceptable.

Figure B-6: Met One Spiral Aerosol Speciation Sampler (SASS™)

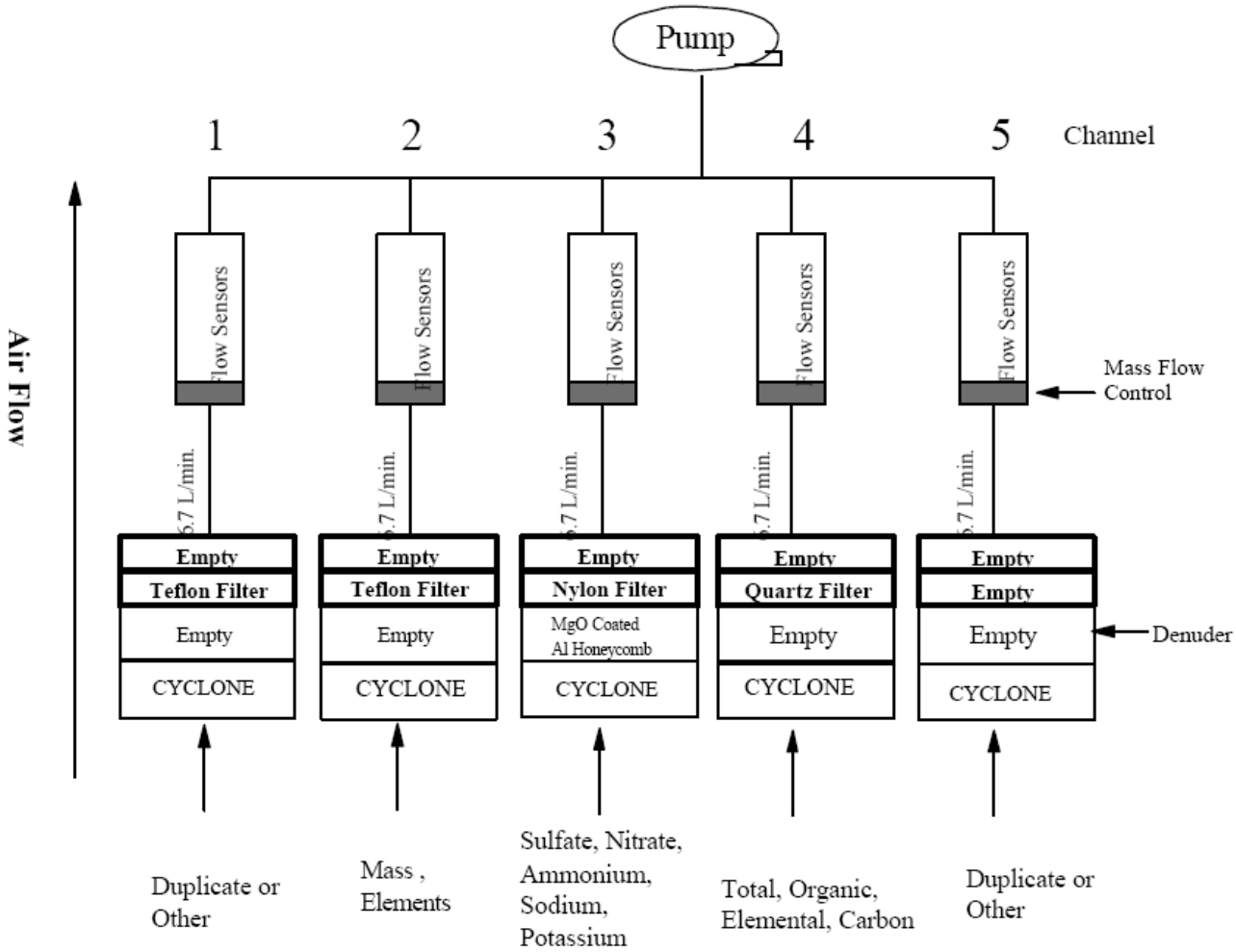


Figure B-7: Schematic of SASS Sampling System

B3 SAMPLE HANDLING AND CUSTODY

An alternate sample handling and custody procedure will be used than what is typically used for EPA STN/IMPROVE sampling. EPA STN sites require samples to be shipped to the EPA contract laboratory within 48 hours of sample collection. Given the logistics involved in shipping samples out of Alaska monitoring locations, an alternate shipping schedule will be used. Samples will be retrieved within 48 hours of collection but then held in cold storage (<4 °C) and shipped to the laboratory in batches. Sample handling will adhere to $PM_{2.5}$ mass holding time guidelines. Sample collection will occur within 30 days of initial filter preparation at the lab. Laboratory analysis will occur within 30 days of sample collection in the field. Sample transport and receipt will be tracked using standard chain of custody forms.

Due to the samples being collected on filters, samples originate in the laboratory, transfer to the field for exposure, then return to the laboratory for analysis. Figure B-8 provides a summary of the filter handling process for the project.

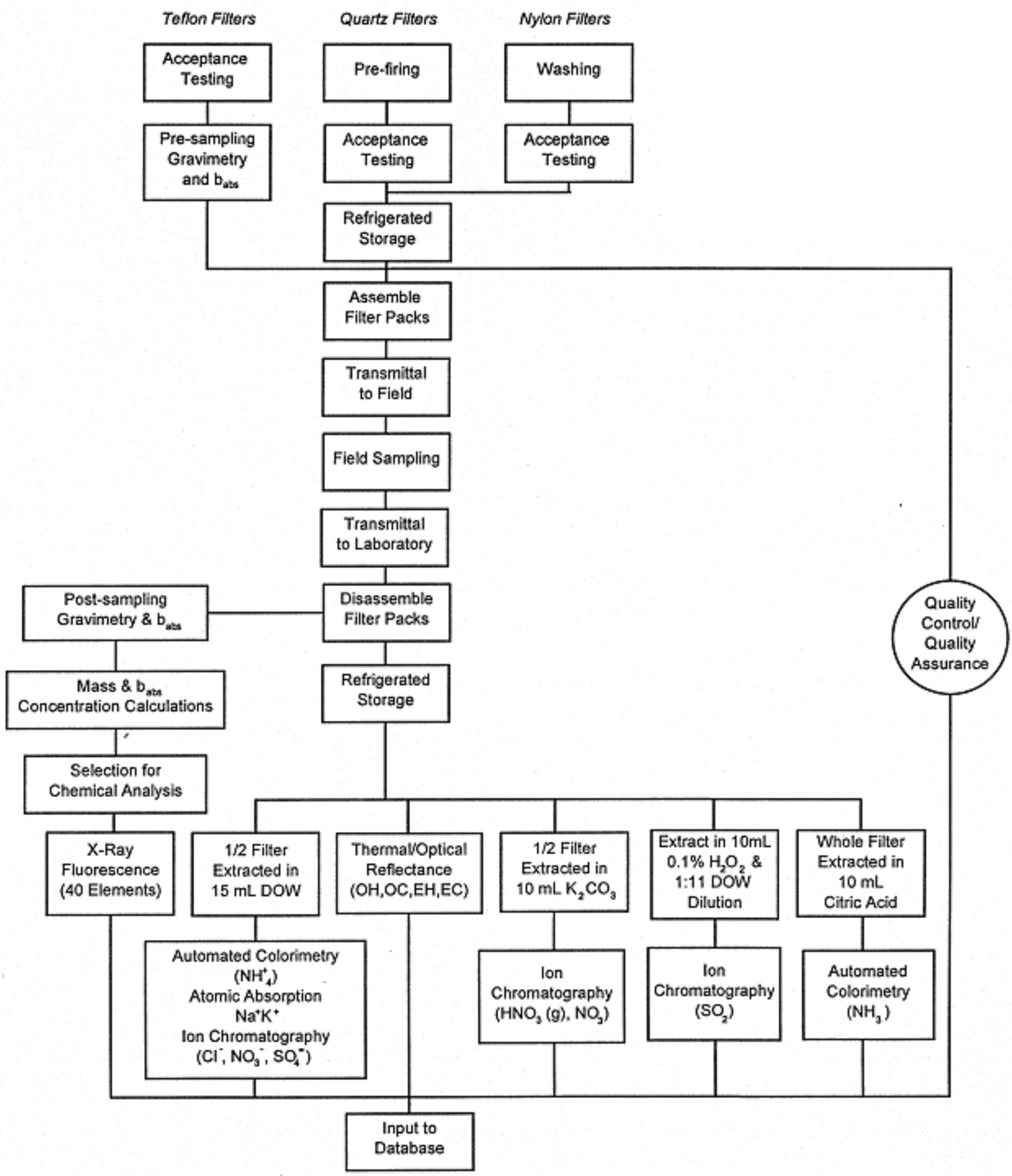


Figure B-8: Filter Flow Diagram Acceptance through Analysis

B4 ANALYTICAL METHODS REQUIREMENTS

B4.1 MASS MEASUREMENT METHODS

Particulate mass concentration is determined by gravimetric analysis using a Teflon filter media. Net mass on a filter is determined by weighing the filter before and after sampling with a balance in a temperature- and relative humidity-controlled environment. To minimize particle volatilization and aerosol liquid water bias, $PM_{2.5}$ reference methods require that filters be equilibrated for 24 hours at a constant (within ±5%) relative humidity between 30% and 40% and at a constant (within ± 2°C) temperature between 20°C and 23°C.

Balance calibrations are established before and after each weighing session using Class M and Class S standards traceable to National Institute of Standards and Technology (NIST) mass standards. Periodic verification occurs every ten filters processed during weighing sessions. Approximately one out of ten filters are re-weighed and used to calculate the precision of the measurement. When quality control results differ from specifications by more than 5% the samples are re-analyzed.

B4.2 ELEMENTAL ANALYSIS METHODS

Elemental analysis is performed using X-ray fluorescence (XRF). XRF is the most commonly used elemental analysis method due to the multi-element capabilities, relatively low cost, low detection limits, and preservation of the filter for other analyses.

In XRF, the filter deposit is irradiated by high energy x-rays (XRF) or protons (PIXE) which eject inner shell electrons from the atoms of each element in the sample. When a higher energy electron drops into the vacant lower energy orbital, a fluorescent x-ray photon is released. The energy of this photon is unique to each element, and the number of photons is proportional to the concentration of the element. Concentrations are quantified by comparing photon counts for a sample with those obtained from thin-film standards of known concentration. XRF analysis is usually performed on Teflon-membrane filters.

Quality control standards and replicates from previous batches are analyzed for every 10 to 20 samples. When quality control results differ from specifications by more than ±10%, or if the replicate concentrations differ from the original values (assuming they are at least 10 times detection limits) by more than ±10%, the samples are re-analyzed.

B4.3 ION CHROMATOGRAPHY METHODS

Ion chromatography (IC) methods rely on the fact that the target analyte is soluble in water. All IC analysis methods require a fraction of the filter to be extracted in water and then filtered to remove insoluble residues prior to analysis. The sample extract passes through an ion-exchange column which separates the ions in time for individual quantification, usually by an electro-conductivity detector. Quartz or Nylon (Nylasorb) filter media are used to collect samples for IC. Nylon filters are the preferred media for nitrate analysis due to the ability to better retain volatile nitrate constituents. Quartz media will be used as a secondary, back-up sampling media to maximize data completeness in the event that nylon filters are damaged or unable to be collected.

Calibration standards are prepared weekly or biweekly in routine operation of ionic analysis. New calibration standards are verified with the previous week's calibration standards to ensure consistency among the measurements. During instrument calibration, if any calibration point varies by more than ±10% of the specified value, the system is rechecked or a new calibration standard prepared to ensure the accuracy of the analysis.

B4.4 CARBON ANALYSIS METHODS

Three classes of carbon are commonly measured in ambient aerosol samples collected on quartz-fiber filters: (1) organic, volatilized, or non-light absorbing carbon; (2) elemental or light-absorbing carbon; and (3) carbonate carbon.

Thermal/optical reflectance (TOR) and Thermal/optical transmittance (TOT) methods of carbon analysis utilizes volatilization at high temperatures to quantify carbon. Temperatures ranging from ambient to 550 °C to 800 °C are used to volatilize carbon, convert it to methane and quantify it, usually with a flame ionization detector. Varying temperature ranges correspond to the different classifications of carbon.

Quality control standards and replicates are analyzed for every 10 to 20 samples. When quality control results differ from specifications by more than ±10%, or if the replicate concentrations differ from the original values (assuming they are at least 10 times detection limits) by more than ±10%, the samples are re-analyzed.

B5 QUALITY CONTROL

Quality Assurance/Quality Control (QA/QC) procedures are required for this project to ensure that the collected data meet standards of reliability and accuracy.

The $PM_{2.5}$ speciation samplers will be installed and calibrated according to manufacturer procedures. Flow quality control verifications will be performed monthly. If flow measurements are found to exceed ±10% of the expected flow rate, samplers are recalibrated. Flow verification transfer standard accuracy is NIST-traceable. Monthly leak checks, barometric pressure, and temperature sensor verifications will also be performed. If temperature measurements are found to exceed ±2°C or barometric pressure sensors are found to exceed ±10mmHg, samplers are recalibrated. Quarterly flow, temperature, and barometric pressure audits and calibrations will be performed.

Field blanks will be provided in each batch of samples and alternate between Chukchi and Beaufort sea monitoring sites resulting in one field blank at each site for every 6 sampling events. These samples will be handled and analyzed in the same manner as ambient samples, but do not have any sample air drawn through them. The subsequent analysis of these filters will be used to assess total measurement system contamination.

The sample handling and gravimetric laboratory is climate controlled for both temperature and relative humidity conditions. Temperature and relative humidity control is through a central heating/air conditioning unit. Temperature is maintained between 20ºC and 23ºC with an allowed twenty-four variation of ±2ºC. Relative humidity is maintained between 30% and 40% with an allowed twenty-four hour variation of ±5%.

The temperature and relative humidity are measured and recorded in the data base with every post-weight measurement. When the temperature or relative humidity range is exceeded, analysis is discontinued until the proper range is achieved.

The mass balances are cleaned and calibrated at the beginning and upon conclusion of the work session. Periodic quality control (QC) verifications using blank and known mass standards are performed during the work session at approximately one check every 10 samples. When quality control measurements exceed the mass QC acceptance range, sample analysis is repeated. Mass standards are Class M or Class S NIST-traceable standards.

XRF systems are calibrated whenever there is a change in the physical configuration, or in the detectors, or when a problem is observed in the routine calibration checks. Thin film standards representing known concentrations of elemental species and blank film standards are used to assess system accuracy. At the beginning of each XRF session, samples from a previous session are reanalyzed with both the low current used with the QC standards and once with the high current used for normal filters. If the reanalysis values differ by more than 5%, the system is recalibrated and samples rerun. All thin film standards are NIST-traceable.

Ion chromatography systems are calibrated initially and re-calibrated whenever QC tests indicate poor system performance. Blanks and QC samples consisting of laboratory prepare matrices of known concentrations are analyzed at the beginning of every analytical batch and at least once for every 20 field samples. If the observed concentrations differ by more than 10% the problem is corrected and samples re-analyzed. Laboratory replicates and matrix spike samples are analyzed at least one for every 20 field samples.

Carbon analysis systems are calibrated initially and re-calibrated whenever QC tests indicate poor system performance. Blanks and QC samples consisting of known concentrations are analyzed at the beginning and end of every analytical batch. Replicate samples are analyzed at the rate of one per every 10 samples. Replicates often exhibit variation due to inconsistency and inhomogeneous deposit of particulate mass on the filter. Inconsistent replicates for which a reason cannot be determined will be reanalyzed.

Field blanks for all analytical procedures will be analyzed at the rate of one per sample shipment. If field blank analysis demonstrates significant concentrations of target species and elements a systemic sample handling problem is likely the cause and data will be flagged as suspicious.

B6 INSTRUMENT/EQUIPMENT TESTING AND INSPECTION

B6.1 ACCEPTANCE TESTING

Prior to installation, all equipment will be visually inspected to ensure no physical damage exists. After installation, and prior to the beginning of the monitoring period, samplers will be calibrated according to the procedures stated in their respective operating manuals. Acceptance testing procedures will be documented on the appropriate calibration forms (provided in Appendix C). To ensure that the samplers continue to properly operate during the monitoring period, calibration checks of the instruments will be conducted monthly. Calibrations are performed according to manufacturer procedures using NIST-traceable flow transfer standards.

Filter media will be inspected at the laboratory. Teflon filters for Gravimetric and XRF analysis are supplied in packs of fifty. The filters are stretched Teflon mesh filters with pore size 3.0µm, and a rigid olefin ring support. Randomly selected filters are visually inspected for unevenly stretched Teflon, holes, and poorly attached or damaged olefin rings. Nylasorb filters for IC analysis are supplied in packs of fifty. Filters are visually inspected for damage when prepared at the laboratory for field use. Quartz filters for TOR / TOT and ion chromatography analysis are supplied in boxes of approximately one hundred. The quantity in each box varies because filters with holes or manufacturing defects are discarded. Quartz filters are pre-fired at 900°C for at least four hours in accordance to laboratory procedures. Filter media is contained in plastic and stored in a freezer.

Random filters of each media type for each batch of samples are retained at the laboratory and analyzed as laboratory blanks to assess potential problems associated with the sampling media.

B6.2 SITE SURVEILLANCE AND SYSTEM CHECK PROCEDURES

SLR station operators will inspect the condition of the monitoring equipment during each site visit. $PM_{2.5}$ speciation sampler flow will be verified monthly and the general station condition will be inspected to ensure that there is no environmental or vandalism damage that would impede the ability to collect valid samples. Station site technicians retrieving samples after collection will monitor equipment and station condition and notify SLR station operators of any significant observations made.

A check list will be used to document work performed during the visits and will be filed with other project field records. In the event that sampler repairs or modifications become necessary, sampler parts will be obtained from the manufacturer.

B6.3 PREVENTIVE MAINTENANCE AND CORRECTIVE ACTIONS

The procedures and schedule for preventive maintenance outlined in the standard operating procedure (SOP) will be followed for this monitoring program (Appendix D). As needed, spare parts and/or equipment will be dispatched to the monitoring station for repair or sampler replacement by qualified SLR personnel.

Preventative maintenance planned for the project includes:

- Regular cleaning of down tube, cyclone and inlet surfaces;
- Replacement of denuder according to manufacturer recommendation;
- Inspect and replace o-rings as needed;
- Inspect and overhaul or replace pump and components as needed;

B7 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Calibration and frequency are discussed in this section. Additional information is available including instrument calibration standard operating procedures (Appendix D) and calibration worksheets (Appendix C).

B7.1 CALIBRATION FREQUENCY

$PM_{2.5}$ speciation sampler flow, barometric pressure, and ambient temperature sensors will be calibrated according to the specified manufacturers' recommendations by SLR personnel. Field calibration is expected upon initial installation and quarterly thereafter. Monthly calibration verification checks will be performed. If calibration verifications indicate deteriorated performance, full system calibration will be performed.

B7.2 CALIBRATION EQUIPMENT

All instruments used for calibration of meteorological sensors will be in current calibration, per manufactures' specifications, and traceable to National Institute of Standards and Technology (NIST) transfer standards. Calibration certifications and records will remain on file at the SLR Anchorage office. All NIST traceable equipment used for calibrations will have the relevant model number, serial number and certification date(s) recorded on accompanying forms.

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

All spare parts inventories will be kept up to date. Each new spare part will be accepted with the same procedures mentioned in Section B6. Serial numbers for spare parts will be recorded by either the station operator or site technicians and copied to the SLR client server folder. Upon deployment of a replacement part by site technicians, the make, model, and serial number will be recorded on the appropriate form. After the repair or replacement, the instrument will be calibrated by the site technicians to ensure that it is properly functioning.

B9 NON-DIRECT MEASUREMENTS

At this time SLR anticipates that the only non-direct measurements or data relevant to this project will be topography, climate history, and the surrounding land use. Any use of outside data will be quality controlled to the extent possible following QA/QC procedures outlined in this QAPP and in applicable EPA guidance documents. Refer to the approved ambient air quality and meteorological monitoring QAPPs mentioned in section A5 for discussions on non-direct measurements.

B10 DATA MANAGEMENT

The proper management of all data associated with this project is critical to assuring the quality and usability of the monitoring results. As such, procedures will be implemented to ensure adequate data acquisition, validation, transmission, reduction, reporting, and storage of electronic and hard copy data. Summaries of the procedures to be implemented in the field and at the SLR Anchorage office for data management are provided in the subsequent sections. Overall data processes are illustrated in Figure B-9.

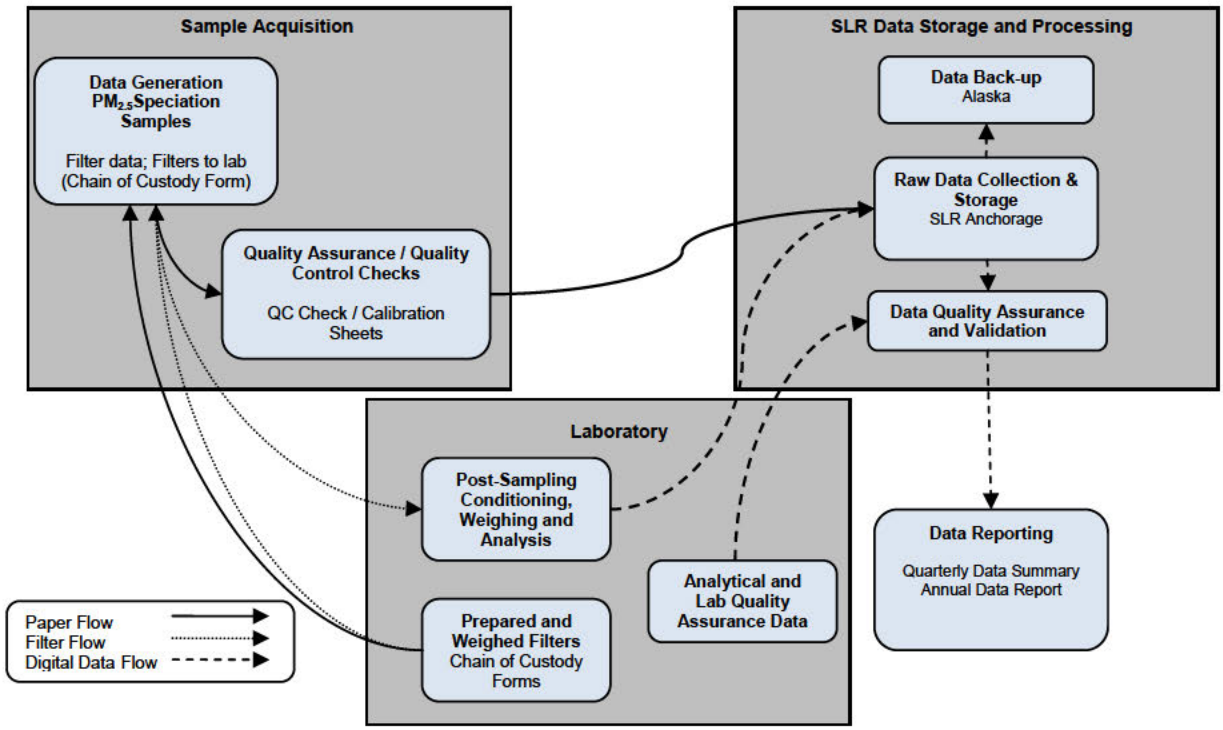


Figure B-9: $PM_{2.5}$ Speciation Data Processes Flow Chart

B10.1 DATA ACQUISITION

Data acquisition will include the collection of electronic data, the generation of hand-written or typed calibration records, and the compilation of previously prepared records (e.g., NIST traceability records).

Field staff will generate electronic site visit forms and/or completed checklists. These records will be kept according to the prescribed format. Additional records pertaining to this project that have been generated by other organizations will also be collected and stored at the SLR Anchorage office as necessary.

B10.2 DATA VALIDATION

During each site visit, SLR field technicians will be responsible for verifying the condition of the monitoring site. All site visits will be documented by means of a site visit memo kept with the project files. Alternately, the site visit may be documented in a designated electronic station log book. These field notes will include the following:

- Time, date, current meteorological conditions (e.g., temperature, barometric pressure, sky conditions), and personnel at the monitoring site;

- Activities completed during visit; and
- As-found and as-left observed conditions of monitoring site equipment.

Sample site visit forms can be found in Appendix C.

The data manager, or her designee, will review all hard copy records received from the field. Problems or irregularities in the records will be brought to the attention of the on-site operator for further clarification. If documentation is not sufficiently defensible, the affected data will be invalidated.

Analytical data and quality assurance documentation will be reviewed by the project manager and quality assurance officer. Problems or irregularities in the records will be brought to the attention of the laboratory project manager for further clarification. If documentation is not sufficiently defensible, the affected data will be invalidated.

B10.3 DATA TRANSMISSION

Field forms, checklists, and other records will be scanned and transmitted to the SLR main office and stored in project files. Laboratory summary data will be transmitted to the SLR Anchorage office by the laboratory in standard report packages.

B10.4 DATA REDUCTION

All calculations and statistical analyses will be performed using standard software packages (e.g., Microsoft Excel and WRPLOT View) that can be easily verified and audited.

B10.5 DATA REPORTING

Data generated for this project will be summarized and presented in quarterly and annual data summary reports. The data summary reports will be prepared within 60 days upon completion of the monitoring period. Upon SOI's authorization, the data summary reports will be submitted to EPA for review and approval.

B10.6 DATA STORAGE

All project documentation, records, data, and reports will be maintained at SLR for a period of at least five years from the completion of the project. Electronic data on the SLR servers are backed up at least once daily and will be archived at a minimum of two separate locations.

C. ASSESSMENTS AND OVERSIGHT

C1 ASSESSMENTS AND RESPONSE ACTIONS

Data Quality Assessments will be performed on all collected data. Data reviews will be conducted by SLR staff to determine whether the data are reasonable and representative. Data that are determined to be unreasonable or unrepresentative will be identified, flagged, and discussed in the data reports. Data reviews will include an independent record audit of field calibration records and laboratory quality control documentation. Instrument performance audits will be provided by the QA auditor on a quarterly basis. The independent record audit program will be conducted by staff independent of monitoring and laboratory operations

C1.1 OPERATIONAL AUDITS

Performance audits of the $PM_{2.5}$ speciation samplers will be conducted quarterly. Performance audits will be completed by measuring the flow rate of the sampler during its normal operating flow rate using a certified flow transfer standard. Additional checks will be completed by collocating certified temperature and barometric pressure transfer standards with the sampler to assess temperature and barometric pressure accuracy. The audit transfer standards will be provided by the station auditor and different standards will be used for audits than are used for calibration. The QA auditor will conduct the performance audits and prepare a formal audit finding report within 45 days of completion of the audit. Performance audits will use the same criteria described in section B5 Quality Control. Performance audit reports will be included as supporting material in the quarterly and annual data reports.

C1.2 PROJECT DOCUMENTATION ASSESSMENTS

Field calibration records and sample shipment documentation will be examined to verify that all measurements were within expected acceptance criteria as described in section A7. Laboratory quality control documentation will be reviewed to verify that all analytical measurements were conducted in a controlled manner.

Any questioned data will be brought to the attention of the Project Manager and Data Manager who will determine whether data will be invalidated or accepted. Questioned data and any associated corrective actions will be discussed in the annual data report.

C1.3 CORRECTIVE ACTIONS

All deficiencies identified during operational audits or data review will be recorded and reported to the project manger within seven working days of discovery. Corrective actions to correct deficiencies will be addressed and documented in a Corrective Action Form (see Appendix C). Corrective Action Forms will include signature blocks for the recommendations(s) approval and task completion.

Any questioned data will be brought to the attention of the Project Manager and Data Manager who will determine whether data will be invalidated or accepted. Questioned data and any associated corrective actions will be discussed in the annual data report.

C1.4 QAPP REVISIONS

Based on the review of the operational audit, it may be necessary to revise this QAPP. The QAPP revisions will address any project deficiencies identified in the operational audit. The project manager and permitting manager will make any necessary changes and the revised QAPP will be submitted to EPA for approval.

C2 REPORTS TO MANAGEMENT

Reports to management are summarized in Table C-1.

Calibration and Sampling Event QC Verifications will be provided in the form of completed field worksheets. These worksheets will be completed and stored in the project document folder within ten days of the field activity. SLR project manager and QA officer will review the worksheets upon submission. Examples of these worksheets can be found in Appendix C.

Laboratory data summary reports will be provided by the laboratory upon completion of the lab analysis for each received filter shipment. Laboratory data summary reports will be provided to the SLR project manager within 30 days of completion of the sample analyses. Laboratory data summary reports will include:

- Sample, field blank, and laboratory blank analytical results;
- Completed chain of custody forms;
- $PM_{2.5}$ gravimetric laboratory environment measurements (temperature and humidity); and
- Calibration and quality control (blank, replicate and control standards) verification measurements for each analytical batch and each measurement method;

Permit conditions S.4 (Beaufort) and R.4 (Chukchi) of the air quality permits require monthly $PM_{2.5}$ and meteorological data summaries be provided to EPA within 45 days of the end of the calendar month. Due to the lag time associated with sample collection, shipment, laboratory analysis, and report preparation, this timeline is not practical for the $PM_{2.5}$ speciation data. Monthly data reports to satisfy these permit conditions will come from Point Lay (Chukchi Sea) and Kaktovik (Beaufort Sea) ambient air quality and meteorological monitoring stations. These reports will contain $PM_{2.5}$, meteorological, and other measurements obtained from the station as well as audit reports for any performance audits performed during that period. Quarterly data summary reports containing $PM_{2.5}$ speciation data will be prepared within 60 days of completion of the monitoring quarter.

An annual data report will be prepared by SLR and provided to SOI within 60 days after the completion of the monitoring year. An electronic copy of the validated data in Excel spreadsheet format will be provided with the annual data report.

This annual report will include the following:

- Project Summary;
- Explanation of any variations from QAPP or other significant events
- Summaries of filter recovery and data completeness;
- Explanations for any missing, flagged, or adjusted data;
- Summaries and results of field calibrations and maintenance activities;
- Summaries of laboratory calibration and QC results;
- Data summary

Table C-1: Summary of Reports to Management

Records / Reports	Frequency	Content	Individual Responsible	Distribution
Calibration	Initial Setup	Accuracy Assessment	Field Operator	SLR Project Manager
Sampling Period QC Verifications	Before and after each monthly sampling period	Accuracy Assessment Summary	Field Operator	SLR Project Manager
Lab Data Summary	After each batch analysis	Analytical Data	Laboratory Project Manager	SLR Project Manager; Data Manager
Quarterly Summary Report	Quarterly	Summarize data	Data Manager	SLR Project Manager, SOI, EPA
Annual Summary Report	Annually	Summarize data	Data Manager	SLR Project Manager, SOI, EPA
Corrective Action Reports and responses	As Needed	Summarizes corrective actions taken to restore station to compliant status	SLR Project Manager	Field Operator, included in Annual Summary Report if needed

D. DATA VALIDATION AND USABILITY

D1 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

D1.1 DATA REVIEW REQUIREMENTS

Data review, verification and validation are assessment techniques used to accept, reject, or qualify data in an objective and consistent manner.

Data review refers to the process that evaluates incoming data for conformance with pre-determined project criteria. During the data review process, site technicians or operators will be responsible for ensuring that:

- Field calibration and verification observations are within the operating limits of the monitoring equipment;
- Data continues to be collected and transmitted as designed; and
- Apparent outliers are identified and investigated to determine if they represent a malfunction or other issue.

Data review will be performed after each field visit to monitor instrument operations and to ensure the data have been reduced and properly formatted for further evaluation. Manual review of the data will include independent review of field documentation to identify any instrument failures.

Data package review will be performed after receipt of each analytical data package from the laboratory. Manual review of the data will include independent review of calibration and quality control documentation to identify any failures to achieve project DQOs. Manual review of the sample and field blank results will identify any abnormal low or high observations (outliers).

Any suspected data will be flagged for further evaluation and brought to the Project Manager's attention immediately. Any corrective actions will be noted on the appropriate checklists and forms.

D1.1.1 Data Calculations

Data completeness for the monitoring project will be calculated using formula D-1. The project objective for data completeness is 80 percent of the total possible number of 24 hour average samples collected for each sampling quarter. As described in section A7, samples will be considered valid if acceptable concentrations are obtained for $PM_{2.5}$ mass, sulfate, elemental carbon, organic carbon, and nitrate.

Data completeness (DC_i) will be determined using equation D-1:

D-1 $$DC_i = S_n/S_i \text{ x } 100$$

Where:

S_n = number of valid samples actually collected

S_i = number of possible samples during the monitoring period.

Accuracy assessment is based on the difference between the analytical observation for a control sample and the expected known concentration of that sample. Two methods of assessment will be used by the project depending on the nature of the analytical procedure. These methods are percent difference and absolute difference.

Accuracy assessments based on percent difference (d_i) will be determined using equation D-2:

D-2 $$d_i = (QC_{o}\text{-}QC_{tv})/QC_{tv} \text{ x } 100$$

Where:

QC_o = Observed concentration for the control sample

QC_{tv} = Expected / known / true value concentration for the control sample

Assessments based on absolute difference (d_{abs}) will be determined using equation D-3:

D-3 $$A_{abs} = QC_{tv} - QC_o$$

Where:

QC_{tv} = Expected / known / true value concentration for the control sample

QC_o = Observed concentration for the control sample

Precision assessments demonstrate the reproducibility of sample measurements. Two methods of precision assessment will be used by the project depending on the nature of the analytical procedure. These methods are relative percent difference and standard deviation of the percent difference of the control measurements.

In the case of replicate measurements, precision assessments will be based on a relative percent difference (d_i) will be determined using equation D-4:

D-4 $$d_i = (X_i\text{-}Y_i) / [(X_i+Y_i)/2] \text{ x } 100$$

Where:

X_i= first concentration measurement

Y_i= second / replicate concentration measurement

The standard deviation of the percent difference (S_j) is calculated using equation D-5:

$$S_j = \sqrt{\frac{1}{n-1}\left[\sum_{i=1}^{n} d_i{}^2 - \frac{1}{n}\left(\sum_{i=1}^{n} d_i\right)^2\right]} \quad \textbf{D-5}$$

Where:

n is the number of precision checks conducted during the monitoring period
d_i is calculated using equation D-2 in the case of assessment of control standards
d_i is calculated using equation D-4 in the case of assessment of replicate measurements

D1.2 DATA VERIFICATION AND VAILIDATION REQUIREMENTS

Data verification refers to the process of evaluating the completeness, correctness, conformance and compliance of a specific data set against the method, procedural, or contractual specifications. The station operator will be responsible for ensuring that:

- Quality control procedures meet acceptance criteria;
- Corrective actions are documented and their effectiveness verified;
- Station log books are kept current and accurately record significant station events; and
- Method specific screening and data validation criteria are applied.

Data validation refers to a systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation is intended to confirm the degree of truth in an analytical sense.

In the data validation process, the project manager or their designee will be responsible for confirming that:

- The instruments were operated and calibrated in accordance with the manufacturers' specifications;
- The calibrations and quality control checks document that the frequency and procedural requirements defined in this QAPP were met;
- Project data completeness, precision, and accuracy goals were met; and
- The project met the specified data quality objectives as defined in this QAPP.

D2 VALIDATION AND VERIFICATION METHODS

For the data to be considered valid, the following conditions must be satisfied:

- The instruments must each be operated and calibrated according to applicable standard operating procedure.
- Calibration records must demonstrate measurements were within acceptable criteria.
- Site visit and calibration documentation supports the validity of the data.

If any of the above are not satisfied, but alternate scientifically reasonable and compelling evidence exists that demonstrates that the data is defensible, the rationale for accepting the data will be explained in the annual data report and presented to regulators and data users for their concurrence.

D2.1 GRAPHICAL DATA REVIEW

Microsoft Excel® or SLR's data management system will be used to calculate data completeness; minimum, maximum and average values; or other statistical assessments. This analysis is intended to identify outliers and anomalies in the data set which point to instruments operating outside of specification. Instrument diagnostic information, when available, is also graphed and compared against manufacturer operating limits.

D2.2 STATION DOCUMENTATION

Station site visit/corrective action records, calibration records, and the data record itself are reviewed to assess the completeness of the measurement documentation. Site visit forms provide an indication of the scheduled and non-scheduled activities that took place during the monitoring project while calibration and laboratory quality control records demonstrate the outcomes of qualitative project assessments. These records should clearly demonstrate that the project quality control and quality assurance measures were met.

Table D-1 summarizes the data review processes and frequencies for the project.

Table D-1: Data Review, Verification, and Validation Schedule

Process	Method	Responsible Person	Frequency
Review	Data Review	Station Operator	Upon receipt of lab data package
Verification	Data Review, Records Review	Project Manager and Station Operator	Upon receipt of lab data package
Validation	Station and Laboratory Documentation	Project Manager and Data Manager	Prior to quarterly report writing

D3 RECONCILIATION WITH USER REQUIREMENTS

The primary objective of the $PM_{2.5}$ Speciation Monitoring Program is to collect $PM_{2.5}$ chemical speciation data and comply with post construction monitoring requirements specified in permit number R10OCS/PSD-AK-09-01 (Noble Discoverer Drillship - Chukchi Sea Exploration Drilling Program) and R10OCS/PSD-AK-2010-01 (Noble Discoverer Drillship - Beaufort Sea Exploration Drilling Program). SLR will conduct an annual or final review at the completion of the monitoring project and report the results obtained during the reporting period. These reports will be compared with the established MQOs to ensure that the scope of the project has been met.

The reconciliation of data for this project will be determined by the data validation and verification process as discussed in Section D2 of this document and based upon *The Five Steps of Statistical DQA* recommended in the *Data Quality Assessment: A Reviewer's Guide* (EPA QA/G-9R):

- A review of the MQOs and sampling design will be conducted to assure data outputs from this program are still applicable. If MQOs have not been developed, MQOs will be specified before evaluating the data. A review will also be conducted of the sampling design and data collection documentation for consistency with the MQOs.
- A review of preliminary data, QA reports, basic statistics calculations, and generated graphs will be used to determine data structure and identify patterns, relationships, or potential anomalies.
- A statistical test will be selected that is most appropriate for summarizing and analyzing the data, based on the review of the MQOs, the sampling design, and the preliminary data review. Key underlying assumptions that must hold for the statistical procedures to be valid will also be identified.
- The actual data and other information about the study will be used to evaluate whether identified assumptions will hold, or whether departures are acceptable.
- Conclusions from the statistical calculations will be evaluated to determine if the monitoring design and its created data meet the required permits for the statistical test. This determination will be documented, as well as inferences drawn, as a result of these calculations. If the design is to be used again, an evaluation will be made on the performance of the sampling design.

If the preliminary data review reveals that data sets are inconsistent with the MQOs, or the underlying assumptions of the statistical test are not supported by the data and fail to meet the criteria and objectives of this monitoring project, then the project design will be reconsidered as described in this QAPP. All final decisions on data limitations will be made by EPA.

APPENDIX A
TERMS, DEFINITIONS, ABBREVIATIONS

List of Acronyms

AAAQS	Alaska Ambient Air Quality Standards
ADEC	Alaska Department of Environmental Conservation
ANWR	Arctic National Wildlife Refuge
CAR	Corrective Action Report
CLN	Chester LabNet
CFR	*Code of Federal Regulations*
DAS	data acquisition system
DQO	Data Quality Objectives
EC	Elemental Carbon
EPA	Environmental Protection Agency
FEM	federal equivalent method
FRM	federal reference method
FTS	Flow Transfer Standard
IC	Ion Chromatography
IMPROVE	Interagency Monitoring of Protected Visual Environments
LDL	lower detectable limit
MFC	mass flow control
MQOs	measurement quality objectives
NAAQS	National Ambient Air Quality Standards
NIST	National Institute of Standards and Technology
OC	Organic Carbon
$PM_{2.5}$	particulate matter (with aerodynamic diameter less than 2.5 µm)
PSD	Prevention of Significant Deterioration
ppb	part per billion
ppm	part per million
QA	Quality Assurance
QC	Quality Control
QAPP	Quality Assurance Project Plan
SASS	Spiral Aerosol Speciation Sampler (SASS™)
SLAMS	state and local air monitoring stations
SLR	SLR International Corp
SOI	Shell Offshore, Inc.
SOP	standard operating procedure
TOR	Thermal Optical Reflectance
TOT	Thermal Optical Transmittance
XRF	X-ray Fluorescence

Glossary

Acceptance Criteria – Specified limits placed on characteristics of an item, process, or service defined in the design, codes, standards, or other requirement documents.

Accuracy – A measure of the overall agreement of a measurement to a known value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations; EPA recommends using the terms *"precision"* and *"bias,"* rather than "accuracy," to convey the information usually associated with accuracy.

Activity – An all-inclusive term describing a specific set of operations or related tasks to be performed, either serially or in parallel that, in total, result in a product or service.

Assessment – The act of reviewing, inspecting, testing, checking, conducting surveillances, auditing, or otherwise determining and documenting whether items, processes, or services meet specified requirements. Assessments are performed by or for senior management.

Audit – A planned and documented activity performed in accordance with procedures to determine by investigation, examination, or evaluation of objective evidence the extent to which applicable elements of a QA division have been developed and documented in accordance with specified requirements. An audit also checks the adequacy of and compliance with established procedures, instructions, drawings, and other applicable documents; and the effectiveness of the QA division's implementation. Audits can be internal examinations of divisions or activities under an organization's control and within its organizational structure, or external examinations of divisions or activities of another organization.

Background – The condition of an environmental medium (or stratum within such medium) that is not impacted by contaminants derived from site-related activities. The range of background levels for each parameter can be defined statistically through the calculation of tolerance limits.

Bias – The systematic or persistent distortion of a measurement process that causes errors in one direction (i.e., the expected sample measurement is different from the sample's true value).

Blank – An artificial sample designed to monitor the introduction of artifacts into the process.

Certificate of Conformance – A document signed or otherwise authenticated by an authorized individual certifying the degree to which items or services meet specified requirements.

Certification The act of determining, verifying, and attesting in writing to the qualifications of personnel, processes, procedures, or items in accordance with specified requirements.

Chain-of-custody – An unbroken record of the trail of accountability ensuring the physical security of samples, data, or records.

Characteristic – Any property or attribute of a datum, item, process, or service that is distinct, describable, and measurable.

Collocated samples – Two or more portions collected at the same point in time and space so as to be considered identical. These samples are also known as field replicates and should be identified as such.

Comparability – A measure of the confidence with which one data set or method can be compared to another.

Completeness – A measure of the amount of valid data obtained from a measurement system.

Conformance – An affirmative indication or judgment that a product or service satisfies the relevant specification, contract, or regulation.

Corrective Action – Measures taken to rectify conditions adverse to quality and, where necessary, to preclude recurrence.

Data – Information acquired from literature reviews, testing, analyses, measurement, inspection, or observation that relate to engineering or scientific matters.

Data Accuracy – A measure of the degree of agreement of a measurement (or an average of measurements), X, with an accepted reference or true value, T. Accuracy is a measure of the bias in a system. Accuracy is assessed by means of reference samples and percent recoveries.

Data Comparability – A measure of the confidence with which one data set can be compared to another.

Data Completeness – A measure of the amount of valid data obtained from a measurement system compared to the amount that was planned or that was expected to be obtained under correct normal corrections.

Data Precision – The measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision in most desirably expressed in terms of the standard deviation. Various measures of precision exist depending upon the "prescribed similar conditions," the measurement of agreement of a set of replicate results among themselves without assumption of any prior information as the true result. Precision is assessed by means of duplicate/replicate sample analysis.

Data Quality – The totality of features and characteristics of data that bear on its ability to satisfy a given purpose. The characteristics of major importance are legibility, accuracy, precision, completeness, representativeness, and comparability.

Data Quality Assessment (DQA) – A statistical and scientific evaluation of a data set used to determine the validity and performance of the data collection design and statistical test, and to determine the adequacy of the data set for its intended use.

Data quality indicators – The quantitative statistics and qualitative descriptors used to interpret the degree of acceptability or utility of data to the user. The principal data quality indicators are bias, precision, accuracy (bias is preferred), comparability, completeness, representativeness, and sensitivity.

Data Quality Objectives (DQOs) – A statement of the precise data, the manner in which such data may be combined, and the acceptable uncertainty in those data in order to resolve an environmental problem or condition. This may also include the criteria or specifications needed to design a study that resolves the question or decision addressed by the DQO process.

Data Reduction – Any and all processes which change either the form of expression or quantity of data values or numbers of data items.

Data Representativeness – The measure of the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition.

Data Validation – A systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation is intended to confirm the degree of truth in an analytical.

Data verification – The process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual specifications.

De minimis – A Latin expression meaning *about minimal things*, in risk assessment it refers to a level of risk that is too small to be concerned with. Some refer to this as a "virtually safe" level.

Design – Specifications, drawings, design criteria, and performance requirements. Also the result of deliberate planning, analysis, mathematical manipulations, and design processes.

Design Change – Any revision or alteration of the technical requirements defined by approved and issued design output documents, and approved and issued changes thereto.

Design Input – Those criteria, parameters, bases, or other design requirements upon which detailed final design is based.

Design Output – Drawings, specifications, and other documents used to define technical requirements of structures, systems, components, and computer divisions.

Design Process – Technical and management processes that commence with identification of design input, and that lead to and include the issuance of design output documents.

Detection limit – A measure of the capability of an analytical method to distinguish samples that do not contain a specific analyte from samples that contain low concentrations of the analyte; the lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated level of probability.

Deviation – A departure from the specified requirements.

Document – Any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures, or results.

Document control – The policies and procedures used by an organization to ensure that its documents and their revisions are proposed, reviewed, approved for release, inventoried, distributed, archived, stored, and retrieved in accordance with the organization’s specifications.

Environmental Conditions – The description of a physical medium (e.g., air, water, soil, sediment) or biological system expressed in terms of its physical, chemical, radiological, or biological characteristics.

Environmental Data – Any measurements or information that describe environmental processes, locations, or conditions; ecological or health effects and consequences; or the performance of environmental technology. For EPA, environmental data include information collected directly from measurements, produced from models, and compiled from other sources such as databases or the literature.

Environmental monitoring – The process of measuring or collecting environmental data.

External Audit – An audit of those portions of another organization's QA division not under the direct control or within the organizational structure of the auditing organization.

Feasibility Study – The step in the CERCLA process in which alternatives for a remedial action system are investigated and screened.

Federal Equivalent Method (FEM) – A method of sampling and analyzing the ambient air for an air pollutant that has been designated as an equivalent method in accordance with 40 CFR part 53.

Federal Reference Method (FRM) – A method of sampling and analyzing the ambient air for an air pollutant that is specified as a reference method in an appendix to 40 CFR part 50 or 40 CFR part 53.

Field blank – A clean analyte-free sample which is carried to the sampling site and then exposed to sampling conditions, returned to the laboratory, and treated as an environmental sample. This blank is used to provide information about contaminants that may be introduced during sample collection, storage, and transport.

Finding – A statement of fact relating to compliance or noncompliance with previously agreed upon codes, standards, specifications or other forms of contractual or legal obligation.

Guidance – A suggested practice that is not mandatory, intended as an aid or example in complying with a standard or specification.

Holding time – The period of time a sample may be stored before analysis. While exceeding the holding time does not necessarily negate the veracity of analytical results, it causes the qualifying or "flagging" of any data not meeting all of the specified acceptance criteria.

Independent assessment – An assessment performed by a qualified individual, group, or organization that is not a part of the organization directly performing and accountable for the work being assessed.

Inspection – The examination or measurement of an item or activity to verify conformance to specifications.

Measurement quality objectives (MQOs) – The individual performance or acceptance goals for the individual Data Quality Indicators such as precision or bias.

Method – A body of procedures and techniques for performing an activity (for example, sampling, chemical analysis, quantification), systematically presented in the order in which they are to be executed.

Method blank – A blank prepared to represent the sample matrix as closely as possible and analyzed exactly like the calibration standards, samples, and quality control (QC) samples. Results of method blanks provide an estimate of the within-batch variability of the blank response and an indication of bias introduced by the analytical procedure.

Nonconformance – A deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate.

Observation – A conclusion that presents the results of a generally subjective evaluation of implementation practices or management systems related to the area under review.

Outlier – An extreme observation that is shown to have a low probability of belonging to a specified data population.

Parameter – A quantity, usually unknown, such as a mean or a standard deviation characterizing a population. Commonly misused for “variable,” “characteristic,” or “property.”

Performance criteria – Address the adequacy of information that is to be collected for the project. These criteria often apply to new data collected for a specific use (“primary” data).

Precision – A measure of agreement among repeated measurements of the same property under identical, of substantially similar, conditions; expressed generally in terms of the standard deviation.

Procedure – A document that specifies or describes how an activity is to be performed.

Process – A series of actions that achieves an end or result.

Proficiency test – A type of assessment in which a sample, the composition of which is unknown to the analyst, is provided to test whether the analyst/laboratory can produce analytical results within the specified acceptance criteria.

Quality – The degree to which an item or process meets or exceeds the user's requirements and expectations.

Quality Assurance (QA) – An integrated system of management activities involving planning, implementing, assessing, reporting, and improving quality to ensure that a process, item, or service is of the type and quality needed and expected by the customer.

Quality Assurance Project Plan (QAPP) – A formal document describing in comprehensive detail the necessary quality assurance procedures, quality control activities, and other technical activities that need to be implemented to ensure that the results of the work performed will satisfy the stated performance or acceptance criteria.

Quality Control (QC) – The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer.

Readiness review – A systematic, documented review of the readiness for the start-up or continued use of a facility, process, or activity. Readiness reviews are typically conducted before proceeding beyond project milestones and before initiation of a major phase of work.

Record – A completed document that provides objective evidence of an item or process. Records may include photographs, drawings, magnetic tape, and other data recording media.

Representativeness – The measure of the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

Self-assessment – The assessments of work conducted by individuals, groups, or organizations directly responsible for overseeing and/or performing the work.

Sensitivity – The capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest.

Sample – A representative portion of any material (aqueous, nonaqueous, or multimedia) collected from any source for which determination of composition or contamination is requested or required.

Service – The performance of work, such as lab analyses, design, fabrication, inspection, nondestructive examination, repair, or installation.

Software – Computer divisions, procedures, rules, and associated documentation and data pertaining to the operation of a computer system.

Software Validation – A process that demonstrates that a mathematical model as embodied in computer software is an acceptable representation of the process of system for which it is intended. The test and evaluation of the completed software is conducted to ensure compliance with software requirements.

Specification – jA document stating requirements and that refers to or includes drawings or other relevant documents. Specifications should indicate the means and the criteria for determining conformance.

Standard Operating Procedure (SOP) – A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and that is officially approved as the method for performing certain routine or repetitive tasks.

Supplier – Any individual or organization that furnishes items or services in accordance with a procurement document. This is an all-inclusive term used in place of any of the following: vendor, seller, contractor, subcontractor, fabricator, consultant, and their sub-tier levels.

Surveillance – The act of monitoring or observing to verify whether an item or activity conforms to specified requirements. Observations or monitoring to determine the acceptability of items or activities are inspections rather than surveillances.

Technical Systems Audit (TSA) – A thorough, systematic, on-site qualitative audit of facilities, equipment, personnel, training, procedures, record keeping, data validation, data management, and reporting aspects of a system.

Validation – An analyte- and sample-specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set.

Verification – The process of evaluating the completeness, correctness, and conformance / compliance of a specific data set against the method, procedural, or contractual specifications.

APPENDIX B
PROGRAM REFERENCES AND CITATIONS

18 AAC 50, Air Quality Control, Alaska Department of Environmental Conservation, As Amended through April, 2011. Juneau, AK.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, Washington 98101-3140

OUTER CONTINENTAL SHELF
PREVENTION OF SIGNIFICANT DETERIORATION
PERMIT TO CONSTRUCT

Permit Number: R10OCS/PSD-AK-2010-01 Issuance Date: September 19, 2011

In accordance with the provisions of Clean Air Act (CAA) Section 328 and Code of Federal Regulations (CFR) Title 40, Part 55, and the provisions of Part C to Title I of the CAA and 40 CFR § 52.21,

Shell Offshore Inc.
3601 C Street, Suite 1000
Anchorage, AK 99503

is authorized to construct and operate the Noble Discoverer (Discoverer) drillship and its air emission units and to conduct other air pollutant emitting activities in accordance with the permit conditions listed in this permit, and only at the following lease blocks from the Beaufort Sea lease sales 195 and 202:

BF 195:	6657	6658	6659	6707	6708	6709	6712	6713	6751	6752	6757	6758	6764	6773	6774	6801
	6802	6814	6815	6822	6823	6824	6851	6873	6874							
BF 202:	6259	6308	6309	6310	6359	6406	6407	6409	6410	6457	6459	6460	6461	6508	6510	6511
	6512	6558	6559	6560	6561	6562	6609	6610	6611	6612	6660	6662				

Terms not otherwise defined in this permit have the meaning assigned to them in the referenced statutes and regulations. All terms and conditions of the permit are enforceable by the United States Environmental Protection Agency (EPA) and citizens under the CAA.

_____/S/_____ ___09/19/2011_____
Richard Albright Date
Director, Office of Air, Waste and Toxics

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ABBREVIATIONS AND ACRONYMS

AAC .....Alaska Administrative Code
BACT. .....Best Available Control Technology
CAA .....Clean Air Act
CDPF.....Catalyzed Diesel Particulate Filter
CFR. .....Code of Federal Regulations
CGA. .....Cylinder Gas Audit
COA .....Corresponding Onshore Area
CTM.....Conditional Test Method
CMS .....Continuous Monitoring Systems
EPA .....United States Environmental Protection Agency
HPU.....Hydraulic Power Unit
MLC.....Mud Line Cellar
NA.....Not applicable
OCS.....Outer Continental Shelf
OTM.....Other Test Method
PDF .....Portable Document Format
PSD .....Prevention of Significant Deterioration
QA.....Quality Assurance
QC .....Quality Control
SCR.....Selective Catalytic Reduction
USCG.....United States Coast Guard

UNITS AND MEASUREMENTS

Btu.....British thermal units
^{o}C.....degree Celsius
dscf.....dry standard cubic foot
^{o}F .....degree Fahrenheit
g.....grams
hp.....brake horsepower
hr .....hour
kW.....kiloWatts (mechanical)
kWe.....kiloWatts electrical
lb .....pounds
MMBtu/hr .....Million British thermal units per hour
ppm .....parts per million
ppmv .....parts per million by volume
scf.....standard cubic foot
tpy .....tons per year

POLLUTANTS

CO .....Carbon Monoxide
CO_2e.....Carbon Dioxide Equivalent
GHG or GHGs .....Greenhouse Gas or Greenhouse Gases
NH_3 .....Ammonia
NMHC.....Non-Methane Hydrocarbons
NO_X.....Oxides of Nitrogen
NO_2 .....Nitrogen Dioxide
PM.....Particulate Matter
$PM_{2.5}$ .....Particulate Matter with an Aerodynamic Diameter less than 2.5 microns
PM_{10} .....Particulate Matter with an Aerodynamic Diameter less than 10 microns
SO_2 .....Sulfur Dioxide
VOC .....Volatile Organic Compound

AUTHORITY

The United States Environmental Protection Agency (EPA) is issuing this outer continental shelf (OCS)/prevention of significant deterioration (PSD) permit pursuant to Section 328 of the CAA, 42 U.S.C. § 7627, and the implementing OCS regulations at 40 CFR Part 55, and pursuant to Part C to Title I of the CAA, 42 U.S.C §§ 7470 to 7492, and the implementing PSD air quality regulations at 40 CFR § 52.21. This action is based upon the application submitted by Shell Offshore Inc. (Shell or permittee) on January 18, 2010, supplemental submittals identified in the administrative record for this permit action, and upon the technical analysis performed by the EPA.

In addition the EPA is issuing this OCS/PSD permit consistent with Article 3 of the State of Alaska Air Quality Control Regulations 18 Alaska Administrative Code (AAC) 50.302 (Construction Permits), and 18 AAC 50.306 (Prevention of Significant Deterioration Permits), the applicable provisions of which have been incorporated into 40 CFR Part 55 Appendix A.

FINDINGS

On the basis of the information in the administrative record, the EPA has determined that:

1. The permittee will meet all of the applicable requirements of the 40 CFR Part 55.
2. The permittee will meet all of the applicable requirements of the 40 CFR § 52.21.
3. The permittee will meet all of the applicable requirements of 18 AAC 50.

APPROVAL CONDITIONS

Shell is authorized to construct and operate the vessels and emission units listed in Tables 1 through 6, at any of the lease blocks identified on Page 1 of this permit, and consistent with the representations in the permit application and subject to the conditions in this permit.

Coast Guard Safety Zone. The permit does not authorize operation unless:

a. The Discoverer is subject to a currently effective safety zone established by the United Sates Coast Guard (USCG) which encompasses an area within at least 500 meters from the center point of the Discoverer and which prohibits members of the public from entering this area except for attending vessels or vessels authorized by the USGC (such area shall be referred to as the “Safety Zone”); and

b. Shell has developed in writing and is implementing a public access control program to:

   - locate, identify, and intercept the general public by radio, physical contact, or other reasonable measures to inform the public that they are prohibited by Coast Guard regulations from entering the Safety Zone; and
   - communicate to the North Slope communities on a periodic basis when exploration activities are expected to begin and end at a drill site, the location of the drill site, and any restrictions on activities in the vicinity of Shell’s exploration operations.

Table:1 – Noble Discoverer Emission Units

ID	Description	Make and Model	Rating[a]
FD-1 – 6	Generator Engines	Caterpillar D399 SCAC 1200 rpm	1,325 hp
FD-7	Propulsion Engine	Mitsubishi 6UEC65	7,200 hp
FD-8	Emergency Generator Seldom Used Sources	Caterpillar 3412 Various	639 hp Various[b]
FD-9 – 11	MLC Compressor Engines	Caterpillar C-15	540 hp
FD-12 – 13	HPU Engines	To be determined	250 hp
FD-14	Port Deck Crane Engine	Caterpillar D343	365 hp
FD-15	Starboard Deck Crane Engine	Caterpillar D343	365 hp
FD-16 – 17	Cementing Unit Engines	Detroit 8V-71N	335 hp
FD-18	Cementing Unit Engine	GM 3-71	147 hp
FD-19	Logging Winch Engine	Caterpillar C7	250 hp
FD-20	Logging Winch Engine	John Deere PE4020TF270D	35 hp
FD-21 – 22	Heat Boilers	Clayton 200	7.97 MMBtu/hr
FD-23	Incinerator	TeamTec GS500C	276 lb/hr
FD-24 -30	Fuel Tanks	Not applicable (NA)	Various
FD-31	Supply Ship Generator Engine(s)[c]	Generic	584 hp
FD-32	Drilling Mud System	NA	NA
FD-33	Shallow Gas Diverter System[d]	NA	NA
FD-34	Cuttings/Mud Disposal Barge[e]	NA	NA

[a] Permit conditions may limit operation to less than rated capacity.
[b] See Condition E.3 for the Discoverer Emergency Generator and Seldom Used Sources (Unit FD-8) aggregate fuel use limit.
[c] Only when attached to the Discoverer.
[d] Permit conditions prohibit the shallow gas diverter system from emitting any air pollutants.
[e] Permit conditions prohibit fuel combustion sources from being operated on the cuttings/mud disposal barge.

Table:2 – Icebreaker #1

Description	Make and Model	Maximum Aggregate Rating[a]
Aggregate of Propulsion Engines and Generator Engines	Various	31,200 hp
Generator Engine(s)	Various	2,800 hp
Heat Boiler(s)	Various	10 MMBtu/hr
Incinerator	Various	154 lbs/hr
Seldom Used Sources	Various	Various[b]

[a] Permit conditions may limit operation to less than rated capacity.
[b] See Condition O.9.3 for the Icebreaker #1 Seldom Used Sources aggregate fuel use limit.

Table:3 – Icebreaker #2

ID	Description	Make and Model	Rating[a]
Tor Viking			
TV-1 - 2	Main Propulsion Engines	Caterpillar MaK 8M32	5,046 hp
TV-3 - 4	Main Propulsion Engines	Caterpillar MaK 6M32	3,784 hp
TV-5 – 6	Non-propulsion Generator Engines	Caterpillar 3412	1,168 hp
TV-7	Heat Boiler	NA	1.37 MMBtu/hr
TV-8	Incinerator	NA	151 lb/hr
	Seldom Used Sources	Various	Various[b]
Hull 247[c]			
	Main Engines	NA	24 MW[d]
	Heat Boiler	NA	4 MMBtu/hr
	Incinerator	NA	151 lb/hr
	Seldom Used Sources	Various	Various[b]

[a] Permit conditions may limit operation to less than rated capacity.

[b] See Condition P.9.5 for the Icebreaker #2 Seldom Used Sources aggregate fuel use limit.

[c] Hull 247 is the shipbuilder's (Edison Chouest) designation for a vessel to be built under contract to Shell. The final name for the vessel may be different than this temporary designation.

[d] This represents an aggregate rating of all engines on board Hull 247.

Table:4 – Supply Ship/Barge and Tug

Description	Make and Model	Maximum Aggregate Rating[a]
Propulsion Engines and Non-Propulsion Generator Engine(s) Excluding Emergency Engine	Various	Various[b]
Emergency Engine(s)	Various	Various

[a] Permit conditions may limit operation to less than rated capacity.

[b] See Condition Q.1 for the Supply Ship/barge and Tug aggregate fuel limit.

Table:5 – Oil Spill Response Fleet

ID	Description	Make and Model	Rating[a]
Offshore Management Ship - Point Class Tug			
PBT-1 – 2	Propulsion Engines	Caterpillar 3512	1050 hp
PBT-3 – 4	Non-propulsion Generator Engines	Caterpillar 3304	150 hp
	Seldom Used Sources	Various	Various [b]
Skimmer - Arctic Endeavor Barge			
AEB-1 –4	Non-propulsion Generator Engines	Various	556 hp
Oil Spill Response Ship – Nanuq			
N-1 - 2	Propulsion Engines	Caterpillar 3608	2,710 kW
N-3 – 4	Non-propulsion Electrical Generators	Caterpillar 3508	1,285 hp
N-5	Emergency Generator	John Deere	166 kW
N-6	Incinerator	ASC/CP100	125 lbs/hr
	Seldom Used Sources	Various	Various [b]
Oil Spill Response Work Boat - Kvichak 34-foot No. 1			
K-1 – 2	Propulsion Engines	Cummins QSB	300 hp
K-3	Generator Engines	Various	12 hp
Oil Spill Response Work Boat - Kvichak 34-foot No. 2			
K-4 – 5	Propulsion Engines	Cummins QSB	300 hp
K-6	Generator Engines	Various	12 hp
Oil Spill Response Work Boat - Kvichak 34-foot No. 3			
K-7 – 8	Propulsion Engines	Cummins QSB	300 hp
K-9	Generator Engines	Various	12 hp
Oil Spill Response Skimmer - Rozema 47-foot			
R-1 –2	Propulsion Engines	Various	700 hp
R-3	Generator Engines	N/A	9 hp

[a] Permit conditions may limit operation to less than rated capacity.
[b] See Condition R.5 for the Nanuq and Point Class Tug Seldom Used Sources aggregate fuel use limit.

Table:6 – Cuttings/Muds Disposal Barge and Tug

ID	Description	Make and Model	Rating
Cuttings/Mud Disposal Barge[a]			
	Non-propulsion Engine(s)	Not Specified	Not Specified
Tug			
	Propulsion Engine(s)	Not Specified	Not Specified
	Non-propulsion Engine(s)	Not Specified	Not Specified

[a] The barge itself has no air quality implications since it has no generators or other fuel-burning equipment.

Effective Date. This permit becomes effective 30 days after the service of notice of the final permit decision, unless review of the permit decision is requested pursuant to 40 CFR § 124.19.

OCS Source. Permit conditions contained in Sections B through R, except for those conditions addressing notification, reporting, and testing, apply only during the time that the Discoverer drillship is an OCS Source. Permit conditions in Sections A and S as well as permit conditions contained in Sections B through R addressing notification, reporting, and testing apply at all times as specified.

For the purpose of this permit:

a. The Discoverer is an "OCS Source" at any time the Discoverer is attached to the seabed at a drill site by at least one anchor; and

b. A drill site is any location at which Shell is authorized to operate under this permit and for which Shell has received from the Bureau of Ocean, Energy, Management and Regulatory Enforcement (BOEMRE) an authorization to drill.

Lease Identification. This major source permit authorizes the mobilization and operation of the Discoverer drillship and its associated fleet at various drill sites in the Beaufort Sea OCS off the North Slope of Alaska in connection with an exploratory oil and gas drilling program (exploration drilling program). The proposed permit will allow Shell to operate the Discoverer drillship and associated fleet for a multi-year exploration drilling program within Shell's current lease blocks in lease sales 195 and 202 on the Beaufort Sea OCS. The group of lease blocks authorized under this permit is located within 25 miles and beyond 25 miles from Alaska's seaward boundary. In some instances, lease blocks are both within and beyond 25 miles from Alaska's seaward boundary. For purpose of the Statement of Basis and the proposed permit, the portion of the OCS which is 25 miles or more miles from the State's seaward boundary is referred to as the "Outer OCS". The portion of the OCS that is within 25 miles of the State's seaward boundary is referred to as the "Inner OCS".

The leases can be divided into the three following groups:

- Lease blocks entirely outside 25 miles of Alaska's seaward boundary – 6529, 6308, 6309, 6310, 6359, and 6410.
- Lease blocks with portions both inside and outside 25 miles of Alaska's seaward boundary – 6406, 6407, 6409, 6459, 6460, 6461, and 6512.
- Lease blocks entirely within 25 miles of Alaska's seaward boundary – 6457, 6508, 6510, 6511, 6558, 6559, 6560, 6561, 6562, 6609, 6610, 6611, 6612, 6657, 6658, 6659, 6660, 6662, 6707, 6708, 6709, 6712, 6713, 6757, 6758, 6764, 6814, 6815, 6773, 6774, 6751, 6752, 6822, 6823, 6824, 6801, 6802, 6873, 6874, and 6851.

When the Discoverer drillship and/or its associated fleet is within the Beaufort Sea Inner OCS, the applicable corresponding onshore area (COA) regulations apply. The provisions in this permit that apply only to operations within 25 miles of the state seaward boundary are identified as "COA Regulations". A reference to any AAC provisions in this permit refers to the ACC provisions incorporated into 40 CFR Part 55 (76 Fed. Reg. 37274, June 27, 2011).

COA REGULATIONS: PERMIT DOCUMENTATION

Date	Document Details
January 18, 2010	Shell Offshore Inc. Outer Continental Shelf Pre-Construction Air Permit Application – Noble Discoverer Beaufort Sea Exploration Drilling Program
June 10, 2011	Supplemental Permit Application Materials
June 22, 2011	Shell Alaska Exploratory Drilling Program Air Quality Permit Application Air Quality Modeling Files for Analysis of Anchor Handler Operations During open Water Conditions
June 23, 2011	Greenhouse Gas Calculation Information

A. GENERALLY APPLICABLE REQUIREMENTS

1. **Construction and Operation.** The permittee shall construct and operate the OCS Source and the Associated Fleet in accordance with the application and supporting materials submitted by the permittee as identified in the Statement of Basis and Supplemental Statement of Basis for this permit action and in accordance with this permit. For purposes of this permit, Icebreaker #1, Icebreaker #2, the Supply Ship/Tug and Barge, the Point Class Tug, Arctic Endeavor Barge, Nanuq, Kvichaks Nos. 1-3, Rozema Skimmer, and Cuttings/Mud Disposal Barge and Tug shall collectively be referred to as the "Associated Fleet."

2. **Overlapping Requirements.** When two or more provisions apply to the same emission unit or activity the permittee must comply with both.

3. **Compliance Required.** The permittee shall comply with all applicable requirements of 40 CFR § 52.21, Part 55, 18 AAC 50, and this permit. Failure to do so shall be considered a violation of Sections 111(e) and 165 of the CAA. All enforcement provisions of the CAA, including but not limited to Sections 113, 114, 120, 167, 303, and 304, apply to the permittee.

4. **Compliance with Other Requirements.** This permit does not relieve the permittee of the responsibility to comply fully with applicable provisions of any other requirements under federal law.

5. **Terms to Make Permit Enforceable.** It is not a defense in an enforcement action to claim that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with a permit term or condition.

6. **Notification to Owners, Operators, and Contractors.** The permittee must notify all other owners or operators, contractors, and the subsequent owners or operators associated with emissions from the source of the conditions of this permit.

7. **Expiration of Approval to Construct.** As provided in 40 CFR § 52.21(f)(4), this approval shall become invalid if construction is not commenced within 18 months after the effective date of this permit, construction is discontinued for a period of 18 months, or construction is not completed within a reasonable time. The EPA may extend the 18-month period upon a satisfactory showing that an extension is justified.

8. **Permit Revision, Termination and, Reissuance.** This permit may be revised, terminated, or revoked and reissued by the EPA for cause. Cause exists to revise, terminate, or revoke and reissue this permit under the following circumstances:

   8.1. This permit contains a material mistake;

   8.2. Materially inaccurate statements were made in establishing the terms or conditions of this permit;

8.3. The permittee fails to comply with any material condition of this permit; or

8.4. This permit must be revised, terminated, or revoked and reissued to assure compliance with CAA requirements.

A request by the permittee for modification, revocation, and reissuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any permit condition.

9. **Credible Evidence.** For the purpose of establishing whether or not the permittee has violated or is in violation of any requirement of this permit, nothing in this permit shall preclude the use, including the exclusive use, of any credible evidence or information relevant to whether the permittee would have been in compliance with applicable requirements if the appropriate performance or reference test or procedure had been performed.

10. **Inspection and Entry.** Upon presentation of credentials and other documents as may be required by law, the permittee shall allow the EPA or an authorized representative to perform the following:

10.1. Enter upon the Discoverer, or any support vessel, in any location where emissions-related activity is conducted, or any location where records must be kept under the conditions of the permit;

10.2. Have access to and copy, at reasonable times, any records that must be kept under the conditions of the permit;

10.3. Inspect at reasonable times any facilities, equipment (including monitoring and air pollution control equipment), practices, or operations regulated or required under the permit; and

10.4. As authorized by the CAA, sample or monitor at reasonable times substances or parameters for the purpose of assuring compliance with the permit or applicable requirements.

11. **Recordkeeping Requirements**. In addition to the specific recordkeeping requirements contained in the source-wide and emission unit sections of this permit, the permittee shall keep records of required monitoring information that include the following:

11.1. The date, place, and time of sampling or measurements;

11.2. The date(s) analyses were performed;

11.3. The company or entity that performed the analyses;

11.4. The analytical techniques or methods used;

11.5. The results of such analyses;

11.6. The operating conditions as existing at the time of sampling or measurement;

11.7. Copies of all reports and certifications submitted pursuant to this permit; and

11.8. The location where samples were taken.

The permittee shall retain records of all required monitoring data and support information for a period of at least 5 years from the date of the monitoring sample, measurement, report, or application. Support information includes all calibration and maintenance records, all original strip-chart recordings for continuous monitoring instrumentation, and copies of all reports required by this permit.

12. **Agency Notifications.** Unless otherwise specified in this permit, any documents required to be submitted under this permit, including reports, test data, monitoring data, notifications, and applications for renewals and permit modifications shall be submitted to:

    OCS/PSD Air Quality Permits

    U.S. EPA - Region 10, AWT-107

    1200 Sixth Avenue, Suite 900

    Seattle, WA 98101

    Facsimile no. 206-553-0110

    Email: R10OCSAirPermits_Reports@epa.gov

13. **Certification.** Any document required to be submitted under this permit shall be certified by a responsible official, as that term is defined in 40 CFR § 71.2, of the permittee as to truth, accuracy, and completeness. Such certification shall state that based on information and belief formed after reasonable inquiry, the statements and information in the document are true, accurate, and complete.

14. **Severability.** The provisions of this permit are severable, and in the event of any challenge to any portion of this permit, or if any portion is held invalid, the remaining permit conditions shall remain valid and in force.

15. **Property Rights.** This permit does not convey any property rights of any sort, or any exclusive privilege.

16. **Information Request.** The permittee shall furnish the EPA, within a reasonable time, any information the EPA requests in writing to determine whether cause exists to modify, revoke and reissue, or terminate the permit or to determine compliance with the permit. Upon request, the permittee shall furnish the EPA with copies of records required to be kept by the permit.

17. **Excess Emission and Permit Deviation Reports.** Except as otherwise provided in this permit, the permittee shall report via fax or email, all emissions or operations that exceed or deviate from the requirements of this permit as follows:

    17.1. As soon as possible after the event commences or is discovered, report:

    17.1.1. Emissions that present a potential threat to human health or safety; and

    17.1.2. Excess emissions that the permittee believes to be unavoidable.

    17.2. Within two working days after the event commenced or was discovered, report an unavoidable emergency, malfunction, or non-routine repair that causes emissions in excess of a technology based emission standard; or any exceedance of an emission limit; or any exceedance of a throughput limit.

17.3. Report all other excess emissions and permit deviations:

17.3.1. Within 30 days after the end of the month during which the emissions or deviation occurred;

17.3.2. If a continuous or recurring excess emissions is not corrected within 48 hours of discovery, within 72 hours of discovery; and

17.3.3. For failure to monitor, as required in other applicable conditions of this permit.

17.4. When reporting excess emissions or permit deviations, the permittee must report using the form contained in Attachment A to this permit. The permittee must provide all information called for by the form.

17.5. If requested by the EPA, the permittee shall provide a more detailed written report as requested to follow up on an excess emissions report.

18. **Operating Reports.** During the life of this permit[1], the permittee shall submit an original and two copies of an Operating Report by March 31 for the preceding calendar year.

18.1. The Operating Report must include all information required to be in Operating Reports by other conditions of this permit.

18.2. If excess emissions or permit deviations that occurred during the reporting period are not reported under Condition A.17, either:

18.2.1. The permittee shall identify:

18.2.1.1. The date of the deviation;

18.2.1.2. The equipment involved;

18.2.1.3. The permit condition affected;

18.2.1.4. A description of the excess emissions or permit deviation; and

18.2.1.5. Any corrective action or preventive measures taken and the date or dates of such actions; or

18.2.2. When excess emissions or permit deviations have already been reported under Condition A.17, the permittee shall cite the date or dates of those reports.

[1] "Life of this permit" is defined as the permit effective date, including any periods of reporting obligations that extend beyond the permit effective date. For example if a permit expires prior to the end of a calendar year, there is still a reporting obligation to provide operating reports for the periods when the permit was in effect.

18.3. The Operating Report must include a listing of emissions monitored which trigger additional testing or monitoring, whether or not the emissions monitored exceed an emission standard. The permittee shall include in the report:

18.3.1. The date of the emissions;

18.3.2. The equipment involved;

18.3.3. The permit condition affected; and

18.3.4. The monitoring result which triggered the additional monitoring.

18.4. The Operating Report must include reports of any required monitoring, including all emission calculations required by the permit.

19. **COA Regulations: Administration Fees.** The permittee shall pay to the EPA all assessed permit administration fees. Administration fee rates are set out in 18 AAC 50.400 and 50.403.

20. **COA Regulations: Assessable Emissions.** The permittee shall pay to the EPA annual emission fees based on the OCS source's (including the Associated Fleet) assessable emissions as determined by the EPA under 18 AAC 50.410. The assessable emission fee rate is set out in 18 AAC 50.410. The EPA will assess fees per ton of each air pollutant that the OCS source emits or has the potential to emit in quantities greater than 10 tons per year (tpy). The quantity for which fees will be assessed is the lesser of:

20.1. The OCS source's (including the Associated Fleet) assessable potential to emit of 576 tpy; or

20.2. The OCS source's (including the Associated Fleet) projected annual rate of emissions that will occur from July 1 to the following June 30, based upon actual annual emissions emitted during the most recent calendar year or another 12 month period approved in writing by the EPA, when demonstrated by:

20.2.1. An enforceable test method described in 18 AAC 50.220;

20.2.2. Material balance calculations;

20.2.3. Emission factors from EPA's publication AP-42, Vol. I, adopted by reference in 18 AAC 50.035; or

20.2.4. Other methods and calculations approved by the EPA.

21. **COA Regulations: Assessable Emissions Estimates.** Emission fees will be assessed as follows:

21.1. No later than March 31 of each year, the permittee may submit an estimate of the OCS source's assessable emissions to the EPA at the address listed in Condition A.12, Agency Notification. The submittal must include all of the assumptions and calculations used to estimate the assessable emissions in sufficient detail so that the EPA can verify the estimates; or

21.2. If no estimate is received on or before March 31 of each year, emission fees for the next fiscal year will be based on the potential to emit set out in Condition A.20.1.

22. **COA Regulations: Annual Compliance Certification.** Each year by March 31 for the preceding calendar year and for reporting periods following the effective date of this permit, the permittee shall compile and submit to the EPA one original and one copy of an annual compliance certification report as follows.

    22.1. For each permit term and condition set forth in the permit including terms and conditions for monitoring, reporting, and recordkeeping:

        22.1.1. Certify the compliance status over the preceding calendar year consistent with the monitoring required by this permit;

        22.1.2. State whether compliance is intermittent or continuous;

        22.1.3. Briefly describe each method used to determine the compliance status; and

        22.1.4. Notarize the responsible official's signature.

23. **COA Regulations: General Source Test Requirements.**

    23.1. **Requested Source Tests.** In addition to any source testing explicitly required by this permit, the permittee shall conduct source testing as requested by the EPA to determine compliance with applicable permit requirements.

    23.2. **Operating Conditions.** Unless otherwise specified by an applicable requirement or test method, the permittee shall conduct source testing:

        23.2.1. At a point or points that characterize the actual discharge into the ambient air; and

        23.2.2. At the maximum rated burning or operating capacity of the source or another rate determined by the EPA to characterize the actual discharge into the ambient air.

    23.3. **Reference Test Methods.** The permittee shall use the following as reference test methods when conducting source testing for compliance with this permit.

        23.3.1. Source testing for compliance with requirements adopted by reference in 18 AAC 50.040(a) must be conducted in accordance with the methods and procedures specified in 40 CFR 60.

        23.3.2. Source testing for compliance with requirements adopted by reference in 18 AAC 50.040(b) must be conducted in accordance with the methods and procedures specified in 40 CFR 61.

        23.3.3. Source testing for compliance with requirements adopted by reference in 18 AAC 50.040(c) must be conducted in accordance with the source test methods and procedures specified in 40 CFR 63.

        23.3.4. Source testing for the reduction in visibility through the exhaust effluent must be conducted in accordance with the procedures set out in Reference Method 9. The permittee may use the form in Appendix B to record data.

23.3.5. Source testing for emissions of total particulate matter (PM), sulfur compounds, nitrogen compounds, carbon monoxide, lead, volatile organic compounds, fluorides, sulfuric acid mist, municipal waste combustor organics, metals, and acid gases must be conducted in accordance with the methods and procedures specified in 40 CFR 60, Appendix A.

23.3.6. Source testing for emissions of PM_{10} must be conducted in accordance with the procedures specified in 40 CFR 51, Appendix M, Method 201A and 202.

23.3.7. Source testing for emissions of any contaminant may be determined using an alternative method approved by the EPA in accordance with 40 CFR 63 Appendix A, Method 301.

23.4. **Excess Air Requirements.** To determine compliance with this permit, standard exhaust gas volumes must include only the volume of gases formed from the theoretical combustion of fuel, plus the excess air volume normal for the specific source type, corrected to standard conditions (dry gas at 68°F and an absolute pressure of 760 millimeters of mercury).

23.5. **Test Exemption.** The permittee is not required to comply with Conditions B.21.2, when the exhaust is observed for visible emissions.

23.6. **Test Deadline Extension.** The permittee may request an extension to a source test deadline established by the EPA. The permittee may delay a source test beyond the original deadline only if the extension is approved in writing by the EPA's appropriate division director or designee.

23.7. **Particulate Matter Calculation**. In source testing for compliance with the PM standards in Condition B.13, the three-hour average is determined using the average of three one-hour test runs.

B. SOURCE-WIDE REQUIREMENTS

1. **Drill Site Notification.** At least 6 months prior to the Discoverer becoming an OCS Source, the permittee shall notify the EPA via facsimile of the following information.

1.1. The location of the proposed drill site, using coordinates in the following formats:

1.1.1. Latitude and longitude; and

1.1.2. Universal Transverse Mercator grid system.

1.2. The lease block within the Beaufort Sea lease sales 195 or 202 where the drill site is located;

1.3. The proposed date that the Discoverer will become an OCS Source at that drill site;

1.4. Confirmation that emissions from the source would impact no Class I area. The confirmation shall include a description of the legal and factual basis for this determination; and

1.5. Confirmation that emissions from the source would impact no area where an applicable increment was known to be violated. The confirmation shall include a description of the legal and factual basis for this determination.

2. **Duration of Exploration Operations.** The permittee shall only conduct exploration drilling operations in the Beaufort Sea between July 1 and November 30 each year (referred to hereafter as the "drilling season").

2.1. During any drilling season, the permittee shall not operate the Discoverer as an OCS Source in excess of 120 calendar days. Each partial day the Discoverer is operated as an OCS source shall be counted as a calendar day.

2.2. During any drilling season, the permittee shall not conduct any drilling activity in excess of 1,632 hours. Drilling activity is defined as any time when the top drive is engaged and turning the conventional rotary bit and any time when conducting mud line cellar (MLC) activity as defined in Condition B.2.3.

2.3. During any drilling season, the permittee shall not conduct any MLC activity in excess of 480 hours. MLC activity is defined as any time when any MLC compressor engine (Units FD-9 – 11) or HPU engine (Units FD-12 – 13) is operating.

2.4. For each drill site at which the Discoverer operates, the permittee shall record the following:

2.4.1. The location of each drill site, using a modern global positioning system to determine the location. Location shall be recorded by providing coordinates in the following formats:

2.4.1.1. Latitude and longitude, and

2.4.1.2. Universal Transverse Mercator grid system.

2.4.2. The lease block within the Beaufort Sea lease sales 195 or 202 where the drill site is located.

2.4.3. The date and hour that the Discoverer became an OCS Source at that drill site.

2.4.4. The date and hour that the Discoverer ceased to be an OCS Source at that drill site.

2.4.5. For each period of drilling activity except for periods of MLC activity, the permittee shall record the following:

2.4.5.1. The date and hour at which the top drive is first engaged and turning the conventional rotary bit; and

2.4.5.2. The date and hour at which the top drive is disengaged and no longer turning the conventional rotary bit.

2.4.6. For each period of MLC activity the permittee shall record the following:

2.4.6.1. The earlier of the following two points in time; the date and hour in which the first MLC compressor engine (Units FD-9 – 11)

begins operation and the date and hour in which the first HPU engine (Units FD-12 - 13) begins operation; and

2.4.6.2. The later of the following two points in time; the date and hour in which the last MLC compressor engine (Units FD-9 – 11) ceases operation, and the date and hour in which the last HPU engine (Units FD-12 – 13) ceases operation.

2.5. Any time spent drilling a relief well shall be included in the time recorded in Conditions B.2.1.

2.6. By the 10th of each month, the permittee shall calculate and record the following operating parameters for the previous month and a running total for the current drill season or 12-month period, based upon recordkeeping performed pursuant to Conditions B.2.1, B.2.2, and B.2.3:

2.6.1. The number of days the Discoverer operated as an OCS source;

2.6.2. The number of hours of drilling activity; and

2.6.3. The number of hours of MLC activity.

3. **Drilling Season Notification.** Each drilling season, the permittee shall report to the EPA via facsimile the information below, within 3 days of occurrence:

3.1. The date and hour that the Discoverer became an OCS Source at the first drill site of that drilling season; and

3.2. The date and hour that the Discoverer ceased to be an OCS Source at the last drill site of that drilling season.

4. **Global Positioning System.** The permittee shall use a global positioning system on the Discoverer and Associated Fleet (except for the Kvichaks Nos. 1-3 and Rozema Skimmer) as follows:

4.1. Monitor and record the date, time and location of the Discoverer and Associated Fleet when the Discoverer becomes and ceases to be an OCS source.

4.2. Monitor and record the date, time and location when each vessel in the Associated Fleet enters or leaves the 25 mile radius area around the Discoverer.

4.3. Once each hour, monitor and record the date, time, and location of the Discoverer and Associated Fleet.

4.4. Once each hour, monitor and record the date, time, direction the bow of the Discoverer is pointed, and wind direction at the Discoverer.

5. **Best Available Control Technology (BACT) for Sulfur Dioxide (SO_2) Emissions from Discoverer Emission Units.** The permittee shall not combust any liquid fuel with sulfur content greater than 0.0015 percent by weight, as determined by Condition B.5.1, in any emission unit on the Discoverer (except for Unit FD-7).

5.1. Representative fuel samples shall be obtained using one of the methods in 40 CFR § 80.330(b). The sulfur content of the fuel shall be determined using ASTM D 5453-08b.

5.2. Monitoring, Recordkeeping and Reporting. The permittee shall:

5.2.1. Prior to mobilizing the Discoverer for the first time at the beginning of a drilling season, determine the sulfur content in each fuel oil storage tank on the Discoverer. The permittee shall obtain a representative sample of the fuel and analyze the sample for sulfur content using the procedures in Condition B.5.1.

5.2.2. Thereafter, determine and record the sulfur content upon receiving each fuel shipment, as follows:

5.2.2.1. Obtain a representative sample of the fuel delivered and analyze the sample for sulfur content using the procedures in Condition B.5.1; or

5.2.2.2. Obtain a single certification of sulfur content for each shipment of fuel from the fuel supplier based on an analysis of the fuel, providing that the certification indicates that the sulfur content has been determined by the ASTM method listed in Condition B.5.1.

5.3. Within 3 business days of identification, report to the EPA any instance of a liquid fuel with sulfur content greater than 0.0015 percent by weight being combusted in any emission unit on the Discoverer (except Unit FD-7).

6. **Greenhouse Gas Potential to Emit Owner Requested Limit for Discoverer and Associated Fleet**

6.1. At all times while the Discoverer is an OCS Source, greenhouse gas (GHG) emissions as defined in 40 CFR § 52.21(b)(49) from the Discoverer and Associated Fleet, when within 25 miles of the Discoverer, shall not exceed 70,000 tons carbon dioxide equivalent (CO_2e) as determined on a rolling 12-month basis by calculating the emissions (tons) for each month and adding the emissions (tons) calculated for the previous 11 months.

6.1.1. For emission units that combust fuel, monthly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions (tons) shall be determined by multiplying the appropriate emission factors for distillate oil in 40 CFR Part 98, Subpart C, Tables C-1 and C-2, by the recorded monthly fuel usage (gallons/month) and dividing by 2000 lb/ton.

6.1.2. For emission units that incinerate waste, monthly CO_2 emissions (tons) shall be determined by multiplying the CO_2 emission factor for incinerators in AP42 Table 2.1-7 (10/96) by the recorded monthly quantities of waste incinerated (tons/month) and dividing by 2000 lb/ton.

6.1.3. To account for mud off-gassing, monthly CH_4 emissions from the drilling mud shall be assumed to be 0.798 tons/month.

6.1.4. Monthly CO_2e emissions (tons) shall be determined by multiplying the calculated monthly emissions for CO_2, CH_4, and N_2O from all emission

units and activities by the applicable global warming potential factors from 40 CFR Part 98, Subpart A, Table A-1, and summing the products.

6.2. At all times while the Discoverer is an OCS Source, the total amount of fuel combusted in engines and boilers on the Discoverer and Associated Fleet, when within 25 miles of the Discoverer, shall not exceed 6,346,493 gallons during any rolling 12-month period.

6.3. At all times while the Discoverer is an OCS Source, the total amount of waste combusted in incinerators on the Discoverer and Associated Fleet, when within 25 miles of the Discoverer, shall not exceed 1,657,440 pounds during any rolling 12-month period.

6.4. Monitoring, Recordkeeping and Reporting. The permittee shall monitor and record monthly fuel consumption and waste incineration as follows:

6.4.1. Equip each fuel combustion source on the Discoverer and Associated Fleet, except for seldom used sources, with a diesel fuel flow meter to continuously measure and record the fuel flow rate:

6.4.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) being served by the meter.

6.4.1.2. Each fuel flow meter shall be totalizing and nonresettable.

6.4.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

6.4.1.4. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

6.4.1.5. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

6.4.2. Measure the fuel combusted in each seldom used fuel combustion source on the Discoverer and Associated Fleet by recording the quantity of fuel in each engine's fuel tank before and after periodic operation of each seldom used source:

6.4.2.1. Fuel tank content measurement may take the form of sight glass, use of a graduated dip stick, or tank instrumentation.

6.4.3. Calculate and record monthly fuel consumption for each fuel combustion source on the Discoverer and Associated Fleet in gallons. Determine the 12-month rolling fuel consumption by adding the gallons for each month to the gallons recorded for the previous 11 months.

6.4.4. For each batch of waste charged to an incinerator:

6.4.4.1. Record the date and time that each batch of waste was charged to the incinerator;

6.4.4.2. Weigh the batch of waste by using a weigh scale used that shall be accurate to within 0.5 lbs; and

6.4.4.3. Record the weight of each batch of waste charged to the incinerator.

6.4.5. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of the weigh scale to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

6.4.6. Maintain the accuracy of the weigh scale in accordance with manufacturer's recommendations.

6.4.7. Calculate and record monthly waste combusted in each incinerator on the Discoverer and Associated Fleet in pounds. Determine the 12-month rolling waste combusted by adding the waste combusted for each month to the waste combusted for the previous 11 months.

7. **Sulfuric Acid Mist Potential to Emit Owner Requested Limit for Associated Fleet.** The permittee shall not combust any liquid fuel with sulfur content greater than 0.0015 percent by weight, as determined by Condition B.7.1, in any emission unit on any vessel in the Associated Fleet.

7.1. Representative fuel samples shall be obtained using one of the methods in 40 CFR § 80.330(b). The sulfur content of the fuel shall be determined using ASTM D 5453-08b.

7.2. Monitoring, Recordkeeping and Reporting. The permittee shall:

7.2.1. Prior to mobilizing the Discoverer for the first time at the beginning of a drilling season, determine the sulfur content in each fuel oil storage tank on the vessels comprising the Associated Fleet. The permittee shall obtain a representative sample of the fuel and analyze the sample for sulfur content using the procedures in Condition B.7.1.

7.2.2. Thereafter, determine and record the sulfur content upon receiving each fuel shipment, as follows:

7.2.2.1. Obtain a representative sample of the fuel delivered and analyze the sample for sulfur content using the procedures in Condition B.7.1; or

7.2.2.2. Obtain a single certification of sulfur content for each shipment of fuel from the fuel supplier based on an analysis of the fuel, providing that the certification indicates that the sulfur content

has been determined by the ASTM method listed in Condition B.7.1.

7.3. Within 3 business days of identification, report to the EPA any instance of a liquid fuel with sulfur content greater than 0.0015 percent by weight being combusted in any emission unit on any vessel in the Associated Fleet.

8. **BACT for Particulate Matter Emissions (PM, PM_{10}, and $PM_{2.5}$) from Discoverer Diesel IC Engine Crankcase Ventilation.** Except for the MLC Diesel Compressor Engines (FD-9 –11) and the Caterpillar C7 Logging Winch Engine (FD-19), each diesel IC engine on the Discoverer shall be equipped with a closed crankcase ventilation system.

9. **COA Regulations: Industrial Process and Fuel-Burning Equipment Visible Emissions Standard.** The permittee shall comply with the following.

9.1. Do not cause or allow visible emissions, excluding condensed water vapor, emitted from Units FD-1 through 22, and FD-31 listed in Table 1 to reduce visibility through the exhaust effluent by more than 20 percent averaged over any six consecutive minutes.

9.2. For Units FD-1 through 22, and FD-31, monitor, record, and report in accordance with Condition B.10.1 – B.12.

9.3. For Units FD-1 through 22, and FD-31, as long as they do not exceed the limits in Condition B.9, monitoring shall consist of an annual compliance certification (as provided in Condition A.22.1) with the opacity standard.

10. **COA Regulations: Visible Emissions Monitoring, Recordkeeping, and Reporting.**

10.1. **Visible Emissions Monitoring.** When required by any of the requirements for Units FD-1 through 31 specified in Sections C through R below, or in the event of replacement during the permit term, the permittee shall observe the exhaust of emission Units FD-1 through 22, and FD-31 listed in Table 1 for visible emissions using either the Method 9 Plan under Condition B.10.2 or the Smoke/No-Smoke Plan under Condition B.10.3. The permittee may change visible-emissions plans for an emission unit at any time unless prohibited from doing so by Condition B.10.4. The permittee may, for each unit, elect to continue the visible emission monitoring schedule in effect from the previous permit at the time a renewal permit is issued, if applicable.

10.2. **Method 9 Plan.** For all 18-minute observations in this plan, observe exhaust, following 40 CFR 60, Appendix A-4, Method 9, adopted by reference in 18 AAC 50.040(a), for 18 minutes to obtain 72 consecutive 15-second opacity observations.

10.2.1. **First Method 9 Observation.** Observe exhaust for 18 minutes within six months after the issue date of this permit. For any emission unit, observe exhaust for 18 minutes within 14 calendar days after changing from the Smoke/No-Smoke Plan of Condition B.10.3. For any emission units replaced during the term of this permit, observe exhaust for 18 minutes within 30 days of startup.

10.2.2. **Monthly Method 9 Observations.** After the first Method 9 observation, perform 18-minute observations at least once in each calendar month that an emission unit operates.

10.2.3. **Annual Method 9 Observations.** After observing emissions for three consecutive operating months under Condition B.10.2.1, unless a six-minute average is greater than 15 percent and one or more observations are greater than 20 percent, perform 18-minute observations at least annually.

10.2.4. **Increased Method 9 Frequency.** If a six-minute average opacity is observed during the most recent set of observations to be greater than 15 percent and one or more observations are greater than 20 percent, then increase or maintain the 18-minute observation frequency for that emission unit to at least monthly intervals, until the criteria in Condition B.10.2.3 for annual monitoring are met.

10.3. **Smoke/No Smoke Plan.** Observe the exhaust for the presence or absence of visible emissions, excluding condensed water vapor.

10.3.1. **Initial Monitoring Frequency.** Observe the exhaust during each calendar day that an emission unit operates.

10.3.2. **Reduced Monitoring Frequency.** After the emission unit has been observed on 30 consecutive operating days, if the emission unit operated without visible smoke in the exhaust for those 30 days, then observe emissions at least once in every calendar month that an emission unit operates.

10.3.3. **Smoke Observed.** If smoke is observed, either begin the Method 9 Plan of Condition B.10.2 or perform the corrective action required under Condition B.10.4.

10.4. **Corrective Actions Based on Smoke/No Smoke Observations.** If visible emissions are present in the exhaust during an observation performed under the Smoke/No Smoke Plan of Condition B.10.3, then the permittee shall either follow the Method 9 plan of Condition B.10.2 or:

10.4.1. Initiate actions to eliminate smoke from the emission unit within 24 hours of the observation;

10.4.2. Keep a written record of the starting date, the completion date, and a description of the actions taken to reduce smoke; and

10.4.3. After completing the actions required under Condition B.10.4.1,

10.4.3.1. Take Smoke/No Smoke observations in accordance with Condition B.10.3.

10.4.3.1.1. At least once per day for the next seven operating days and until the initial 30 day observation period is completed; and

10.4.3.1.2. Continue as described in Condition B.10.3.2; or

10.4.3.2. If the actions taken under Condition B.10.4.1 do not eliminate the smoke, or if subsequent smoke is observed under the schedule of Condition B.10.4.3.1.1, then observe the exhaust using the Method 9 Plan unless the EPA gives written approval to resume observations under the Smoke/No Smoke Plan; after observing smoke and making observations under the Method 9 Plan, the permittee may at any time take corrective action that eliminates smoke and restart the Smoke/No Smoke Plan under Condition B.10.3.1.

11. **COA Regulations: Visible Emissions Recordkeeping.** The permittee shall keep records as follows.

11.1. If using the Method 9 Plan of Condition B.10.2,

11.1.1. The observer shall record:

11.1.1.1. The name of the OCS Source, emission unit and location, emission unit type, observer's name and affiliation, and the date on the Visible Emissions Field Data Sheet in Appendix B;

11.1.1.2. The time, estimated distance to the emissions location, sun location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds), plume background, and operating rate (load or fuel consumption rate) on the sheet at the time opacity observations are initiated and completed;

11.1.1.3. The presence or absence of an attached or detached plume and the approximate distance from the emissions outlet to the point in the plume at which the observations are made;

11.1.1.4. Opacity observations to the nearest five percent at 15-second intervals on the Visible Emissions Field Data Sheet in Appendix B; and

11.1.1.5. The minimum number of observations required by the permit; each momentary observation recorded shall be deemed to represent the average opacity of emissions for a 15-second period.

11.1.2. To determine the six-minute average opacity, divide the observations recorded on the record sheet into sets of 24 consecutive observations; sets need not be consecutive in time and in no case shall two sets overlap; for each set of 24 observations, calculate the average by summing the opacity of the 24 observations and dividing this sum by 24; record the average opacity on the sheet; and

11.1.3. Calculate and record the highest 6-minuite and 18-consecutive-minute averages observed.

11.2. If using the Smoke/No Smoke Plan of Condition 10.3, record the following information in a written log for each observation and submit copies of the recorded information upon request of the EPA:

11.2.1. The date and time of the observation;

11.2.2. From Table 1, the emission unit identification number of the emission unit observed;

11.2.3. Whether visible emissions are present or absent in the exhaust;

11.2.4. A description of the background to the exhaust during the observation;

11.2.5. If the emission unit starts operation on the day of the observation, the startup time of the emission unit;

11.2.6. Name and title of the person making the observation; and

11.2.7. Operating rate (load or fuel consumption rate).

12. **COA Regulations: Visible Emissions Reporting.** The permittee shall report visible emissions as follows.

12.1. Include in each Operating Report under Condition A.18:

12.1.1. Which visible-emissions plan of Condition B.10.1 was used for each emission unit; if more than one plan was used, give the time periods covered by each plan;

12.1.2. For each emission unit under the Method 9 Plan,

12.1.2.1. Copies of the observation results (i.e. opacity observations) for each emission unit that used the Method 9 Plan, except for the observations the permittee has already supplied to the EPA; and

12.1.2.2. A summary to include:

12.1.2.2.1. Number of days observations were made;

12.1.2.2.2. Highest six-minute average observed; and

12.1.2.2.3. Dates when one or more observed six-minute averages were greater than 20 percent.

12.1.3. For each emission unit under the Smoke/No Smoke Plan, the number of days that Smoke/No Smoke observations were made and which days, if any, that smoke was observed; and

12.1.4. A summary of any monitoring or record keeping required under Conditions B.10.1 and B.10.4.3.2 that was not done.

12.2. Report under Condition A.17:

12.2.1. The results of Method 9 observations that exceed an average 20 percent for any six-minute period; and

12.2.2. If any monitoring under Condition B.10.1 was not performed when required, report within three days of the date the monitoring was required.

13. **COA Regulations: Industrial Process and Fuel-Burning Equipment Particulate Matter Standard.** The permittee shall not cause or allow PM emitted from Units FD-1 through 22, and FD-31 listed in Table 1 to exceed 0.05 grains per cubic foot of exhaust gas corrected to standard conditions and averaged over three hours.

13.1. For Units FD-1 through 22, and FD-31 listed in Table 1, monitor, record and report in accordance with Conditions B.14 – B.15.

13.2. For Units FD-1 through 22, and FD-31, as long as they do not exceed the limits in Condition B.13, monitoring shall consist of an annual compliance certification (as provided in Condition A.22.1) with the PM standard.

13.3. In source testing for compliance with the PM standards in 18 AAC 50.050 or 18 AAC 50.055, the three-hour average is determined using the average of three one-hour test runs. The source test must account for those emissions caused by soot blowing, grate cleaning, or other routine maintenance activities by ensuring that at least one test run includes the emissions caused by the routine maintenance activity and is conducted under conditions that lead to representative emissions

$$E = E_M \left[(A + B)\, x \frac{S}{R\ x\ A} \right] + E_{NM} \left[\frac{(R - S)}{R} - \frac{BS}{R\ x\ A} \right]$$

from that activity. The emissions must be quantified using the following equation:

Where:

E = the total particulate emissions of the source in grains per dry standard cubic foot (gr/dscf).

E_M = the particulate emissions in gr/dscf measured during the test that included the routine maintenance activity.

E_{NM} = the arithmetic average of particulate emissions in gr/dscf measured by the test runs that did not include routine maintenance activity.

A = the period of routine maintenance activity occurring during the test run that included routine maintenance activity, expressed to the nearest hundredth of an hour.

B = the total period of the test run, less A.

R = the maximum period of source operation per 24 hours, expressed to the nearest hundredth of an hour.

S = the maximum period of routine maintenance activity per 24 hours, expressed to the nearest hundredth of an hour.

14. **COA Regulations: Particulate Matter Monitoring, Recordkeeping, and Reporting.** PM Monitoring for Diesel Engines. The permittee shall conduct source tests on diesel engines Units FD-1 through 20, and FD-31 to determine the concentration of (PM) in the exhaust of a source in accordance with Condition B.14.

14.1. Within six months of exceeding the criteria of Conditions B.14.2.1 or B.14.2.2, either:

14.1.1. Conduct a PM source test according to requirements set out in Condition B.21, or

14.1.2. Make repairs so that emissions no longer exceed the criteria of Condition B.14.2; to show that emissions are below those criteria, observe emissions as described in Condition B.10.2 under load conditions comparable to those when the criteria were exceeded.

14.2. Conduct the test according to Condition B.14.1 if:

14.2.1. 18 consecutive minutes of Method 9 observations result in an 18-minute average opacity greater than 20 percent; or

14.2.2. For a source with an exhaust stack diameter that is less than 18 inches, 18 consecutive minutes of Method 9 observations result in an 18-minute average opacity that is greater than 15 percent and not more than 20 percent, unless the EPA has waived this requirement in writing.

14.3. During each one-hour PM source test run, observe the exhaust for 60 minutes in accordance with Method 9 and calculate the average opacity measured during each one-hour test run. Submit a copy of these observations with the source test report.

14.4. The automatic PM source test requirements in Conditions B.14.1 and B.14.2 is waived for an emissions unit if a PM source test on that emission unit has shown compliance with the PM standard during this permit term.

15. **COA Regulations: Particulate Matter Record Keeping for Diesel Engines.** Within 180 calendar days after the effective date of this permit, the permittee shall record the exhaust stack diameter(s) of Units FD-1 through 20 and FD-31 from Table 1 in the permit. Report the stack diameter(s) in the next Operating Report under Condition A.18.

15.1. PM Reporting for Diesel Engines. The permittee shall report as follows:

15.1.1. Report under Condition A.17:

15.1.1.1. The results of any PM source test that exceeds the PM emissions limit; or

15.1.1.2. If one of the criteria of Condition B.14.2 was exceeded and the permittee did not comply with either Condition B.14.1.1 or B.14.1.2, this must be reported by the day following the day compliance with Condition B.14.1 was required;

15.2. Report observations in excess of the threshold of Condition B.14.2.2 within 30 days of the end of the month in which the observations occur.

15.3. In each OCS source Operating Report under Condition A.18, include:

15.3.1. The dates, EU ID(s), and results when an observed 18-minute average was greater than an applicable threshold in Condition B.14.2;

15.3.2. A summary of the results of any PM testing under Condition B.14; and

15.3.3. Copies of any visible emissions observation results (opacity observations) greater than the thresholds of Condition B.14.2, if they were not already submitted.

16. **COA Regulations: Particulate Matter Monitoring for Liquid-Fired Boilers and Heaters.** The permittee shall conduct source tests on Units FD-21 through 22 to determine the concentration of PM in the exhaust of Units FD-21 through 22 as follows.

16.1. Conduct a PM source test according to the requirements set out in Condition B.21 no later than 90 calendar days after any time corrective maintenance fails to eliminate visible emissions greater than the 20 percent opacity threshold for two or more 18-minute observations in a consecutive six-month period.

16.2. During each one-hour PM source test run, observe the exhaust for 60 minutes in accordance with Method 9 and calculate the average opacity measured during each one-hour test run.

16.3. The PM source test requirement in Condition B.16 is waived for an emission unit if:

16.3.1. A PM source test during the most recent annual reporting period on that emission unit shows compliance with the PM standard since permit issuance, or

16.3.2. If a follow-up visible emission observation conducted using Method-9 during the 90 days shows that the excess visible emissions described in Condition B.10.2.4 no longer occur.

17. **COA Regulations: Particulate Matter Recordkeeping for Liquid Fired Boilers and Heaters.** The permittee shall keep records of the results of any PM testing and visible emissions observations conducted under Condition B.16. The permittee shall report as follows:

17.1. In each OCS source Operating Report required by Condition A.18, include:

17.1.1. The dates, emission units, and results when an 18-minute opacity observation was greater than the applicable threshold criterion in Condition B.10.2.4; and

17.1.2. A summary of the results of any PM testing and visible emissions observations conducted under Condition B.16.

17.2. Report as excess emissions, in accordance with Condition A.17, any time the results of a source test for PM exceeds the PM emission limit stated in Condition B.13.

18. **COA Regulations: Sulfur Compound Emissions Standard.** Sulfur Compound Emissions. In accordance with 18 AAC 50.055(c), the permittee shall not cause or allow sulfur compound emissions, expressed as SO_2, from Units FD-1 through 22, and FD-31 listed in Table 1 to exceed 500 parts per million (ppm) averaged over three hours.

18.1. For Units FD-1 through 22, and FD-31, monitor, record and report in accordance with Conditions B.19 through B.20.

19. **COA Regulations: Sulfur Compound Monitoring, Recordkeeping, and Reporting Liquid Fuel-fired Sources.** Sulfur Compound Emissions – Monitoring and Recordkeeping.

19.1. If a load of fuel contains greater than 0.0015 percent sulfur by weight, the permittee shall calculate SO_2, emissions in ppm using the SO_2, Material Balance Calculation as described below or Method 19 of 40 CFR 60, Appendix A-7, adopted by reference in 18 AAC 50.040(a).

SO_2 Material Balance Calculation

If a fuel shipment contains more than 0.0015 percent sulfur by weight, calculate the three-hour exhaust concentration of SO_2 using the following equations:

A = 31,200 x [**wt%S_{fuel}**] = 31,200 x _____ = _____

B = 0.148 x [**wt%S_{fuel}**] = 0.148 x _____ = _____

C = 0.396 x [**wt%C_{fuel}**] = 0.396 x _____ = _____

D = 0.933 x [**wt%H_{fuel}**] = 0.933 x _____ = _____

E = B + C + D = _____ + _____ + _____ = _____

F = 21 – [**vol%dry$O_{2,\ exhaust}$**] = 21 - _____ = _____

G = [**vol%dry$O_{2,\ exhaust}$**] ÷ F = _____ ÷ _____ = _____

H = 1 + G = 1 + _____ = _____

I = E x H = _____ x _____ = _____

SO_2 concentration = A ÷ I = _____ ÷ _____ = _____ PPM

The **wt%S_{fuel}**, **wt%C_{fuel}**, and **wt%H_{fuel}** are equal to the weight percents of sulfur, carbon, and hydrogen in the fuel. These percentages should total 100%.

The fuel weight percent (wt%) of sulfur is obtained pursuant to Condition B.5.2.2. The fuel weight percents of carbon and hydrogen are obtained from the fuel refiner.

The volume percent of oxygen in the exhaust (**vol%dry$O_{2,\ exhaust}$**) is obtained from oxygen meters, manufacturer's data, or from the most recent analysis under 40 CFR 60, Appendix A-2, Method 3, adopted by reference in 18 AAC 50.040(a), at the same engine load used in the calculation.

Enter all of the data in percentages without dividing the percentages by 100. For example, if wt% S_{fuel} = 1.0%, then enter 1.0 into the equation not 0.01 and if the vol%dry$O_{2,}$ exhaust = 3.00% then enter 3.00, not 0.03.

20. **COA Regulations: Sulfur Compound Emissions – Reporting.** The permittee shall report as follows.

    20.1. If SO_2, emissions are calculated under Condition B.19.1 to exceed 500 ppm, the permittee shall report under Condition A.17. When reporting under this Condition B.20.1 include the calculation under Condition B.19.1.

    20.2. The permittee shall include in the report required by Condition A.18 a list of the fuel grades received at the OCS Source during the reporting period:

        20.2.1. For any grade with a maximum fuel sulfur greater than 0.0015 percent sulfur, the fuel sulfur of each shipment; and

        20.2.2. For fuel with a sulfur content greater than 0.0015 percent, the calculated SO_2 emissions in ppm.

21. **General Testing Requirements.** Whenever conducting a stack test required by this permit, and unless specifically stated otherwise in this permit, the permittee shall comply with the following testing requirements in addition to the specific testing requirements contained in the emission unit sections of this permit.

    21.1. The permittee shall provide the EPA at least 30 days prior notice of any stack test. If after 30 days notice for an initially scheduled stack test, there is a delay in conducting the scheduled stack test, the permittee shall notify the EPA as soon as possible of any delay in the original test date, either by providing at least 7 days prior notice of the rescheduled date of the stack test, or by arranging a rescheduled date with the EPA by mutual agreement.

    21.2. The permittee shall submit to the EPA a complete stack test plan within 60 days after receiving a request by the EPA and at least 30 days prior to any required testing unless the EPA agrees in writing to some other time period. Retesting may be done without resubmitting the plan provided it is conducted in accordance with the previously submitted plan. The permittee shall follow the submitted test plan except as otherwise agreed to in writing by EPA prior to the testing. The source test plan shall include and address the following elements:

        21.2.1. Purpose and scope of testing;

        21.2.2. Source description, including a description of the operating scenarios and mode of operation during testing and including fuel sampling and analysis procedures;

        21.2.3. Schedule/dates of testing;

        21.2.4. Process data to be collected during the test and reported with the results, including source-specific data identified in the emission unit sections of this permit;

        21.2.5. Sampling and analysis procedures, specifically requesting approval for any proposed alternatives to the reference test methods, and addressing minimum test length (e.g., one hour, 8 hours, 24 hours, etc.) and minimum sample volume;

21.2.6. Sampling location description and compliance with the reference test methods;

21.2.7. Analysis procedures and laboratory identification;

21.2.8. Quality assurance plan;

21.2.9. Calibration procedures and frequency;

21.2.10. Sample recovery and field documentation;

21.2.11. Chain of custody procedures;

21.2.12. Quality Assurance (QA)/Quality Control (QC) project flow chart;

21.2.13. Data processing and reporting;

21.2.14. Description of data handling and QC procedures; and

21.2.15. Report content and timing.

21.3. Unless otherwise specified in this permit, or the EPA determines in writing that other operating conditions are representative of normal operations or unless specified in the emission unit sections of this permit, the source shall be operated at a capacity of at least 90 percent but no more than 100 percent of maximum during all tests.

21.4. Unless otherwise specified by an applicable requirement or test method, the permittee shall conduct source testing at a point or points that characterize the actual discharge into the ambient air.

21.5. Only regular operating staff may adjust the processes or emission control devices during or within 2 hours prior to the start of a source test. Any operating adjustments made during a source test, that are a result of consultation during the tests with source testing personnel, equipment vendors, or consultants, may render the source test invalid.

21.6. For the duration of each test run (unless otherwise specified), the permittee shall record the following information:

21.6.1. All data which is required to be monitored during the test in the emission unit sections of this permit; and

21.6.2. All continuous monitoring system data which is required to be routinely monitored in the emission unit sections of this permit for the emission unit being tested.

21.7. Each source test shall follow the reference test methods specified by this permit and consist of at least three (3) valid test runs. For purposes of this permit:

21.7.1. EPA Test Methods 1, 2, 3A, 4, 5, 6C, 7E, 9, 10, 19, and 25A are set forth in 40 CFR Part 60, Appendix A;

21.7.2. EPA Test Methods 201A and 202 are set forth in 40 CFR Part 51, Subpart M;

21.7.3. Conditional Test Method 027 (CTM-027), "Procedure for Collection and Analysis of Ammonia in Stationary Sources," is set forth at http://www.epa.gov/ttn/emc/ctm.html;

21.7.4. Conditional Test Method 038 (CTM-038), "Measurement of Ammonia Emissions from Highway, Nonroad, and Stationary Use Diesel Engines by Extractive Fourier Transform Infrared (FTIR) Spectroscopy," is set forth at http://www.epa.gov/ttn/emc/ctm.html;

21.7.5. Other Test Method 27 (OTM 27), "Determination of PM_{10} and $PM_{2.5}$ Emissions from Stationary Sources (Constant Sampling Rate Procedure)," is set forth at http://www.epa.gov/ttn/emc/prelim.html; and

21.7.6. ASTM D 5453-09 is set forth at http://www.astm.org/Standards/D5453.htm.

21.8. Facilities for performing and observing the emission testing shall be provided that meet the requirements of 40 CFR § 60.8(e) and EPA Method 1.

21.9. Emission test reports shall be submitted to the EPA within 45 days of completing any emission test required by this permit along with items required to be recorded in Condition B.21.6 above.

21.10. EPA Methods 1, 2, 3A, 3B, 4 and 19 shall be used as necessary to convert the measured NO_X, PM, PM_{10}, $PM_{2.5}$, and CO emissions into units of the emission limits in the permit.

21.11. Source test emission data shall be reported as the arithmetic average of all valid test runs and in the terms of any applicable emission limit, unless otherwise specified in the emission unit sections of this permit.

21.12. An alternative test method or a deviation from a test method identified in this permit may be approved as follows.

21.12.1. The permittee must submit a written request to the EPA at least 60 days before the stack test is scheduled to begin which includes the reasons why the alternative or deviation is needed and the rationale and data to demonstrate that the alternative test method or deviation from the reference test method:

21.12.1.1. Provides equal or improved accuracy and precision as compared to the specified reference test method; and

21.12.1.2. Does not decrease the stringency of the standard as compared to the specified reference test method.

21.12.2. If requested by the EPA, the demonstration referred to in Condition B.21.12.1 must use Method 301 in 40 CFR Part 63, Appendix A, to validate the alternative test method or deviation.

21.12.3. The EPA must approve the request in writing.

21.12.4. Until the EPA has given written approval to use an alternative test method or to deviate from the test method specified in this permit, the permittee is

required to use the test method specified in this permit when conducting a source test under this permit.

21.13. The permittee may request an extension to a source test deadline established by the EPA. The permittee may delay a source test beyond the original deadline only if the extension is approved in writing by the EPA.

21.14. In addition to any source testing explicitly required by this permit, the permittee shall conduct source testing as requested by the EPA to determine compliance with applicable permit requirements.

21.15. For any source test requiring the use of Method 201A, the permittee may substitute the use of Method 5. In either case, Method 202 shall also be employed for condensable PM, and the test results shall consider all PM to be $PM_{2.5}$.

22. **Prohibited Activities.** The permittee shall not:

22.1. Flow test wells;

22.2. Flare gas;

22.3. Store liquid hydrocarbons recovered during well testing;

22.4. Refuel any vessel (excluding the Discoverer, the Kvichak workboats, and Rozema Skimmer) within 25 miles of the Discoverer while the Discoverer is an OCS Source, or

22.5. Allow any vessel associated with this project, and that is not authorized by Tables 1 through 5 of this permit, to approach within 25 miles of the Discoverer, while the Discoverer is an OCS Source.

23. **Monthly Emissions Calculations.** By the tenth of each month, the permittee shall, using monitoring data collected pursuant to the requirements of this permit, calculate and record the monthly emissions of CO, NO_X, $PM_{2.5}$, PM_{10}, SO_2, VOC, and GHG emissions for the preceding month. For NO_X, the permittee shall also calculate and record the monthly emissions for the preceding month for each engine, boiler, or incinerator (or groups of engines or boilers) that are subject to an annual NO_X emission limit in this permit.

24. **Rolling 12-Month Emissions Calculations.** By the tenth of each month, the permittee shall calculate and record the rolling 12-month emissions of CO, NO_X, $PM_{2.5}$, PM_{10}, SO_2, VOC, and GHG emissions by using the monthly emissions calculated for the previous 12 months pursuant to Condition B.22.5. For NO_X, the permittee shall also calculate and record the rolling 12-month emissions for each engine, boiler, or incinerator (or groups of engines or boilers) that are subject to an annual NO_X emission limit in this permit.

25. **Good Operating and Maintenance Requirements.** At all times, including periods of startup, shutdown, and malfunction, the permittee shall, to the extent practicable, maintain and operate each emission unit, including any associated air pollution control equipment, in a manner consistent with good air pollution control practices for minimizing emissions. Determination of whether acceptable operating and maintenance procedures are being used will be based on information available to the EPA which may include, but is not limited to, monitoring results, opacity observations, review of operating and maintenance procedures,

and inspection of the source. The permittee shall keep records of any maintenance that would have a significant effect on emissions (the records may be kept in electronic format) and keep a copy of either the manufacturer's or the operator's maintenance procedures.

26. **COA Regulations: Good Air Pollution Control Practice.** The permittee shall do the following for Units FD-1 through 23 and FD-31:

    26.1. Perform regular maintenance considering the manufacturer's or the operator's maintenance procedures;

    26.2. Keep records of any maintenance that would have a significant effect on emissions; the records may be kept in electronic format; and

    26.3. Keep a copy of either the manufacturer's or the operator's maintenance procedures.

27. **COA Regulations: Air Pollution Prohibited.** No person may permit any emission which is injurious to human health or welfare, animal or plant life, or property, or which would unreasonably interfere with the enjoyment of life or property.

    27.1. If emissions present a potential threat to human health or safety, the permittee shall report any such emissions according to Condition A.17.

    27.2. As soon as practicable after becoming aware of a complaint that is attributable to emissions from the emission units regulated under this permit, the permittee shall investigate the complaint to identify emissions that the permittee believes have caused or are causing a violation of Condition B.27.

    27.3. The permittee shall initiate and complete corrective action necessary to eliminate any violation identified by a complaint or investigation as soon as practicable if:

        27.3.1. After an investigation because of a complaint or other reason, the permittee believes that emissions from the OCS source have caused or are causing a violation of Condition B.27; or

        27.3.2. The EPA notifies the permittee that it has found a violation of Condition B.27.

    27.4. The permittee shall keep records of:

        27.4.1. The date, time, and nature of all emissions complaints received;

        27.4.2. The name of the person or persons that complained, if known;

        27.4.3. A summary of any investigation, including reasons the permittee does or does not believe the emissions have caused a violation of Condition B.27; and

        27.4.4. Any corrective actions taken or planned for complaints attributable to emissions from the OCS source.

    27.5. With each OCS Operating Report under Condition A.18, the permittee shall include a brief summary report which must include:

        27.5.1. The number of complaints received;

27.5.2. The number of times the permittee or the EPA found corrective action necessary;

27.5.3. The number of times action was taken on a complaint within 24 hours; and

27.5.4. The status of corrective actions the permittee or the EPA found necessary that were not taken within 24 hours.

27.6. The permittee shall notify the EPA of a complaint that is attributable to emissions from the emission units regulated under this permit within 24 hours after receiving the complaint, unless the permittee has initiated corrective action within 24 hours of receiving the complaint.

28. **Selective Catalytic Reduction (SCR) Control Device Monitoring.** For any emission unit that is required by this permit to be controlled by an SCR control device, the permittee shall install, calibrate, operate, and maintain (in accordance with manufacturer specifications) continuous monitoring systems (CMS) to measure and record inlet temperature in degrees Fahrenheit (ºF), urea feed rate (gallons/min), and catalyst activity (NO_X ppm concentration) as follows:

28.1. Prepare and submit 60 days before the first drilling season a site-specific monitoring plan that addresses the monitoring system design, data collection, quality assurance, and quality control elements outlined in this condition. Install, calibrate, operate, and maintain each CMS according to the procedures in the approved site-specific monitoring plan. The plan shall address the performance criteria and design specifications for the monitoring system equipment, including the sample interface, detector signal analyzer, sensor tolerance and sensitivity, and data acquisition and calculations; sampling interface (e.g., thermocouple, flow meter) location such that the monitoring system will provide representative measurements; equipment performance checks, system accuracy audits, or other audit procedures; ongoing operation and maintenance procedures; and ongoing reporting and recordkeeping procedures.

28.2. The temperature and urea CMS shall collect data at least once every 15 minutes.

28.3. Conduct the CMS equipment performance checks, system accuracy audits, or other audit procedures specified in the site-specific monitoring plan within 60 days prior to each drilling season and at least once every 3 months for the duration of the drilling season.

28.4. Conduct a performance evaluation of each CMS in accordance with the site-specific monitoring plan.

28.5. Except for periods of monitoring system malfunctions, repairs associated with monitoring system malfunctions, and required monitoring system quality assurance or quality control activities (including, as applicable, system accuracy audits and required zero and span adjustments), operate the CMS at all times the affected source is operating. A monitoring system malfunction is any sudden, infrequent, not reasonably preventable failure of the monitoring system to provide valid data. Monitoring system failures that are caused in part by poor maintenance or careless operation are not malfunctions. Complete monitoring system repairs in response to

monitoring system malfunctions and return the monitoring system to operation as expeditiously as practicable.

28.6. Monitor and record NO_X emissions (ppm) from the exhaust of each SCR unit once per week using a portable NO_X monitor that meets the requirements of EPA OTM 13 found at http://www.epa.gov/ttn/emc/prelim/otm13.pdf.

28.7. Report as a deviation under Condition A.17.3 any periods during which the urea pump is not operating, the inlet temperature is less than 250°C, or the NO_X concentration is 150% or more than the NO_X concentration measured during the most recent previous source test that produced compliance data or emission factors for this permit.

29. **Oxidation Catalyst Control Device Monitoring.** For any emission unit that is required by this permit to be controlled by an oxidation catalyst control device, the permittee shall install, calibrate, operate, and maintain (in accordance with manufacturer specifications) CMS to measure and record inlet temperature (ºF), and catalyst activity (CO ppm concentration) as follows:

29.1. Prepare and submit 60 days before the first drilling season a site-specific monitoring plan that addresses the monitoring system design, data collection, quality assurance, and quality control elements outlined in this condition. Install, calibrate, operate, and maintain each CMS according to the procedures in the approved site-specific monitoring plan. The plan shall address the performance criteria and design specifications for the monitoring system equipment, including the sample interface, detector signal analyzer, sensor tolerance and sensitivity, and data acquisition and calculations; sampling interface (e.g., thermocouple) location such that the monitoring system will provide representative measurements; equipment performance checks, system accuracy audits, or other audit procedures; ongoing operation and maintenance procedures; and ongoing reporting and recordkeeping procedures.

29.2. The temperature CMS shall collect data at least once every 15 minutes.

29.3. Conduct the CMS equipment performance checks, system accuracy audits, or other audit procedures specified in the site-specific monitoring plan within 60 days prior to each drilling season and at least once every 3 months for the duration of the drilling season.

29.4. Conduct a performance evaluation of each CMS in accordance with the site-specific monitoring plan.

29.5. Except for periods of monitoring system malfunctions, repairs associated with monitoring system malfunctions, and required monitoring system quality assurance or quality control activities (including, as applicable, system accuracy audits and required zero and span adjustments), operate the CMS at all times the affected source is operating. A monitoring system malfunction is any sudden, infrequent, not reasonably preventable failure of the monitoring system to provide valid data. Monitoring system failures that are caused in part by poor maintenance or careless operation are not malfunctions. Complete monitoring system repairs in response to

monitoring system malfunctions and return the monitoring system to operation as expeditiously as practicable.

29.6. Monitor and record CO emissions (ppm) from the exhaust of each oxidation catalyst unit once per week using a portable CO monitor that meets the requirements of EPA OTM 13 found at http://www.epa.gov/ttn/emc/prelim/otm13.pdf.

29.7. Report as a permit deviation under Condition A.17.3 any periods during which the inlet temperature is less than 300°C, or the CO concentration is 120% or more than the CO concentration measured during the most recent previous source test that produced compliance data or emission factors for this permit.

C. DISCOVERER GENERATOR ENGINES (FD-1 – 6)

1. **Operation of Selective Catalytic Reduction (SCR) Unit.** At all times that any of Units FD-1 – 6 are in operation, the exhaust from each emission unit shall be directed to an operating SCR emission unit.

2. **Operation of Oxidation Catalyst.** At all times that any of Units FD-1 – 6 are in operation, the exhaust from each emission unit shall be directed to an operating oxidation catalyst.

3. **BACT Limits.** Emissions from each generator engine (Units FD-1 – 6) shall not exceed the emission limits specified for each of the pollutants below:

3.1. **Nitrogen oxides (NO_X):** 0.50 grams (g) per kilowatt-hour (kW-hr)

3.1.1. For compliance with Condition C.3.1, measurement of NO_X shall be determined using EPA Method 7E.

3.2. **Ammonia (NH_3):** 5 parts per million by volume (ppmv) at actual stack gas conditions

3.2.1. For compliance with Condition C.3.2, measurement of NH_3 shall be determined using EPA Conditional Test Method 027 or 038.

3.3. **Particulate Matter:** 0.127 g/kW-hr

3.3.1. For compliance with Condition C.3.3, measurement of PM shall be determined using EPA Method 5.

3.4. **Particulate Matter with an aerodynamic diameter less than 10 microns (PM_{10}):** 0.127 g/kW-hr

3.4.1. For compliance with Condition C.3.4, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

3.5. **Particulate Matter with an aerodynamic diameter less than 2.5 microns ($PM_{2.5}$):** 0.127 g/kW-hr.

3.5.1. For compliance with Condition C.3.5, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

3.6. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

3.6.1. For compliance with Condition C.3.6, measurement of visible emissions shall be determined using EPA Method 9.

3.7. **Carbon Monoxide (CO):** 0.1790 g/kW-hr

3.7.1. For compliance with Condition C.3.7, measurement of CO shall be determined using EPA Method 10.

3.8. **Volatile Organic Compounds (VOC):** 0.0230 g/kW-hr

3.8.1. For compliance with Condition C.3.8, measurement of VOC shall be determined using EPA Method 25A.

4. **Annual Emission Limits.** Emissions from all six generator engines in aggregate (Units FD-1 – 6) shall not exceed the emission limits specified for each of the pollutants below.

4.1. **Nitrogen oxides (NO_X):** 5.83 tons/rolling 12-month period

4.1.1. For compliance with Condition C.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limit.** Emissions from all six generation engines in aggregate (Units FD-1 –6) shall not exceed the emission limits specified for each of the pollutants below:

5.1. **Nitrogen oxides (NO_X):** 4.64 lb/hr

5.1.1. For compliance with Condition C.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from all six generator engines in aggregate (Units FD-1 – 6) shall not exceed the emission limits specified for each of the pollutants below:

6.1. **Particulate Matter with an aerodynamic diameter less than 10 microns (PM_{10}):** 28.3 lbs/day

6.1.1. For compliance with Condition C.6, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

6.2. **Particulate Matter with an aerodynamic diameter less than 2.5 microns ($PM_{2.5}$):** 28.3 lbs/day

6.2.1. For compliance with Condition C.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

7. **Electrical Power Output Limit.** The permittee shall not operate Units FD-1 – 6 such that aggregate electrical power from the attached generators is in excess of 3,872 kWe for any hour that these emission units are operated.

8. **Stack Test Requirements.** The permittee shall stack test all of Units FD-1 – 6 as follows:

   8.1. At the start of the first drilling season that the Discoverer operates under this permit in the Beaufort Sea, all six of Units FD-1 – 6 shall have been stack tested under the requirements of this section.

   8.2. Each stack test shall be conducted at three different loads: 50 percent, 75 percent, and 100 percent.

   8.3. Each stack test run shall test for emissions of CO, NO_X, NO_2, $PM_{2.5}$, PM_{10}, VOC, ammonia, and visible emissions.

   8.4. During each test run, the permittee shall monitor and record the following information:

      8.4.1. Quantity of fuel used (in gallons);

      8.4.2. Density of the fuel used (in lbs/gallon);

      8.4.3. Heat content of the fuel used (in Btu/gallon);

      8.4.4. Electrical power produced (in kWe-hr);

      8.4.5. The stack temperature upstream of the SCR catalyst in ºC or ºF;

      8.4.6. The quantity of urea reagent (in gallons) and the concentration of the urea reagent (in weight percent) introduced into the SCR control system; and

      8.4.7. The NO_X concentration (ppm) indicated by the periodic NO_X monitor used for the SCR control system.

   8.5. For each engine, each load, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, g/kWe-hr, lbs/kW-hr, lbs/kWe-hr, and lbs/gallon.

9. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

   9.1. Equip each of the generator engines (Units FD-1 – 6) on board the Discoverer with a electrical output monitoring device:

      9.1.1. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine with an accuracy equal to or better than 2 percent of the engine's maximum output (in kWe);

      9.1.2. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine at least once every 10 minutes; and

      9.1.3. Each electrical output monitoring device shall be equipped to record each reading taken as well as provide and record average loads for each hour.

   9.2. Maintain the accuracy of each electrical output monitoring device in accordance with manufacturer's recommendations.

9.3. Monitor and record the power output, in kWe, resulting from the operation of each of Units FD-1 – 6 at least once every 10 minutes.

9.4. Each month, calculate and record NO_X emissions in g/kW-hr from each engine for each hour during the month, using the emission factors collected under Condition C.8.5, and power output data collected under Condition C.9.3, and converted to kW (mechanical).

9.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Condition C.8.5 and electrical load data collected under Condition C.9.3, to determine emissions from that source. Emissions shall be calculated for each ten-minute load reading for each engine.

9.6. For the purposes of Conditions C.9.4 and C.9.5, if a specific emission unit has not been tested yet, the permittee shall use the highest emission factor for the corresponding load from the test results for any of the generator engines that have already been tested.

9.7. For the purposes of Condition C.9.5, if a specific load reading is missing, the permittee shall calculate the emissions for that missing load reading by using the emission factor and load combination that results in the highest emissions rate for that emissions unit. If the engine in question has not been tested yet, the permittee shall use the emission factor as provided for in Condition C.9.6.

9.8. For the purpose of Condition C.9.5, if either the urea pump is not operating or if the catalyst inlet temperature, measured in Condition B.28, is less than 250°C, calculate emissions of NO_X for the affected time period by using an uncontrolled emission factor obtained by applying a 95 percent NO_X reduction efficiency to the emission factor determined pursuant to Condition C.8.5.

D. DISCOVERER PROPULSION ENGINE (FD-7)

1. The permittee shall not operate Unit FD-7 for any reason when operating the Discoverer as an OCS Source.

2. The permittee shall report to the EPA via facsimile or email, any deviation from Condition D.1 within 3 business days of identification.

E. DISCOVERER EMERGENCY GENERATOR AND SELDOM USED SOURCES (FD-8)

1. **Discoverer Seldom Used Sources.** For purposes of this permit, Discoverer seldom used sources means any fuel burning unit on the Discoverer except for the emergency generator and Units FD 1 – 7 and FD 9 – 22.

2. **Emergency Generator Reliability Testing Limits.** The permittee shall operate the emergency generator:

   2.1. For no more than 120 minutes during any one day;

   2.2. For no more than 10 hours during any drilling season; and

   2.3. The emergency generator shall only operate during the period of 12 pm to 2 pm.

3. **Fuel Usage Limit**. The permittee shall not use in excess of 150 gallons of fuel in aggregate in the Discoverer emergency generator and all Discoverer seldom used sources in any rolling 7-day period.

4. **Emergency Generator Hourly Emission Limits.** Emissions from the emergency generator shall not exceed the emission limits specified for each of the pollutants below:

   4.1. **Nitrogen oxides (NO_X):** 19.73 lb/hr

      4.1.1. For compliance with Condition E.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Emergency Generator Daily Emission Limits.** Emissions from the emergency generator shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **PM_{10}:** 2.77 lbs/day

      5.1.1. For compliance with Condition E.5.1, measurement of PM_{10} shall be determined using EPA Method s 201A and 202.

   5.2. **$PM_{2.5}$:** 2.77 lbs/day

      5.2.1. For compliance with Condition E.5.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Monitoring, Recordkeeping and, Reporting.** For each instance in which the Discoverer emergency generator or each Discoverer seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

   6.1. Record the duration of the episode for the Discoverer emergency generator and each Discoverer seldom used source;

   6.2. Record the fuel consumption on a daily basis for the Discoverer emergency generator and each Discoverer seldom used source as provided in Condition B.6.4.2;

   6.3. Calculate and record for the previous 6 calendar days the a rolling 7-day fuel consumption for the Discoverer emergency generator and all Discoverer seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days;

   6.4. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day from the emergency generator by multiplying an emission factor (0.587 lbs/gal for NO_X and 0.022 lbs/gal for $PM_{2.5}$ and PM_{10}) and recorded fuel use; and

6.5. The permittee shall report to the EPA via facsimile or email, any deviation from Conditions E.2 and E.3within 3 business days of identification.

7. **BACT Good Combustion Practices for NO_X, PM_{10}, $PM_{2.5}$, VOC, and CO (Carbon Monoxide).** The permittee shall:

7.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

7.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

7.3. Have the maintenance specialist inspect, at least once each week, each emission unit for proper operation and maintenance consistent with the manufacturer's recommendations;

7.4. Ensure that the operation and maintenance manual provided by the manufacturer for each emission unit shall be kept on board the Discoverer at all times;

7.5. Follow the manufacturer's recommended operation and maintenance procedures for each of emission unit;

7.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions E.7.2, E.7.3, and E.7.5, respectively; and

7.7. No less than 30 days prior to each deployment of the Discoverer to the Beaufort Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions E.7.1 and E.7.2 for the upcoming drilling season.

F. MUD LINE CELLAR COMPRESSOR ENGINES (FD-9 – 11)

1. **Operation of Oxidation Catalyst.** At all times that any of Units FD-9 – 11 are in operation, the exhaust from each emission unit shall be directed to an operating oxidation catalyst.

2. **BACT Limits.** Emissions from each MLC compressor engine (Units FD-9 – 11) shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X and non-methane hydrocarbons (NMHC), in aggregate:** 4.0 g/kW-hr

2.1.1. For compliance with Condition F.2.1, measurement of NO_X shall be determined using EPA Method 7E.

2.1.2. For compliance with Condition F.2.1, measurement of NMHC shall be determined using EPA Method 25A.

2.2. **PM:** 0.10 g/kW-hr

2.2.1. For compliance with Condition F.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:** 0.10 g/kW-hr

2.3.1. For compliance with Condition F.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:** 0.10 g/kW-hr

2.4.1. For compliance with Condition F.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition F.2.5, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:** 1.86 g/kW-hr

2.6.1. For compliance with Condition F.2.6, measurement of CO shall be determined using EPA Method 10.

3. **Annual Emission Limits.** Emissions from all three MLC compressor engines (Units FD-9 – 11) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

3.1. **NO_X:** 1.71 tons/rolling 12-month period

3.1.1. For compliance with Condition F.3.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Hourly Emission Limits.** Emissions from all three MLC compressor engines (Units FD-9 – 11) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 7.11 lbs/hour

4.1.1. For compliance with Condition F.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Daily Emission Limits.** Emissions from all three MLC compressor engine (Units FD-9 – 11) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **PM_{10}:** 4.26 lbs/day

5.1.1. For compliance with Condition F.5.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

5.2. **$PM_{2.5}$:** 4.26 lbs/day

5.2.1. For compliance with Condition F.5.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Fuel Usage Limit.** The permittee shall not use in excess of 81,346 gallons of fuel in all three of Units FD-9 – 11 in aggregate during any rolling 12-month period.

7. **Stack Test Requirements.** The permittee shall stack test all of Units FD-9 – 11 as follows:

7.1. At the start of the first drilling season that the Discoverer operates under this permit in the Beaufort Sea, all three of Units FD-9 – 11 shall have been stack tested under the requirements of this section.

7.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

7.2.1.	**CO**	at one load between 50 and 70 percent load;
7.2.2.	**NO_X**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
7.2.3.	**NO_2**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
7.2.4.	**NMHC**	at one load between 50 and 70 percent load;
7.2.5.	**$PM_{2.5}$**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
7.2.6.	**PM_{10}**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads; and
7.2.7.	**Visible emissions**	at one load between 50 and 70 percent load.

7.3. During each test run, the permittee shall monitor and record the following information:

7.3.1. Quantity of fuel used (in gallons);

7.3.2. Density of the fuel used (in lbs/gallon);

7.3.3. Heat content of the fuel used (in Btu/gallon); and

7.3.4. Mechanical power output (in kW).

7.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr, and lbs/gallon.

8. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

8.1. Equip each of Units FD-9 – 11 with a diesel fuel flow meter, or install a single fuel meter for all of Units FD-9 -11:

8.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

8.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

8.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

8.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

8.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

8.4. Monitor and record fuel usage for each engine on a hourly basis.

8.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition F.7.4 and fuel usage data collected under Condition F.8.4.

G. HYDRAULIC POWER UNIT (HPU) ENGINES (FD-12 – 13)

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times that any of Units FD-12 – 13 are in operation, the exhaust from each emission unit shall be directed to an operating CleanAIR Systems CDPF, Part No. FDA300.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units FD-12 – 13 is operated, the exhaust temperature shall be above 300°C, or 572°F for at least 30 percent of the time.

2. **BACT Limits**. Emissions from each HPU engine (Units FD-12 – 13) shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X and NMHC, in aggregate:** 4.0 g/kW-hr

2.1.1. For compliance with Condition G.2.1, measurement of NO_X shall be determined using EPA Method 7E.

2.2. **PM:** 0.030 g/kW-hr

2.2.1. For compliance with Condition G.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:** 0.030 g/kW-hr

2.3.1. For compliance with Condition G.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:** 0.030 g/kW-hr

2.4.1. For compliance with Condition G.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition G.2.5, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:** 0.70 g/kW-hr

2.6.1. For compliance with Condition G.2.6, measurement of CO shall be determined using EPA Method 10.

3. **BACT Good Combustion Practices for NO_X.** The permittee shall:

3.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

3.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

3.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-12 – 13 for proper operation and maintenance consistent with the manufacturer's recommendations;

3.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-12 – 13 shall be kept on board the Discoverer at all times;

3.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-12 – 13;

3.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions G.3.2, G.3.3, and G.3.5, respectively; and

3.7. No less than 30 days prior to each deployment of the Discoverer to the Beaufort Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions G.3.1 and G.3.2 for the upcoming drilling season.

4. **Annual Emission Limits.** Emissions from both HPU engines (Units FD-12 – 13) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 0.79 tons/rolling 12-month period

4.1.1. For compliance with Condition G.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limits.** Emissions from both HPU engines (Units FD-12 – 13) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **NO_X:** 3.29 lbs/hour

      5.1.1. For compliance with Condition G.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from both HPU engines (Units FD-12 – 13) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **PM_{10}:** 0.59 lbs/day

      6.1.1. For compliance with Condition G.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and202.

   6.2. **$PM_{2.5}$:** 0.59 lbs/day

      6.2.1. For compliance with Condition G.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and202.

7. **Annual Fuel Usage Limit.** The permittee shall not use in excess of 44,338 gallons of fuel in both of Units FD-12 – 13 in aggregate during any rolling 12-month period.

8. **Daily Fuel Usage Limits/Alternative Operating Scenarios.** Units FD-12, FD-13 and FD-23 shall be operated under one of three operating scenarios: Base Operating Scenario, Alternative Operating Scenario #1 or Alternative Operating Scenario #2. The permittee shall not use fuel in excess of the following limits while operating under the operating scenarios:

   8.1. Under Base Operating Scenario, the permittee shall not operate either of Units FD-12 – 13;

   8.2. Under Alternative Operating Scenario #1, the permittee shall not use in excess of 352 gallons of fuel in both of Units FD-12 – 13 in aggregate during any calendar day;

   8.3. Under Alternative Operating Scenario #2, the permittee shall not use in excess of 704 gallons of fuel in both of Units FD-12 – 13 in aggregate during any calendar day; and

   8.4. For each calendar day that the permittee intends to operate under either of Alternative Operating Scenarios #1 or 2, the permittee shall record in a log, at the beginning of the calendar day, which scenario it will be operating under for the day. In the absence of a log entry, the permittee shall comply with the requirements applicable to the Base Operating Scenario.

9. **Stack Test Requirements.** The permittee shall stack test both of Units FD-12 – 13 as follows:

   9.1. At the start of the first drilling season that the Discoverer operates under this permit in the Beaufort Sea, both of Units FD-12 – 13 shall have been stack tested under the requirements of this section.

9.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

9.2.1.	**CO**	at one load between 50 and 70 percent load;
9.2.2.	**NO_X**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.3.	**NO_2**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.4.	**$PM_{2.5}$**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.5.	**PM_{10}**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.6.	**VOC**	at one load between 50 and 70 percent load; and
9.2.7.	**Visible emissions**	at one load between 50 and 70 percent load.

9.3. During each test run, the permittee shall monitor and record the following information:

9.3.1. Quantity of fuel used (in gallons);

9.3.2. Density of the fuel used (in lbs/gallon);

9.3.3. Heat content of the fuel used (in Btu/gallon); and

9.3.4. Mechanical power output (in kW).

9.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr and lbs/gallon.

10. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

10.1. Equip each of Units FD-12 – 13 with a diesel fuel flow meter, or install a single fuel meter for both of Units FD-12 - 13:

10.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

10.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

10.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

10.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

10.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

10.4. Monitor and record fuel usage for each engine on a hourly basis.

10.5. Monitor the exhaust temperature of each engine by use of the HiBACK monitor and alarm unit, whenever the engine is in operation.

10.6. Each day, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

10.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition G.9.4 and fuel usage data collected under Condition G.10.4.

H. DECK CRANES (FD-14 – 15)

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times that any of Units FD-14 – 15 in operation, the exhaust from each emission unit shall be directed to an operating CleanAIR Systems CDPF, Part No. 07040401AF.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units FD-14 -15 is operated, the exhaust temperature shall be above 300°C, or 572°F, for at least 30 percent of the time.

2. **BACT Limits.** Emissions from each deck crane engine (Units FD-14 – 15) shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X:** 10.327 g/kW-hr

2.1.1. For compliance with Condition H.2.1, measurement of NO_X shall be determined using EPA Method 7E.

2.2. **PM:** 0.0715 g/kW-hr

2.2.1. For compliance with Condition H.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:** 0.0715 g/kW-hr

2.3.1. For compliance with Condition H.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:** 0.0715 g/kW-hr

2.4.1. For compliance with Condition H.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition H.0, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:** 0.220 g/kW-hr

2.6.1. For compliance with Condition H.2.6, measurement of CO shall be determined using EPA Method 10.

2.7. **VOC:** 0.0640 g/kW-hr

2.7.1. For compliance with Condition H.2.7, measurement of VOC shall be determined using EPA Method 25A.

3. **BACT Good Combustion Practices for NO_X.** The permittee shall:

3.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

3.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

3.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-14 – 15 for proper operation and maintenance consistent with the manufacturer's recommendations;

3.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-14 – 15 shall be kept on board the Discoverer at all times;

3.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-14 – 15;

3.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions H.3.2, H.3.3, and H.3.5 respectively; and

3.7. No less than 30 days prior to initial deployment of the Discoverer to the Beaufort Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions H.3.1 and H.3.2 for the upcoming drilling season.

4. **Annual Emission Limits.** Emissions from both deck crane engines (Units FD-14 – 15) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 2.76 tons/rolling 12-month period

4.1.1. For compliance with Condition H.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limits.** Emissions from both deck cranes engines (Units FD-14 – 15) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **NO_X:** 2.48 lbs/hour

      5.1.1. For compliance with Condition H.5.1 measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from both deck crane engines (Units FD-14 – 15) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **PM_{10}:** 0.41 lbs/day

      6.1.1. For compliance with Condition H.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A 202.

   6.2. **$PM_{2.5}$:** 0.41 lbs/day

      6.2.1. For compliance with Condition H.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

7. **Fuel Usage Limit.** The permittee shall not use in excess of 63,661 gallons of fuel in both of Units FD-14 – 15 in aggregate during any rolling 12-month period.

8. **Stack Test Requirements.** The permittee shall stack test both of Units FD-14 – 15 as follows:

   8.1. At the start of the first drilling season that the Discoverer operates under this permit in the Beaufort Sea, both of Units FD-14 – 15 shall have been stack tested under the requirements of this section.

   8.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

      7.1.1 **CO** at one load between 60 and 80 percent load;

      7.1.2 **NO_X** at two loads – between 60 and 80 percent and between 80 and 100 percent loads;

      7.1.3 **NO_2** at two loads – between 60 and 80 percent and between 80 and 100 percent loads;

      7.1.4 **$PM_{2.5}$** at two loads – between 60 and 80 percent and between 80 and 100 percent loads;

      7.1.5 **PM_{10}** at two loads – between 60 and 80 percent and between 80 and 100 percent loads;

      7.1.6 **VOC** at one load between 60 and 80 percent load; and

      7.1.7 **Visible emissions** at one load between 60 and 80 percent load.

   8.3. During each test run, the permittee shall monitor and record the following information:

      8.3.1. Quantity of fuel used (in gallons);

8.3.2. Density of the fuel used (in lbs/gallon);

8.3.3. Heat content of the fuel used (in Btu/gallon); and

8.3.4. Mechanical power output (in kW).

8.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr and lbs/gallon.

9. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

9.1. Equip each of Units FD-14 -15 with a diesel fuel flow meter or install a single fuel meter for both of Units FD-14 - 15:

9.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

9.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

9.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

9.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

9.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

9.4. Monitor and record fuel usage for each engine on a hourly basis.

9.5. Monitor and record the exhaust temperature of each engine by use of the HiBACK monitor and alarm unit, while the engine is in operation.

9.6. Each day, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

9.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pound per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day, using the highest emission factor collected under Condition H.8.4 and fuel usage data collected under Condition H.9.4 .

I. CEMENTING UNIT AND LOGGING WINCH ENGINES (FD-16 – 20)

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times that any of the cementing unit and logging winch engines (Units FD-16 – 20) are in operation, the exhaust from each emission unit shall be directed to operating CleanAIR Systems CDPF, Part No. FDA300 for Units FD-16 and 17, Part No. FDA225 for Unit FD-18, and as specified by CleanAIR Systems for Units FD-19 – 20.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units FD-16 – 20 is operated, the exhaust temperature shall be above 300°C, or 572°F, for at least 30 percent of the time.

2. **BACT Limits.** Emissions from each of Units FD-16 – 20 shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X:**

FD-16	13.155	g/kW-hr
FD-17	13.155	g/kW-hr
FD-18	15.717	g/kW-hr
FD-19	4.0	g/kW-hr
FD-20	7.50	g/kW-hr

2.1.1. For compliance with Condition I.2.1, measurement of NO_X shall be determined using EPA Method 7E.

2.2. **PM:**

FD-16	0.253	g/kW-hr
FD-17	0.253	g/kW-hr
FD-18	0.386	g/kW-hr
FD-19	0.03	g/kW-hr
FD-20	0.090	g/kW-hr

2.2.1. For compliance with Condition I.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:**

FD-16	0.253	g/kW-hr
FD-17	0.253	g/kW-hr
FD-18	0.386	g/kW-hr
FD-19	0.03	g/kW-hr
FD-20	0.090	g/kW-hr

2.3.1. For compliance with Condition I.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:**

FD-16	0.253	g/kW-hr
FD-17	0.253	g/kW-hr
FD-18	0.386	g/kW-hr
FD-19	0.03	g/kW-hr
FD-20	0.090	g/kW-hr

2.4.1. For compliance with Condition I.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition I.0, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:**

FD-16	0.40	g/kW-hr
FD-17	0.40	g/kW-hr
FD-18	0.880	g/kW-hr
FD-19	0.70	g/kW-hr
FD-20	0.550	g/kW-hr

2.6.1. For compliance with Condition I.2.6, measurement of CO shall be determined using EPA Method 10.

2.7. **VOC:**

FD-16	0.20	g/kW-hr
FD-17	0.20	g/kW-hr
FD-18	0.270	g/kW-hr
FD-19	4.0	g/kW-hr
FD-20	0.750	g/kW-hr

2.7.1. For compliance with Condition I.2.7, measurement of VOC shall be determined using EPA Method 25A.

3. **BACT Good Combustion Practices for NO_X.** The permittee shall:

3.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

3.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

3.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-16 – 20 for proper operation and maintenance consistent with the manufacturer's recommendations;

3.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-16 – 20 shall be kept on board the Discoverer at all times;

3.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-16 – 20;

3.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions I.3.2, I.3.3 and I.3.5 respectively; and

3.7. No less than 30 days prior to initial deployment of the Discoverer to the Beaufort Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions I.3.1 and I.3.2 for the upcoming drilling season.

4. **Annual Emission Limits.** Emissions from all cementing unit and logging winch engines (Units FD-16 – 20) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 4.09 tons/rolling 12-month period

4.1.1. For compliance with Condition I.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limits.** Emissions from all cementing unit and logging winch engines (Units FD-16 - 20) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **NO_X:** 6.56 lbs/hour

5.1.1. For compliance with Condition I.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from all cementing unit and logging winch engines (Units FD-16 – 20) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

6.1. **PM_{10}:** 3.87 lbs/day

6.1.1. For compliance with Condition I.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

6.2. **$PM_{2.5}$:** 3.87 lbs/day

6.2.1. For compliance with Condition I.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and202.

7. **Fuel Usage Limit.** The permittee shall not use in excess of:

7.1. 53,760 gallons of fuel in all Units FD-16 – 20 in aggregate during any rolling 12-month period; and

7.2. 320 gallons of fuel in all Units FD-16 – 20 in aggregate during any calendar day.

8. **Operational Limit.** The permittee shall not operate any cementing unit or logging winch engines (unit FD-16 – 20) while conducting MLC activities as defined in Condition B.2.3.

9. **Stack Test Requirements.** The permittee shall stack test all of Units FD-16 – 20 as follows:

9.1. At the start of the first drilling season that the Discoverer operates under this permit in the Beaufort Sea, all of Units FD-16 – 20 shall have been stack tested under the requirements of this section.

9.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

9.2.1.	**CO**	at one load between 50 and 70 percent load;
9.2.2.	**NO_X**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.3.	**NO_2**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.4.	**$PM_{2.5}$**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.5.	**PM_{10}**	at two loads – between 50 and 70 percent and between 80 and 100 percent loads;
9.2.6.	**VOC**	at one load between 50 and 70 percent load; and
9.2.7.	**Visible emissions**	at one load between 50 and 70 percent load.

9.3. During each test run, the permittee shall monitor and record the following information:

9.3.1. Quantity of fuel used (in gallons);

9.3.2. Density of the fuel used (in lbs/gallon);

9.3.3. Heat content of the fuel used (in Btu/gallon); and

9.3.4. Mechanical power output (in kW).

9.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr and lbs/gallon.

10. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

10.1. Equip each of Units FD-16 – 20 with a diesel fuel flow meter or install a single fuel meter for all of Units FD-16 - 20:

10.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

10.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

10.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

10.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

10.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

10.4. Monitor and record fuel usage for each engine on a hourly basis.

10.5. Monitor and record the exhaust temperature of each of engines FD-16 – 20 by use of the HiBACK monitor and alarm unit, while the engine is in operation.

10.6. Each day, for each of engines FD-16 – 20, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

10.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions from $PM_{2.5}$ and PM_{10} in pounds per day, using the highest emission factor collected under Condition I.9.4 and fuel usage data collected under Condition I.10.4.

J. HEAT BOILERS (FD-21 – 22)

1. **BACT Limits.** Emissions from each of the heat boilers (Units FD-21 – 22) shall not exceed the emission limits specified for each of the pollutants below:

1.1. **NO_X:** 0.20 lbs/MMBtu

1.1.1. For compliance with Condition J.1.1, measurement of NO_X shall be determined using EPA Method 7E.

1.2. **PM:** 0.0235 lbs/MMBtu

1.2.1. For compliance with Condition J.1.2, measurement of PM shall be determined using EPA Method 5.

1.3. **PM_{10}:** 0.0235 lbs/MMBtu

1.3.1. For compliance with Condition J.1.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

1.4. **$PM_{2.5}$:** 0.0235 lbs/MMBtu

1.4.1. For compliance with Condition J.1.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

1.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

1.5.1. For compliance with Condition J.1.5, measurement of visible emissions shall be determined using EPA Method 9.

1.6. **CO:** 0.0770 lbs/MMBtu

1.6.1. For compliance with Condition J.0, measurement of CO shall be determined using EPA Method 10.

1.7. **VOC:** 0.00140 lbs/MMBtu

1.7.1. For compliance with Condition J.1.7, measurement of VOC shall be determined using EPA Method 25A.

2. **BACT Good Combustion Practices for NO_X, PM, $PM_{2.5}$, PM_{10}, CO, and VOC.** The permittee shall:

2.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

2.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

2.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-21 – 22 for proper operation and maintenance consistent with the manufacturer's recommendations;

2.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-21 – 22 shall be kept on board the Discoverer at all times;

2.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-21 – 22;

2.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions J.2.2, J.2.3, and J.2.5 respectively; and

2.7. No less than 30 days prior to initial deployment of the Discoverer to the Beaufort Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions J.2.1 and J.2.2 for the upcoming drilling season.

3. **Annual Emission Limits.** Emissions from all heat boilers (Units FD-21 – 22) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

3.1. **NO_X:** 4.59 tons/rolling 12-month period

3.1.1. For compliance with Condition J.3.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Hourly Emission Limits.** Emissions from all heat boilers (Units FD-21 – 22) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 3.19 lbs/hour

4.1.1. For compliance with Condition J.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Daily Emission Limits.** Emissions from all heat boilers (Units FD-21 – 22) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **PM_{10}:** 8.99 lbs/day

5.1.1. For compliance with Condition J.5.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

5.2. **$PM_{2.5}$:** 8.99 lbs/day

5.2.1. For compliance with Condition J.5.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Stack Test Requirements.** The permittee shall stack test both of Units FD-21 – 22 as follows:

6.1. At the start of the first drilling season that the Discoverer operates under this permit in the Beaufort Sea, both of Units FD-21 – 22 shall have been stack tested under the requirements of this section.

6.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

6.2.1. **CO** at 100 percent load;

6.2.2. **NO_X** at 50 percent and 100 percent loads;

6.2.3. **NO_2** at 50 percent and 100 percent loads;

6.2.4. **$PM_{2.5}$** at 50 percent and 100 percent loads;

6.2.5. **PM_{10}** at 50 percent and 100 percent loads;

6.2.6. **VOC** at 100 percent load; and

6.2.7. **Visible emissions** at 100 percent load.

6.3. During each test run, the permittee shall monitor and record the following information:

6.3.1. Quantity of fuel used (in gallons);

6.3.2. Density of the fuel used (in lbs/gallon); and

6.3.3. Heat content of the fuel used (in Btu/gallon).

6.4. For each boiler, each load range and each pollutant, the permittee shall determine emission factors in the following units: lbs/MMBtu and lbs/gallon.

7. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

7.1. Equip each of Units FD-21 – 22 with a diesel fuel flow meter or install a single fuel meter for both of Units FD-21 – 22:

7.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the boiler(s) or boiler group being served by the meter;

7.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

7.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

7.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

7.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

7.4. Monitor and record fuel usage for each boiler on a hourly basis.

7.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X, $PM_{2.5}$ and PM_{10} using the highest emission factor collected under Condition J.6.4 and fuel usage data collected under Condition J.7.4.

K. WASTE INCINERATOR (FD-23)

1. **BACT Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

1.1. **NO_X:** 5.0 lbs/ton of waste incinerated

1.1.1. For compliance with Condition K.1.1, measurement of NO_X shall be determined using EPA Method 7E.

1.2. **PM:** 8.20 lbs/ ton of waste incinerated

1.2.1. For compliance with Condition K.1.2, measurement of PM shall be determined using EPA Method 5.

1.3. **PM_{10}:** 8.20 lbs/ton of waste incinerated

1.3.1. For compliance with Condition K.1.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

1.4. **$PM_{2.5}$:** 7.00 lbs/ton of waste incinerated

1.4.1. For compliance with Condition K.1.4, measurement of $PM_{2.5}$ shall be determined using OTM 27 and EPA Methods 201A and 202.

1.5. **CO:** 31.0 lbs/ton of waste incinerated

1.5.1. For compliance with Condition K.1.5, measurement of CO shall be determined using EPA Method 10.

1.6. **VOC:** 3.0 lbs/ton of waste incinerated

1.6.1. For compliance with Condition K.1.6, measurement of VOC shall be determined using EPA Method 25A.

2. **BACT Good Combustion Practices for NO_X, PM, $PM_{2.5}$, PM_{10}, CO, and VOC.** The permittee shall:

   2.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

   2.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hour of identification;

   2.3. Have the maintenance specialist inspect, at least once each week, Unit FD-23 for proper operation and maintenance consistent with the manufacturer's recommendations;

   2.4. Ensure that the operation and maintenance manual provided by the manufacturer for Unit FD-23 shall be kept on board the Discoverer at all times;

   2.5. Follow the manufacturer's recommended operation and maintenance procedures for Unit FD-23;

   2.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions K.2.2, K.2.3, and K.2.5 respectively; and

   2.7. No less than 30 days prior to initial deployment of the Discoverer to the Beaufort Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions K.2.1 and K.2.2 for the upcoming drilling season.

3. **Annual Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   3.1. **NO_X:** 0.20 tons/rolling 12-month period

   3.1.1. For compliance with Condition K.3.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Hourly Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   4.1. **NO_X:** 0.65 lb/hr

   4.1.1. For compliance with Condition K.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Daily Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **PM_{10}:** 5.33 lbs/day

   5.1.1. For compliance with Condition K.5.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   5.2. **$PM_{2.5}$:** 4.55 lbs/day

   5.2.1. For compliance with Condition K.5.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Throughput-Based Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **PM_{10}:** 8.20 lbs/ton of waste incinerated

   6.1.1. For compliance with Condition K.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   6.2. **$PM_{2.5}$:** 7.00 lbs/ton of waste incinerated

   6.2.1. For compliance with Condition K.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

   6.3. **SO_2:** 2.50 lbs/ton of waste incinerated

   6.3.1. For compliance with Condition K.6.3, measurement of SO_2 shall be determined using EPA Method 6C.

7. **Annual Waste Throughput Limit.** The permittee shall not incinerate in excess of 50,400 lbs of all types of waste in Unit FD-23 during any rolling 12-month period.

8. **Daily Fuel Usage Limits/Alternative Operating Scenarios.** Units FD-12, FD-13 and FD-23 shall be operated under one of three operating scenarios: Base Operating Scenario, Alternative Operating Scenario #1 or Alternative Operating Scenario #2. The permittee shall not incinerate waste in excess of the following limits while operating under the operating scenarios:

   8.1. Under Base Operating Scenario, the permittee shall not incinerate in excess of 1300 lbs of waste during any calendar day;

   8.2. Under Alternative Operating Scenario #1, the permittee shall not incinerate in excess of 800 lbs of waste during any calendar day;

   8.3. Under Alternative Operating Scenario #2, the permittee shall not incinerate in excess of 300 lbs of waste during any calendar day; and

   8.4. For each calendar day that the permittee intends to operate under either of Alternative Operating Scenarios #1 or 2, the permittee shall record as specified in Condition G.8.4.

9. **Waste Segregation Work Practice.** The permittee shall develop and implement a written waste segregation work practice plan to ensure that non-combustible items containing heavy metals that could be volatilized and emitted from the incinerator as PM are not introduced into the incinerator. The plan shall be submitted to the EPA Region 10 at least 30 days prior to initial deployment of the Discoverer to the Beaufort Sea.

10. **Stack Test Requirements.** Prior to each of the first three drilling seasons that the Discoverer operates under this permit in the Beaufort Sea, the permittee shall stack test the incinerator (Unit FD-23) as follows:

   10.1. Each stack test shall be conducted at full rated capacity.

   10.2. For the first drilling season, each stack test run shall test for emissions of CO, NO_X, NO_2, $PM_{2.5}$, PM_{10}, SO_2, and VOC.

10.3. For subsequent drilling seasons, each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, PM_{10}, and SO_2.

10.4. During each test run, the permittee shall monitor and record the following information:

10.4.1. Quantity of fuel used (in gallons);

10.4.2. Density of the fuel used (in lbs/gallon);

10.4.3. Heat content of the fuel used (in Btu/gallon);

10.4.4. Quantity of waste incinerated (tons); and

10.4.5. Type of waste incinerated.

10.5. For each pollutant, the permittee shall determine emission factors in the following units: lbs/ton of waste incinerated.

11. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

11.1. For each batch of waste charged to the incinerator:

11.1.1. Record the date and time that each batch of waste was charged to the incinerator;

11.1.2. Weigh the batch of waste by using a weigh scale used that shall be accurate to within 0.5 lbs; and

11.1.3. Record the weight of each batch of waste charged to the incinerator.

11.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of the weigh scale to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

11.3. Maintain the accuracy of the weigh scale in accordance with manufacturer's recommendations.

11.4. Monitor and record the exhaust temperature of the incinerator at least every 15 minutes.

11.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition K.10.5 and waste material incinerated throughput collected under Condition K.11.1.

12. **COA Regulations: Incinerator Visible Emissions.** The permittee shall comply with the following.

12.1. Do not cause or allow visible emissions, excluding condensed water vapor, through the exhaust of Unit FD-23, to reduce visibility by more than 20 percent averaged over any six consecutive minutes.

12.2. Observe, record, and report the exhaust of Unit FD-23 using the visible emission monitoring, recordkeeping, and reporting Conditions B.10 through B.12.

L. SUPPLY SHIP GENERATOR ENGINE (FD-31)

1. **Operational Limits**. For events where the supply ship is attached to the Discoverer, the permittee shall:

   1.1. Not use in excess of 184.0 gallons of fuel per day in the non-propulsion generators (not including the emergency engine), in aggregate; and

   1.2. Not use in excess of 1472.0 gallons of fuel during any rolling 12-month period in the non-propulsion generators (not including the emergency engine), in aggregate.

2. **Annual Emission Limits.** For events where the supply ship is attached to the Discoverer, emissions from operation of the supply ship generator engine (Unit FD-31) shall not exceed the emission limits specified for each of the pollutants below:

   2.1. **NO_X:** 0.43 tons/rolling 12-month period

      2.1.1. For compliance with Condition L.2.1, measurement of NO_X shall be determined using EPA Method 7E.

3. **Daily Emission Limits.** For events where the supply ship is attached to the Discoverer, emissions from operation of the supply ship generator engine (Unit FD-31) shall not exceed the emission limits specified for each of the pollutants below:

   3.1. **PM_{10}:** 7.60 lbs/day

      3.1.1. For compliance with Condition L.3.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   3.2. **$PM_{2.5}$:** 7.60 lbs/day

      3.2.1. For compliance with Condition L.3.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4. **Stack Test Requirements.** Prior to the first supply ship trip of each drilling season to resupply the Discoverer while the Discoverer is operating under this permit in the Beaufort Sea, the permittee shall stack test the supply ship generator engine (Unit FD-31) as follows:

   4.1. If the generator from the intended supply ship has already been tested pursuant to Conditions L.4.2 through L.4.5 during the past 5 years, no additional stack testing is required.

   4.2. Each stack test shall be conducted at 100 percent load.

   4.3. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

   4.4. During each test run, the permittee shall monitor and record the following information:

      4.4.1. Manufacturer and model no. of the engine;

      4.4.2. The rated capacity of the engine (in hp);

      4.4.3. Quantity of fuel used (in gallons);

4.4.4. Density of the fuel used (in lbs/gallon);

4.4.5. Heat content of the fuel used (in Btu/gallon); and

4.4.6. Electrical power output (in kWe).

4.5. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

5. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

5.1. Equip each of the non-propulsion generator engines (not including the emergency engine) with a diesel fuel flow meter, or install a single fuel meter for all of these engines:

5.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

5.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

5.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

5.2. No less than 60 days before the first deployment to the Beaufort Sea of a vessel as the supply ship, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to departure of the supply vessel to the Beaufort Sea.

5.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

5.4. Monitor and record fuel usage for the non-propulsion generators on a hourly basis while the supply vessel is attached to the Discoverer.

5.5. For each event, record the date and time that the supply ship attaches to the Discoverer.

5.6. For each event, record the date and time that the supply ship detaches from the Discoverer.

5.7. For each event, record the manufacturer, model no. and rated capacity (in hp) of the supply ship generator engine.

5.8. For each event, calculate daily emissions of NO_X, $PM_{2.5}$, and PM_{10} using the highest emission factor collected under Condition L.4.5 and fuel usage data collected under Condition L.5.4

6. **Supply Ship Events.** The total number of events during which the supply ship transits to and from the Discoverer and either attaches to the Discoverer or operates in dynamic positioning mode shall not exceed 8 in any drilling season.

7. **Supply Barge and Tug Alternative.** If a supply barge and tug is used in lieu of the supply ship the permittee shall not operate any emission units on the supply barge when it

is attached to the Discoverer. At no time shall the supply barge tug be attached to the Discoverer.

7.1. For each event, record the date and time that the supply barge attaches to the Discoverer.

7.2. For each event, record the date and time that the supply barge detaches from the Discoverer.

M. SHALLOW GAS DIVERTER SYSTEM (FD-33)

1. **Shallow Gas Diverter System.** There shall be no emissions of any regulated NSR pollutants or GHGs from the shallow gas diverter system.

2. **Shallow Gas Diversions.** The permittee shall:

2.1. Record the frequency and duration of each shallow gas diversion.

2.2. Report the frequency and duration of each shallow gas diversion no later than March 1st for the time period beginning January 1st and ending December 31st of the preceding year.

N. CUTTINGS/MUD DISPOSAL BARGE (FD-34)

1. **Operational Limits.** The permittee shall not operate any fuel combustion sources on the cuttings/mud disposal barge when it is attached to the Discoverer. At no time shall the cuttings/mud disposal barge tug be attached to the Discoverer.

1.1. No later than 45 days prior to deployment to the Beaufort Sea each drilling season, the permittee shall provide notification to the EPA of the selected cuttings/mud disposal barge. The notification shall include a list of all emission sources on board the barge.

1.2. For each event, record the date and time that the cuttings/mud disposal barge attaches to the Discoverer.

1.3. For each event, record the date and time that the cuttings/mud disposal barge detaches from the Discoverer.

O. ICEBREAKER #1

1. **Operation of SCR Unit.** At all times that any of the propulsion or generator engines on board Icebreaker #1 are in operation, the exhaust from each engine shall be directed to an operating SCR emission unit.

2. **Operation of Oxidation Catalyst.** At all times that any of the propulsion or generator engines on board Icebreaker #1 are in operation, the exhaust from each engine shall be directed to an operating oxidation catalyst emission unit.

3. **Aggregate Capacity Limits.** For a given drilling season, the permittee may select any vessel as Icebreaker #1, subject to the following conditions:

   3.1. The total capacity of all propulsion engines on Icebreaker #1 shall not exceed 28,400 hp.

   3.2. The total capacity of all generator engines on Icebreaker #1 shall not exceed 2,800 hp.

   3.3. The total capacity of all boilers on Icebreaker #1 shall not exceed 10 MMBtu/hr.

   3.4. The total capacity of all incinerators on Icebreaker #1 shall not exceed 154 lbs/hr.

   3.5. Total uncontrolled emissions of $PM_{2.5}$ from all emission sources on board Icebreaker #1 shall not exceed 42.20 lbs/hour.

      3.5.1. For compliance with Condition O.3.5 measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

      3.5.2. For the purposes of Condition O.3.5, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

   3.6. Total uncontrolled emissions of PM_{10} from all emission sources on board Icebreaker #1 shall not exceed 48.0 lbs/hour.

      3.6.1. For compliance with Condition O.3.6, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

      3.6.2. For the purposes of Condition O.3.6, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

   3.7. No later than 45 days prior to deployment to the Beaufort Sea each drilling season, the permittee shall provide notification to the EPA of the vessel selected as Icebreaker #1. The notification shall include a list of all emission sources on board the vessel as well as manufacturer, model, and rated capacity of each such emission source, and the conversion efficiency (mechanical to electrical) of each generator on board.

4. **Capacity Limit on Icebreaker #1 Propulsion Engines.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, the permittee shall limit operation of the propulsion engines in Icebreaker #1 to no greater than 80 percent of rated capacity.

5. **Annual Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #1 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **NO_X:** 41.59 tons/rolling 12-month period

5.1.1. For compliance with Condition O.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Hourly Emission Limits.** Emissions from all emission sources on Icebreaker #1 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

6.1. **NO_X:** 67.96 lbs/hour

6.1.1. For compliance with Condition O.6.1, measurement of NO_X shall be determined using EPA Method 7E.

7. **Daily Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #1 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

7.1. **PM_{10}:** 277.47 lbs/day

7.1.1. For compliance with Condition O.7.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

7.2. **$PM_{2.5}$:** 269.66 lbs/day

7.2.1. For compliance with Condition O.7.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

8. **Electrical Power Output Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, the permittee shall not operate the internal combustion engines in excess of:

8.1. 28,233,704 kWe-hr from all of the generators on board Icebreaker #1 in aggregate during any rolling 12-month period; or

8.2. 420,188 kWe-hr from all of the generators on board Icebreaker #1 in aggregate during any calendar day.

9. **Fuel Usage Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, the permittee shall not use fuel in excess of:

9.1. 302,400 gallons in all heat boilers on board Icebreaker #1 in aggregate during any rolling 12-month period; or

9.2. 1,800 gallons in all heat boilers on board Icebreaker #1 in aggregate during any calendar day; or

9.3. 100 gallons in Icebreaker #1 seldom used sources in aggregate during any rolling 7-day period. Icebreaker #1 seldom used sources include engines on Icebreaker #1, that are not otherwise identified in the permit as emission units or categories of emission units on Icebreaker #1.

10. **Attachment to Discoverer.** At no time shall Icebreaker #1 be attached to the Discoverer.

11. **Stack Height Limit for Icebreaker #1.** The permittee shall ensure that the stack height of Icebreaker #1 is no less than 24.38 meters. For the purposes of this condition, the permittee shall obtain the stack height information for each vessel to be used as Icebreaker #1.

12. **Stack Test Requirements.** Prior to each of the first two drilling seasons that a vessel is used as Icebreaker #1, and while the Discoverer is operating under this permit in the Beaufort Sea, the permittee shall stack test each propulsion engine, non-propulsion generator engine, boiler and incinerator on Icebreaker #1 as follows:

    12.1. Each stack test on the propulsion engines shall be conducted at three different loads: 30 percent, 60 percent, and 80 percent.

    12.2. Each stack test on the non-propulsion generator engines shall be conducted at two different load ranges: 50 - 60 percent and 90 - 100 percent.

    12.3. Each stack test on the boilers shall be conducted at full loads.

    12.4. Each stack test on the incinerator shall be conducted at full load.

    12.5. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

    12.6. During each test run for the propulsion engines, generator engines, and boilers, the permittee shall monitor and record the following information:

        12.6.1. Quantity of fuel used (in gallons);

        12.6.2. Density of the fuel used (in lbs/gallon);

        12.6.3. Heat content of the fuel used (in Btu/gallon);

        12.6.4. For the engines, electrical power output (in kWe);

        12.6.5. The stack temperature upstream of the SCR catalysis ºC or ºF;

        12.6.6. The quantity of urea reagent (in gallons) and the concentration of the urea reagent (in weight percent) introduced into the SCR control system; and

        12.6.7. The NO_X concentration (ppm) indicated by the periodic NO_X monitor used for the SCR control system.

    12.7. During each test run for the incinerator, the permittee shall monitor and record the quantity of waste material incinerated (in lbs).

    12.8. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

    12.9. For each boiler, and each pollutant, the permittee shall determine emission factors in the following units: lbs/MMBtu and lbs/gallon.

    12.10. For each incinerator, and each pollutant, the permittee shall determine emission factors in the following units: lbs/ton of waste combusted.

13. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

    13.1. Equip each of the propulsion engines and generator engines on board Icebreaker #1 with an electrical output monitoring device:

13.1.1. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine with an accuracy equal to or better than 2 percent of the engine's maximum output (in kWe);

13.1.2. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine at least once every 10 minutes; and

13.1.3. Each electrical output monitoring device shall be equipped to record each reading taken as well as provide and record average loads for each hour.

13.2. Maintain the accuracy of each electrical output monitoring device in accordance with manufacturer's recommendations.

13.3. Monitor and record the electrical load for each engine at least once every ten minutes, and record the average hourly load for each hour.

13.4. Equip each of the boilers on board Icebreaker #1 with a diesel fuel flow meter or install a single fuel meter for all of the boilers:

13.4.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the boiler(s) or boiler group being served by the meter;

13.4.2. Each fuel flow meter shall be totalizing and nonresettable; and

13.4.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

13.5. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

13.6. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

13.7. Monitor and record the hourly fuel usage for each boiler.

13.8. For each instance in which an Icebreaker #1 seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

13.8.1. Record the duration of the episode for each suchseldom used source;

13.8.2. Record the fuel consumption on a daily basis for each such seldom used source as provided in Condition B.6.4.2; and

13.8.3. Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of Icebreaker #1 seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

13.9. At least 45 days before deployment to the Discoverer each drilling season, the permittee shall notify the EPA of the stack height of Icebreaker #1.

13.10. Record any instance that Icebreaker #1 attaches to the Discoverer.

13.11. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from the boilers and incinerator by using the highest emission factor for each tested boiler or incinerator collected under Conditions O.12.9 and O.12.10 and fuel usage data collected under Condition O.13.7, to determine emissions from that source. For the purposes of this condition, the permittee shall assume that the incinerator has been operated continuously at the maximum operating rate, and shall use the highest emission factor collected under Condition O.12.10.

13.12. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Condition O.12.8 and electrical load data collected under Condition O.13.3, to determine emissions from that source. Emissions shall be calculated for each ten-minute load reading for each engine.

13.13. For the purposes of Conditions O.13.11 and O.13.3, if a specific emission unit has not been tested yet, the permittee shall use the highest emission factor for the corresponding load from the test results for any equivalent emission unit in equivalent service that has already been tested.

13.14. For the purposes of Conditions O.13.11 and O.13.3, if a specific load reading is missing, the permittee shall calculate the emissions for that missing load reading by using the emission factor and load combination that results in the highest emissions rate for that emissions unit. If the engine in question has not been tested yet, the permittee shall use the emission factor as provided for in Condition O.13.13.

13.15. For the purpose of Condition O.13.12, if either the urea pump is not operating or if the catalyst inlet temperature, measured in Condition B.28 , is less than 250°C, calculate emissions of NO_X for the affected time period by using an uncontrolled emission factor obtained by applying a 95 percent NO_X-reduction efficiency to the emission factor determined pursuant to Condition O.12.8.

P. ICEBREAKER #2

1. **Operation of SCR Unit.** At all times that any of the propulsion or generator engines on board Icebreaker #2 are in operation, the exhaust from each engine shall be directed to an operating SCR emission unit.

2. **Operation of Oxidation Catalyst.** At all times that any of the propulsion or generator engines on board Icebreaker #2 are in operation, the exhaust from each engine shall be directed to an operating oxidation catalyst emission unit.

3. **Icebreaker #2 Vessel Alternatives.** For a given drilling season, the permittee may use either the Tor Viking or Hull 247 as Icebreaker #2, subject to the conditions in Section P of this permit. Hull 247 is a temporary vessel name assigned by the shipbuilder, Edison

Chouest. This permit is intended to apply to this vessel even when renamed with its permanent name.

3.1. The total capacity of all propulsion engines on Icebreaker #2 shall not exceed 17,660 hp for the Tor Viking and 24,000 kW for Hull 247.

3.2. The total capacity of all non-propulsion generator engines on Icebreaker #2 shall not exceed 2,336 hp for the Tor Viking and 0 hp for Hull 247 shall not have electrical generation capacity in addition to the engines specified in Condition P.3.1.

3.3. The total capacity of all boilers on Icebreaker #2 shall not exceed 1.37 MMBtu/hr for the Tor Viking and 4.00 MMBtu/hr for Hull 247.

3.4. The total capacity of all incinerators on Icebreaker #2 shall not exceed 151.23 lbs/hr.

3.5. Total uncontrolled emissions of $PM_{2.5}$ from all emission sources on board Icebreaker #2 shall not exceed 11.4 lbs/hour.

3.5.1. For compliance with Condition P.3.5, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

3.5.2. For the purposes of Condition P.3.5, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

3.6. Total uncontrolled emissions of PM_{10} from all emission sources on board Icebreaker #2 shall not exceed 11.7 lbs/hour.

3.6.1. For compliance with Condition P.3.6, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

3.6.2. For the purposes of Condition P.3.6, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

3.7. No later than 45 days prior to deployment to the Beaufort Sea each drilling season, the permittee shall provide notification to the EPA of the vessel selected as Icebreaker #2. The notification shall include a list of all emission sources on board the vessel as well as manufacturer, model, and rated capacity of each emission source.

4. **Capacity Limit on Icebreaker #2 Propulsion Engines.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, the permittee shall limit operation of the propulsion engines in Icebreaker #2 to 80 percent of rated capacity.

5. **Annual Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #2 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **NO_X:** 99.45 tons/rolling 12-month period

      5.1.1. For compliance with Condition P.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Hourly Emission Limits.** Emissions from all emission sources on Icebreaker #2 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **NO_X:** 69.06 lbs/hour

      6.1.1. For compliance with Condition P.6.1, measurement of NO_X shall be determined using EPA Method 7E.

7. **Daily Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #2 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   7.1. **PM_{10}:** 281.46 lbs/day

      7.1.1. For compliance with Condition P.7.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   7.2. **$PM_{2.5}$:** 273.82 lbs/day

      7.2.1. For compliance with Condition P.7.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

8. **Electrical Power Output Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, the permittee shall not operate the internal combustion engines in excess of:

   8.1. 25,223,168 kWe-hr from all of the generators on board the Tor Viking in aggregate during any rolling 12-month period.

   8.2. 44,562.643 kWe-hr from all of the generators on board Hull 247 in aggregate during any rolling 12-month period.

   8.3. 395,100 kWe-hr from all of the generators on board the Tor Viking in aggregate during any calendar day.

   8.4. 592,141 kWe-hr from all of the generators on board Hull 247 in aggregate during any calendar day.

9. **Fuel Usage Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, the permittee shall not use fuel in excess of:

   9.1. 40,320 gallons in all heat boilers on board the Tor Viking in aggregate during any rolling 12-month period.

9.2. 120,960 gallons in all heat boilers on board Hull 247 in aggregate during any rolling 12-month period.

9.3. 240 gallons in all heat boilers on board the Tor Viking in aggregate during any calendar day.

9.4. 720 gallons in all heat boilers on board Hull 247 in aggregate during any calendar day.

9.5. 100 gallons in Icebreaker #2 seldom used sources in aggregate during any rolling 7-day period. Icebreaker #2 seldom used sources include engines on Icebreaker # 2, that are not otherwise identified in the permit as emission units or categories of emission units on Icebreaker #2.

10. **Attachment to Discoverer**. At no time shall Icebreaker #2 be attached to the Discoverer.

11. **Stack Height Limit for Icebreaker #2**. The permittee shall ensure that the stack height of Icebreaker #2 is no less than 24.38 meters. For the purposes of this condition, the permittee shall obtain the stack height information for each vessel to be used as Icebreaker #2.

12. **Stack Test Requirements.** Prior to each of the first two drilling seasons that a vessel is used as Icebreaker #2, and while the Discoverer is operating under this permit in the Beaufort Sea, the permittee shall stack test each propulsion engine, non-propulsion generator engine, boiler and incinerator on Icebreaker #2 as follows:

12.1. Each stack test on the propulsion engines shall be conducted at four different loads: 20 percent, 40 percent, 60 percent, and 80 percent.

12.2. Each stack test on the non-propulsion generator engines shall be conducted at two different load ranges: 50 - 60 percent and 90 - 100 percent.

12.3. Each stack test on the boilers shall be conducted at full loads.

12.4. Each stack test on the incinerator shall be conducted at full load.

12.5. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

12.6. During each test run for the propulsion engines, generator engines, and boilers, the permittee shall monitor and record the following information:

12.6.1. Quantity of fuel used (in gallons);

12.6.2. Density of the fuel used (in lbs/gallon);

12.6.3. Heat content of the fuel used (in Btu/gallon);

12.6.4. For the engines, electrical power output (in kWe);

12.6.5. The stack temperature upstream of the SCR catalyst ºC or ºF;

12.6.6. The quantity of urea reagent (in gallons) and the concentration of the urea reagent (in weight percent) introduced into the SCR control system; and

12.6.7. The NO_X concentration (ppm) indicated by the periodic NO_X monitor used for the SCR control system.

12.7. During each test run for the incinerator, the permittee shall monitor and record the quantity of waste material incinerated (in lbs).

12.8. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

12.9. For each boiler, and each pollutant, the permittee shall determine emission factors in the following units: lbs/MMBtu and lbs/gallon.

12.10. For each incinerator, and each pollutant, the permittee shall determine emission factors in the following units: lbs/ton of waste combusted.

13. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

13.1. Equip each of the propulsion engines and generator engines on board Icebreaker #2 with an electrical output monitoring device:

13.1.1. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine with an accuracy equal to or better than 2 percent of the engine's maximum output (in kWe).

13.1.2. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine at least once every 10 minutes.

13.1.3. Each electrical output monitoring device shall be equipped to record each reading taken as well as provide and record average loads for each hour.

13.2. Maintain the accuracy of each electrical output monitoring device in accordance with manufacturer's recommendations.

13.3. Monitor and record the electrical load for each engine at least once every ten minutes, and record the average hourly load for each hour.

13.4. Equip each of the boilers on board Icebreaker #2 with a diesel fuel flow meter or install a single fuel meter for all of the boilers:

13.4.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the boiler(s) or boiler group being served by the meter;

13.4.2. Each fuel flow meter shall be totalizing and non-resettable; and

13.4.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

13.5. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

13.6. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

13.7. Monitor and record the hourly fuel usage for each boiler.

13.8. For each instance in which an Icebreaker #2 seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

13.8.1. Record the duration of the episode for each such seldom used source;

13.8.2. Record the fuel consumption on a daily basis for each Icebreaker #2 seldom used source as provided in Condition B.6.4.2; and

13.8.3. Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of such seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

13.9. At least 45 days before deployment to the Discoverer each drilling season, the permittee shall notify the EPA of the stack height of Icebreaker #2.

13.10. Record any instance that Icebreaker #2 attaches to the Discoverer.

13.11. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from the boilers and incinerator by using the highest emission factor for each tested boiler or incinerator collected under Conditions P.12.9 and P.12.10 and fuel usage data collected under Condition P.13.7, to determine emissions from that source. For the purposes of this condition, the permittee shall assume that the incinerator has been operated continuously at the maximum operating rate, and shall use the highest emission factor collected under Condition P.12.10.

13.12. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Conditions P.12.8 and electrical load data collected under Condition P.13.3, to determine emissions from that source. Emissions shall be calculated for each ten-minute load reading for each engine.

13.13. For the purposes of Conditions P.13.11 and P.13.12, if a specific emission unit has not been tested yet, the permittee shall use the highest emission factor for the corresponding load from the test results from an equivalent emission unit in equivalent service that has already been tested.

13.14. For the purposes of Conditions P.13.11 and P.13.12, if a specific load reading is missing, the permittee shall calculate the emissions for that missing load reading by using the emission factor and load combination that results in the highest emissions rate for that emissions unit. If the engine in question has not been tested yet, the permittee shall use the emission factor as provided for in Condition P.13.13.

13.15. For the purpose of Condition P.13.12, if either the urea pump is not operating or if the catalyst inlet temperature, measured in Condition B.28, is less than $250^{o}C$, calculate emissions of NO_X for the affected time period by using an uncontrolled emission factor obtained by applying a 95 percent NO_X-reduction efficiency to the emission factor determined pursuant to Condition P.12.8.

Q. SUPPLY SHIP/BARGE AND TUG

1. **Operational Limits on Supply Ship Engines.** At all times while the Discoverer is an OCS Source and the supply ship is within 25 miles of the Discoverer, the permittee shall:

   1.1. Not operate the emergency engine on the supply ship.

   1.2. Not use fuel in excess of 1,200 gallons in the supply ship propulsion engines and non-propulsion engines in aggregate during any calendar day when in transit to and from the Discoverer.

   1.3. Not use fuel in excess of 4,800 gallons in the supply ship propulsion engines and non-propulsion engines in aggregate during any calendar day when operating in dynamic positioning mode.

2. **Hourly Emission Limits on Supply Ship in Dynamic Positioning Mode.** Emissions from all generator and propulsion engines in aggregate on the supply ship shall not exceed the emission limits specified for each of the pollutants below:

   2.1. **Nitrogen oxides (NO_X):** 117.39 lb/hr

      2.1.1. For compliance with Condition Q.2.1, measurement of NO_X shall be determined using EPA Method 7E.

3. **Daily Emission Limits on Supply Ship in Dynamic Positioning Mode.** Emissions from all generator and propulsion engines in aggregate on the supply ship shall not exceed the emission limits specified for each of the pollutants below:

   3.1. **PM_{10}:** 75.09 lbs/day

      3.1.1. For compliance with Condition Q.3.1, measurement of PM_{10} shall be determined using EPA Method s 201A and 202.

   3.2. **$PM_{2.5}$:** 75.09 lbs/day

      3.2.1. For compliance with Condition Q.3.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4. **Stack Test Requirements.** Prior to each of the first two drilling seasons that the supply ship is used and while the Discoverer is operating under this permit in the Beaufort Sea, the permittee shall stack test each propulsion engine and non-propulsion generator engine on the supply ship as follows:

   4.1. Each stack test on the propulsion engines shall be conducted at four different loads: 20 percent, 40 percent, 60 percent, and 80 percent.

   4.2. Each stack test on the non-propulsion generator engines shall be conducted at two different load ranges: 50 - 60 percent and 90 - 100 percent.

   4.3. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

   4.4. During each test run for the propulsion engines and generator engines, the permittee shall monitor and record the following information:

      4.4.1. Quantity of fuel used (in gallons);

4.4.2. Density of the fuel used (in lbs/gallon);

4.4.3. Heat content of the fuel used (in Btu/gallon); and

4.4.4. For the engines, electrical power output (in kWe);

4.5. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

5. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

5.1. At all times while the Discoverer is an OCS Source and the supply ship is within 25 miles of the Discoverer, monitor the power output of each propulsion engine on the supply ship at least once every 15 minutes.

5.1.1. The monitored power output shall be recorded as a direct readout value as well as a percentage of the rated capacity of each engine.

5.2. Equip each of the propulsion and non-propulsion engines on the Supply Ship with a diesel fuel flow meter or install a single fuel meter for all of the engines:

5.2.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

5.2.2. Each fuel flow meter shall be totalizing and non-resettable; and

5.2.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

5.3. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

5.4. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

5.5. Monitor and record the hourly fuel usage for the supply ship.

5.6. For each trip to the Discoverer while the Discoverer is an OCS Source, the permittee shall record the following:

5.6.1. The date and time that the supply ship came within 25 miles of the Discoverer; and

5.6.2. After the delivery to the Discoverer, the date and time that the supply ship was no longer within 25 miles of the Discoverer.

5.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Condition Q.4.5 and recorded fuel use under Condition Q.5.5.

5.8. Record the date and time the supply ship begins operation in dynamic positioning mode.

5.9. Record the date and time the supply ship ceases operation in dynamic positioning mode.

6. **Supply Ship Events.** The total number of events during which the supply ship transits to and from the Discoverer and either attaches to the Discoverer or operates in dynamic positioning mode shall not exceed 8 in any drilling season. Each 24-hour period of operation in dynamic positioning mode is considered a separate supply ship event.

7. **Supply Barge and Tug Alternative.** If a supply barge/tug is used in lieu of the supply ship, the barge and tug shall:

7.1. No later than 45 days prior to deployment to the Beaufort Sea each drilling season, the permittee shall provide notification to the EPA of the selected supply barge and tug. The notification shall include a list of all emission sources on board the vessel as well as manufacturer, model, and rated capacity of each emission source.

7.2. Operational Limits on Supply Barge and Tug Engines. At all times while the Discoverer is an OCS Source and the supply barge and tug is within 25 miles of the Discoverer, the permittee shall:

7.2.1. Limit operation of all engines to an aggregate of 5760 hp.

7.2.2. Each transit of a tug to and from the Discoverer shall equal one supply ship event for purpose of Condition Q.6

7.3. In addition the supply barge and tug will comply with Conditions Q.4 above.

R. OIL SPILL RESPONSE FLEET

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times while the Discoverer is an OCS Source and the Nanuq is within 25 miles of the Discoverer, and any of the Nanuq propulsion engines (Units N-1 – 2) or non-propulsion generator engines (Units N-3 – 4) are in operation, the exhaust from each emission unit shall be directed to operating CleanAIR Systems CDPF, as specified by CleanAIR Systems.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units N-1 – 4 is operated, the exhaust temperature shall be above 300°C, or 572°F, for at least 30 percent of the time.

2. **Annual Emission Limits.** At all times while the Discoverer is an OCS source and the Oil Spill Response fleet is within 25 miles of the Discoverer, emissions of NO_X from the Oil Spill Response Fleet shall not exceed the emission limits specified below:

2.1. **Nanuq propulsion engines and generators in aggregate (Units N-1 – 4):** 97.11 tons/rolling 12-month period

2.2. **Point Class Tug and Arctic Endeavor Barge period propulsion engines and generators in aggregate (Units PBT-1-4, AEB-1-4):** 71.55 tons/rolling 12-month period

2.3. **Kvichak Nos. 1-3 and Rozema Skimmer propulsion engines in aggregate (Units K1-2, K4-5, K7-8, R1-2):** 19.07 tons/rolling 12-month period

2.3.1. For compliance with Conditions R.2.1, R.2.2, and 2.3, measurement of NO_X shall be determined using EPA Method 7E.

3. **Hourly Emission Limits.** At all times while the Discoverer is an OCS source and the Oil Spill Response fleet is within 25 miles of the Discoverer, emissions of NO_X from the Oil Spill Response Fleet shall not exceed the emission limits specified below:

3.1. Nanuq propulsion engines and generators in aggregate (Units N-1 – 4)

3.1.1. **NO_X** 67.44 lb/hr

3.1.1.1. For compliance with Condition R.3.1.1, measurement of NO_X shall be determined using EPA Method 7E.

3.2. Point Class Tug and Arctic Endeavor Barge propulsion engines and generators in aggregate (Units PBT-1-4, AEB-1-4):

3.2.1. **NO_X** 49.69lb/hr

3.2.1.1. For compliance with Condition R.3.2.1, measurement of NO_X shall be determined using EPA Method 7E.

3.3. Kvichak Nos. 1-3 and Rozema Skimmer propulsion engines in aggregate (Units K1-2, K4-5, K7-8, R1-2):

3.3.1. **NO_X** 13.24lb/hr

3.3.1.1. For compliance with Condition R.3.3.1 measurement of NO_X shall be determined using EPA Method 7E.

4. **Daily Emission Limits.** At all times while the Discoverer is an OCS source and the Oil Spill Response fleet is within 25 miles of the Discoverer, emissions from the Oil Spill Response Fleet shall not exceed the emission limits specified:

4.1. Nanuq propulsion engines and generators in aggregate (Units N-1 – 4):

4.1.1. **PM_{10}:** 3.03 lbs/day

4.1.1.1. For compliance with Condition R.4.1.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

4.1.2. **$PM_{2.5}$:** 3.03 lbs/day

4.1.2.1. For compliance with Condition R.4.1.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4.2. Point Class Tug and Arctic Endeavor Barge in aggregate (Units PBT-1-4, AEB-1-4):

4.2.1. **PM_{10}:** 21.35 lbs/day

4.2.1.1. For compliance with Condition R.4.2.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

4.2.2. **$PM_{2.5}$:** 21.35 lbs/day

4.2.2.1. For compliance with Condition R.4.2.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4.3. Kvichak Nos. 1-3 and Rozema Skimmer in aggregate (Units K1-2, K4-5, K7-8, R1-2):

4.3.1. **PM_{10}:** 24.34 lbs/day

4.3.1.1. For compliance with Condition R.4.3.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

4.3.2. **$PM_{2.5}$:** 24.34 lbs/day

4.3.2.1. For compliance with Condition R.4.3.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

5. **Fuel Usage Limit.** At all times while the Discoverer is an OCS Source and the OSR Fleet is within 25 miles of the Discoverer, the permittee shall not use in excess of:

5.1. 456,000 gallons of fuel in the Nanuq propulsion engines (Units N-1 – 2) and non-propulsion electrical generators (Units N-3 – 4) in aggregate during any rolling 12-month period.

5.2. 3,800 gallons of fuel in the Nanuq propulsion engines (Units N-1 – 2) and non-propulsion electrical generators (Units N-3 – 4) in aggregate during any calendar day.

5.3. 336,000 gallons of fuel in the Point Class Tug propulsion engines (Units PBT-1 – 2) and non-propulsion generator engines (Units PBT-3 – 4) and the Arctic Endeavor Barge non-propulsion generation engines (Units AEB-1 – 4) in aggregate during any rolling 12-month period.

5.4. 2,800 gallons of fuel in the Point Class Tug propulsion engines (Units PBT-1 – 2) and non-propulsion generator engines (Units PBT-3 – 4) and the Arctic Endeavor Barge non-propulsion generation engines (Units AEB-1 – 4) in aggregate during any calendar day.

5.5. 100 gallons of fuel in the Nanuq seldom used sources in aggregate during any rolling 7-day period and 100 gallons of fuel in the Point Class Tug seldom used sources in aggregate during any rolling 7-day period. The Nanuq and Point Class Tug seldom used sources include engines on the Nanuq and Point Class Tug that are not otherwise identified in the permit as emission units or categories of emission units on the Nanuq and Point Class Tug.

5.6. 2856 gallons of fuel in the Kvichak Nos. 1-3 and the Rozema Skimmer in aggregate during any rolling 7-day period.

6. **Operating Location.** Except for transport of crew and supplies to and from the Discoverer or when responding to an oil spill, the oil spill response fleet shall operate at a location that is downwind from the Discoverer.

7. **Attachment to Discoverer.** At no time shall the Arctic Endeavor Barge, Point Class Tug, Nanuq, Rozema Skimmer or any of the Kvichak work boats be attached to the Discoverer.

8. **Stack Test Requirements.** Prior to each of the first two drilling seasons while the Discoverer is operating under this permit in the Beaufort Sea, the permittee shall stack test at least one of the Nanuq propulsion engines (Units N-1 – 2) one of the Nanuq non-propulsion generator engines (Units N-3 – 4), one of the Point Class Tug propulsion engines (Units PBT-1 – 2), one of the Point Class Tug non-propulsion engines (Units PBT-1 – 2) and all of the Endeavor Barge engines (Units AEB-1 – 4) as follows:

   8.1. At the end of two drilling seasons that the Discoverer operates under this permit in the Beaufort Sea, all of Units N-1 – 4 shall have been stack tested under the requirements of this section.

   8.2. Each stack test shall be conducted at four different loads - 25 percent, 50 percent, 75 percent and 100 percent for the propulsion engines and at two loads - 50 percent and 100 percent for the non-propulsion engines.

   8.3. Each stack test run shall test for emissions of NO_X and NO_2.

   8.4. During each test run, the permittee shall monitor and record the following information:

      8.4.1. Quantity of fuel used (in gallons);

      8.4.2. Density of the fuel used (in lbs/gallon);

      8.4.3. Heat content of the fuel used (in Btu/gallon); and

      8.4.4. Electrical power output (in kWe).

   8.5. For each engine, each load, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

9. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

   9.1. Equip each of Units FD-N-1 - 4 with a diesel fuel flow meter or install a single fuel meter for all of Units FD-N-1 - 4:

      9.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

      9.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

      9.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

   9.2. No less than 60 days before initial deployment of the Discoverer to the Beaufort Sea for the first drilling season, collect information from the manufacturer of each

fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Beaufort Sea.

9.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

9.4. Monitor and record fuel usage for each propulsion and generator engine (Units N-1 – 4) on a hourly basis.

9.5. For each instance in which a Nanuq seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

9.5.1. Record the duration of the episode for each such seldom used source;

9.5.2. Record the fuel consumption on a daily basis for each such seldom used source as provided in Condition B.6.4.2; and

9.5.3. Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of the Nanuq seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

9.6. For each instance in which a Point Class Tug seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

9.6.1. Record the duration of the episode for each such seldom used source;

9.6.2. Record the fuel consumption on a daily basis for each such seldom used source as provided in Condition B.6.4.2; and

9.6.3. Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of the Point Class Tug seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

9.7. Record any instance that the Arctic Endeavor Barge, Point Class Tug, Nanuq, Rozema Skimmer or Kvichak work boats attach to the Discoverer.

9.8. Each day, calculate and record for the previous calendar day, the emissions of NO_X, in pounds per hour and pounds per day using the highest emission factor for each tested engine collected under Condition R.8.5 and fuel usage data collected under Condition R.9.4.

9.9. Monitor and record the exhaust temperature of each engine by use of the HiBACK monitor and alarm unit, while the engine is in operation.

9.10. Each day, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

S. POST-CONSTRUCTION AMBIENT AIR QUALITY MONITORING

1. **Ambient Air Quality Monitoring Station.** The permittee shall install, operate and maintain a Federal Reference Method or Federal Equivalent Method ambient air quality monitoring station to measure and record $PM_{2.5}$ concentration data in accordance with the EPA, 1984a: Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), EPA-450/4-87-007, May 1987, U.S. Environmental Protection Agency, Research Triangle Park, NC.

   1.1. An alternative $PM_{2.5}$ monitoring station may be used in lieu of the required monitoring station provided that approval of the monitoring station is obtained from the EPA;

   1.2. The permittee shall use a continuous sampler and a manual sampler to measure $PM_{2.5}$. In addition, filters from the manual sampler shall be analyzed as provided for in the EPA-approved ambient air quality and meteorological monitoring plan required pursuant to Condition S.3 to allow for the chemical speciation of $PM_{2.5}$ constituents, including but not limited to sulfates, nitrates, organics, metals, sea salt, and crustal matter;

   1.3. The monitoring period shall commence within 120 days after the final permit is issued and shall continue for a minimum of 1 year after commencement of initial operation of the Discoverer in the Beaufort Sea as an OCS Source;

   1.4. The data recovery shall be as provided for in the EPA-approved ambient air quality and meteorological monitoring plan required pursuant to Condition S.3; and

   1.5. The monitoring station shall continue to operate and record data until such time that written approval is obtained from the EPA authorizing the termination of its operation.

2. **Meteorological Monitoring Station.** The permittee shall install, operate and maintain a meteorological monitoring station to monitor and record data in accordance with the EPA, 1984a: Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), EPA-450/4-87-007, May 1987, U.S. Environmental Protection Agency, Research Triangle Park, NC.

   2.1. An alternative meteorological monitoring station may be used in lieu of the required monitoring station provided that approval of the monitoring station is obtained from the EPA;

   2.2. Data shall include horizontal wind direction and speed, temperature, solar radiation, and temperature difference;

   2.3. Each quarter's data recovery shall be as provided for in the EPA-approved ambient air quality and meteorological monitoring plan required pursuant to Condition S.3;

   2.4. The monitoring period shall commence within 120 days after the final permit is issued and shall continue for a minimum of 1 year after commencement of operation of the OCS Source; and

2.5. The monitoring station shall continue to operate and record data until such time that written approval is obtained from the EPA authorizing the termination of its operation.

3. **Ambient Air Quality and Meteorological Monitoring Plan.** At least 60 days prior to the commencement of the data collection, the permittee shall submit to the EPA for approval an ambient air quality and meteorological monitoring plan for the post-construction monitoring requirements specified in Conditions S.1 and S.2 in accordance with the requirements of 40 CFR Part 58, Appendix A "Quality Assurance Requirements for SLAMS, SPMs and PSD Air Monitoring." The plan shall include a description of the proposed monitoring site.

4. **Monthly Reporting.** Within 45 days after the end of each calendar month, the permittee shall submit to the EPA a printed summary of the $PM_{2.5}$ and meteorological monitoring data collected during the prior calendar month.

5. **Audit Reports.** The permittee shall submit audit reports with 45 days after the following events:

   5.1. Completion of the post-installation equipment audit;

   5.2. Completion of independent performance and system audits;

   5.3. Completion of quarterly audits required for ambient air quality data collection system; and

   5.4. Completion of the semi-annual audits required for the meteorological data collection system.

   Quarterly and semi-annual audit periods shall be based on a calendar year.

6. **Annual Report.** Within 60 days after the end of each calendar year and following completion of the collection of monitoring, the permittee shall submit to the EPA annual/final reports in text, tabular, and graphic forms, including data in digitized format. The digitized formats of the measured air quality and meteorological data shall be in ASCII format and AIRS format.

7. **System and Performance Audit Report.** Within 60 days after completion of data collection, the permittee shall also submit the final report for the system and performance audits required prior to monitoring termination.

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ATTACHMENT A: EPA NOTIFICATION FORM

Excess Emissions and Permit Deviation Reporting

OCS Source (Facility) Name **Air Quality Permit Number**

Company Name

When did you discover the Excess Emissions/Permit Deviation?
Date: / / Time: :

When did the event/deviation?
Begin: Date: / / Time: : (please use 24hr clock)
End: Date: / / Time: : (please use 24hr clock)

What was the duration of the event/deviation: : (hrs:min) or days
(total # of hrs, min, or days, if intermittent then include only the duration of the actual emissions/deviation)

Reason for notification: (please check only 1 box and go to the corresponding section)
☐Excess Emissions Complete Section 1 and Certify
☐Deviation from Permit Conditions Complete Section 2 and Certify
☐Deviation from COBC, CO, or Settlement Agreement Complete Section 2 and Certify

Section 1. Excess Emissions

(a) Was the exceedance ☐Intermittent or ☐Continuous

(b) Cause of Event (Check one that applies):
☐Start Up/Shut Down ☐Natural Cause (weather/earthquake/flood)
☐Control Equipment Failure ☐Scheduled Maintenance/Equipment Adjustments
☐Bad fuel/coal/gas ☐Upset Condition ☐Other

(c) Description:
Describe briefly what happened and the cause. Include the parameters/operating conditions exceeded, limits, monitoring data and exceedance.

(d) Emission Units Involved:
Identify the emission units involved in the event, using the same identification number and name as in the permit. Identify each emission standard potentially exceeded during the event and the exceedance.

Unit ID	Emission Unit Name	Permit Condition Exceeded/Limit/ Potential Exceedance

(e) Type of Incident (please check only one):

☐Opacity percent ☐Venting (gas/scf) ☐Control Equipment Down
☐Fugitive Emissions ☐Emission Limit Exceeded ☐Record Keeping Failure
☐Marine Vessel Opacity ☐Flaring ☐Other:

(f) Unavoidable Emissions:
Do you intend to assert that these excess emissions were unavoidable? ☐YES ☐NO
Do you intend to assert the affirmative defense of 18 AAC 50.235? ☐YES ☐NO

Certify Report (go to end of form)

Section 2. Permit Deviations

(a) Permit Deviation Type (check one only) (check boxes correspond with sections in permit):
☐Source Specific
☐Failure to monitor/report
☐General Source Test/Monitoring Requirements
☐Recordkeeping/Reporting/Compliance Certification
☐Standard Conditions Not Included in Permit
☐Generally Applicable Requirements
☐Reporting/Monitoring for Diesel Engines
☐Insignificant Source
☐Facility Wide
☐Other Section: (title of section and section # of your permit)

(b) Emission Units Involved:
Identify the emission units involved in the event, using the same identification number and name as in the permit. List the corresponding Permit condition and the deviation.

Unit ID	Emission Unit Name	Permit Condition /Potential Deviation

(c) Description of Potential Deviation:
Describe briefly what happened and the cause. Include the parameters/operating conditions and the potential deviation.

(d) Corrective Actions:
Describe actions taken to correct the deviation or potential deviation and to prevent future recurrence.

Certification:
Based on information and belief formed after reasonable inquiry, I certify that the statements and information in and attached to this document are true, accurate, and complete.

Printed Name **Title** **Date**

Signature **Phone number**

NOTE: *This document must be certified in accordance with 18 AAC 50.345(j)*

To Submit this Report:

1. Fax this form to: Facsimile no. 206-553-0110

   Or

2. E-mail to: R10OCSAirPermits_Reports@epa.gov

   Or

3. Mail to: OCS/PSD Air Quality Permits
   U.S. EPA - Region 10, AWT-107
   1200 Sixth Avenue, Suite 900
   Seattle, WA 98101

ATTACHMENT B: VISIBLE EMISSIONS FIELD DATA SHEET

Permit No. R10OCS/PSD-AK-2010-01

Certified Observer: _____

Company & Stationary Source: _____

Location: _____

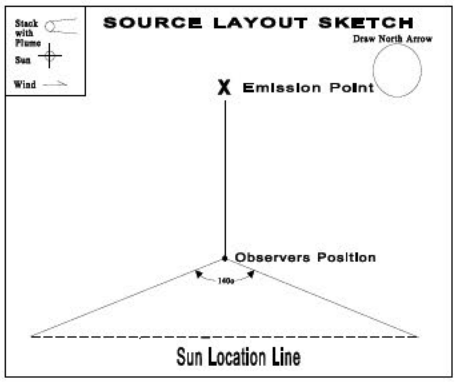
Test No.: _____ Date: _____

Emission Unit: _____

Operating Rate: _____

_____

_____



Clock Time	Initial				Final
Observer location Distance to discharge					
Direction from discharge					
Height of observer point					
Background description					
Weather conditions Wind Direction					
Wind speed					
Ambient temperature					
Relative humidity					
Sky conditions: (clear, overcast, % clouds, etc.)					
Plume description: Color					
Distance visible					
Water droplet plume? (Attached or detached?)					
Other information					

Page ___ of ___

Company & Stationary Source_____ Certified Observer_____

Test Number _____ Clock time_____

Date:		Visibility Reduction Every 15 Seconds (Opacity)				Steam Plume (check if applicable)		Comments
Hr	Min	0	15	30	45	Attached	Detached	

Additional information:

_____ _____
Observer Signature and Date Certified By and Date

Data Reduction:

Duration of Observation Period (minutes) _____ Duration Required by Permit (minutes)_____
Number of Observations _____ Highest Six –Minute Average Opacity (%)_____
Number of Observations exceeding 20 % _____

Average Opacity Summary

Set Number	Time Start—End	Opacity	
		Sum	Average

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, Washington 98101-3140

OUTER CONTINENTAL SHELF
PREVENTION OF SIGNIFICANT DETERIORATION
PERMIT TO CONSTRUCT

Permit Number: R10OCS/PSD-AK-09-01 Issuance Date: September 19, 2011

In accordance with the provisions of Clean Air Act (CAA) Section 328 and Code of Federal Regulations (CFR) Title 40, Part 55, and the provisions of Part C to Title I of the CAA and 40 CFR § 52.21,

Shell Gulf of Mexico Inc.
3601 C Street, Suite 1000
Anchorage, AK 99503

is authorized to construct and operate the Noble Discoverer (Discoverer) drillship and its air emission units and to conduct other air pollutant emitting activities in accordance with the permit conditions listed in this permit, and only at the following lease blocks from the Chukchi Sea lease sale 193:

NR02-02:	6819	6820	6821	6822	6868	6869	6870	6871	6872	6918	6919	6920	6921	6922	6968	6969
	6970	6971	6972	7018	7019	7020	7021	7022	7023	7068	7069	7072				
NR03-01:	6105	6106	6155	6156	6161	6162	6211	6212	6261	6363	6364	6413	6414	6415	6418	6419
	6462	6463	6464	6465	6467	6468	6469	6512	6513	6514	6515	6516	6517	6518	6519	6562
	6563	6564	6565	6567	6568	6569	6612	6613	6614	6615	6616	6617	6618	6665	6666	6667
	6668	6705	6706	6712	6715	6716	6717	6753	6754	6755	6756	6761	6762	6765	6766	6767
	6803	6804	6805	6810	6811	6812	6813	6814	6815	6816	6817	6853	6854	6855	6860	6861
	6862	6863	6864	6865	6866	6903	6904	6905	6908	6909	6910	6911	6912	6913	6914	6915
	6916	6953	6954	6955	6956	6957	6958	6959	6960	6961	6962	6963	6964	6965	7006	7007
	7008	7009	7010	7011	7012	7013	7014	7056	7057	7058	7059	7060	7061	7062	7063	7106
	7107	7108	7109	7110	7119											
NR03-02:	6114	6115	6161	6163	6164	6165	6213	6214	6215	6220	6259	6261	6263	6264	6265	6270
	6271	6321	6322	6359	6360	6371	6372	6409	6410	6422	6423	6459	6508	6558	6608	6658
	6671	6672	6708	6713	6714	6715	6721	6722	6757	6761	6762	6763	6764	6765	6766	6771
	6807	6811	6812	6813	6814	6815	6816	6817	6856	6862	6863	6864	6865	6866	6905	6912
	6913	6914	6915	6916	6962	6963	6964	6965								
NR04-01:	6352	6401	6402	6452	6453	6503	6504	6554	6604							
NR03-03:	6007	6008	6009	6010	6017	6018	6020	6056	6057	6058	6059	6067	6068	6070	6108	6219
	6560	6561	6609	6610	6611	6658	6659	6660	6709	6721	6722	6723	6759	6771	6772	6773
	6823															

Terms not otherwise defined in this permit have the meaning assigned to them in the referenced statutes and regulations. All terms and conditions of the permit are enforceable by the United States Environmental Protection Agency (EPA) and citizens under the CAA.

_____/s/_____ _____9/19/2011_____
Richard Albright Date
Director, Office of Air, Waste and Toxics

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ABBREVATIONS AND ACRONMYS

BACT. .....Best Available Control Technology
CAA .....Clean Air Act
CDPF.....Catalyzed Diesel Particulate Filter
CFR. .....Code of Federal Regulations
CGA. .....Cylinder Gas Audit
CMS .....Continuous Monitoring Systems
CTM.....Conditional Test Method
COA .....Corresponding Onshore Area
EPA .....United States Environmental Protection Agency
HPU.....Hydraulic Power Unit
MLC.....Mud Line Cellar
NA.....Not applicable
OCS.....Outer Continental Shelf
PSD .....Prevention of Significant Deterioration
PTE .....Potential to Emit
PDF .....Portable Document Format
QA.....Quality Assurance
QC.....Quality Control
SCR.....Selective Catalytic Reduction
USCG.....United States Coast Guard

UNITS AND MEASUREMENTS

Btu.....British thermal units
^{o}C.....degree Celsius
dscf.....dry standard cubic foot
^{o}F .....degree Fahrenheit
g.....grams
hp.....brake horsepower
hr .....hour
kW.....kiloWatts (mechanical)
kWe .....kiloWatts electrical
lb .....pounds
MMBtu/hr .....Million British thermal units per hour
ppm .....parts per million
ppmv .....parts per million by volume
scf.....standard cubic foot
tpy .....tons per year

POLLUTANTS

CO .....Carbon Monoxide
CO_2e.....Carbon Dioxide Equivalent
GHG or GHGs .....Greenhouse Gas or Greenhouse Gases
NH_3 .....Ammonia
NMHC.....Non-Methane Hydrocarbons
NO_X.....Oxides of Nitrogen
NO_2 .....Nitrogen Dioxide
PM.....Particulate Matter
$PM_{2.5}$ .....Particulate Matter with an Aerodynamic Diameter less than 2.5 microns
PM_{10} .....Particulate Matter with an Aerodynamic Diameter less than 10 microns
SO_2 .....Sulfur Dioxide
VOC .....Volatile Organic Compound

AUTHORITY

The United States Environmental Protection Agency (EPA) is issuing this outer continental shelf (OCS)/prevention of significant deterioration (PSD) permit pursuant to Section 328 of the CAA, 42 U.S.C. § 7627, and the implementing OCS regulations at 40 CFR Part 55, and pursuant to Part C to Title I of the CAA, 42 USC §§ 7470 to 7492, and the implementing PSD air quality regulations at 40 CFR § 52.21. This proposed action is based upon the application initially submitted by Shell Offshore Inc. (Shell or permittee) on December 19, 2008, supplemental submittals identified in the administrative record for this permit action, and upon the technical analysis performed by the EPA.

FINDINGS

On the basis of the information in the administrative record, the EPA has determined that:

1. The permittee will meet all of the applicable requirements of the 40 CFR Part 55.
2. The permittee will meet all of the applicable requirements of the 40 CFR § 52.21.

APPROVAL CONDITIONS

Shell is authorized to construct and operate the vessels and emission units listed in Tables 1 through 5, at any of the lease blocks identified on Page 1 of this permit, and consistent with the representations in the permit application and subject to the conditions in this permit.

Coast Guard Safety Zone. The permit does not authorize operation unless:

a. The Discoverer is subject to a currently effective safety zone established by the United Sates Coast Guard (USCG) which encompasses an area within at least 500 meters from the center point of the Discoverer and which prohibits members of the public from entering this area except for attending vessels or vessels authorized by the USGC (such area shall be referred to as the “Safety Zone”); and

b. Shell has developed in writing and is implementing a public access control program to:

- locate, identify, and intercept the general public by radio, physical contact, or other reasonable measures to inform the public that they are prohibited by Coast Guard regulations from entering the Safety Zone; and
- communicate to the North Slope communities on a periodic basis when exploration activities are expected to begin and end at a drill site, the location of the drill site, and any restrictions on activities in the vicinity of Shell’s exploration operations.

Table 1 – Noble Discoverer Emission Units

ID	Description	Make and Model	Rating[a]
FD-1 – 6	Generator Engines	Caterpillar D399 SCAC 1200 rpm	1,325 hp
FD-7	Propulsion Engine	Mitsubishi 6UEC65	7,200 hp
FD-8	Emergency Generator Seldom Used Sources	Caterpillar 3412 Various	639 hp Various[b]
FD-9 – 11	MLC Compressor Engines	Caterpillar C-15	540 hp
FD-12 – 13	HPU Engines	To be determined	250 hp
FD-14	Port Deck Crane Engine	Caterpillar D343	365 hp
FD-15	Starboard Deck Crane Engine	Caterpillar D343	365 hp
FD-16 – 17	Cementing Unit Engines	Detroit 8V-71N	335 hp
FD-18	Cementing Unit Engine	GM 3-71	147 hp
FD-19	Logging Winch Engine	Caterpillar C7	250 hp
FD-20	Logging Winch Engine	John Deere PE4020TF270D	35 hp
FD-21 – 22	Heat Boilers	Clayton 200	7.97 MMBtu/hr
FD-23	Incinerator	TeamTec GS500C	276 lb/hr
FD-24 -30	Fuel Tanks	Not applicable (NA)	Various
FD-31	Supply Ship Generator Engine(s) [c]	Generic	584 hp
FD-32	Drilling Mud System	NA	NA
FD-33	Shallow Gas Diverter System[d]	NA	NA

[a] Permit conditions may limit operation to less than rated capacity.
[b] See Condition E.3 for the Discoverer Emergency Generator and Seldom Used Sources (Unit FD-8) aggregate fuel use limit.
[c] Only when attached to the Discoverer.
[d] Permit condition prohibits the shallow gas diverter system from emitting any air pollutants.

Table 2 – Icebreaker #1

Description	Make and Model	Maximum Aggregate Rating[a]
Aggregate of Propulsion Engines and Generator Engines	Various	31,200 hp
Generator Engine(s)	Various	2,800 hp
Heat Boiler(s)	Various	10 MMBtu/hr
Incinerator	Various	154 lbs/hr
Seldom Used Sources	Various	Various[b]

[a] Permit conditions may limit operation to less than rated capacity.
[b] See Condition N.9.3 for the Icebreaker #1 Seldom Used Sources aggregate fuel use limit.

Table 3 – Icebreaker #2

ID	Description	Make and Model	Rating[a]
Tor Viking			
TV-1 - 2	Main Propulsion Engines	Caterpillar MaK 8M32	5,046 hp
TV-3 - 4	Main Propulsion Engines	Caterpillar MaK 6M32	3,784 hp
TV-5 – 6	Non-propulsion Generator Engines	Caterpillar 3412	1,168 hp
TV-7	Heat Boiler	NA	1.37 MMBtu/hr
TV-8	Incinerator	NA	151 lb/hr
	Seldom Uses Sources	Various	Various[b]
Hull 247[c]			
	Main Engines	NA	24 MW[d]
	Heat Boiler	NA	4 MMBtu/hr
	Incinerator	NA	151 lb/hr
	Seldom Uses Sources	Various	Various[b]

[a] Permit conditions may limit operation to less than rated capacity.

[b] See Condition O.9.5 for the Icebreaker #2 Seldom Used Sources aggregate fuel use limit.

[c] Hull 247 is the shipbuilder's (Edison Chouest) designation for a vessel to be built under contract to Shell. The final name for the vessel may be different than this temporary designation.

[d] This represents an aggregate rating of all engines on board Hull 247.

Table 4 – Supply Ship

Description	Make and Model	Maximum Aggregate Rating[a]
Propulsion Engines and Non-Propulsion Generator Engine(s), Excluding Emergency Engine	Various	Various[b]
Emergency Engine	Various	Various[b]

[a] Permit conditions may limit operation to less than rated capacity.

[a] See Condition P.1 for the Supply Ship/Barge and Tug aggregate fuel use limit.

Table 5 – Oil Spill Response Fleet

ID	Description	Make and Model	Rating[a]
Oil Spill Response Main Ship - Nanuq			
N-1 – 2	Propulsion Engines	Caterpillar 3608	2,710 kW
N-3 – 4	Electrical Generators	Caterpillar 3508	1,285 hp
N-5	Emergency Generator	John Deere	166 kW
N-6	Incinerator	ASC/CP100	125 lbs/hr
	Seldom Used Sources	Various	Various[b]
Oil Spill Response Work Boat - Kvichak 34-foot No. 1			
K-1 – 2	Propulsion Engines	Cummins QSB	300 hp
K-3	Generator Engines	Various	12 hp
Oil Spill Response Work Boat - Kvichak 34-foot No. 2			
K-4 – 5	Propulsion Engines	Cummins QSB	300 hp
K-6	Generator Engines	Various	12 hp
Oil Spill Response Work Boat - Kvichak 34-foot No. 3			
K-7 – 8	Propulsion Engines	Cummins QSB	300 hp
K-9	Generator Engines	Various	12 hp

[a] Permit conditions may limit operation to less than rated capacity.
[b] See Condition Q.5 for the Nanuq Seldom Used Sources aggregate fuel use limit.

Effective Date**.** This permit becomes effective 30 days after the service of notice of the final permit decision, unless review of the permit decision is requested pursuant to 40 CFR § 124.19.

OCS Source. Permit conditions contained in Sections B through Q, except for those conditions addressing notification, reporting and testing, apply only during the time that the Discoverer drillship is an OCS Source. Permit conditions in Sections A and R as well as permit conditions contained in Sections B through Q addressing notification, reporting and testing apply at all times as specified.

For the purpose of this permit:

a. The Discoverer is an "OCS Source" at any time the Discoverer is attached to the seabed at a drill site by at least a one anchor; and

b. A drill site is any location at which Shell is authorized to operate under this permit and for which Shell has received from the Bureau of Ocean, Energy, Management and Regulatory Enforcement (BOEMRE) an authorization to drill.

A. GENERALLY APPLICABLE REQUIREMENTS

1 **Construction and Operation.** The permittee shall construct and operate the OCS Source and the Associated Fleet in accordance with the application and supporting materials submitted by the permittee as identified in the Statement of Basis and Supplemental Statement of Basis for this permit action and in accordance with this permit. For purposes of this permit, Icebreaker #1, Icebreaker #2, the supply ship, the Nanuq and Kvichaks No. 1-3 shall collectively be referred to as the "Associated Fleet."

2 **Compliance Required.** The permittee shall comply with all requirements of 40 CFR § 52.21, Part 55, and this permit. Failure to do so shall be considered a violation of Section 111(e) and 165 of the CAA. All enforcement provisions of the CAA, including but not limited to, Section 113, 114, 120, 167, 303, and 304 apply to the permittee.

3 **Compliance with Other Requirements.** This permit does not relieve the permittee of the responsibility to comply fully with applicable provisions of any other requirements under federal law.

4 **Notification to Owners, Operators, and Contractors.** The permittee must notify all other owners or operators, contractors, and the subsequent owners or operators associated with emissions from the source of the conditions of this permit.

5 **Expiration of Approval to Construct.** As provided in 40 CFR § 52.21(f)(4), this approval shall become invalid if construction is not commenced within 18 months after the effective date of this permit, construction is discontinued for a period of 18 months, or construction is not completed within a reasonable time. The EPA may extend the 18-month period upon a satisfactory showing that an extension is justified.

6 **Permit Revision, Termination and Reissuance.** This permit may be revised, terminated, or revoked and reissued by the EPA for cause. Cause exists to revise, terminate, or revoke and reissue this permit under the following circumstances:

6.1 This permit contains a material mistake;

6.2 Materially inaccurate statements were made in establishing the terms or conditions of this permit;

6.3 The permittee fails to comply with any material condition of this permit; or

6.4 This permit must be revised, terminated, or revoked and reissued to assure compliance with CAA requirements.

A request by the permittee for modification, revocation and reissuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any permit condition.

7 **Credible Evidence.** For the purpose of establishing whether or not the permittee has violated or is in violation of any requirement of this permit, nothing in this permit shall preclude the use, including the exclusive use, of any credible evidence or information relevant to whether the permittee would have been in compliance with applicable

requirements if the appropriate performance or reference test or procedure had been performed.

8 **Inspection and Entry.** Upon presentation of credentials and other documents as may be required by law, the permittee shall allow the EPA or an authorized representative to perform the following:

8.1 Enter upon the Discoverer, any support vessel, any location where emissions-related activity is conducted, or any location where records must be kept under the conditions of the permit;

8.2 Have access to and copy, at reasonable times, any records that must be kept under the conditions of the permit;

8.3 Inspect at reasonable times any facilities, equipment (including monitoring and air pollution control equipment), practices, or operations regulated or required under the permit; and

8.4 As authorized by the CAA, sample or monitor at reasonable times substances or parameters for the purpose of assuring compliance with the permit or applicable requirements.

9 **Recordkeeping Requirements.** In addition to the specific recordkeeping requirements contained in the source-wide and emission unit sections of this permit, the permittee shall keep records of required monitoring information that include the following:

9.1 The date, place, and time of sampling or measurements;

9.2 The date(s) analyses were performed;

9.3 The company or entity that performed the analyses;

9.4 The analytical techniques or methods used;

9.5 The results of such analyses;

9.6 The operating conditions as existing at the time of sampling or measurement;

9.7 Copies of all reports and certifications submitted pursuant to this permit; and

9.8 The locations where samples were taken.

The permittee shall retain records of all required monitoring data and support information for a period of at least 5 years from the date of the monitoring sample, measurement, report, or application. Support information includes all calibration and maintenance records, all original strip-chart recordings for continuous monitoring instrumentation, and copies of all reports required by this permit.

10 **Agency Notifications.** Unless otherwise specified in this permit, any documents required to be submitted under this permit, including reports, test data, monitoring data, notifications, and applications for renewals and permit modifications shall be submitted to:

OCS/PSD Air Quality Permits

U.S. EPA - Region 10, AWT-107

1200 Sixth Avenue, Suite 900

Seattle, WA 98101

Facsimile no. 206-553-0110

Email: R10OCSAirPermits_Reports@epa.gov

11 **Certification.** Any document required to be submitted under this permit shall be certified by a responsible official, as that term is defined in 40 CFR § 71.2, of the permittee as to truth, accuracy, and completeness. Such certification shall state that based on information and belief formed after reasonable inquiry, the statements and information in the document are true, accurate and complete.

12 **Severability.** The provisions of this permit are severable, and in the event of any challenge to any portion of this permit, or if any portion is held invalid, the remaining permit conditions shall remain valid and in force.

13 **Property Rights.** This permit does not convey any property rights of any sort, or any exclusive privilege.

14 **Information Request.** The permittee shall furnish the EPA, within a reasonable time, any information the EPA requests in writing to determine whether cause exists to modify, revoke and reissue, or terminate the permit or to determine compliance with the permit. Upon request, the permittee shall furnish the EPA with copies of records required to be kept by the permit.

15 **Excess Emission and Permit Deviation Reports.** Except as otherwise provided in this permit , the permittee shall report via fax and email, all emissions or operations that exceed or deviate from the requirements of this permit as follows:

15.1 As soon as possible after the event commences or is discovered, report:

15.1.1 Emissions that present a potential threat to human health or safety; and

15.1.2 Excess emissions that the permittee believes to be unavoidable.

15.2 Within two working days after the event commenced or was discovered, report an unavoidable emergency, malfunction, or non-routine repair that causes emissions in excess of a technology based emission standard; any other exceedance of an emission limit; or any exceedance of a throughput limit.

15.3 Report all other excess emissions and permit deviations:

15.3.1 Within 30 days after the end of the month during with the emissions or deviation occurred;

15.3.2 If a continuous or recurring excess emissions is not corrected within 48 hours of discovery, within 72 hours of discovery; and

15.3.3 For failure to monitor, as required in other applicable conditions of this permit.

15.4 When reporting excess emissions or permit deviations, the permittee must report using the form contained in Attachment A to this permit. The permittee must provide all information called for by the form.

15.5 If requested by the EPA, the permittee shall provide a more detailed written report as requested to follow up on an excess emissions report.

16 **Operating Reports.** During the life of this permit[1], the permittee shall submit an original and two copies of an Operating Report by March 31 for the preceding calendar year.

16.1 The Operating Report must include all information required to be in Operating Reports by other conditions of this permit.

16.2 If excess emissions or permit deviations that occurred during the reporting period are not reported under Condition A.15, either:

16.2.1 The permittee shall identify:

16.2.1.1 The date of the deviation;

16.2.1.2 The equipment involved;

16.2.1.3 The permit condition affected;

16.2.1.4 A description of the excess emissions or permit deviation; and

16.2.1.5 Any corrective action or preventive measures taken and the date or dates of such actions; or

16.2.2 When excess emissions or permit deviations have already been reported under Condition A.15, the permittee shall cite the date or dates of those reports.

16.3 The Operating Report must include a listing of emissions monitored which trigger additional testing or monitoring, whether or not the emissions monitored exceed an emission standard. The permittee shall include in the report:

16.3.1 The date of the emissions;

16.3.2 The equipment involved;

16.3.3 The permit condition affected; and

[1] "Life of this permit" is defined as the permit effective date, including any periods of reporting obligations that extend beyond the permit effective date. For example, if a permit expires prior to the end of a calendar year, there is still a reporting obligation to provide operating reports for the periods when the permit was in effect.

16.3.4 The monitoring result which triggered the additional monitoring.

16.4 The Operating Report must include reports of any required monitoring, including all emission calculations required by the permit.

B. SOURCE WIDE REQUIREMETNS

1. **Drill Site Notification.** At least 6 months prior to the Discoverer becoming an OCS Source, the permittee shall notify the EPA via facsimile of the following information:

1.1. The location of the proposed drill site, using coordinates in the following formats:

1.1.1. Latitude and longitude, and

1.1.2. Universal Transverse Mercator grid system.

1.2. The lease block within the Chukchi Sea lease sale 193 where the drill site is located;

1.3. The proposed date that the Discoverer will become an OCS Source at that drill site;

1.4. Confirmation that emissions from the source would impact no Class I area. The confirmation shall include a description of the legal and factual basis for this determination; and

1.5. Confirmation that emissions from the source would impact no area where an applicable increment was known to be violated. The confirmation shall include a description of the legal and factual basis for this determination.

2. **Duration of Exploration Operations.** The permittee shall only conduct exploration drilling operations in the Chukchi Sea between July 1 and November 30 each year (referred to hereafter as the "drilling season").

2.1. During any drilling season, the permittee shall not operate the Discoverer as an OCS Source in excess of 120 calendar days. Each partial day the Discoverer is operated as an OCS source shall be counted as a calendar day.

2.2. During any drilling season, the permittee shall not conduct any drilling activity in excess of 1,632 hours. Drilling activity is defined as any time when the top drive is engaged and turning the conventional rotary bit and any time when conducting mud line cellar (MLC) activity as defined in Condition B.2.3.

2.3. During any drilling season, the permittee shall not conduct any MLC activity in excess of 480 hours. MLC activity is defined as any time when any MLC compressor engine (Units FD-9 – 11) or HPU engine (Units FD-12 – 13) is operating.

2.4. For each drill site at which the Discoverer operates, the permittee shall record the following:

2.4.1. The location of each drill site, using a modern global positioning system to determine the location. Location shall be recorded by providing coordinates in the following formats:

2.4.1.1. Latitude and longitude, and

2.4.1.2. Universal Transverse Mercator grid system.

2.4.2. The lease block within the Chukchi Sea lease sale 193 where the drill site is located.

2.4.3. The date and hour that the Discoverer became an OCS Source at that drill site.

2.4.4. The date and hour that the Discoverer ceased to be an OCS Source at that drill site.

2.4.5. For each period of drilling activity except for periods of MLC activity, the permittee shall record the following:

2.4.5.1. The date and hour at which the top drive is first engaged and turning the conventional rotary bit; and

2.4.5.2. The date and hour at which the top drive is disengaged and no longer turning the conventional rotary bit.

2.4.6. For each period of MLC activity the permittee shall record the following:

2.4.6.1. The earlier of the following two points in time; the date and hour in which the first MLC compressor engine (Units FD-9 – 11) begins operation and the date and hour in which the first HPU engine (Units FD-12 – 13) begins operation; and

2.4.6.2. The later of the following two points in time: the date and hour in which the last MLC compressor engine (Units FD-9 – 11) ceases operation and the date and hour in which the last HPU engine (Units FD-12 – 13) ceases operation.

2.5. Any time spent drilling a relief well shall be included in the time recorded in Condition B.2.1.

2.6. By the 10th of each month, the permittee shall calculate and record the following operating parameters for the previous month and a running total for the current drill season or 12-month period, based upon recordkeeping performed pursuant to Conditions B.2.1, B.2.2, and B.2.3:

2.6.1. The number of days the Discoverer operated as an OCS source;

2.6.2. The number of hours of drilling activity; and

2.6.3. The number of hours of MLC activity.

3. **Drilling Season Notification.** Each drilling season, the permittee shall report to the EPA via facsimile the information below, within 3 days of occurrence:

3.1. The date and hour that the Discoverer became an OCS Source at the first drill site of that drilling season; and

3.2. The date and hour that the Discoverer ceased to be an OCS Source at the last drill site of that drilling season.

4. **Global Positioning System.** The permittee shall use a modern global positioning system on the Discoverer and Associated Fleet (except for the Kvichaks Nos. 1-3) as follows:

   4.1. Monitor and record the date, time and location of the Discoverer and Associated Fleet when the Discoverer becomes and ceases to be an OCS source.

   4.2. Monitor and record the date, time and location when each vessel in the Associated Fleet enters or leaves the 25 mile radius area around the Discoverer.

   4.3. Once each hour, monitor and record the date, time, and location of the Discoverer and Associated Fleet.

   4.4. Once each hour, monitor and record the date, time, direction the bow of the Discoverer is pointed, and wind direction at the Discoverer.

5. **Best Available Control Technology (BACT) for Sulfur Dioxide (SO_2) Emissions from Discoverer Emission Units.** The permittee shall not combust any liquid fuel with sulfur content greater than 0.0015 percent by weight, as determined by Condition B.5.1, in any emission unit on the Discoverer (except for Unit FD-7).

   5.1. Representative fuel samples shall be obtained using one of the methods in 40 CFR § 80.330(b). The sulfur content of the fuel shall be determined using ASTM D 5453-08b.

   5.2. Monitoring, Recordkeeping and Reporting. The permittee shall:

      5.2.1. Prior to mobilizing the Discoverer for the first time at the beginning of a drilling season, determine the sulfur content in each fuel oil storage tank on the Discoverer. The permittee shall obtain a representative sample of the fuel and analyze the sample for sulfur content using the procedures in Condition B.5.1.

      5.2.2. Thereafter, determine and record the sulfur content upon receiving each fuel shipment, as follows:

         5.2.2.1. Obtain a representative sample of the fuel delivered and analyze the sample for sulfur content using the procedures in Condition B.5.1; or

         5.2.2.2. Obtain a single certification of sulfur content for each shipment of fuel from the fuel supplier based on an analysis of the fuel, providing that the certification indicates that the sulfur content has been determined by the ASTM method listed in Condition B.5.1.

   5.3. Within 3 business days of identification, report to the EPA any instance of a liquid fuel with sulfur content greater than 0.0015 percent by weight being combusted in any emission unit on the Discoverer (except Unit FD-7).

6. **Greenhouse Gas Potential to Emit Owner Requested Limit for Discoverer and Associated Fleet**

   6.1. At all times while the Discoverer is an OCS Source, greenhouse gas (GHG) emissions as defined in 40 CFR § 52.21(b)(49) from the Discoverer and Associated

Fleet, when within 25 miles of the Discoverer, shall not exceed 70,000 tons carbon dioxide equivalent (CO_2e) as determined on a rolling 12-month basis by calculating the emissions (tons) for each month and adding the emissions (tons) calculated for the previous 11 months.

6.1.1. For emission units that combust fuel, monthly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions (tons) shall be determined by multiplying the appropriate emission factors for distillate oil in 40 CFR Part 98, Subpart C, Tables C-1 and C-2, by the recorded monthly fuel usage (gallons/month) and dividing by 2000 lb/ton.

6.1.2. For emission units that incinerate waste, monthly CO_2 emissions (tons) shall be determined by multiplying the CO_2 emission factor for incinerators in AP42 Table 2.1-7 (10/96) by the recorded monthly quantities of waste incinerated (tons/month) and dividing by 2000 lb/ton.

6.1.3. To account for mud off-gassing, monthly CH_4 emissions from the drilling mud shall be assumed to be 0.798 tons/month.

6.1.4. Monthly CO_2e emissions (tons) shall be determined by multiplying the calculated monthly emissions for CO_2, CH_4, and N_2O from all emission units and activities by the applicable global warming potential factors from 40 CFR Part 98, Subpart A, Table A-1, and summing the products.

6.2. At all times while the Discoverer is an OCS Source, the total amount of fuel combusted in engines and boilers on the Discoverer and Associated Fleet, when within 25 miles of the Discoverer, shall not exceed 6,346,493 gallons during any rolling 12-month period.

6.3. At all times while the Discoverer is an OCS Source, the total amount of waste combusted in incinerators on the Discoverer and Associated Fleet, when within 25 miles of the Discoverer, shall not exceed 1,657,440 pounds during any rolling 12-month period.

6.4. Monitoring, Recordkeeping and Reporting. The permittee shall monitor and record monthly fuel consumption and waste incineration as follows:

6.4.1. Equip each fuel combustion source on the Discoverer and Associated Fleet, except for seldom used sources, with a diesel fuel flow meter to continuously measure and record the fuel flow rate:

6.4.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) being served by the meter.

6.4.1.2. Each fuel flow meter shall be totalizing and non-resettable.

6.4.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

6.4.1.4. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect

information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

6.4.1.5. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

6.4.2. Measure the fuel combusted in each seldom used fuel combustion source on the Discoverer and Associated Fleet by recording the quantity of fuel in each engine's fuel tank before and after periodic operation of each seldom used source:

6.4.2.1. Fuel tank content measurement may take the form of sight glass, use of a graduated dip stick, or tank instrumentation.

6.4.3. Calculate and record monthly fuel consumption for each fuel combustion source on the Discoverer and Associated Fleet in gallons. Determine the 12-month rolling fuel consumption by adding the gallons for each month to the gallons recorded for the previous 11 months.

6.4.4. For each batch of waste charged to an incinerator:

6.4.4.1. Record the date and time that each batch of waste was charged to the incinerator;

6.4.4.2. Weigh the batch of waste by using a weigh scale used that shall be accurate to within 0.5 lbs; and

6.4.4.3. Record the weight of each batch of waste charged to the incinerator.

6.4.5. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of the weigh scale to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

6.4.6. Maintain the accuracy of the weigh scale in accordance with manufacturer's recommendations.

6.4.7. Calculate and record monthly waste combusted in each incinerator on the Discoverer and Associated Fleet in pounds. Determine the 12-month rolling waste combusted by adding the waste combusted for each month to the waste combusted for the previous 11 months.

7. **Sulfuric Acid Mist Potential to Emit Owner Requested Limit for Associated Fleet.** The permittee shall not combust any liquid fuel with sulfur content greater than 0.0015 percent by weight, as determined by Condition B.7.1, in any emission unit on any vessel in the Associated Fleet.

7.1. Representative fuel samples shall be obtained using one of the methods in 40 CFR § 80.330(b). The sulfur content of the fuel shall be determined using ASTM D 5453-08b.

7.2. Monitoring, Recordkeeping and Reporting. The permittee shall:

7.2.1. Prior to mobilizing the Discoverer for the first time at the beginning of a drilling season, determine the sulfur content in each fuel oil storage tank on the vessels comprising the Associated Fleet. The permittee shall obtain a representative sample of the fuel and analyze the sample for sulfur content using the procedures in Condition B.7.1.

7.2.2. Thereafter, determine and record the sulfur content upon receiving each fuel shipment, as follows:

7.2.2.1. Obtain a representative sample of the fuel delivered and analyze the sample for sulfur content using the procedures in Condition B.7.1; or

7.2.2.2. Obtain a single certification of sulfur content for each shipment of fuel from the fuel supplier based on an analysis of the fuel, providing that the certification indicates that the sulfur content has been determined by the ASTM method listed in Condition B.7.1.

7.3. Within 3 business days of identification, report to the EPA any instance of a liquid fuel with sulfur content greater than 0.0015 percent by weight being combusted in any emission unit on any vessel in the Associated Fleet.

8. **BACT for Particulate Matter Emissions (PM, PM_{10}, and $PM_{2.5}$) from Discoverer Diesel IC Engine Crankcase Ventilation.** Except for the MLC Diesel Compressor Engines (FD-9 - 11) and the Caterpillar C7 Logging Winch Engine (FD-19), each diesel IC engine on the Discoverer shall be equipped with a closed crankcase ventilation system.

9. **General Testing Requirements.** Whenever conducting a stack test required by this permit, and unless specifically stated otherwise in this permit, the permittee shall comply with the following testing requirements in addition to the specific testing requirements contained in the emission unit sections of this permit:

9.1. The permittee shall provide the EPA at least 30 days prior notice of any stack test. If after 30 days notice for an initially scheduled stack test, there is a delay in conducting the scheduled stack test, the permittee shall notify the EPA as soon as possible of any delay in the original test date, either by providing at least 7 days prior notice of the rescheduled date of the stack test, or by arranging a rescheduled date with the EPA by mutual agreement.

9.2. The permittee shall submit to the EPA a complete stack test plan within 60 days after receiving a request by the EPA and at least 30 days prior to any required testing unless the EPA agrees in writing to some other time period. Retesting may be done without resubmitting the plan provided it is conducted in accordance with the previously submitted plan. The permittee shall follow the submitted test plan except as otherwise agreed to in writing by EPA prior to the testing. The source test plan shall include and address the following elements:

9.2.1. Purpose and scope of testing;

9.2.2. Source description, including a description of the operating scenarios and mode of operation during testing and including fuel sampling and analysis procedures;

9.2.3. Schedule/dates of testing;

9.2.4. Process data to be collected during the test and reported with the results, including source-specific data identified in the emission unit sections of this permit;

9.2.5. Sampling and analysis procedures, specifically requesting approval for any proposed alternatives to the reference test methods, and addressing minimum test length (e.g., one hour, 8 hours, 24 hours, etc.) and minimum sample volume;

9.2.6. Sampling location description and compliance with the reference test methods;

9.2.7. Analysis procedures and laboratory identification;

9.2.8. Quality assurance plan;

9.2.9. Calibration procedures and frequency;

9.2.10. Sample recovery and field documentation;

9.2.11. Chain of custody procedures;

9.2.12. Quality Assurance (QA)/Quality Control (QC) project flow chart;

9.2.13. Data processing and reporting;

9.2.14. Description of data handling and QC procedures; and

9.2.15. Report content and timing.

9.3. Unless otherwise specified in this permit, or the EPA determines in writing that other operating conditions are representative of normal operations or unless specified in the emission unit sections of this permit, the source shall be operated at a capacity of at least 90 percent but no more than 100 percent of maximum during all tests.

9.4. Unless otherwise specified by an applicable requirement or test method, the permittee shall conduct source testing at a point or points that characterize the actual discharge into the ambient air.

9.5. Only regular operating staff may adjust the processes or emission control devices during or within 2 hours prior to the start of a source test. Any operating adjustments made during a source test, that are a result of consultation during the tests with source testing personnel, equipment vendors, or consultants, may render the source test invalid.

9.6. For the duration of each test run (unless otherwise specified), the permittee shall record the following information:

9.6.1. All data which is required to be monitored during the test in the emission unit sections of this permit; and

9.6.2. All continuous monitoring system data which is required to be routinely monitored in the emission unit sections of this permit for the emission unit being tested.

9.7. Each source test shall follow the reference test methods specified by this permit and consist of at least three (3) valid test runs. For purposes of this permit:

9.7.1. EPA Test Methods 1, 2, 3A, 4, 5, 6C, 7E, 9, 10, 19, and 25A are set forth in 40 CFR Part 60, Appendix A;

9.7.2. EPA Test Methods 201A and 202 are set forth in 40 CFR Part 51, Subpart M;

9.7.3. Conditional Test Method 027 (CTM-027), "Procedure for Collection and Analysis of Ammonia in Stationary Sources," is set forth at http://www.epa.gov/ttn/emc/ctm.html;

9.7.4. Conditional Test Method 038 (CTM-038), "Measurement of Ammonia Emissions from Highway, Nonroad, and Stationary Use Diesel Engines by Extractive Fourier Transform Infrared (FTIR) Spectroscopy," is set forth at http://www.epa.gov/ttn/emc/ctm.html;

9.7.5. Other Test Method 27 (OTM 27), "Determination of PM_{10} and $PM_{2.5}$ Emissions from Stationary Sources (Constant Sampling Rate Procedure)," is set forth at http://www.epa.gov/ttn/emc/prelim.html; and

9.7.6. ASTM D 5453-09 is set forth at http://www.astm.org/Standards/D5453.htm.

9.8. Facilities for performing and observing the emission testing shall be provided that meet the requirements of 40 CFR § 60.8(e) and EPA Method 1.

9.9. Emission test reports shall be submitted to the EPA within 45 days of completing any emission test required by this permit along with items required to be recorded in Condition B.9.6 above.

9.10. EPA Methods 1, 2, 3A, 3B, 4, and 19 shall be used as necessary to convert the measured NO_X, PM, PM_{10}, $PM_{2.5}$, and CO emissions into units of the emission limits in the permit.

9.11. Source test emission data shall be reported as the arithmetic average of all valid test runs and in the terms of any applicable emission limit, unless otherwise specified in the emission unit sections of this permit.

9.12. An alternative test method or a deviation from a test method identified in this permit may be approved as follows:

9.12.1. The permittee must submit a written request to the EPA at least 60 days before the stack test is scheduled to begin which includes the reasons why the alternative or deviation is needed and the rationale and data to demonstrate that the alternative test method or deviation from the reference test method:

9.12.1.1. Provides equal or improved accuracy and precision as compared to the specified reference test method; and

9.12.1.2. Does not decrease the stringency of the standard as compared to the specified reference test method.

9.12.2. If requested by the EPA, the demonstration referred to in Condition B.9.12.1 must use Method 301 in 40 CFR Part 63, Appendix A, to validate the alternative test method or deviation.

9.12.3. The EPA must approve the request in writing.

9.12.4. Until the EPA has given written approval to use an alternative test method or to deviate from the test method specified in this permit, the permittee is required to use the test method specified in this permit when conducting a source test under this permit.

9.13. The permittee may request an extension to a source test deadline established by the EPA. The permittee may delay a source test beyond the original deadline only if the extension is approved in writing by the EPA.

9.14. In addition to any source testing explicitly required by this permit, the permittee shall conduct source testing as requested by the EPA to determine compliance with applicable permit requirements.

9.15. For any source test requiring the use of Method 201A, the permittee may substitute the use of Method 5. In either case, Method 202 shall also be employed for condensable PM, and the test results shall consider all PM to be $PM_{2.5}$.

10. **Prohibited Activities.** The permittee shall not:

10.1. Flow test wells,

10.2. Flare gas,

10.3. Store liquid hydrocarbons recovered during well testing,

10.4. Refuel any vessel (including the Discoverer, and excluding the Kvichak workboats) within 25 miles of the Discoverer, while the Discoverer is an OCS Source, or

10.5. Allow any vessel associated with this project, and that is not authorized by Tables 1 through 5 of this permit, to approach within 25 miles of the Discoverer, while the Discoverer is an OCS Source.

11. **Monthly Emissions Calculations.** By the tenth of each month, the permittee shall, using monitoring data collected pursuant to the requirements of this permit, calculate and record the monthly emissions of CO, NO_X, $PM_{2.5}$, PM_{10}, SO_2, VOC, and GHG emissions for the preceding month. For NO_X, the permittee shall also calculate and record the monthly emissions for the preceding month for each engine, boiler, or incinerator (or groups of engines or boilers) that are subject to an annual NO_X emission limit in this permit.

12. **Rolling 12-Month Emissions Calculations.** By the tenth of each month, the permittee shall calculate and record the rolling 12-month emissions of CO, NO_X, $PM_{2.5}$, PM_{10}, SO_2, VOC, and GHG emissions by using the monthly emissions calculated for the previous 12 months pursuant to Condition B.11. For NO_X, the permittee shall also calculate and record the rolling 12-month emissions for each engine, boiler, or incinerator (or groups of engines or boilers) that are subject to an annual NO_X emission limit in this permit.

13. **Good Operating and Maintenance Requirements.** At all times, including periods of startup, shutdown, and malfunction, the permittee shall, to the extent practicable, maintain and operate each emission unit, including any associated air pollution control equipment, in a manner consistent with good air pollution control practices for minimizing emissions. Determination of whether acceptable operating and maintenance procedures are being used will be based on information available to the EPA which may include, but is not limited to, monitoring results, opacity observations, review of operating and maintenance procedures, and inspection of the source. The permittee shall keep records of any maintenance that would have a significant effect on emissions (the records may be kept in electronic format) and keep a copy of either the manufacturer's or the operator's maintenance procedures.

14. **Selective Catalytic Reduction (SCR) Control Device Monitoring.** For any emission unit that is required by this permit to be controlled by an SCR control device, the permittee shall install, calibrate, operate, and maintain (in accordance with manufacturer specifications) continuous monitoring systems (CMS) to measure and record inlet temperature in degrees Fahrenheit (ºF), urea feed rate (gallons/min), and catalyst activity (NO_X ppm concentration) as follows:

    14.1. Prepare and submit 60 days before the first drilling season a site-specific monitoring plan that addresses the monitoring system design, data collection, quality assurance, and quality control elements outlined in this condition. Install, calibrate, operate, and maintain each CMS according to the procedures in the approved site-specific monitoring plan. The plan shall address the performance criteria and design specifications for the monitoring system equipment, including the sample interface, detector signal analyzer, sensor tolerance sensitivity, and data acquisition and calculations; sampling interface (e.g., thermocouple, flow meter) location such that the monitoring system will provide representative measurements; equipment performance checks, system accuracy audits, or other audit procedures; ongoing operation and maintenance procedures; and ongoing reporting and recordkeeping procedures.

    14.2. The temperature and urea CMS shall collect data at least once every 15 minutes.

    14.3. Conduct the CMS equipment performance checks, system accuracy audits, or other audit procedures specified in the site-specific monitoring plan within 60 days prior to each drilling season and at least once every 3 months for the duration of the drilling season.

    14.4. Conduct a performance evaluation of each CMS in accordance with the site-specific monitoring plan.

    14.5. Except for periods of monitoring system malfunctions, repairs associated with monitoring system malfunctions, and required monitoring system quality assurance or quality control activities (including, as applicable, system accuracy audits and required zero and span adjustments), operate the CMS at all times the affected source is operating. A monitoring system malfunction is any sudden, infrequent, not reasonably preventable failure of the monitoring system to provide valid data. Monitoring system failures that are caused in part by poor maintenance or careless operation are not malfunctions. Complete monitoring system repairs in response to

monitoring system malfunctions and return the monitoring system to operation as expeditiously as practicable.

14.6. Monitor and record NO_X emissions (ppm) from the exhaust of each SCR unit once per week using a portable NO_X monitor that meets the requirements of EPA OTM 13 found at http://www.epa.gov/ttn/emc/prelim/otm13.pdf.

14.7. Report as a deviation under Condition A.0 any periods during which the urea pump is not operating, the inlet temperature is less than 250°C, or the NO_X concentration is 150 percent or more than the NO_X concentration measured during the most recent previous source test that produced compliance data or emission factors for this permit.

15. **Oxidation Catalyst Control Device Monitoring.** For any emission unit that is required by this permit to be controlled by an oxidation catalyst control device, the permittee shall install, calibrate, operate, and maintain (in accordance with manufacturer specifications) CMS to measure and record inlet temperature (ºF), and catalyst activity (CO ppm concentration) as follows:

15.1. Prepare and submit 60 days before the first drilling season a site-specific monitoring plan that addresses the monitoring system design, data collection, quality assurance, and quality control elements outlined in this condition. Install, calibrate, operate, and maintain each CMS according to the procedures in the approved site-specific monitoring plan. The plan shall address the performance criteria and design specifications for the monitoring system equipment, including the sample interface, detector signal analyzer, sensor tolerance and sensitivity, and data acquisition and calculations; sampling interface (e.g., thermocouple) location such that the monitoring system will provide representative measurements; equipment performance checks, system accuracy audits, or other audit procedures; ongoing operation and maintenance procedures; and ongoing reporting and recordkeeping procedures.

15.2. The temperature CMS shall collect data at least once every 15 minutes.

15.3. Conduct the CMS equipment performance checks, system accuracy audits, or other audit procedures specified in the site-specific monitoring plan within 60 days prior to each drilling season and at least once every 3 months for the duration of the drilling season.

15.4. Conduct a performance evaluation of each CMS in accordance with the site-specific monitoring plan.

15.5. Except for periods of monitoring system malfunctions, repairs associated with monitoring system malfunctions, and required monitoring system quality assurance or quality control activities (including, as applicable, system accuracy audits and required zero and span adjustments), operate the CMS at all times the affected source is operating. A monitoring system malfunction is any sudden, infrequent, not reasonably preventable failure of the monitoring system to provide valid data. Monitoring system failures that are caused in part by poor maintenance or careless operation are not malfunctions. Complete monitoring system repairs in response to

monitoring system malfunctions and return the monitoring system to operation as expeditiously as practicable.

15.6. Monitor and record CO emissions (ppm) from the exhaust of each oxidation catalyst unit once per week using a portable CO monitor that meets the requirements of EPA OTM 13 found at http://www.epa.gov/ttn/emc/prelim/otm13.pdf.

15.7. Report as a permit deviation under Condition A.0 any periods during which the inlet temperature is less than 300°C, or the CO concentration is 120 percent or more than the CO concentration measured during the most recent previous source test that produced compliance data or emission factors for this permit.

C. DISCOVERER GENERATOR ENGINES (FD-1 – 6)

1. **Operation of Selective Catalytic Reduction (SCR) Unit.** At all times that any of Units FD-1 – 6 are in operation, the exhaust from each emission unit shall be directed to an operating SCR unit.

2. **Operation of Oxidation Catalyst.** At all times that any of Units FD-1 – 6 are in operation, the exhaust from each emission unit shall be directed to an operating oxidation catalyst.

3. **BACT Limits.** Emissions from each generator engine (Units FD-1 – 6) shall not exceed the emission limits specified for each of the pollutants below:

3.1. **Nitrogen oxides (NO_X):** 0.50 grams (g) per kilowatt-hour (kW-hr)

3.1.1. For compliance with Condition C.3.1, measurement of NO_X shall be determined using EPA Method 7E.

3.2. **Ammonia (NH_3):** 5 parts per million by volume (ppmv) at actual stack gas conditions

3.2.1. For compliance with Condition C.3.2, measurement of NH_3 shall be determined using EPA Conditional Test Method 027 or 038.

3.3. **Particulate Matter (PM):** 0.127 g/kW-hr

3.3.1. For compliance with Condition C.3.3, measurement of PM shall be determined using EPA Method 5.

3.4. **Particulate Matter with an aerodynamic diameter less than 10 microns (PM_{10}):** 0.127 g/kW-hr

3.4.1. For compliance with Condition C.3.4, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

3.5. **Particle** Matter with an aerodynamic diameter **less than 2.5 microns ($PM_{2.5}$):** 0.127 g/kW-hr

3.5.1. For compliance with Condition C.3.5, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

3.6. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

3.6.1. For compliance with Condition C.3.6, measurement of visible emissions shall be determined using EPA Method 9.

3.7. **Carbon Monoxide (CO):** 0.1790 g/kW-hr

3.7.1. For compliance with Condition C.3.7, measurement of CO shall be determined using EPA Method 10.

3.8. **Volatile Organic Compounds (VOC):** 0.0230 g/kW-hr

3.8.1. For compliance with Condition C.3.8, measurement of VOC shall be determined using EPA Method 25A.

4. **Annual Emission Limits.** Emissions from all six generator engines in aggregate (Units FD-1 – 6) shall not exceed the emission limits specified for each of the pollutants below:

4.1. **Nitrogen oxides (NO_X):** 5.83 tons/rolling 12-month period

4.1.1. For compliance with Condition C.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limit.** Emissions from all six generation engines in aggregate (Units FD-1 –6) shall not exceed the emission limits specified for each of the pollutants below:

5.1. **Nitrogen oxides (NO_X):** 4.64 lb/hr

5.1.1. For compliance with Condition C.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from all six generator engines in aggregate (Units FD-1 – 6) shall not exceed the emission limits specified for each of the pollutants below:

6.1. **Particulate Matter with an aerodynamic diameter less than 10 microns (PM_{10}):** 28.3 lbs/day

6.1.1. For compliance with Condition C.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

6.2. **Particulate Matter with an aerodynamic diameter less than 2.5 microns ($PM_{2.5}$):** 28.3 lbs/day

6.2.1. For compliance with Condition C.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

7. **Electrical Power Output Limit.** The permittee shall not operate Units FD-1 – 6 such that aggregate electrical power from the attached generators is in excess of 3,872 kWe for any hour that these units are operated.

8. **Stack Test Requirements.** The permittee shall stack test all of Units FD-1 – 6 as follows:

8.1. At the start of the first drilling season that the Discoverer operates under this permit in the Chukchi Sea, all six of Units FD-1 – 6 shall have been stack tested under the requirements of this section.

8.2. Each stack test shall be conducted at three different loads: 50 percent, 75 percent and 100 percent.

8.3. Each stack test run shall test for emissions of CO, NO_X, NO_2, $PM_{2.5}$, PM_{10}, VOC, ammonia and visible emissions.

8.4. During each test run, the permittee shall monitor and record the following information:

8.4.1. Quantity of fuel used (in gallons);

8.4.2. Density of the fuel used (in lbs/gallon);

8.4.3. Heat content of the fuel used (in Btu/gallon);

8.4.4. Electrical power produced (in kWe-hr);

8.4.5. The stack temperature upstream of the SCR catalysis in ºC or ºF;

8.4.6. The quantity of urea reagent (in gallons) and the concentration of the urea reagent (in weight percent) introduced into the SCR control system; and

8.4.7. The NO_X concentration (ppm) indicated by the periodic NO_X monitor used for the SCR control system.

8.5. For each engine, each load, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, g/kWe-hr, lbs/kW-hr, lbs/kWe-hr and lbs/gallon.

9. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

9.1. Equip each of the generator engines (Units FD-1 – 6) on board the Discoverer with a electrical output monitoring device:

9.1.1. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine with an accuracy equal to or better than 2 percent of the engine's maximum output (in kWe);

9.1.2. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine at least once every 10 minutes; and

9.1.3. Each electrical output monitoring device shall be equipped to record each reading taken as well as provide and record average loads for each hour.

9.2. Maintain the accuracy of each electrical output monitoring device in accordance with manufacturer's recommendations.

9.3. Monitor and record the power output, in kWe, resulting from the operation of each of Units FD-1 – 6 at least once every 10 minutes.

9.4. Each month, calculate and record NO_X emissions in g/kW-hr from each engine for each hour during the month, using the emission factors collected under Condition

C.8.5, and power output data collected under Condition C.9.3, and converted to kW (mechanical).

9.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Condition C.8.5 and electrical load data collected under Condition C.9.3, to determine emissions from that source. Emissions shall be calculated for each ten-minute load reading for each engine.

9.6. For the purposes of Conditions C.9.4 and C.9.5, if a specific emission unit has not been tested yet, the permittee shall use the highest emission factor for the corresponding load from the test results for any of the generator engines that have already been tested.

9.7. For the purposes of Condition C.9.5, if a specific load reading is missing, the permittee shall calculate the emissions for that missing load reading by using the emission factor and load combination that results in the highest emissions rate for that emissions unit. If the engine in question has not been tested yet, the permittee shall use the emission factor as provided for in Condition C.9.6.

9.8. For the purpose of Condition C.9.5, if either the urea pump is not operating or if the catalyst inlet temperature, measured in Condition B.14, is less than 250°C, calculate emissions of NO_X for the affected time period by using an uncontrolled emission factor obtained by applying a 95 percent NO_X reduction efficiency to the emission factor determined pursuant to Condition C.8.5.

D. DISCOVERER PROPULSION ENGINE (FD-7)

1. The permittee shall not operate Unit FD-7 for any reason when operating the Discoverer as an OCS Source.

2. The permittee shall report to the EPA via facsimile or email any deviation from Condition D.1 within 3 business days of identification.

E. DISCOVERER EMERGENCY GENERATOR AND SELDOM USED SOURCES (FD-8)

1. **Discoverer Seldom Used Sources.** For purposes of this permit, Discoverer seldom used sources means any fuel burning unit on the Discoverer except for the emergency generator and Units FD 1 – 7 and FD 9 – 22.

2. **Emergency Generator Reliability Testing Limits.** The permittee shall operate the emergency generator:

   2.1. For no more than120 minutes during any one day;

   2.2. For no more than 10 hours during any drilling season; and

   2.3. The emergency generator shall only operate during the period of 12 pm to 2 pm.

3. **Fuel Usage Limit**. The permittee shall not use in excess of 150 gallons of fuel in aggregate in the Discoverer emergency generator and all Discoverer seldom used sources in any rolling 7-day period.

4. **Emergency Generator Hourly Emission Limits.** Emissions from the emergency generator shall not exceed the emission limits specified for each of the pollutants below:

   4.1. **Nitrogen oxides (NO_X):** 19.73 lb/hr

      4.1.1. For compliance with Condition E.4.1 measurement of NO_X shall be determined using EPA Method 7E.

5. **Emergency Generator Daily Emission Limits.** Emissions from the emergency generator shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **PM_{10}:** 2.77 lbs/day

      5.1.1. For compliance with Condition E.5.1, measurement of PM_{10} shall be determined using EPA Method s 201A and 202.

   5.2. **$PM_{2.5}$:** 2.77 lbs/day

      5.2.1. For compliance with Condition E.5.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Monitoring, Recordkeeping, and Reporting.** For each instance in which the Discoverer emergency generator or each Discoverer seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

   6.1. Record the duration of the episode for the Discoverer emergency generator and each Discoverer seldom used source;

   6.2. Record the daily fuel consumption of the Discoverer emergency generator and each Discoverer seldom used source as provided in condition B.6.4.2;

   6.3. Calculate and record for the previous 6 calendar days the rolling 7- day fuel consumption for the Discoverer emergency generator and all Discoverer seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days;

   6.4. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day from the emergency generator by multiplying an emission factor (0.587 lbs/gal for NO_X and 0.022 lbs/gal for $PM_{2.5}$ and PM_{10}) and recorded fuel use; and

   6.5. The permittee shall report to the EPA via facsimile or email, any deviation from Conditions E.2 and E.3 within 3 business days of identification.

7. **BACT Good Combustion Practices for NO_X, PM_{10}, $PM_{2.5}$, VOC, and CO (Carbon Monoxide)**. The permittee shall:

   7.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

7.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

7.3. Have the maintenance specialist inspect, at least once each week, each emission unit for proper operation and maintenance consistent with the manufacturer's recommendations;

7.4. Ensure that the operation and maintenance manual provided by the manufacturer for each emission unit shall be kept on board the Discoverer at all times;

7.5. Follow the manufacturer's recommended operation and maintenance procedures for each emission unit;

7.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions E.7.2, E.7.3, and E.7.5, respectively; and

7.7. No less than 30 days prior to each deployment of the Discoverer to the Chukchi Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions E.7.1 and E.7.2 for the upcoming drilling season.

F. MLC COMPRESSOR ENGINES (FD-9 - 11)

1. **Operation of Oxidation Catalyst.** At all times that any of Units FD-9 – 11 are in operation, the exhaust from each emission unit shall be directed to an operating oxidation catalyst.

2. **BACT Limits.** Emissions from each MLC compressor engine (Units FD-9 – 11) shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X and Non-Methane Hydrocarbons (NMHC), in aggregate:** 4.0 g/kW-hr

2.1.1. For compliance with Condition F.2.1, measurement of NO_X shall be determined using EPA Method 7E.

2.1.2. For compliance with Condition F.2.1, measurement of NMHC shall be determined using EPA Method 25A.

2.2. **PM:** 0.10 g/kW-hr

2.2.1. For compliance with Condition F.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:** 0.10 g/kW-hr

2.3.1. For compliance with Condition F.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:** 0.10 g/kW-hr

2.4.1. For compliance with Condition F.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition F.2.5, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:** 1.86 g/kW-hr

2.6.1. For compliance with Condition F.2.6, measurement of CO shall be determined using EPA Method 10.

3. **Annual Emission Limits**. Emissions from all three MLC compressor engine (Units FD-9 – 11) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

3.1. **NO_X:** 1.71 tons/rolling 12-month period

3.1.1. For compliance with Condition F.3.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Hourly Emission Limits.** Emissions from all three MLC compressor engines (Units FD-9 – 11) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 7.11 lbs/hour

4.1.1. For compliance with Condition F.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Daily Emission Limits**. Emissions from all three MLC compressor engine (Units FD-9 – 11) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **PM_{10}:** 4.26 lbs/day

5.1.1. For compliance with Condition F.5.1, measurement of PM_{10} shall be determined using EPA Methods 201A and202.

5.2. **$PM_{2.5}$:** 4.26 lbs/day

5.2.1. For compliance with Condition F.5.1, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Fuel Usage Limit.** The permittee shall not use in excess of 81,346 gallons of fuel in all three of Units FD-9 – 11 in aggregate during any rolling 12-month period.

7. **Stack Test Requirements.** The permittee shall stack test all of Units FD-9 – 11 as follows:

7.1. At the start of the first drilling season that the Discoverer operates under this permit in the Chukchi Sea, all three of Units FD-9 – 11 shall have been stack tested under the requirements of this section.

7.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

7.2.1.	**CO**	at one load between 50 and 70% load;
7.2.2.	**NO_X**	at two loads – between 50 and 70% and between 80 and 100% loads;
7.2.3.	**NO_2**	at two loads – between 50 and 70% and between 80 and 100% loads;
7.2.4.	**NMHC**	at one load between 50 and 70% load;
7.2.5.	**$PM_{2.5}$**	at two loads – between 50 and 70% and between 80 and 100% loads;
7.2.6.	**PM_{10}**	at two loads – between 50 and 70% and between 80 and 100% loads; and
7.2.7.	**Visible emissions**	at one load between 50 and 70% load.

7.3. During each test run, the permittee shall monitor and record the following information:

7.3.1. Quantity of fuel used (in gallons);

7.3.2. Density of the fuel used (in lbs/gallon);

7.3.3. Heat content of the fuel used (in Btu/gallon); and

7.3.4. Mechanical power output (in kW).

7.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr, and lbs/gallon.

8. **Monitoring, Recordkeeping and Reporting:** The permittee shall:

8.1. Equip each of Units FD-9 -11 with a diesel fuel flow meter, or install a single fuel meter for all of Units FD-9 -11:

8.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

8.1.2. Each fuel flow meter shall be totalizing and non-resettable; and

8.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

8.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each

fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

8.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

8.4. Monitor and record fuel usage for each engine on a hourly basis.

8.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition F.7.4 and fuel usage data collected under Condition F.8.4.

G. HPU ENGINES (FD-12 - 13)

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times that any of Units FD-12 – 13 are in operation, the exhaust from each emission unit shall be directed to an operating CleanAIR Systems CDPF, Part No. FDA300.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units FD-12 -13 is operated, the exhaust temperature shall be above 300°C, or 572°F for at least 30 percent of the time.

2. **BACT Limits.** Emissions from each HPU engine (Units FD-12 – 13) shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X and NMHC, in aggregate:** 4.0 g/kW-hr

2.1.1. For compliance with Condition G.2.1, measurement of NOX shall be determined using EPA Method 7E.

2.2. **PM:** 0.030 g/kW-hr

2.2.1. For compliance with Condition G.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:** 0.030 g/kW-hr

2.3.1. For compliance with Condition G.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:** 0.030 g/kW-hr

2.4.1. For compliance with Condition G.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition G.2.6, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:** 0.70 g/kW-hr

2.6.1. For compliance with Condition G.2.6, measurement of CO shall be determined using EPA Method 10.

3. **BACT Good Combustion Practices for NO_X.** The permittee shall:

3.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

3.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

3.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-12 – 13 for proper operation and maintenance consistent with the manufacturer's recommendations;

3.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-12 – 13 shall be kept on board the Discoverer at all times;

3.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-12 – 13;

3.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions G.3.2, G.3.3, and G.3.5 respectively; and

3.7. No less than 30 days prior to each deployment of the Discoverer to the Chukchi Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions G.3.1 and G.3.2, for the upcoming drilling season.

4. **Annual Emission Limits.** Emissions from both HPU engines (Units FD-12 – 13) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 0.79 tons/rolling 12-month period

4.1.1. For compliance with Condition G.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limits.** Emissions from both HPU engines (Units FD-12 – 13) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **NO_X:** 3.29 lbs/hour

5.1.1. For compliance with Condition G.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from both HPU engines (Units FD-12 – 13) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

6.1. **PM_{10}:** 0.59 lbs/day

6.1.1. For compliance with Condition G.0, measurement of PM_{10} shall be determined using EPA Methods 201A and202.

6.2. **$PM_{2.5}$:** 0.59 lbs/day

6.2.1. For compliance with Condition G.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

7. **Annual Fuel Usage Limit.** The permittee shall not use in excess of 44,338 gallons of fuel in both of Units FD-12 – 13 in aggregate during any rolling 12-month period.

8. **Daily Fuel Usage Limits/Alternative Operating Scenarios.** Units FD-12, FD-13 and FD-23 shall be operated under one of three operating scenarios: Base Operating Scenario, Alternative Operating Scenario #1 or Alternative Operating Scenario #2. The permittee shall not use fuel in excess of the following limits while operating under the operating scenarios:

8.1. Under Base Operating Scenario, the permittee shall not operate either of Units FD-12 - 13;

8.2. Under Alternative Operating Scenario #1, the permittee shall not use in excess of 352 gallons of fuel in both of Units FD-12 – 13 in aggregate during any calendar day;

8.3. Under Alternative Operating Scenario #2, the permittee shall not use in excess of 704 gallons of fuel in both of Units FD-12 – 13 in aggregate during any calendar day; and

8.4. For each calendar day that the permittee intends to operate under either of Alternative Operating Scenarios #1 or 2, the permittee shall record in a log, at the beginning of the calendar day, which scenario it will be operating under for the day. In the absence of a log entry, the permittee shall comply with the requirements applicable to the Base Operating Scenario.

9. **Stack Test Requirements.** The permittee shall stack test both of Units FD-12 – 13 as follows:

9.1. At the start of the first drilling season that the Discoverer operates under this permit in the Chukchi Sea, both of Units FD-12 – 13 shall have been stack tested under the requirements of this section.

9.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

9.2.1. **CO** at one load between 50 and 70% load;

9.2.2. **NO_X** at two loads – between 50 and 70% and between 80 and 100% loads;

9.2.3. **NO_2** at two loads – between 50 and 70% and between 80 and 100% loads;

9.2.4. **$PM_{2.5}$** at two loads – between 50 and 70% and between 80 and 100% loads;

9.2.5. **PM_{10}** at two loads – between 50 and 70% and between 80 and 100% loads;

9.2.6. **VOC** at one load between 50 and 70% load; and

9.2.7. **Visible emissions** at one load between 50 and 70% load.

9.3. During each test run, the permittee shall monitor and record the following information:

9.3.1. Quantity of fuel used (in gallons);

9.3.2. Density of the fuel used (in lbs/gallon);

9.3.3. Heat content of the fuel used (in Btu/gallon); and

9.3.4. Mechanical power output (in kW).

9.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr and lbs/gallon.

10. **Monitoring, Recordkeeping and Reporting.** The permittee shall:

10.1. Equip each of Units FD-12 -13 with a diesel fuel flow meter, or install a single fuel meter for both of Units FD-12 -13:

10.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

10.1.2. Each fuel flow meter shall be totalizing and non-resettable; and

10.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

10.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

10.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

10.4. Monitor and record fuel usage for each engine on a hourly basis.

10.5. Monitor the exhaust temperature of each engine by use of the HiBACK monitor and alarm unit, whenever the engine is in operation.

10.6. Each day, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

10.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition G.9.4 and fuel usage data collected under Condition G.10.4.

H. DECK CRANES (FD-14 - 15)

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times that any of Units FD-14 – 15 in operation, the exhaust from each Unit shall be directed to an operating CleanAIR Systems CDPF, Part No. 07040401AF.

   1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

   1.2. During each day that each of Units FD-14 -15 is operated, the exhaust temperature shall be above 300°C, or 572°F, for at least 30 percent of the time.

2. **BACT Limits**. Emissions from each deck crane engine (Units FD-14 – 15) shall not exceed the emission limits specified for each of the pollutants below:

   2.1. **NO_X:** 10.327 g/kW-hr

   2.1.1. For compliance with Condition H.2.1, measurement of NO_X shall be determined using EPA Method 7E.

   2.2. **PM:** 0.0715 g/kW-hr

   2.2.1. For compliance with Condition H.2.2, measurement of PM shall be determined using EPA Method 5.

   2.3. **PM_{10}:** 0.0715 g/kW-hr

   2.3.1. For compliance with Condition H.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   2.4. **$PM_{2.5}$:** 0.0715 g/kW-hr

   2.4.1. For compliance with Condition H.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods201A and 202.

   2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

   2.5.1. For compliance with Condition H.2.5, measurement of visible emissions shall be determined using EPA Method 9.

   2.6. **CO:** 0.220 g/kW-hr

   2.6.1. For compliance with Condition H.2.6, measurement of CO shall be determined using EPA Method 10.

   2.7. **VOC:** 0.0640 g/kW-hr

   2.7.1. For compliance with Condition H.2.7, measurement of VOC shall be determined using EPA Method 25A.

3. **BACT Good Combustion Practices for NO_X.** The permittee shall:

   3.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

   3.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

   3.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-14 – 15 for proper operation and maintenance consistent with the manufacturer's recommendations;

   3.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-14 – 15 shall be kept on board the Discoverer at all times;

   3.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-14 – 15;

   3.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions H.3.2, H.3.3, and H.3.5, respectively; and

   3.7. No less than 30 days prior to initial deployment of the Discoverer to the Chukchi Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions H.3.1 and H.3.2 for the upcoming drilling season.

4. **Annual Emission Limits.** Emissions from both deck crane engines (Units FD-14 – 15) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   4.1. **NO_X:** 2.76 tons/rolling 12-month period

      4.1.1. For compliance with Condition H.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limits.** Emissions from both deck cranes engines (Units FD-14 – 15) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **NO_X:** 2.48 lbs/hour

      5.1.1. For compliance with Condition H.5.1 measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from both deck crane engines (Units FD-14 – 15) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **PM_{10}**: 0.41 lbs/day

      6.1.1. For compliance with Condition H.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   6.2. **$PM_{2.5}$:** 0.41 lbs/day

      6.2.1. For compliance with Condition H.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

7. **Fuel Usage Limit.** The permittee shall not use in excess of 63,661 gallons of fuel in both of Units FD-14 – 15 in aggregate during any rolling 12-month period.

8. **Stack Test Requirements.** The permittee shall stack test both of Units FD-14 – 15 as follows:

   8.1. At the start of the first drilling season that the Discoverer operates under this permit in the Chukchi Sea, both of Units FD-14 – 15 shall have been stack tested under the requirements of this section.

   8.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

8.2.1.	**CO**	at one load between 60 and 80% load;
8.2.2.	**NO_X**	at two loads – between 60 and 80% and between 80 and 100% loads;
8.2.3.	**NO_2**	at two loads – between 60 and 80% and between 80 and 100% loads;
8.2.4.	**$PM_{2.5}$**	at two loads – between 60 and 80% and between 80 and 100% loads;
8.2.5.	**PM_{10}**	at two loads – between 60 and 80% and between 80 and 100% loads;
8.2.6.	**VOC**	at one load between 60 and 80% load; and
8.2.7.	**Visible emissions**	at one load between 60 and 80% load.

   8.3. During each test run, the permittee shall monitor and record the following information:

   8.3.1. Quantity of fuel used (in gallons);

   8.3.2. Density of the fuel used (in lbs/gallon);

   8.3.3. Heat content of the fuel used (in Btu/gallon); and

   8.3.4. Mechanical power output (in kW).

   8.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr and lbs/gallon.

9. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

   9.1. Equip each of Units FD-14 -15 with a diesel fuel flow meter, or install a single fuel meter for both of Units FD-14 -15:

   9.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

   9.1.2. Each fuel flow meter shall be totalizing and non resettable; and

   9.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

9.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

9.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

9.4. Monitor and record fuel usage for each engine on a hourly basis.

9.5. Monitor and record the exhaust temperature of each engine by use of the HiBACK monitor and alarm unit, while the engine is in operation.

9.6. Each day, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

9.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition H.8.4and fuel usage data collected under Condition H.9.4.

I. CEMENTING UNIT AND LOGGING WINCH ENGINES (FD-16 - 20)

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times that any of the cementing unit and logging winch engines (Units FD-16 – 20) are in operation, the exhaust from each emission unit shall be directed to operating CleanAIR Systems CDPF, Part No. FDA300 for Units FD-16 and 17, Part No. FDA225 for Unit FD-18, and as specified by CleanAIR Systems for Units FD-19 - 20.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units FD-16 – 20 is operated, the exhaust temperature shall be above 300°C, or 572°F, for at least 30 percent of the time.

2. **BACT Limits**. Emissions from each of Units FD-16 – 20 shall not exceed the emission limits specified for each of the pollutants below:

2.1. **NO_X:**

FD-16	13.155	g/kW-hr
FD-17	13.155	g/kW-hr
FD-18	15.717	g/kW-hr
FD-19	4.0	g/kW-hr
FD-20	7.50	g/kW-hr

2.1.1. For compliance with Condition I.2.1, measurement of NO_X shall be determined using EPA Method 7E.

2.2. **PM:**

FD-16	0.253	g/kW-hr
FD-17	0.253	g/kW-hr
FD-18	0.386	g/kW-hr
FD-19	0.03	g/kW-hr
FD-20	0.090	g/kW-hr

2.2.1. For compliance with Condition I.2.2, measurement of PM shall be determined using EPA Method 5.

2.3. **PM_{10}:**

FD-16	0.253	g/kW-hr
FD-17	0.253	g/kW-hr
FD-18	0.386	g/kW-hr
FD-19	0.03	g/kW-hr
FD-20	0.090	g/kW-hr

2.3.1. For compliance with Condition I.2.3, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

2.4. **$PM_{2.5}$:**

FD-16	0.253	g/kW-hr
FD-17	0.253	g/kW-hr
FD-18	0.386	g/kW-hr
FD-19	0.03	g/kW-hr
FD-20	0.090	g/kW-hr

2.4.1. For compliance with Condition I.2.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

2.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

2.5.1. For compliance with Condition I.2.5, measurement of visible emissions shall be determined using EPA Method 9.

2.6. **CO:**

FD-16	0.40	g/kW-hr
FD-17	0.40	g/kW-hr
FD-18	0.880	g/kW-hr
FD-19	0.70	g/kW-hr
FD-20	0.550	g/kW-hr

2.6.1. For compliance with Condition I.2.6, measurement of CO shall be determined using EPA Method 10.

2.7. VOC:

FD-16	0.20	g/kW-hr
FD-17	0.20	g/kW-hr
FD-18	0.270	g/kW-hr
FD-19	4.0	g/kW-hr
FD-20	0.750	g/kW-hr

2.7.1. For compliance with Condition I.2.7, measurement of VOC shall be determined using EPA Method 25A.

3. **BACT Good Combustion Practices for NO_X.** The permittee shall:

3.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

3.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

3.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-16 – 20 for proper operation and maintenance consistent with the manufacturer's recommendations;

3.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-16 – 20 shall be kept on board the Discoverer at all times;

3.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-16 – 20;

3.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions I.3.2, I.3.3, and I.3.5 respectively; and

3.7. No less than 30 days prior to initial deployment of the Discoverer to the Chukchi Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions I.3.1and I.3.2 for the upcoming drilling season.

4. **Annual Emission Limits.** Emissions from all cementing unit and logging winch engines (Units FD-16 – 20) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 4.09 tons/rolling 12-month period

4.1.1. For compliance with Condition I.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Hourly Emission Limits.** Emissions from all cementing unit and logging winch engines (Units FD-16 - 20) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **NO_X:** 6.56 lbs/hour

5.1.1. For compliance with Condition I.5.1, measurement of NO_X shall be determined using EPA Method 7E.

6. **Daily Emission Limits.** Emissions from all cementing unit and logging winch engines (Units FD-16 – 20) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **PM_{10}:** 3.87 lbs/day

      6.1.1. For compliance with Condition I.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   6.2. **$PM_{2.5}$:** 3.87 lbs/day

      6.2.1. For compliance with Condition I.6.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

7. **Fuel Usage Limit.** The permittee shall not use in excess of:

   7.1. 53,760 gallons of fuel in all Units FD-16 – 20 in aggregate during any rolling 12-month period; and

   7.2. 320 gallons of fuel in all Units FD-16 – 20 in aggregate during any calendar day.

8. **Operational Limit.** The permittee shall not operate any cementing unit or engine (Units FD-16 – 20) while conducting MLC activities as defined in Condition B.2.3.

9. **Stack Test Requirements.** The permittee shall stack test all of Units FD-16 – 20 as follows:

   9.1. At the start of the first drilling season that the Discoverer operates under this permit in the Chukchi Sea, all of Units FD-16 – 20 shall have been stack tested under the requirements of this section.

   9.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

      9.2.1. **CO** at one load between 50 and 70% load;

      9.2.2. **NO_X** at two loads – between 50 and 70% and between 80 and 100% loads;

      9.2.3. **NO_2** at two loads – between 50 and 70% and between 80 and 100% loads;

      9.2.4. **$PM_{2.5}$** at two loads – between 50 and 70% and between 80 and 100% loads;

      9.2.5. **PM_{10}** at two loads – between 50 and 70% and between 80 and 100% loads;

      9.2.6. **VOC** at one load between 50 and 70% load; and

      9.2.7. **Visible emissions** at one load between 50 and 70% load.

   9.3. During each test run, the permittee shall monitor and record the following information:

      9.3.1. Quantity of fuel used (in gallons);

      9.3.2. Density of the fuel used (in lbs/gallon);

9.3.3. Heat content of the fuel used (in Btu/gallon); and

9.3.4. Mechanical power output (in kW).

9.4. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: g/kW-hr, lbs/kW-hr, and lbs/gallon.

10. **Monitoring, Recordkeeping and Reporting.** The permittee shall:

10.1. Equip each of Units FD-16 - 20 with a diesel fuel flow meter, or install a single fuel meter for all of Units FD-16 - 20:

10.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

10.1.2. Each fuel flow meter shall be totalizing and non-resettable; and

10.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

10.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

10.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

10.4. Monitor and record fuel usage for each engine on a hourly basis.

10.5. Monitor and record the exhaust temperature of each of engines FD-16 - 20 by use of the HiBACK monitor and alarm unit, while the engine is in operation.

10.6. Each day, for each of engines FD-16 - 20, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

10.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions from $PM_{2.5}$ and PM_{10} in pounds per day, using the highest emission factor collected under Condition I.9.4and fuel usage data collected under Condition I.10.4.

J. HEAT BOILERS (FD-21 - 22)

1. **BACT Limits.** Emissions from each of the heat boilers (Units FD-21 – 22) shall not exceed the emission limits specified for each of the pollutants below:

1.1. **NO_X:** 0.20 lbs/MMBtu

1.1.1. For compliance with Condition J.1.1, measurement of NO_X shall be determined using EPA Method 7E.

1.2. **PM:** 0.0235 lbs/MMBtu

1.2.1. For compliance with Condition J.1.2, measurement of PM shall be determined using EPA Method 5.

1.3. **PM_{10}:** 0.0235 lbs/MMBtu

1.3.1. For compliance with Condition J.1.3, measurement of PM_{10} shall be determined using EPA Methods 201A and Method 202.

1.4. **$PM_{2.5}$:** 0.0235 lbs/MMBtu

1.4.1. For compliance with Condition J.1.4, measurement of PM2.5 shall be determined using EPA Methods 201A and Method 202.

1.5. **Visible Emissions:** Visible emissions, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

1.5.1. For compliance with Condition J.1.5, measurement of visible emissions shall be determined using EPA Method 9.

1.6. **CO:** 0.0770 lbs/MMBtu

1.6.1. For compliance with Condition J.1.6, measurement of CO shall be determined using EPA Method 10.

1.7. **VOC:** 0.00140 lbs/MMBtu

1.7.1. For compliance with Condition J.1.7, measurement of VOC shall be determined using EPA Method 25A.

2. **BACT Good Combustion Practices for NO_X, PM, $PM_{2.5}$, PM_{10}, CO and VOC.** The permittee shall:

2.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

2.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hours of identification;

2.3. Have the maintenance specialist inspect, at least once each week, each of Units FD-21 – 22 for proper operation and maintenance consistent with the manufacturer's recommendations;

2.4. Ensure that the operation and maintenance manual provided by the manufacturer for each of Units FD-21 – 22 shall be kept on board the Discoverer at all times;

2.5. Follow the manufacturer's recommended operation and maintenance procedures for each of Units FD-21 – 22;

2.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions J.2.2, J.2.3, and J.2.5, respectively; and

2.7. No less than 30 days prior to initial deployment of the Discoverer to the Chukchi Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions J.2.1and J.2.2 for the upcoming drilling season.

3. **Annual Emission Limits**. Emissions from all heat boilers (Units FD-21 – 22) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

3.1. **NO_X:** 4.59 tons/rolling 12-month period

3.1.1. For compliance with Condition J.3.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Hourly Emission Limits.** Emissions from all heat boilers (Units FD-21 – 22) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

4.1. **NO_X:** 3.19 lbs/hour

4.1.1. For compliance with Condition J.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Daily Emission Limits.** Emissions from all heat boilers (Units FD-21 – 22) in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **PM_{10}:** 8.99 lbs/day

5.1.1. For compliance with Condition J.5.1, measurement of PM_{10} shall be determined using EPA Methods 201A and202.

5.2. **$PM_{2.5}$:** 8.99 lbs/day

5.2.1. For compliance with Condition J.5.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

6. **Stack Test Requirements.** The permittee shall stack test both of Units FD-21 – 22 as follows:

6.1. At the start of the first drilling season that the Discoverer operates under this permit in the Chukchi Sea, both of Units FD-21 – 22 shall have been stack tested under the requirements of this section.

6.2. Each stack test shall be conducted for the following pollutants, and at the different loads specified:

6.2.1. **CO** at 100% load;

6.2.2. **NO_X** at 50% and 100% loads;

6.2.3. **NO_2** at 50% and 100% loads;

6.2.4. **$PM_{2.5}$** at 50% and 100% loads;

6.2.5. **PM_{10}** at 50% and 100% loads;

6.2.6. **VOC** at 100% load; and

6.2.7. **Visible emissions** at 100% load.

6.3. During each test run, the permittee shall monitor and record the following information:

6.3.1. Quantity of fuel used (in gallons);

6.3.2. Density of the fuel used (in lbs/gallon); and

6.3.3. Heat content of the fuel used (in Btu/gallon).

6.4. For each boiler, each load range and each pollutant, the permittee shall determine emission factors in the following units: lbs/MMBtu and lbs/gallon.

7. **Monitoring, Recordkeeping and Reporting.** The permittee shall:

7.1. Equip each of Units FD-21 - 22 with a diesel fuel flow meter, or install a single fuel meter for both of Units FD-21 - 22:

7.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the boiler(s) or boiler group being served by the meter;

7.1.2. Each fuel flow meter shall be totalizing and nonresettable; and

7.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

7.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

7.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

7.4. Monitor and record fuel usage for each boiler on a hourly basis.

7.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X $PM_{2.5}$, and PM_{10} using the highest emission factor collected under Condition J.6.4 and fuel usage data collected under Condition J.7.4.

K. INCINERATOR (FD-23)

1. **BACT Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

1.1. **NO_X:** 5.0 lbs/ton of waste incinerated

1.1.1. For compliance with Condition K.1.1, measurement of NO_X shall be determined using EPA Method 7E.

1.2. **PM:** 8.20 lbs/ ton of waste incinerated

1.2.1. For compliance with Condition K.1.2, measurement of PM shall be determined using EPA Method 5.

1.3. **PM_{10}:** 8.20 lbs/ton of waste incinerated

1.3.1. For compliance with Condition K.0, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

1.4. **$PM_{2.5}$:** 7.00 lbs/ton of waste incinerated

1.4.1. For compliance with Condition K.1.4, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

1.5. **CO:** 31.0 lbs/ton of waste incinerated

1.5.1. For compliance with Condition K.1.5, measurement of CO shall be determined using EPA Method 10.

1.6. **VOC:** 3.0 lbs/ton of waste incinerated

1.6.1. For compliance with Condition K.1.6, measurement of VOC shall be determined using EPA Method 25A.

2. **BACT Good Combustion Practices for NO_X, PM, $PM_{2.5}$, PM_{10}, CO, and VOC.** The permittee shall:

2.1. Ensure that a full-time equipment maintenance specialist shall be on board at all times during operation as an OCS Source;

2.2. Train operating personnel to identify signs of improper operation and maintenance, including visible plumes, and to report these events to the maintenance specialist as soon as possible, but no later than within three hour of identification;

2.3. Have the maintenance specialist inspect, at least once each week, Unit FD-23 for proper operation and maintenance consistent with the manufacturer's recommendations;

2.4. Ensure that the operation and maintenance manual provided by the manufacturer for Unit FD-23 shall be kept on board the Discoverer at all times;

2.5. Follow the manufacturer's recommended operation and maintenance procedures for Unit FD-23;

2.6. Maintain, on board the Discoverer, a log detailing when reporting, inspections and maintenance are conducted pursuant to Conditions K.2.2, K.2.3, and K.2.5, respectively; and

2.7. No less than 30 days prior to initial deployment of the Discoverer to the Chukchi Sea, the permittee shall provide notice to the EPA on how the permittee shall comply with the requirements of Conditions K.2.1and K.2.2 for the upcoming drilling season.

3. **Annual Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

3.1. **NO_X:** 0.20 tons/rolling 12-month period

3.1.1. For compliance with Condition K.3.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Hourly Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   4.1. **Nitrogen oxides (NO_X):** 0.65 lb/hr

      4.1.1. For compliance with Condition K.4.1, measurement of NO_X shall be determined using EPA Method 7E.

5. **Daily Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   5.1. **PM_{10}:** 5.33 lbs/day

      5.1.1. For compliance with Condition K.5.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   5.2. **$PM_{2.5}$:** 4.55 lbs/day

      5.2.1. For compliance with Condition K.5.2, measurement of PM2.5 shall be determined using EPA Methods 201A and 202.

6. **Throughput-Based Emission Limits.** Emissions from the incinerator (Unit FD-23) shall not exceed the emission limits specified for each of the pollutants below:

   6.1. **PM_{10}:** 8.20 lbs/ton of waste incinerated

      6.1.1. For compliance with Condition K.6.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   6.2. **$PM_{2.5}$:** 7.00 lbs//ton of waste incinerated

      6.2.1. For compliance with Condition K.6.2, measurement of PM2.5 shall be determined using EPA Methods 201A and 202.

   6.3. **SO_2:** 2.50 lbs//ton of waste incinerated

      6.3.1. For compliance with Condition K.6.3, measurement of SO2 shall be determined using EPA Method 6C.

7. **Annual Waste Throughput Limit.** The permittee shall not incinerate in excess of 50,400 lbs of all types of waste in Unit FD-23 during any rolling 12-month period.

8. **Daily Fuel Usage Limits/Alternative Operating Scenarios.** Units FD-12, FD-13 and FD-23 shall be operated under one of three operating scenarios: Base Operating Scenario, Alternative Operating Scenario #1 or Alternative Operating Scenario #2. The permittee shall not incinerate waste in excess of the following limits while operating under the operating scenarios:

   8.1. Under Base Operating Scenario, the permittee shall not incinerate in excess of 1300 lbs of waste during any calendar day;

   8.2. Under Alternative Operating Scenario #1, the permittee shall not incinerate in excess of 800 lbs of waste during any calendar day;

   8.3. Under Alternative Operating Scenario #2, the permittee shall not incinerate in excess of 300 lbs of waste during any calendar day; and

8.4. For each calendar day that the permittee intends to operate under either of Alternative Operating Scenarios #1 or 2, the permittee shall record as specified in Condition G.8.4.

9. **Waste Segregation Work Practice.** The permittee shall develop and implement a written waste segregation work practice plan to ensure that non-combustible items containing heavy metals that could be volatilized and emitted from the incinerator as PM are not introduced into the incinerator. The plan shall be submitted to the EPA Region 10 at least 30 days prior to initial deployment of the Discoverer to the Chukchi Sea.

10. **Stack Test Requirements.** Prior to each of the first three drilling seasons that the Discoverer operates under this permit in the Chukchi Sea, the permittee shall stack test the incinerator (Unit FD-23) as follows:

10.1. Each stack test shall be conducted at full rated capacity.

10.2. For the first drilling season, each stack test run shall test for emissions of CO, NO_X, NO_2, $PM_{2.5}$, PM_{10}, SO_2, and VOC.

10.3. For subsequent drilling seasons, each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, PM_{10}, and SO_2.

10.4. During each test run, the permittee shall monitor and record the following information:

10.4.1. Quantity of fuel used (in gallons);

10.4.2. Density of the fuel used (in lbs/gallon);

10.4.3. Heat content of the fuel used (in Btu/gallon);

10.4.4. Quantity of waste incinerated (tons); and

10.4.5. Type of waste incinerated.

10.5. For each pollutant, the permittee shall determine emission factors in the following units: lbs/ton of waste incinerated.

11. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

11.1. For each batch of waste charged to the incinerator:

11.1.1. Record the date and time that each batch of waste was charged to the incinerator;

11.1.2. Weigh the batch of waste by using a weigh scale used that shall be accurate to within 0.5 lbs; and

11.1.3. Record the weight of each batch of waste charged to the incinerator.

11.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of the weigh scale to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

11.3. Maintain the accuracy of the weigh scale in accordance with manufacturer's recommendations.

11.4. Monitor and record the exhaust temperature of the incinerator at least every 15 minutes.

11.5. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day using the highest emission factor collected under Condition K.10.5 and waste material incinerated throughput collected under Condition K.11.1.

L. SUPPLY SHIP GENERATOR ENGINE (FD-31)

1. **Operational Limits.** For events where the supply ship is attached to the Discoverer, the permittee shall:

   1.1. Not use in excess of 184.0 gallons of fuel per day in the non-propulsion generators (not including the emergency engine), in aggregate; and

   1.2. Not use in excess of 1472.0 gallons of fuel during any rolling 12-month period in the non-propulsion generators (not including the emergency engine), in aggregate.

2. **Annual Emission Limits.** For events where the supply ship is attached to the Discoverer, emissions from operation of the supply ship generator engine (Unit FD-31) shall not exceed the emission limits specified for each of the pollutants below:

   2.1. **NO_X:** 0.43 tons/rolling 12-month period

      2.1.1. For compliance with Condition L.2.1, measurement of NOX shall be determined using EPA Method 7E.

3. **Daily Emission Limits.** For events where the supply ship is attached to the Discoverer, emissions from operation of the supply ship generator engine (Unit FD-31) shall not exceed the emission limits specified for each of the pollutants below:

   3.1. **PM_{10}:** 7.60 lbs/day

      3.1.1. For compliance with Condition L.3.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

   3.2. **$PM_{2.5}$:** 7.60 lbs/day

      3.2.1. For compliance with Condition L.3.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4. **Stack Test Requirements.** Prior to the first supply ship trip of each drilling season to resupply the Discoverer while the Discoverer is operating under this permit in the Chukchi Sea, the permittee shall stack test the supply ship generator engine (Unit FD-31) as follows:

   4.1. If the generator from the intended supply ship has already been tested pursuant to Conditions L.4.2 through L.4.5 during the past 5 years, no additional stack testing is required.

   4.2. Each stack test shall be conducted at 100 percent load.

   4.3. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

4.4. During each test run, the permittee shall monitor and record the following information:

4.4.1. Manufacturer and model no. of the engine;

4.4.2. The rated capacity of the engine (in hp);

4.4.3. Quantity of fuel used (in gallons);

4.4.4. Density of the fuel used (in lbs/gallon);

4.4.5. Heat content of the fuel used (in Btu/gallon); and

4.4.6. Electrical power output (in kWe).

4.5. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

5. **Monitoring, Recordkeeping and Reporting.** The permittee shall:

5.1. Equip each of the non-propulsion generator engines (not including the emergency engine) with a diesel fuel flow meter, or install a single fuel meter for all of these engines:

5.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

5.1.2. Each fuel flow meter shall be totalizing and non-resettable; and

5.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value

5.2. No less than 60 days before the first deployment to the Chukchi Sea of a vessel as the supply ship, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to departure of the supply vessel to the Chukchi Sea.

5.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

5.4. Monitor and record fuel usage for the non-propulsion generators on a hourly basis while the supply vessel is attached to the Discoverer.

5.5. For each event, record the date and time that the supply ship attaches to the Discoverer.

5.6. For each event, record the date and time that the supply ship detaches from the Discoverer.

5.7. For each event, record the manufacturer, model no. and rated capacity (in hp) of the supply ship generator engine.

5.8. For each event, calculate daily emissions of NO_X, $PM_{2.5}$, and PM_{10} using the using the highest emission factor collected under Condition L.4.5and fuel usage data collected under Condition L.5.4.

6. **Supply Ship Events.** The total number of events during which the supply ship transits to and from the Discoverer and either attaches to the Discoverer or operates in dynamic positioning mode shall not exceed 8 in any drilling season.

M. SHALLOW GAS DIVERTER SYSTEM (FD-33)

1. **Shallow Gas Diverter System.** There shall be no emissions of any regulated NSR pollutants or GHGs from the shallow gas diverter system.
2. **Shallow Gas Diversions.** The permittee shall:
   - 2.1. Record the frequency and duration of each shallow gas diversion.
   - 2.2. Report the frequency and duration of each shallow gas diversion no later than February 1st for the time period beginning January 1st and ending December 31st of the preceding year.

N. ICEBREAKER #1

1. **Operation of SCR Unit.** At all times that any of the propulsion or generator engines on board Icebreaker #1 are in operation, the exhaust from each engine shall be directed to an operating SCR emission unit.
2. **Operation of Oxidation Catalyst.** At all times that any of the propulsion or generator engines on board Icebreaker #1 are in operation, the exhaust from each engine shall be directed to an operating oxidation catalyst emission unit.
3. **Aggregate Capacity Limits.** For a given drilling season, the permittee may select any vessel as Icebreaker #1, subject to the following conditions:
   - 3.1. The total capacity of all propulsion engines on Icebreaker #1 shall not exceed 28,400 hp.
   - 3.2. The total capacity of all generator engines on Icebreaker #1 shall not exceed 2,800 hp.
   - 3.3. The total capacity of all boilers on Icebreaker #1 shall not exceed 10 MMBtu/hr.
   - 3.4. The total capacity of all incinerators on Icebreaker #1 shall not exceed 154 lbs/hr.
   - 3.5. Total uncontrolled emissions of $PM_{2.5}$ from all emission sources on board Icebreaker #1 shall not exceed 42.20 lbs/hour.
     - 3.5.1. For compliance with Condition N.3.5, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.
     - 3.5.2. For the purposes of Condition N.3.5, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.
   - 3.6. Total uncontrolled emissions of PM_{10} from all emission sources on board Icebreaker #1 shall not exceed 48.0 lbs/hour.

3.6.1. For compliance with Condition N.3.6, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

3.6.2. For the purposes of Condition N.3.6, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

3.7. No later than 45 days prior to deployment to the Chukchi Sea each drilling season, the permittee shall provide notification to the EPA of the vessel selected as Icebreaker #1. The notification shall include a list of all emission sources on board the vessel as well as manufacturer, model and rated capacity of each such emission source, and the conversion efficiency (mechanical to electrical) of each generator on board.

4. **Capacity Limit on Icebreaker #1 Propulsion Engines.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, the permittee shall limit operation of the propulsion engines in Icebreaker #1 to no greater than 80 percent of rated capacity.

5. **Annual Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #1 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1. **NO_X:** 41.59 tons/rolling 12-month period

5.1.1. For compliance with Condition N.5.1, measurement of NOX shall be determined using EPA Method 7E.

6. **Hourly Emission Limits.** Emissions from all emission sources on Icebreaker #1 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

6.1. **NO_X:** 67.96 lbs/hour

6.1.1. For compliance with Condition N.6.1, measurement of NO_X shall be determined using EPA Method 7E.

7. **Daily Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #1 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

7.1. **PM_{10}:** 277.47 lbs/day

7.1.1. For compliance with Condition N.7.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

7.2. **$PM_{2.5}$:** 269.66 lbs/day

7.3. For compliance with Condition N.7.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

8. **Electrical Power Output Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, the permittee shall not operate the internal combustion engines in excess of:

   8.1. 28,233,704 kWe-hr from all of the generators on board Icebreaker #1 in aggregate during any rolling 12-month period; or

   8.2. 420,188 kWe-hr from all of the generators on board Icebreaker #1 in aggregate during any calendar day;

9. **Fuel Usage Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #1 is within 25 miles of the Discoverer, the permittee shall not use fuel in excess of:

   9.1. 302,400 gallons in all heat boilers on board Icebreaker #1 in aggregate during any rolling 12-month period; or

   9.2. 1,800 gallons in all heat boilers on board Icebreaker #1 in aggregate during any calendar day; or

   9.3. 100 gallons in Icebreaker #1 seldom used sources in aggregate during any rolling 7-day period. Icebreaker #1 seldom used sources include engines on Icebreaker #1, that are not otherwise identified in the permit as emission units or categories of emission units on Icebreaker #1.

10. **Attachment to Discoverer.** At no time shall Icebreaker #1 be attached to the Discoverer.

11. **Stack Height Limit for Icebreaker #1.** The permittee shall ensure that the stack height of Icebreaker #1 is no less than 24.38 meters. For the purposes of this condition, the permittee shall obtain the stack height information for each vessel to be used as Icebreaker #1.

12. **Stack Test Requirements.** Prior to each of the first two drilling seasons that a vessel is used as Icebreaker #1, and while the Discoverer is operating under this permit in the Chukchi Sea, the permittee shall stack test each propulsion engine, non-propulsion generator engine, boiler and incinerator on Icebreaker #1 as follows:

   12.1. Each stack test on the propulsion engines shall be conducted at three different loads: 30 percent, 60 percent and 80 percent.

   12.2. Each stack test on the non-propulsion generator engines shall be conducted at two different load ranges: 50 – 60 percent and 90 – 100 percent.

   12.3. Each stack test on the boilers shall be conducted at full loads.

   12.4. Each stack test on the incinerator shall be conducted at full load.

   12.5. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

   12.6. During each test run for the propulsion engines, generator engines, and boilers, the permittee shall monitor and record the following information:

      12.6.1. Quantity of fuel used (in gallons);

      12.6.2. Density of the fuel used (in lbs/gallon);

      12.6.3. Heat content of the fuel used (in Btu/gallon);

12.6.4. For the engines, electrical power output (in kWe);

12.6.5. The stack temperature upstream of the SCR catalysis ºC or ºF;

12.6.6. The quantity of urea reagent (in gallons) and the concentration of the urea reagent (in weight percent) introduced into the SCR control system; and

12.6.7. The NO_X concentration (ppm) indicated by the periodic NO_X monitor used for the SCR control system.

12.7. During each test run for the incinerator, the permittee shall monitor and record the quantity of waste material incinerated (in lbs).

12.8. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

12.9. For each boiler, and each pollutant, the permittee shall determine emission factors in the following units: lbs/MMBtu and lbs/gallon.

12.10. For each incinerator, and each pollutant, the permittee shall determine emission factors in the following units: lbs/ton of waste combusted.

13. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

13.1. Equip each of the propulsion engines and generator engines on board Icebreaker #1 with an electrical output monitoring device:

13.1.1. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine with an accuracy equal to or better than 2 percent of the engine's maximum output (in kWe);

13.1.2. Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine at least once every 10 minutes; and

13.1.3. Each electrical output monitoring device shall be equipped to record each reading taken as well as provide and record average loads for each hour.

13.2. Maintain the accuracy of each electrical output monitoring device in accordance with manufacturer's recommendations.

13.3. Monitor and record the electrical load for each engine at least once every ten minutes, and record the average hourly load for each hour.

13.4. Equip each of the boilers on board Icebreaker #1 with a diesel fuel flow meter, or install a single fuel meter for all of the boilers:

13.4.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the boiler(s) or boiler group being served by the meter;

13.4.2. Each fuel flow meter shall be totalizing and nonresettable; and

13.4.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

13.5. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each

fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

13.6. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

13.7. Monitor and record the hourly fuel usage for each boiler.

13.8. For each instance in which an Icebreaker #1 seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

13.8.1. Record the duration of the episode for each such seldom used source;

13.8.2. Record the fuel consumption on a daily basis for each such seldom used source as provided in Condition B.6.4.2; and

13.8.3. Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of Icebreaker #1 seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

13.9. At least 45 days before deployment to the Discoverer each drilling season, the permittee shall notify the EPA of the stack height of Icebreaker #1.

13.10. Record any instance that Icebreaker #1 attaches to the Discoverer.

13.11. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from the boilers and incinerator by using the highest emission factor for each tested boiler or incinerator collected under Conditions N.12.9 and N.12.10 and fuel usage data collected under Condition N.13.7, to determine emissions from that source. For the purposes of this condition, the permittee shall assume that the incinerator has been operated continuously at the maximum operating rate, and shall use the highest emission factor collected under Condition N.12.10.

13.12. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Conditions N.12.8 and electrical load data collected under Condition N.13.3, to determine emissions from that source. Emissions shall be calculated for each ten-minute load reading for each engine.

13.13. For the purposes of Conditions N.13.11 and N.13.3, if a specific emission unit has not been tested yet, the permittee shall use the highest emission factor for the corresponding load from the test results for any equivalent emission unit in equivalent service that has already been tested.

13.14. For the purposes of Conditions N.13.11 and N.13.3, if a specific load reading is missing, the permittee shall calculate the emissions for that missing load reading by using the emission factor and load combination that results in the highest emissions rate for that emissions unit. If the engine in question has not been tested yet, the permittee shall use the emission factor as provided for in Condition N.13.13.

13.15. For the purpose of Condition P.13.12, if either the urea pump is not operating or if the catalyst inlet temperature, measured in Condition B.14, is less than 250°C, calculate emissions of NO_X for the affected time period by using an uncontrolled emission factor obtained by applying a 95 percent NO_X reduction efficiency to the emission factor determined pursuant to Condition P.12.8

O. ICEBREAKER #2

1. **Operation of SCR Unit.** At all times that any of the propulsion or generator engines on board Icebreaker #2 are in operation, the exhaust from each engine shall be directed to an operating SCR emission unit.

2. **Operation of Oxidation Catalyst.** At all times that any of the propulsion or generator engines on board Icebreaker #2 are in operation, the exhaust from each engine shall be directed to an operating oxidation catalyst emission unit.

3. **Icebreaker #2 Vessel Alternatives.** For a given drilling season, the permittee may use either the Tor Viking or Hull 247 as Icebreaker #2, subject to the conditions in Section O of this permit. Hull 247 is a temporary vessel name assigned by the shipbuilder, Edison Chouest. This permit is intended to apply to this vessel even when renamed with its permanent name.

   3.1 The total capacity of all propulsion engines on Icebreaker #2 shall not exceed 17,660 hp for the Tor Viking and 24,000 kW for Hull247.

   3.2 The total capacity of all non-propulsion generator engines on Icebreaker #2 shall not exceed 2,336 hp for the Tor Viking and Hull 247 shall not have electrical generation capacity in addition to the engines specified in Condition O.3.1.

   3.3 The total capacity of all boilers on Icebreaker #2 shall not exceed 1.37 MMBtu/hr for the Tor Viking and 4.00 MMBtu/hr for Hull 247.

   3.4 The total capacity of all incinerators on Icebreaker #2 shall not exceed 151.23 lbs/hr.

   3.5 Total uncontrolled emissions of $PM_{2.5}$ from all emission sources on board Icebreaker #2 shall not exceed 11.4 lbs/hour.

      3.5.1 For compliance with Condition O.3.5, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

      3.5.2 For the purposes of Condition O.3.5, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

   3.6 Total uncontrolled emissions of PM_{10} from all emission sources on board Icebreaker #2 shall not exceed 11.7 lbs/hour.

      3.6.1 For compliance with Condition O.3.6, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

3.6.2 For the purposes of Condition O.3.6, emissions from each emission unit shall be based on operation of that emission unit at 100 percent of rated capacity, except for the propulsion engines, for which emissions shall be based on operation of that emission unit at 80 percent of rated capacity.

3.7 No later than 45 days prior to deployment to the Chukchi Sea each drilling season, the permittee shall provide notification to the EPA of the vessel selected as Icebreaker #2. The notification shall include a list of all emission sources on board the vessel as well as manufacturer, model and rated capacity of each emission source.

4. **Capacity Limit on Icebreaker #2 Propulsion Engines.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, the permittee shall limit operation of the propulsion engines in Icebreaker #2 to 80 percent of rated capacity.

5. **Annual Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #2 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

5.1 **NO_X:** 99.45 tons/rolling 12-month period

5.1.1 For compliance with Condition O.5.1, measurement of NOX shall be determined using EPA Method 7E.

6. **Hourly Emission Limits.** Emissions from all emission sources on Icebreaker #2 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

6.1 **NO_X:** 69.06 lbs/hour

6.1.1 For compliance with Condition O.6.1, measurement of NOX shall be determined using EPA Method 7E.

7. **Daily Emission Limits.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, emissions from all emission sources on Icebreaker #2 in aggregate shall not exceed the emission limits specified for each of the pollutants below:

7.1 **PM_{10}:** 281.46 lbs/day

7.1.1 For compliance with Condition O.7.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

7.2 **$PM_{2.5}$:** 273.82 lbs/day

7.2.1 For compliance with Condition O.7.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and202.

8. **Electrical Power Output Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, the permittee shall not operate the internal combustion engines in excess of:

8.1 25,223,168 kWe-hr from all of the generators on board the Tor Viking in aggregate during any rolling 12-month period.

8.2 44,562,643 kWe-hr from all of the generators on board Hull 247 in aggregate during any rolling 12-month period.

8.3 395,100 kWe-hr from all of the generators on board the Tor Viking in aggregate during any calendar day.

8.4 592,141 kWe-hr from all of the generators on board Hull 247 in aggregate during any calendar day.

9. **Fuel Usage Limit.** At all times while the Discoverer is an OCS Source and Icebreaker #2 is within 25 miles of the Discoverer, the permittee shall not use fuel in excess of:

9.1 40,320 gallons in all heat boilers on board the Tor Viking in aggregate during any rolling 12-month period.

9.2 120,960 gallons in all heat boilers on board Hull 247 in aggregate during any rolling 12-month period.

9.3 240 gallons in all heat boilers on board the Tor Viking in aggregate during any calendar day.

9.4 720 gallons in all heat boilers on board Hull 247 in aggregate during any calendar day.

9.5 100 gallons in Icebreaker #2 seldom used sources in aggregate during any rolling 7-day period. Icebreaker #2 seldom used sources include engines on Icebreaker # 2, that are not otherwise identified in the permit as emission units or categories of emission units on Icebreaker #2.

10. **Attachment to Discoverer.** At no time shall Icebreaker #2 be attached to the Discoverer.

11. **Stack Height Limit for Icebreaker #2.** The permittee shall ensure that the stack height of Icebreaker #2 is no less than 24.38 meters. For the purposes of this condition, the permittee shall obtain the stack height information for each vessel to be used as Icebreaker #2.

12. **Stack Test Requirements.** Prior to each of the first two drilling seasons that a vessel is used as Icebreaker #2, and while the Discoverer is operating under this permit in the Chukchi Sea, the permittee shall stack test each propulsion engine, non-propulsion generator engine, boiler and incinerator on Icebreaker #2 as follows:

12.1 Each stack test on the propulsion engines shall be conducted at four different loads: 20 percent, 40 percent, 60 percent, and 80 percent.

12.2 Each stack test on the non-propulsion generator engines shall be conducted at two different load ranges: 50 – 60 percent and 90 - 100 percent.

12.3 Each stack test on the boilers shall be conducted at full loads.

12.4 Each stack test on the incinerator shall be conducted at full load.

12.5 Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

12.6 During each test run for the propulsion engines, generator engines, and boilers, the permittee shall monitor and record the following information:

12.6.1 Quantity of fuel used (in gallons);

12.6.2 Density of the fuel used (in lbs/gallon);

12.6.3 Heat content of the fuel used (in Btu/gallon);

12.6.4 For the engines, electrical power output (in kWe);

12.6.5 The stack temperature upstream of the SCR catalysis ºC or ºF;

12.6.6 The quantity of urea reagent (in gallons) and the concentration of the urea reagent (in weight percent) introduced into the SCR control system; and

12.6.7 The NO_X concentration (ppm) indicated by the periodic NO_X monitor used for the SCR control system.

12.7 During each test run for the incinerator, the permittee shall monitor and record the quantity of waste material incinerated (in lbs).

12.8 For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

12.9 For each boiler, and each pollutant, the permittee shall determine emission factors in the following units: lbs/MMBtu and lbs/gallon.

12.10 For each incinerator, and each pollutant, the permittee shall determine emission factors in the following units: lbs/ton of waste combusted.

13. **Monitoring, Recordkeeping, and Reporting.** The permittee shall:

13.1 Equip each of the propulsion engines and generator engines on board Icebreaker #2 with an electrical output monitoring device:

13.1.1 Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine with an accuracy equal to or better than 2 percent of the engine's maximum output (in kWe).

13.1.2 Each electrical output monitoring device shall measure the electrical output of the generator attached to each engine at least once every 10 minutes; and

13.1.3 Each electrical output monitoring device shall be equipped to record each reading taken as well as provide and record average loads for each hour.

13.2 Maintain the accuracy of each electrical output monitoring device in accordance with manufacturer's recommendations.

13.3 Monitor and record the electrical load for each engine at least once every ten minutes, and record the average hourly load for each hour.

13.4 Equip each of the boilers on board Icebreaker #2 with a diesel fuel flow meter, or install a single fuel meter for all of the boilers:

13.4.1 Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the boiler(s) or boiler group being served by the meter;

13.4.2 Each fuel flow meter shall be totalizing and non-resettable; and

13.4.3 Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

13.5 No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

13.6 Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

13.7 Monitor and record the hourly fuel usage for each boiler.

13.8 For each instance in which an Icebreaker #2 seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

13.8.1 Record the duration of the episode for each such seldom used source;

13.8.2 Record the fuel consumption on a daily basis for each seldom used source as provided in Condition B.6.4.2; and

13.8.3 Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of such seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

13.9 At least 45 days before deployment to the Discoverer each drilling season, the permittee shall notify the EPA of the stack height of Icebreaker #2.

13.10 Record any instance that Icebreaker #2 attaches to the Discoverer.

13.11 Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from the boilers and incinerator by using the highest emission factor for each tested boiler or incinerator collected under Conditions O.12.9 and O.12.10 and fuel usage data collected under Condition O.13.7, to determine emissions from that source. For the purposes of this condition, the permittee shall assume that the incinerator has been operated continuously at the maximum operating rate, and shall use the highest emission factor collected under Condition O.12.10.

13.12 Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and emissions of $PM_{2.5}$ and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Conditions O.12.8 and electrical load data collected under Condition O.13.3, to determine emissions from that source. Emissions shall be calculated for each ten-minute load reading for each engine.

13.13 For the purposes of Conditions O.13.11 and O.13.12, if a specific emission unit has not been tested yet, the permittee shall use the highest emission factor for the corresponding load from the test results from an equivalent emission unit in equivalent service that has already been tested.

13.14 For the purposes of Conditions O.13.11 and O.13.12, if a specific load reading is missing, the permittee shall calculate the emissions for that missing load reading by using the emission factor and load combination that results in the highest emissions

rate for that emissions unit. If the engine in question has not been tested yet, the permittee shall use the emission factor as provided for in Condition O.13.13.

13.15 For the purpose of Condition O.13.12 if either the urea pump is not operating or if the catalyst inlet temperature, measured in Condition B.14, is less than 250°C, calculate emissions of NO_X for the affected time period by using an uncontrolled emission factor obtained by applying a 95 percent NO_X reduction efficiency to the emission factor determined pursuant to Condition O.12.8.

P. SUPPLY SHIP

1. **Operational Limits on Supply Ship Engines.** At all times while the Discoverer is an OCS Source and the supply ship is within 25 miles of the Discoverer, the permittee shall:

   1.1. Not operate the emergency engine on the supply ship.

   1.2. Not use fuel in excess of 1,200 gallons in the Supply Ship propulsion engines and non-propulsion engines in aggregate during any calendar day when in transit to and from the Discoverer.

   1.3. Not use fuel in excess of 4,800 gallons in the supply ship propulsion engines and non-propulsion engines in aggregate during any calendar day when operating in dynamic positioning mode.

2. **Hourly Emission Limits on Supply Ship in Dynamic Positioning Mode.** Emissions from all generator and propulsion engines in aggregate on the supply ship shall not exceed the emission limits specified for each of the pollutants below:

   2.1. **Nitrogen oxides (NO_X):** 117.39 lb/hr

      2.1.1. For compliance with Condition P.2.1, measurement of NO_X shall be determined using EPA Method 7E.

3. **Daily Emission Limits on Supply Ship in Dynamic Positioning Mode.** Emissions from all generator and propulsion engines in aggregate on the supply ship shall not exceed the emission limits specified for each of the pollutants below:

   3.1. **PM_{10}:** 75.09 lbs/day

      3.1.1. For compliance with Condition P.3.1, measurement of PM_{10} shall be determined using EPA Method s 201A and 202.

   3.2. **$PM_{2.5}$:** 75.09 lbs/day

      3.2.1. For compliance with Condition P.3.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4. **Stack Test Requirements.** Prior to each of the first two drilling seasons that the supply ship is used and while the Discoverer is operating under this permit in the Chukchi Sea, the permittee shall stack test each propulsion engine and non-propulsion generator engine on the supply ship as follows:

   4.1. Each stack test on the propulsion engines shall be conducted at four different loads: 20 percent, 40 percent, 60 percent, and 80 percent.

4.2. Each stack test on the non-propulsion generator engines shall be conducted at two different load ranges: 50 - 60 percent and 90 - 100 percent.

4.3. Each stack test run shall test for emissions of NO_X, NO_2, $PM_{2.5}$, and PM_{10}.

4.4. During each test run for the propulsion engines and generator engines the permittee shall monitor and record the following information:

4.4.1. Quantity of fuel used (in gallons);

4.4.2. Density of the fuel used (in lbs/gallon);

4.4.3. Heat content of the fuel used (in Btu/gallon);

4.4.4. For the engines, electrical power output (in kWe);

4.5. For each engine, each load range, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

5. **Monitoring, Recordkeeping and, Reporting**. The permittee shall:

5.1. At all times while the Discoverer is an OCS Source and the supply ship is within 25 miles of the Discoverer, monitor the power output of each propulsion engine on the supply ship at least once every 15 minutes.

5.1.1. The monitored power output shall be recorded as a direct readout value as well as a percentage of the rated capacity of each engine.

5.2. Equip each of the propulsion and non-propulsion engines on the Supply Ship with a diesel fuel flow meter or install a single fuel meter for all of the engines:

5.2.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

5.2.2. Each fuel flow meter shall be totalizing and non-resettable; and

5.2.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

5.3. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

5.4. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

5.5. Monitor and record the hourly fuel usage for the supply ship.

5.6. For each trip to the Discoverer while the Discoverer is an OCS Source, the permittee shall record the following:

5.6.1. The date and time the supply ship came within 25 miles of the Discoverer; and

5.6.2. After the delivery to the Discoverer, the date and time that the supply ship was no longer within 25 miles of the Discoverer.

5.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X in pounds per hour and pounds per day and the emissions of $PM_{2.5}$, and PM_{10} in pounds per day from each engine by using the emission factors for each tested engine collected under Condition P.4.5and recorded fuel use under Condition P.5.5.

5.8. Record the date and time the supply ship ceases operation in dynamic positioning mode.

5.9. Record the date and time the supply ship ceases operation in dynamic positioning mode.

6. **Supply Ship Events.** The total number of events during which the supply ship transits to and from the Discoverer and either attaches to the Discoverer or operates in dynamic positioning mode shall not exceed 8 in any drilling season. Each 24-hour period of operation in dynamic positioning mode is considered a separate supply ship event.

Q. OIL SPILL RESPONSE FLEET

1. **Operation of Catalyzed Diesel Particulate Filter (CDPF).** At all times while the Discoverer is an OCS Source and the Nanuq is within 25 miles of the Discoverer, and any of the Nanuq propulsion engines (Units N-1 - 2) or non-propulsion generator engines (Units N-3 -4) are in operation, the exhaust from each emission unit shall be directed to operating CleanAIR Systems CDPF, as specified by CleanAIR Systems.

1.1. Each CDPF shall be equipped with an operating HiBACK monitor and alarm unit, that records exhaust pressure and temperature.

1.2. During each day that each of Units N-1 - 4 is operated, the exhaust temperature shall be above 300°C, or 572°F, for at least 30 percent of the time.

2. **Annual Emission Limits.** At all times while the Discoverer is an OCS source and the Oil Spill Response fleet is within 25 miles of the Discoverer, emissions of NO_X from the Oil Spill Response Fleet shall not exceed the emission limits specified below:

2.1. **Nanuq propulsion engines and generators in aggregate (Units N-1 – 4):** 97.11 tons/rolling 12-month period

2.2. **Kvichak Nos. 1-3 propulsion engines in aggregate (Units K1-2, K4-5, and K7-8):** 19.07 tons/rolling 12-month period

2.2.1. For compliance with Conditions Q.2.1and Q.2.2, measurement of NO_X shall be determined using EPA Method 7E.

3. **Hourly Emission Limits:** At all times while the Discoverer is an OCS source and the Oil Spill Response fleet is within 25 miles of the Discoverer, emissions of NO_X from the Oil Spill Response Fleet shall not exceed the emission limits specified below:

3.1. Nanuq propulsion engines and generators in aggregate (Units N-1 – 4):

3.1.1. **NO_X:** 67.44 lbs/hour

3.1.1.1. For compliance with Condition Q.3.1.1, measurement of NO_X shall be determined using EPA Method 7E.

3.2. Kvichak Nos. 1-3 propulsion engines in aggregate (Units K1-2, K4-5, and K7-8):

3.2.1. **NO_X:** 13.24 lb/hr

3.2.1.1. For compliance with Condition Q.3.2.1, measurement of NO_X shall be determined using EPA Method 7E.

4. **Daily Emission Limits:** At all times while the Discoverer is an OCS source and the Oil Spill Response fleet is within 25 miles of the Discoverer, emissions from the Oil Spill Response Fleet shall not exceed the emission limits specified:

4.1. Nanuq propulsion engines and generators in aggregate (Units N-1 – 4):

4.1.1. **PM_{10}:** 3.03 lbs/day

4.1.1.1. For compliance with Condition Q.4.1.1, measurement of PM_{10} shall be determined using EPA Method s 201A and 202.

4.1.2. **$PM_{2.5}$:** 3.03 lbs/day

4.1.2.1. For compliance with Condition Q.4.1.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

4.2. Kvichak Nos. 1-3 in aggregate (Units K1-2, K4-5, and K7-8):

4.2.1. **PM_{10}:** 24.34 lbs/day

4.2.1.1. For compliance with Condition Q.4.2.1, measurement of PM_{10} shall be determined using EPA Methods 201A and 202.

4.2.2. **$PM_{2.5}$:** 24.34 lbs/day

4.2.2.1. For compliance with Condition Q.4.2.2, measurement of $PM_{2.5}$ shall be determined using EPA Methods 201A and 202.

5. **Fuel Usage Limit.** At all times while the Discoverer is an OCS Source and the Nanuq is within 25 miles of the Discoverer, the permittee shall not use in excess of:

5.1. 456,000 gallons of fuel in the Nanuq propulsion engines (Units N-1 – 2) and non-propulsion electrical generators (Units N-3 – 4) in aggregate during any rolling 12-month period.

5.2. 3,800 gallons of fuel in the Nanuq propulsion engines (Units N-1 – 2) and non-propulsion electrical generators (Units N-3 – 4) in aggregate during any calendar day.

5.3. 100 gallons of fuel in the Nanuq seldom used sources in aggregate during any rolling 7-day period. The Nanuq seldom used sources include engines on the Nanuq that are not otherwise identified in the permit as emission units or categories of emission units on the Nanuq.

5.4. 2856 gallons of fuel in the Kvichak Nos. 1-3 in aggregate during any rolling 7-day period.

6. **Operating Location.** Except for transport of crew and supplies to and from the Discoverer or when responding to an oil spill, the oil spill response fleet shall operate at a location that is downwind from the Discoverer.

7. **Attachment to Discoverer.** At no time shall the Nanuq or any of the Kvichak work boats be attached to the Discoverer.

8. **Stack Test Requirements.** Prior to each of the first two drilling seasons while the Discoverer is operating under this permit in the Chukchi Sea, the permittee shall stack test at least one of the Nanuq propulsion engines (Units N-1 – 2) and one of the Nanuq non-propulsion generator engines (Units N-3 – 4) as follows:

   8.1. At the end of two drilling seasons that the Discoverer operates under this permit in the Chukchi Sea, all of Units N-1 – 4 shall have been stack tested under the requirements of this section.

   8.2. Each stack test shall be conducted at four different loads - 25 percent, 50 percent, 75 percent and 100 percent for the propulsion engines and at two loads – 50 percent and 100 percent for the non-propulsion engines.

   8.3. Each stack test run shall test for emissions of NO_X and NO_2.

   8.4. During each test run, the permittee shall monitor and record the following information:

      8.4.1. Quantity of fuel used (in gallons);

      8.4.2. Density of the fuel used (in lbs/gallon);

      8.4.3. Heat content of the fuel used (in Btu/gallon); and

      8.4.4. Electrical power output (in kWe).

   8.5. For each engine, each load, and each pollutant, the permittee shall determine emission factors in the following units: lbs/kWe-hr and lbs/gallon.

9. **Monitoring, Recordkeeping and Reporting.** The permittee shall:

   9.1. Equip each of Units FD-N-1 - 4 with a diesel fuel flow meter, or install a single fuel meter for all of Units FD-N-1 - 4:

      9.1.1. Each fuel flow meter shall be located so that there is no potential for fuel inflows or outflows between it and the engine(s) or engine group being served by the meter;

      9.1.2. Each fuel flow meter shall be totalizing and non-resettable; and

      9.1.3. Each fuel flow meter shall measure the fuel flow rate with accuracy equal to or better than 2 percent of the meter's upper range value.

   9.2. No less than 60 days before initial deployment of the Discoverer to the Chukchi Sea for the first drilling season, collect information from the manufacturer of each fuel flow meter so as to determine its accuracy. Submit this information to the EPA no less than 30 days prior to operation within the Chukchi Sea.

   9.3. Maintain the accuracy of each fuel flow meter in accordance with manufacturer's recommendations.

   9.4. Monitor and record fuel usage for each propulsion and generator engine (Units N-1 – 4) on a hourly basis.

9.5. For each instance in which a Nanuq seldom used source is operated while the Discoverer is an OCS Source, the permittee shall:

9.5.1. Record the duration of the episode for each such seldom used source;

9.5.2. Record the fuel consumption on a daily basis for each such seldom used source as provided in Condition B.6.4.2; and

9.5.3. Calculate and record for the previous 6 calendar days the rolling 7-day fuel consumption of the Nanuq seldom used sources in aggregate by adding each day's fuel consumption to the total fuel consumed in the previous 6-calendar days.

9.6. Record any instance that the Nanuq or Kvichak work boats attach to the Discoverer.

9.7. Each day, calculate and record for the previous calendar day, the emissions of NO_X, in pounds per hour and pounds per day using the highest emission factor for each tested engine collected under Condition Q.8.5 and fuel usage data collected under Condition Q.9.4.

9.8. Monitor and record the exhaust temperature of each engine by use of the HiBACK monitor and alarm unit, while the engine is in operation.

9.9. Each day, calculate and record for the previous calendar day, the percent of operational time for each engine that the exhaust temperature was above 300°C (572°F).

R. POST-CONSTRUCTION AMBIENT AIR QUALITY MONITORING

1. **Ambient Air Quality Monitoring Station.** The permittee shall install, operate and maintain a Federal Reference Method or Federal Equivalent Method ambient air quality monitoring station to measure and record $PM_{2.5}$ concentration data in accordance with EPA, 1984a: Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), EPA-450/4-87-007, May 1987, U.S. Environmental Protection Agency, Research Triangle Park, NC.

1.1. An alternative $PM_{2.5}$ monitoring station may be used in lieu of the required monitoring station provided that approval of the monitoring station is obtained from the EPA;

1.2. The permittee shall use a continuous sampler and a manual sampler to measure $PM_{2.5}$. In addition, filters from the manual sampler shall be analyzed as provided for in the EPA-approved ambient air quality and meteorological monitoring plan required pursuant to Condition R.3 to allow for the chemical speciation of $PM_{2.5}$ constituents, including but not limited to sulfates, nitrates, organics, metals, sea salt and crustal matter.

1.3. The monitoring period shall commence within 120 days after the final permit is issued and shall continue for a minimum of 1 year after commencement of initial operation of the Discoverer in the Chukchi Sea as an OCS Source;

1.4. The data recovery shall be as provided for in the EPA-approved ambient air quality and meteorological monitoring plan required pursuant to Condition R.3; and

1.5. The monitoring station shall continue to operate and record data until such time that written approval is obtained from the EPA authorizing the termination of its operation.

2. **Meteorological Monitoring Station.** The permittee shall install, operate and maintain a meteorological monitoring station to monitor and record data in accordance with EPA, 1984a: Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), EPA-450/4-87-007, May 1987, U.S. Environmental Protection Agency, Research Triangle Park, NC.

2.1. An alternative meteorological monitoring station may be used in lieu of the required monitoring station provided that approval of the monitoring station is obtained from the EPA;

2.2. Data shall include horizontal wind direction and speed, temperature, solar radiation and temperature difference;

2.3. Each quarter's data recovery shall be as provided for in the EPA-approved ambient air quality and meteorological monitoring plan required pursuant to Condition R.3;

2.4. The monitoring period shall commence within 120 days after the final permit is issued and shall continue for a minimum of 1 year after commencement of operation of the OCS Source; and

2.5. The monitoring station shall continue to operate and record data until such time that written approval is obtained from the EPA authorizing the termination of its operation.

3. **Ambient Air Quality and Meteorological Monitoring Plan.** At least 60 days prior to the commencement of the data collection, the permittee shall submit to the EPA for approval an ambient air quality and meteorological monitoring plan for the post-construction monitoring requirements specified in Conditions R.1 and R.2 in accordance with the requirements of 40 CFR Part 58, Appendix A "Quality Assurance Requirements for SLAMS, SPMs and PSD Air Monitoring." The plan shall include a description of the proposed monitoring site.

4. **Monthly Reporting.** Within 45 days after the end of each calendar month, the permittee shall submit to the EPA a printed summary of the $PM_{2.5}$ and meteorological monitoring data collected during the prior calendar month.

5. **Audit Reports.** The permittee shall submit audit reports with 45 days after the following events:

5.1. Completion of the post-installation equipment audit;

5.2. Completion of independent performance and system audits;

5.3. Completion of quarterly audits required for ambient air quality data collection system; and

5.4. Completion of the semi-annual audits required for the meteorological data collection system.

Quarterly and semi-annual audit periods shall be based on a calendar year.

6. **Annual Report.** Within 60 days after the end of each calendar year and following completion of the collection of monitoring, the permittee shall submit to the EPA annual/final reports in text, tabular, and graphic forms, including data in digitized format. The digitized formats of the measured air quality and meteorological data shall be in ASCII format and AIRS format.

7. **System and Performance Audit Report**. Within 60 days after completion of data collection, the permittee shall also submit the final report for the system and performance audits required prior to monitoring termination.

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ATTACHMENT A: EPA NOTIFICATION FORM

Excess Emissions and Permit Deviation Reporting

OCS Source (Facility) Name **Air Quality Permit Number**

Company Name

When did you identify the Excess Emissions/Permit Deviation?

Date: / / Time: :

When did the event/deviation occur?

Begin: Date: / / Time: : (please use 24hr clock)

End: Date: / / Time: : (please use 24hr clock)

What was the duration of the event/deviation: : (hrs:min) or days
(total # of hrs, min, or days, if intermittent then include only the duration of the actual emissions/deviation)

Reason for notification: (please check only 1 box and go to the corresponding section)
☐Excess Emissions Complete Section 1 and Certify
☐Deviation from Permit Conditions Complete Section 2 and Certify
☐Deviation from Compliance Order by Consent, Compliance Order, or Settlement Agreement Complete Section 2 and Certify

Section 1. Excess Emissions

(a) Was the exceedance ☐Intermittent or ☐Continuous

(b) Cause of Event (Check one that applies):
☐Start Up/Shut Down ☐Natural Cause (weather/earthquake/flood)
☐Control Equipment Failure ☐Scheduled Maintenance/Equipment Adjustments
☐Bad fuel/coal/gas ☐Upset Condition ☐Other

(c) Description:
Describe briefly what happened and the cause. Include the parameters/operating conditions exceeded, limits, monitoring data and exceedance.

(d) Emission Units Involved:
Identify the emission units or source involved in the event, using the same identification number and name as in the permit. Identify each emission standard (including any throughput limit) potentially exceeded during the event and the exceedance.

Unit ID	Emission Unit Name	Permit Condition Exceeded/Limit/ Potential Exceedance

(e) Type of Incident (please check only one):

☐Opacity percent ☐Venting (gas/scf) ☐Control Equipment Down
☐Fugitive Emissions ☐Emission Limit Exceeded ☐Record Keeping Failure
☐Marine Vessel Opacity ☐Flaring ☐Other:

(f) Unavoidable Emissions:
Do you intend to assert that these excess emissions were unavoidable? ☐YES ☐NO

Certify Report (go to end of form)

Section 2. Permit Deviations

(a) Permit Deviation Type (check one only) (check boxes correspond with sections in permit):
☐ Source Specific
☐ Failure to monitor/report
☐ General Source Test/Monitoring Requirements
☐ Recordkeeping/Reporting/Compliance Certification
☐ Standard Conditions Not Included in Permit
☐ Generally Applicable Requirements
☐ Reporting/Monitoring for Diesel Engines
☐ Insignificant Source
☐ Facility Wide
☐ Other Section: (title of section and section # of your permit)

(b) Emission Units Involved:
Identify the source involved in the event, using the same identification number and name as in the permit. List the corresponding Permit condition and the deviation.

Unit ID	Emission Unit Name	Permit Condition /Potential Deviation

(c) Description of Potential Deviation:
Describe briefly what happened and the cause. Include the parameters/operating conditions and the potential deviation.

(d) Corrective Actions:
Describe actions taken to correct the deviation or potential deviation and to prevent future recurrence.

Certification:
Based on information and belief formed after reasonable inquiry, I certify that the statements and information in and attached to this document are true, accurate, and complete.

Printed Name **Title** **Date**

Signature **Phone number**

Page ___ of ___

Company & Stationary Source_____ Certified Observer_____

Test Number _____ Clock time_____

Date:		Visibility Reduction Every 15 Seconds (Opacity)				Steam Plume (check if applicable)		Comments
Hr	Min	0	15	30	45	Attached	Detached	

Additional information:

_____ _____
Observer Signature and Date Certified By and Date

Data Reduction:
Duration of Observation Period (minutes) _____ Duration Required by Permit (minutes)_____
Number of Observations _____ Highest Six –Minute Average Opacity (%)_____
Number of Observations exceeding 20 % _____

Average Opacity Summary

Set Number	Time Start—End	Opacity	
		Sum	Average

To Submit this Report:

1. Fax this form to: Facsimile no. 206-553-0110

   Or

2. E-mail to: R10OCSAirPermits_Reports@epa.gov

   Or

3. Mail to: OCS/PSD Air Quality Permits
   U.S. EPA - Region 10, AWT-107
   1200 Sixth Avenue, Suite 900
   Seattle, WA 98101

ATTACHMENT B: VISIBLE EMISSIONS FIELD DATA SHEET

Permit No. R10OCS/PSD-AK-09-01

Certified Observer: _____

Company & Stationary Source: _____

Location: _____

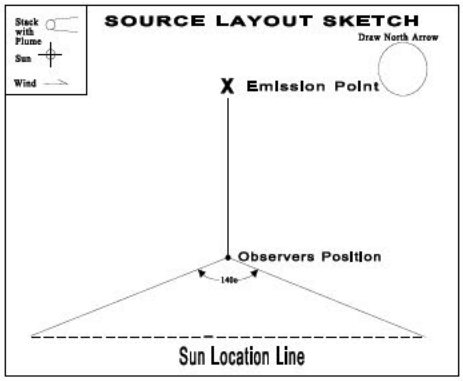
Test No.: _____ Date: _____

Emission Unit: _____

Operating Rate: _____

_____

_____



Clock Time	Initial				Final
Observer location Distance to discharge					
Direction from discharge					
Height of observer point					
Background description					
Weather conditions Wind Direction					
Wind speed					
Ambient temperature					
Relative humidity					
Sky conditions: (clear, overcast, % clouds, etc.)					
Plume description: Color					
Distance visible					
Water droplet plume? (Attached or detached?)					
Other information					

2012 Monitoring Schedule

3-day & 6-day Monitoring Schedule for TSP, Pb, PM-10, PM-2.5, and VOC. 12-day Monitoring Schedule for PM-2.5 Collocation.

January

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29			

March

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

April

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

May

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

June

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

July

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

August

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

September

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

October

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

November

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

December

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

& & = 1/3 day sampling

& = 1/6 day sampling

= 1/12 day sampling

APPENDIX C
PROJECT FORMS

Site Training Check List

This form should be included with the site visit memos. All training is site-specific and is to be given by qualified SLR personal only.

Date of Training: _____

Station Name:_____ Project No._____

Name of Trainer: _____ Position: _____

Name of Trainee: _____ Position: _____

Nature of Training: _____

Is the trainee SLR personnel? If not specify associated company. Yes ☐ No ☐

Specify company name: _____ Position: _____

_____

Site surveillances/maintenances visits:

- ☐ Has the specific monitoring project overview and objectives been discussed?
- ☐ Has site location and all safety concerns been discussed in detail?
- ☐ Has the scope of the site surveillances visit been discussed?
- ☐ Have all specific concerns pertaining to meteorological station been discussed.
- ☐ Have all site surveillance visit forms and filling procedures been discussed in detail?
- ☐ Have all site surveillances/maintenances visit task been clearly explained and demonstrate, including all equipment and senor operation, and safety practices pertaining to these tasks?
- ☐ Have all "as left" procedures been explained and demonstrated?

Audit and Calibration Visits:

- ☐ Has the specific monitoring project overview and objectives been discussed?
- ☐ Has the scope of the audit or calibration visit been discussed in detail?
- ☐ Have all specific concerns pertaining to meteorological station including any environmental safety concerns been discussed?
- ☐ Have all the audit or calibration forms, site visit documentation and filling procedures been discussed in detail?
- ☐ Have the functions and operations of each instrument located at the site been explained and demonstrated in detail?
- ☐ Have all audit or calibration task, tests, and recording techniques been clearly explained and demonstrated?
- ☐ Have all safety practices penetrating to the above task been clearly explained and demonstrated?
- ☐ Have all filling procedure and deadlines been discussed in detail?
- ☐ Have all "as left" procedures been explained and demonstrated?

Comments:

_____
_____
_____
_____
_____
_____
_____
_____
_____

Trainers Signature: _____

Trainees Signature: _____

Corrective Action Form

Revision: 1.0
Effective Date: 04/27/2011

Project Title: _____ **Project No.** _____

Key Personnel	*Approved Recommendation(s)*	*Date*	*Task(s) Completion*	*Date*
Station Operator:				
Project Manager:				
Data Manager:				
Station Owner (If necessary):				

I. Request for Assistance:

Problem Summary:

_____

_____

_____

_____

_____

_____

II. Proposed Corrective Action

Recommended Action:

_____

_____

_____

_____

_____

_____

III. Results of Proposed Action

Action Results:

_____

_____

_____

_____

_____

BAR CODE GOES HERE Custody/Data Form No.	**$PM_{2.5}$ STN CUSTODY AND FIELD DATA FORM**	White – return to lab Yellow – site retains Pink – lab retains

A. CUSTODY RECORD (Name, Date)

1. Laboratory, Out _____ Date_____
2. Site, In _____ Date_____
3. Site, Out _____ Date_____
4. Lab, In _____ Date_____

B. SITE AND SAMPLER INFORMATION

1. Site AIRS Code _____
2. Sampler S/N _____
3. Sampler Type _____
4. Sampler POC _____
5. Site Name _____
6. Intended date of use _____
7. Date of sampler set-up _____
8. Operator's name _____

C. SAMPLER CHANNEL COMPONENTS

Channel Number	Component ID No.	Component Description
1	kept at site	SASS cyclone
1	I1234568	SASS cassette (Teflon filter) (GREEN)
2	kept at site	SASS cyclone
2	I1234570	SASS cassette (MgO denuder, nylon filter) (RED)
3	kept at site	SASS cyclone
3	I1234572	SASS cassette (quartz filter) (ORANGE)

D. START, END, AND RETRIEVAL TIMES

Channel No.	Start date	Start time	End date	End time	Retrieval date	Retrieval time
1						
2						
3						

E. SAMPLER CHANNEL INFORMATION (Post-Sampling)

Channel No.	Run Time	Run Time, Flag	Sample Volume (m3)	Avg. flow (L/min)	Avg. flow CV (L/min)	Avg. ambient T (°C)	Max. ambient T (°C)	Min. ambient T (°C)
1								
2								
3								

Channel No.	• T Flag	Avg. Filter T (°C)	Max. Filter T (°C)	Min. Filter T (°C)	Avg. BP (mm Hg)	Max. BP (mm Hg)	Min. BP (mm Hg)
1							
2							
3							

QA/QC Form No.	**$PM_{2.5}$ STN QA/QC REPORT FORM**	c. 1 (site retains) c. 2 (Agency QAM) c. 3 (Send to Lab)

A. SITE AND SAMPLER INFORMATION

1. Site AIRS Code	5. Site Name
2. Sampler S/N	6. Interval: Month _____ Quarter _____ Special _____
3. Sampler Type	7. Date(s) of QA/QC Checks
4. Sampler POC	8. Operator's Name

B. DATE AND TIME CHECKS (Transfer Standard Name _____ Transfer Standard ID Number _____)

Sample display date/time	Transfer standard date/time	Date and time agree ±5 min?	Action taken[a]

C. LEAK CHECKS (Transfer Standard Name _____ Transfer Standard ID Number _____)

Channel number	Manufacturer's specifications met?	Action taken and recheck results[a]
1		
2		
3, etc.		

D. TEMPERATURE CHECKS (Transfer Standard Name _____ Transfer Standard ID Number _____)

Sensor location	Sampler display (°C)	Transfer standard (°C)	Agreement ± 2 °C ?	Action taken and recheck results[a]
Ambient				
Filter				
Dry gas meter				
Manifold				

E. PRESSURE CHECKS (Transfer Standard Name _____ Transfer Standard ID Number _____)

Sensor location	Sampler display, (mmHg)	Transfer standard, (mmHg)	Agreement within ±10 mmHg?	Action taken and recheck results[a]
Ambient				
Manifold				

F. FLOW RATE CHECKS (Transfer Standard Name _____ Transfer Standard ID Number _____)

Channel number	Sampler display, (L/min)	Transfer standard display, (L/min)	Design flow rate, (L/min)	Agreement within ± 10 percent?[b]	Action taken and recheck results[a]
1					
2					
3, etc.					

PM2.5 Speciation Sampler Acceptance and Installation Checklist

Check or Criteria	Yes?	No?
1. Check the enclosed packing list. Were all parts included in the delivery of the sampler? (Including filter packs, denuders, and an operator's manual)		
2. Were any of the enclosed parts broken during shipment of the sampler?		
3. Check the enclosed assembly instructions. Did all the parts fit together during assembly of the sampler?		
4. Does the sampler's pump turn on when supplied with electrical power?		
5. Using an independent timer, check to ensure the timer (clock) operates properly. Check to see if the timer will automatically turn the sampler on and off during a fixed time by setting the timer to turn the sampler on and off for a short period while the operator observes.		
6. Does the sampler's computer (display screen) boot up and operate properly? Check to see if the computer (microprocessor) has working software (firmware) by performing manual input of information to the sampler through the keyboard and observe the results on the display screen.		
7. Does the computer download information properly? Check this process by attempting to download stored information through the RS232 port to a computer and then to a diskette.		
8. Does the internal cooling fan operate properly? Check this function by supplying electrical power to the unit and listening for and observing the fan turn on and off.		
9. Do the temperature sensors operate properly? Check this function by comparing sensor readings to an independent thermometer (or by warming the sensor tip between your fingers to see if the temperature rises).		
10. Does the filter holder (sampling module, cassette, or filter pack) hold the filter correctly and does it connect easily and snugly to other components of the sampling stream? Check this function by installing a filter in the sampling module and by connecting the module to the sampling manifold, denuder, and so on.		
11. Does the sampler's casing or other enclosure protect internal units from the weather? Check by visually inspecting the unit's latches, locks, seals, and gaskets for gaps, holes, and leaks. Do not disassemble the unit.		
12. Does the support structure (base, tripod, and so on) hold the sampling unit secure, upright, and level?		
13. When all sampler parts are assembled and operated as a unit, does the sampler function properly? Check this function by assembling the unit per instructions, installing a filter or sampling module, setting the timer, activating the sampler, and running it for 24 h as would be done for routine sampling.		
Certifying Official's Signature _____Date_____ Circle one - -	**Accept?**	**Reject?**

APPENDIX D
Standard Operating Procedures

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1. Model SASS™ & SuperSASS™ $PM_{2.5}$ Ambient Chemical Speciation Samplers Field Operation Manual
2. NIOSH Method 7903 Ion Chromatography measurement of inorganic acids on solid sorbent media
3. Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air. Compendium Method IO-3.3 Determination of Metals in Ambient Particulate Matter Using X-Ray Fluorescence (XRF) Spectroscopy
4. Thermal/Optical Carbon Analysis (TOR/TOT) of Aerosol Filter Samples – Method IMPROVE-A. Prepared by Desert Research Institute as Method IMPROVE-A to support the IMPROVE monitoring network carbon analysis program. Procedures and equipment modified for use by Chester LabNet.

MODEL SASSÔ & SuperSASSÔ
$PM_{2.5}$ AMBIENT CHEMICAL SPECIATION SAMPLERS

FIELD OPERATION MANUAL
Document No. SASS-9800 Rev D.

U.S. ENVIRONMENTALPROTECTION AGENCY
NATIONAL CONTRACT
AMBIENT CHEMICAL SPECIATION SAMPLER CANDIDATE
68-D-98-048

December 27, 2001

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MODEL SASSÔ & SuperSASSÔ
$PM_{2.5}$ AMBIENT CHEMICAL
SPECIATION SAMPLERS

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Technical Support

Should you require support, please consult your printed documentation to resolve your problem. If you are still experiencing difficulty, you may contact a Technical Service representative during normal business hours—7:30 a.m. to 4:00 p.m. Pacific Standard Time, Monday through Friday.

Voice: (541) 471-7111

Fax: (541) 471-7116

E-Mail: service@metone.com

Mail: Technical Services Department
Met One Instruments, Inc.
1600 Washington Boulevard
Grants Pass, OR 97526

SASS/SuperSASS OPERATORS MANUAL
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AMBIENT $PM_{2.5}$ CHEMICAL SPECIATION SAMPLERS
MET ONE MODELS "SASSÔ & SuperSASSÔ"

1.0 GENERAL INFORMATION

1.1 Introduction

The manual covers both the operation of the Met One Instruments, SASS™ (Speciation Air Sampling System) and the second generation of the SASS™ called SuperSASS™. SASS™ and SuperSASS™ are trademarks of Met One Instruments, Inc. The SuperSASS includes all of the operating benefits of the SASS plus expanded sampling canister stations, and the addition of sequential programming in groups of sample collection canisters. The SASS and SuperSASS have developed from the field tests performed by the US-EPA and the suggestions of our customers. The term SASS will be used in this manual to identify basic concepts used in the SASS and the SuperSASS. SuperSASS will be used to identify specific features or details of the SuperSASS.

The SASS (Speciation Air Sampler System) chemical sampler was developed under contract from the United States Environmental Protection Agency – US-EPA by Met One Instruments. The SASS collects samples for the chemical and gravimetric analysis of ambient air $PM_{2.5}$ particles. $PM_{2.5}$ refers to those airborne particles with diameters smaller than 2.5 µm. These particles are comprised of sulfates, nitrates, organic carbon, soot-like carbon and metals. With the recently enacted fine particle standard for $PM_{2.5}$, the US-EPA has mandated a new sampling network for determining the concentration of each of these species. The SASS has been specifically designed to meet these needs.

The measurement techniques for the different chemical constituents, including semi-volatile components such as nitrates, have been developed through special sampling programs[1-3]. These studies have shown that different sampling techniques are required for analyzing the different chemical constituents of $PM_{2.5}$. Met One Instruments has worked closely with the US-EPA and with potential end users to develop the SASS and the SuperSASS in order to comply with government regulations but to also incorporate features which the end user is likely to find desirable. These features include portability, and a design, which allows collection of samples without the user having to handle either the sample filter or the denuder.

1.2 Specifications

The basic SASS accommodates up to five (5) sampling canisters while the SuperSASS accommodates eight (8) sampling canisters used in groups of up to four. The SASS has active flow control on canisters 1 thru 3 with canisters 4 and 5 using a critical orifice for flow setting. The SuperSASS can operate in groups, each with active flow control. In both systems, each individual canister has its own $PM_{2.5}$ sharp cutoff cyclone inlet; denuder ring and tandem 47 FRM filter holders. As such, each canister contains all necessary components for excluding particles above 2.5 µm, for removing interfering gases, and for collecting ambient fine particles.

The canisters are mounted in a wind aspirated radiation shield that maintains sampler temperature close to ambient. Inlets are approximately 72 inches above the ground. There are no transport lines or plenums ahead of the canisters. The sample flow rate is controlled at a

flow rate of 6.7 L/min per canister depending on filter media and denuder material pressures. The critical orifice channels are set for 6.9 L/min of the SASS.

The $PM_{2.5}$ separation is produced by a sharp cut cyclone (SCC)[4] that removes both solid and liquid coarse particles with equal efficiency without the use of impaction grease or oil. Particle penetration through the SCC mimics the $PM_{2.5}$ cutoff curve of the WINS impactor as defined by the Environmental Protection Agency[5]. The denuders are of a multi-cell configuration. They are 25 mm in length, and are housed in a 47-mm O.D. aluminum sleeve. The nitric acid denuder is made of aluminum with 350 parallel, hexagonal channels, and is coated with Magnesium oxide, Empty sleeves are provided for use in canisters and flow channels operated without a denuder.

The filter size (media) used in the sample canister is 47 mm O.D. Each canister can hold either one or two 47-mm filters in tandem. The collection media used for each cassette can be varied as needed for the types of analyses to be performed. The filter holders are FRM design specified and interchangeable with all commercially available FRM samplers.

The solar and heat radiation shield is of the design used for the maintenance of the samples at near ambient temperature. Both the sample filter and ambient temperatures are logged throughout the sampling period. The filter temperature is measured immediately downstream of the filter media in each canister of the SuperSASS and at canister #1 of SASS.

The SASS makes use of three active volumetric flow controllers to provide precise flow control. The SuperSASS is standard with four active volumetric flow controllers. Additionally, each sampling line has a check valve to shut off the flow if the sampling line is not used, or for performing a dynamic field leak check. Volumetric flow rate measurement is made independently for each of the active flow channels, displayed instantaneously and logged with five-minute averages. Flow rate errors are flagged both on the display and in the data logger. Volumetric flows are measured and recorded with four independent electronic mass flow sensors. The mass flow sensors in conjunction with ambient temperature, and the barometric pressure readings, are used by the control unit microprocessor to calculate the actual volumetric flow. This provides site-specific flow measurements so no correction is needed in the field or for data reporting at true volumetric readings.

All routine maintenance can be done in the field. Sample canisters are transported to the laboratory for inspection, cleaning and changing of sampling substrates. Every element of the sampler that is contacted by the sampled air stream ahead of the filter, including the inlet can be cleaned with each sample change. This approach eliminates the typical inlet line and plenum related contamination problems. Samplers employing sample lines and plenums upstream of the filter are prone to contamination and unreliable results.

1.3 Technical Description

The SASS sampler is shown in Figure 1.1. Ambient air enters each of the selected active canisters mounted within the solar radiation shield. Particles larger than 2.5 µm aerodynamic diameter are removed by the cyclonic inlet mounted with each canister. Remaining $PM_{2.5}$ particles are collected on the filter media installed within each canister. Canisters may be equipped with a diffusion denuder ahead of the filter to remove selected gaseous compounds.

The SASS was designed with individual sharp cut cyclone inlets. This approach minimizes the chance for contamination and significantly reduces the required field maintenance of the unit.

Table 1.1. Specifications for the SuperSASS Ambient Chemical Speciation Aerosol Sampler

Analytes:	$PM_{2.5}$ mass and trace metals $PM_{2.5}$ organic and elemental carbon $PM_{2.5}$ sulfate, nitrate and other ions $PM_{2.5}$ elements
Number of Canisters:	SASS = Five (5), SuperSASS = Eight (8) maximum
Sample Flow Rate:	6.7 Liters/minute ± 2% per canister (active flow controlled channels) 6.9 Liters/minute per canister (critical orifice channels)
Inlet:	Sharp cut cyclone (SCC), (D_{50} 2.5µm AED) Detachable from Canister
Denuders:	Multicell, magnesium oxide, sodium carbonate, citric
Filter size:	47 mm OD typical FRM filter
Filters per canister	One or two in series
Plenum:	None
Transport Lines	None
Logged Parameters	Ambient temperature, °C (-30 to 50) Filter temperature, °C (-30 to 50) Sample start date and time, Sample stop date and time Status of Sampler, Flags Volumetric flow rates (L/m), and Volume (m^3/hr)
Logging Interval	5 minute averaging
Support Stand	Tripod with mounting feet and mast.
Solar radiation	Shield, 20” Diameter. x 12”H, Wind Aspirated
Control Box	NEMA Environmental Enclosure 14”L x 14”W x 19.5”H including mounting base.
Pump	Two head diaphragm vacuum, 110/60AC
Power	110AC/60 Hz input to pump system and fan 12 VDC
Ambient Temp	(-30 to 50°C) Bead thermocouple in naturally aspirated radiation shield
Filter Temp	(-30 to 50°C) Bead thermocouple at inlet of each canister

Figure 1.1. SASS showing aspirated Solar radiation shield, Canister Inlets, Tripod, Control Box, and Vacuum Pump Box.

The SASS flow system is shown in Figure 1.2 with the SuperSASS flow system shown in Figure 1.3. Individual flow lines lead from each sampling canister through the support pole to the pump box mounted on the ground. The flow from each of the first 3 or 4 canisters enters a volumetric flow controller.

Note: *In the standard SASS, canister #4 and #5 flows are set by a precision critical orifice.*

The check valve fitting on the side of the pump box for each canister can be used to close sample lines not in use. In the SuperSASS, a set of 8 solenoid valves are used to select which of the canisters are used during each test sequence. Vacuum lines for each orifice or flow controller, leads to an electronic mass flow monitor. The lines are then connected to a common manifold. A vacuum line from the manifold leads to the pump, which is housed in a fan-ventilated box.

The electronic mass flow sensor measures the sample flow rate and the processor uses the ambient temperature and barometric pressure reading to calculate and control actual volumetric flow at site conditions. These volumetric flow rates are shown instantaneously on the LCD display and logged on a five-minute average in the processor data logger.

Sample flow rates can be validated manually at the canister cyclone inlet before and after each sample event using an external NIST traceable device. Note: A low-pressure bubble meter, frictionless piston or venturi is recommended.

The physical configuration of the SASS is the similar to that of the Two-Week Sampler[6-8]. That sampler also uses a $PM_{2.5}$ inlet (although of a different type than SASS) mounted directly in the sample canister are housed underneath a solar radiation shield with downward pointing flow inlets. It has operated continuously at twelve sites since 1994, with collocated sampling precision of 5% for most species[9].

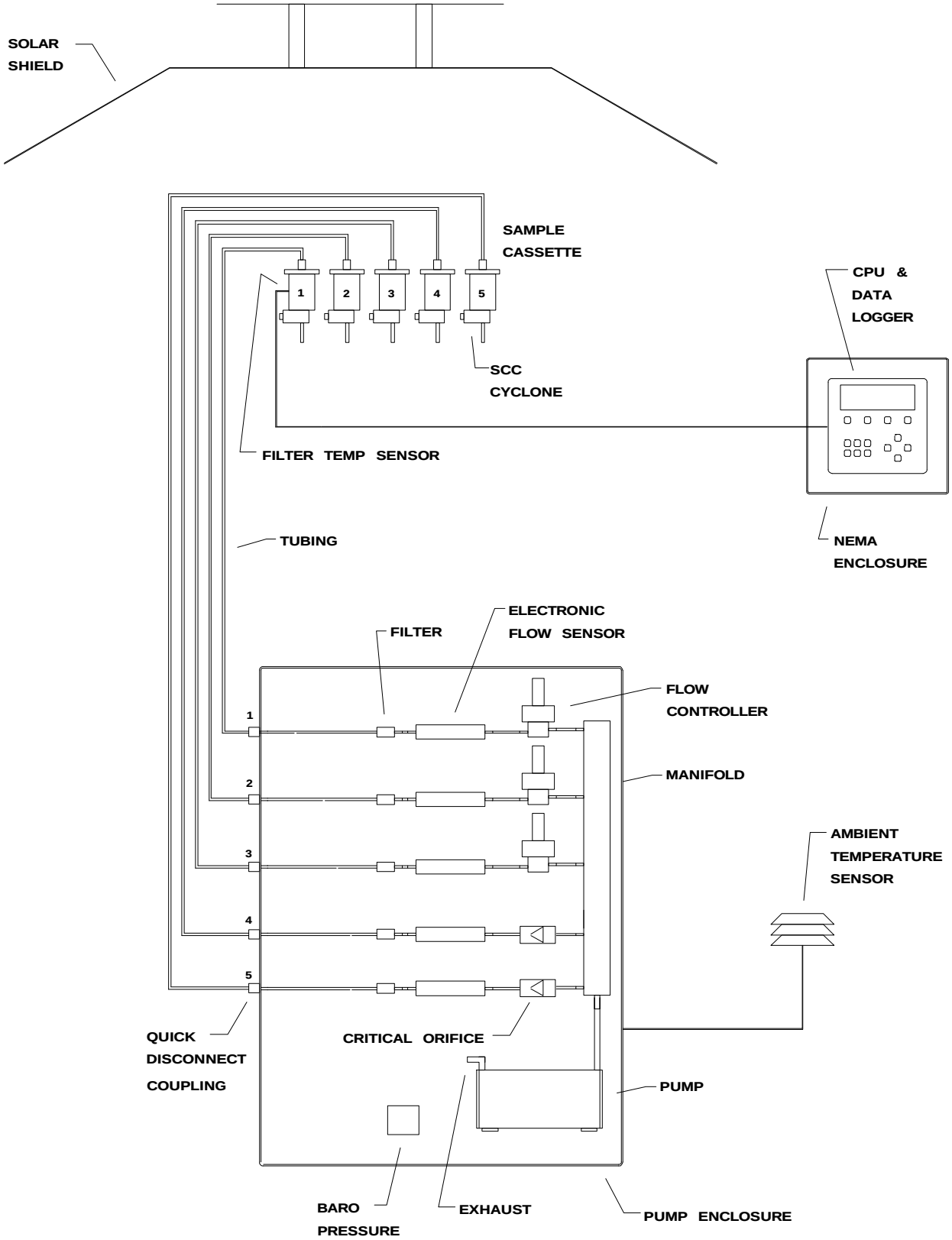


Figure 1.2. Flow Diagram for the SASS, showing solar radiation shield, sample canisters, ambient temperature sensor, control box, and pump box.

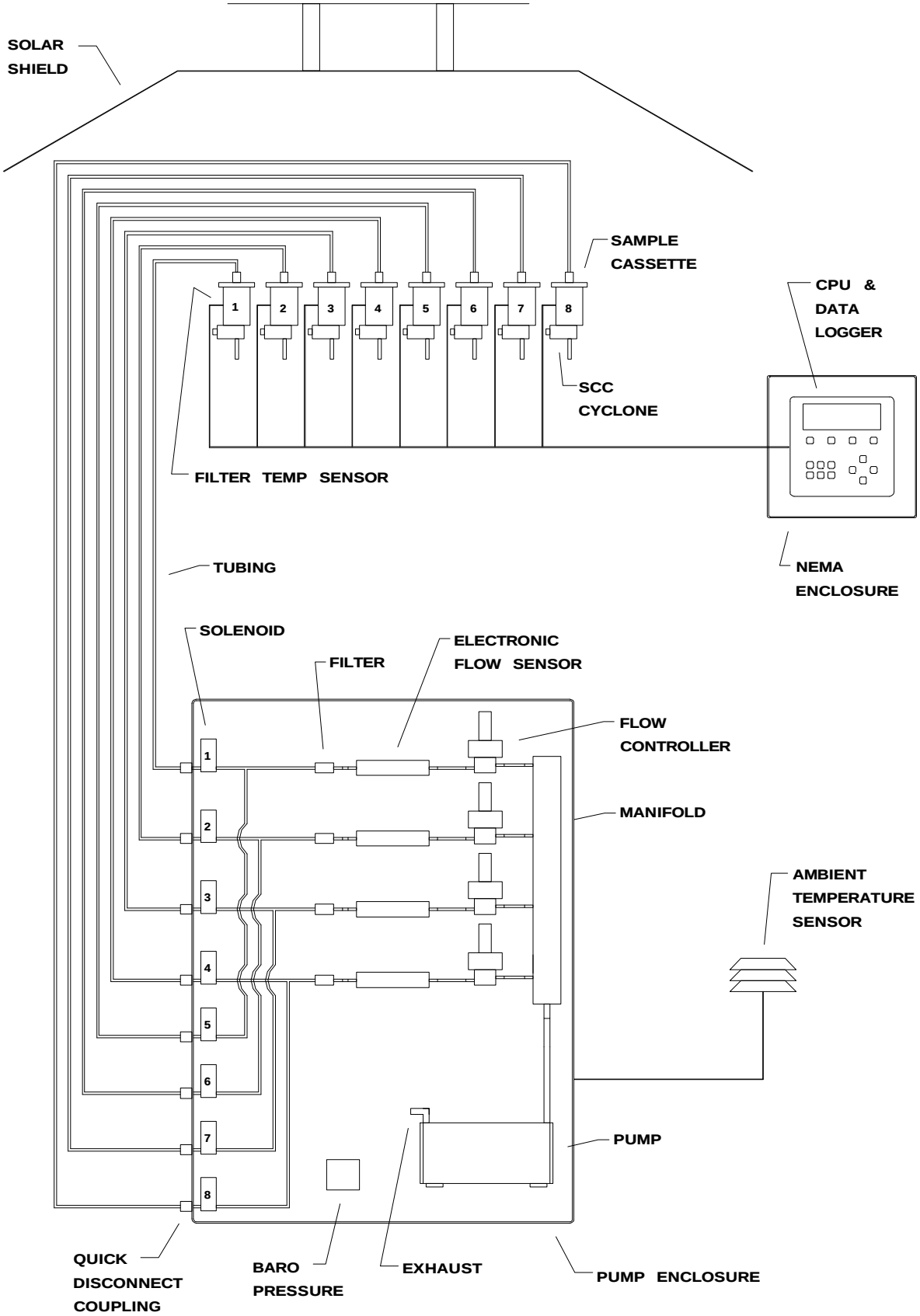


Figure 1.3. Flow Diagram for the SuperSASS, showing solar radiation shield, sample canisters, ambient temperature sensor, control box, and pump box.

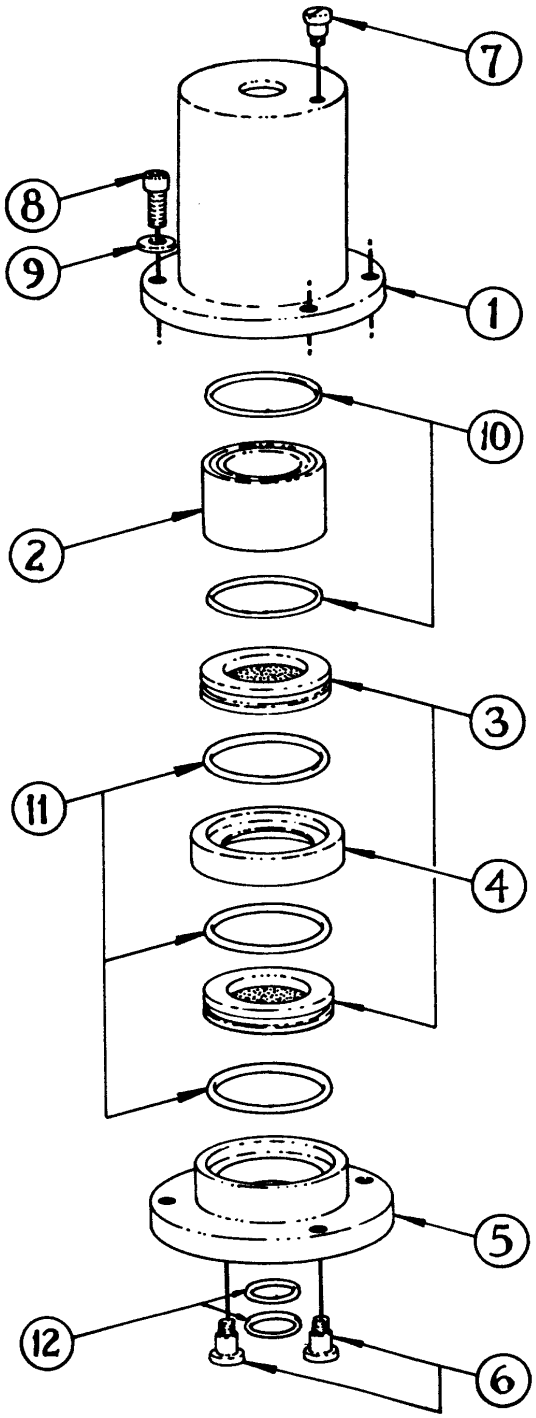
1.3.1 The Integrated SASS Canister

The integrated sampler canister is shown in Figure 1.4. It contains the following components:

- Sharp cut cyclone at 6.7 L/M to remove particles larger than 2.5 µm aerodynamic diameter.
- Denuder to remove nitric acid or other interfering gases, or an empty denuder ring.
- 47mm Front filter for particle capture.
- 47mm Tandem or Backup filter, as needed.
- Cover to hold and protect the components

An empty denuder sleeve is used when no denuder is needed. If only one filter is used, it is placed in the front filter position, with the second filter holder being empty. Assembly details can be see in Figure 1.5.

Figure 1.4 Photograph of the disassembled SASS Canister, showing the SCC Inlet, the MgO denuder, the front and back filters and the protective canister.



1- Cover #8379
2- Denuder Sleeve #8380
3- Filter Cassette, FRM #460128 (2 each)
4- Filter Spacer #8652
5- Outlet Plate #8378
6- Shoulder Screw #860024 (2 each)
7- Shoulder Screw #860029
8- Socket Head Cap Screw, 1/4"-20 X 5/8" lg. (3 each)
9- Flat Washer, 1/4" (3 each)
10- Viton O-Ring, #2-030 (2 each)
11- Viton O-Ring, #2-135 (3 each)
12- Viton O-Ring, #2-115 (2 each)

Figure 1.5 Speciation Sample Canister (PN 8370) Exploded View

1.3.2 The Sharp cut cyclone (SCC)l Inlet: Description and Performance

The SASS inlet selectively transmits airborne particles according to the EPA's $PM_{2.5}$ criteria[5]. After exiting the inlet tube (Figure 1.6), the aerosol moves cyclonically within the body of the cyclone where the larger particles are transported due to their inertia against the outer wall. It is the unique design of this computer-modeled cyclone[10], which produces the desired sampling efficiency[4]. The curvatures of the cyclone body causes particles to inertialy move towards the outside wall and migrate into the collection or grip cup to be disposed. Because the drift velocity is small compared to the velocity along the channel, deposition of particles is relatively gentle and at a tangential angle, which accounts for the observed lack of particle bounce, even without greased surfaces. The grit cup should be cleaned periodically.

Figure 1.6. View of the Sharp cut cyclone Inlet that provides the $PM_{2.5}$ cut-point. Canister is shown Inverted in Canister Assembly Block

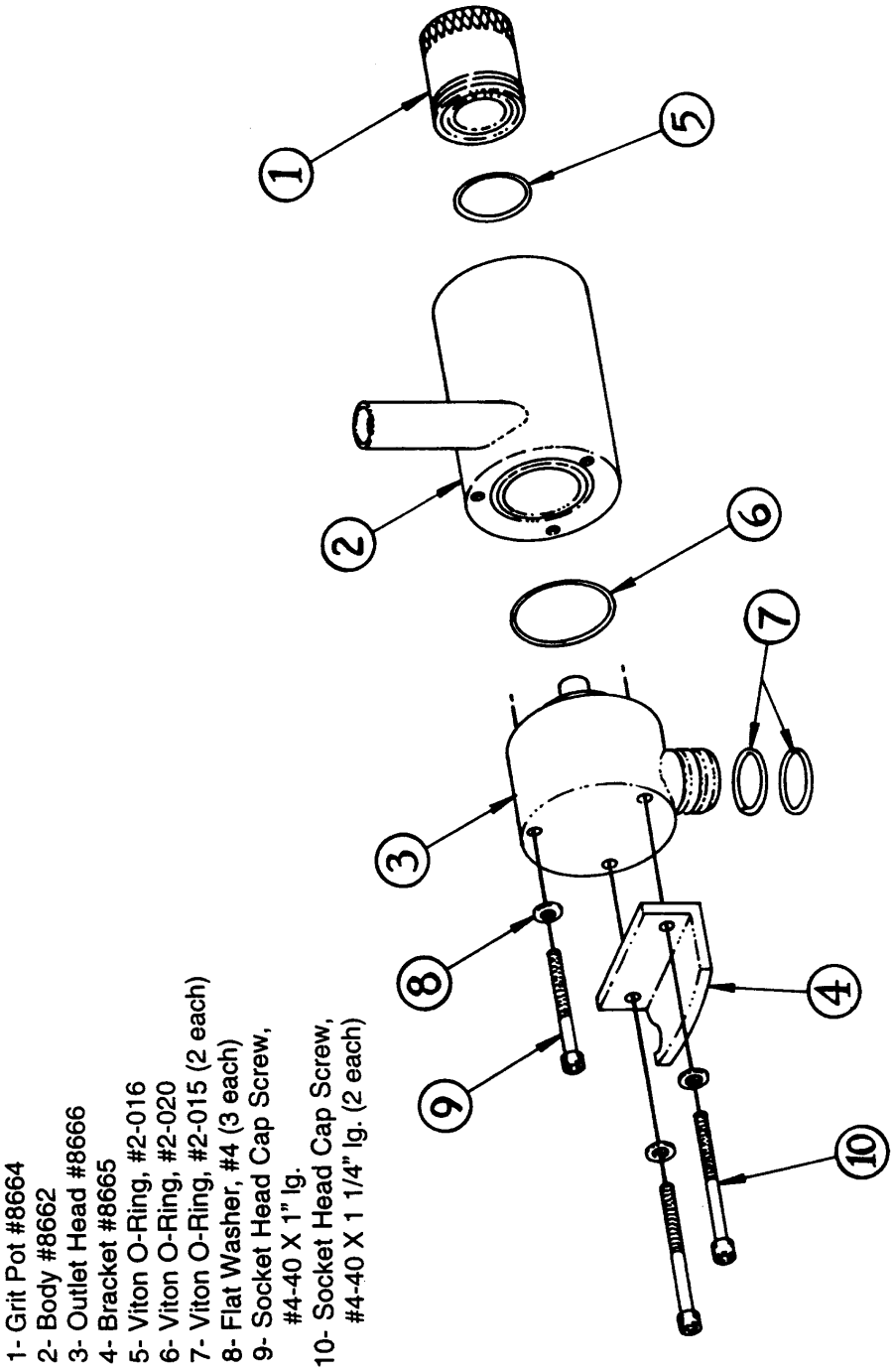


Figure 1.7 SCC Cyclone (PN 8670) Exploded View

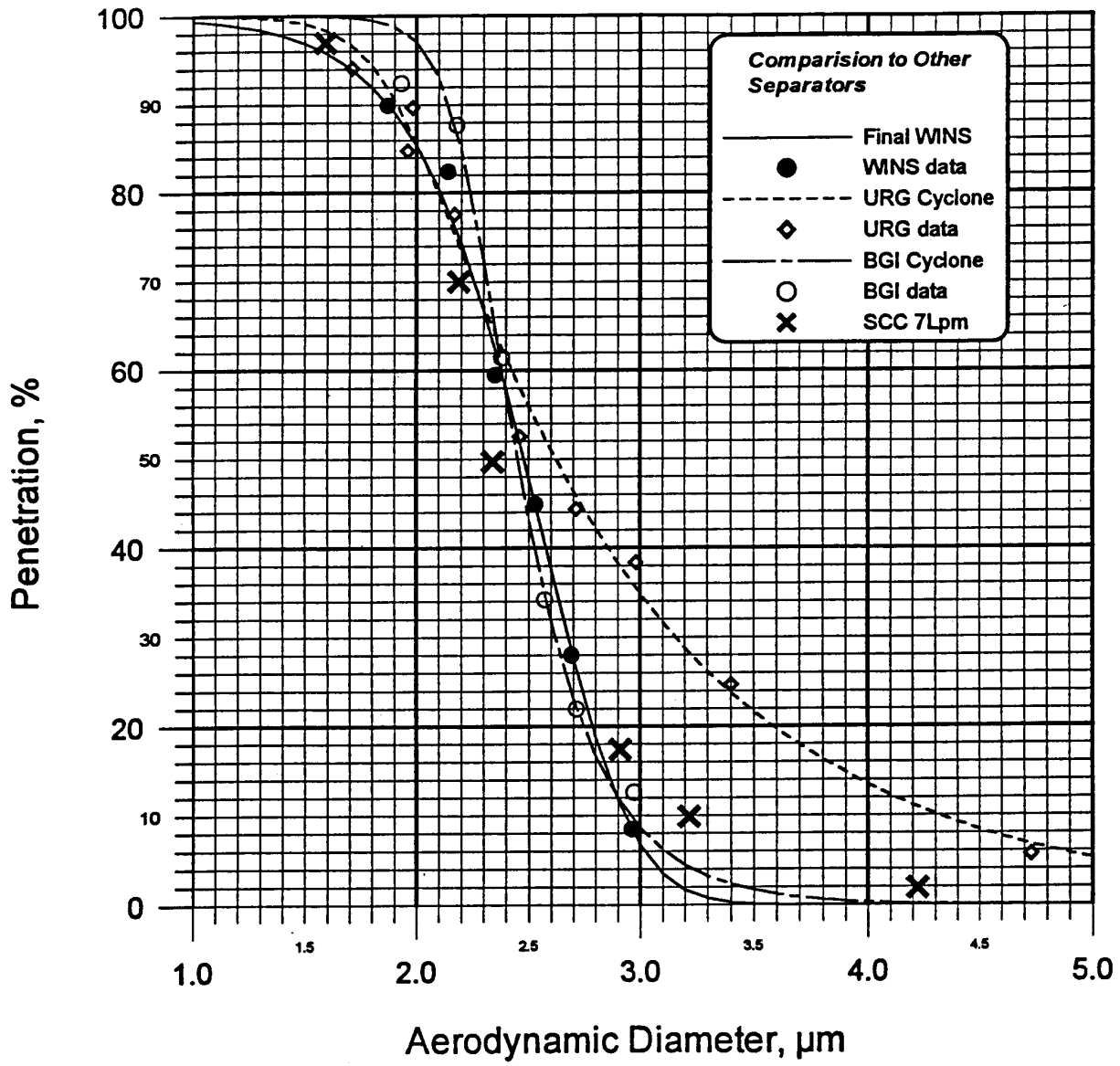


Figure 1.8. Penetration curve of the Sharp cut cyclone (Diameter 2.141mm) compared to the U.S. EPA WINS Impactor curve for $PM_{2.5}$.

1.3.3 The Multicell Denuder

Denuders consist of tubes or annular spaces that capture reactive gases while allowing the particles to penetrate. Gases have a large diffusion coefficient, and their random motion brings them into contact with the walls of the denuder. With appropriate coatings or selection of the denuder material, semi-volatile vapors are captured by the denuder walls. In contrast, the particles follow the airflow stream lines, and pass through the denuder without contacting the walls. The particles penetrate the denuder and are captured by a filter placed downstream of the denuder. The filter medium is selected so that it adsorbs vapor from any subsequent volatilization of the collected particles.

The SASS nitric acid denuder is an aluminum hexagonal cell material, coated with Magnesium oxide. There are approximately 350 hexagonal channels, each approximately 1.6-mm diameter. The denuder is 25 long. Calculations based on the Gormely-Kennedy relations show 100% collection for depositing vapors, with 99% to 100% penetration of particles greater than 0.08 µm in diameter.

Particle penetration through the denuder was measured in the laboratory using the aerodynamic particle sizer described above. These tests were conducted for both liquid and solid particles in the size range from 0.5 µm to 1.5 µm. First, tests with filtered air confirmed that there is no shedding of MgO particles from the denuder. Second, tests confirm 100% penetration of both liquid and solid particles in the size range tested.

The nitric acid collection efficiency of the SASS denuder was measured in the laboratory using a permeation tube source diluted with purified (ammonia free) laboratory air, and a catalyst equipped chemiluminescent nitrogen oxides analyzer detector. The measured nitric acid efficiency at the design flow rate of 6 L/min is 95%. Denuder performance results are summarized in Table 1.2.

Table 1.2. Results of SASS Denuder Performance Tests

Denuder	Parameter Tested	Test	Result
Multicell Aluminum. coated with MgO Length: 25 mm # of channels:~350	Liquid particle penetration	Penetration of oleic acid particles with diameters in the range from 0.5 µm to 1.5 µm	100% penetration for all particle sizes tested
"	Solid particle penetration	Penetration of solid particles with diameters in the range from 0.5 µm to 1.5 µm	100% penetration for all particle sizes tested
"	Collection efficiency for nitric acid	Measured the penetration of nitric acid through the denuder at concentrations of 50 ppb and 100 ppb	95-99% collection efficiency

1.3.4 Filter Media and Detection Limits

Several types of filter media are needed for assaying the different chemical constituents of ambient particles. The filter media must be suitable for the type of analysis to be done. For example, Teflon™ filters are used for gravimetric mass and trace metal determinations. Quartz filters are used for analysis of total organic carbon because, unlike other filter media, they contain very small amounts of carbon.

Detection limits for 24-hr samples collected on 47 mm filters at the standard SASS flow rate of 6 L/min are listed in Table 1.3. Values are based on analytical detection limits and filter blank variability, as reported by Chow and Watson[11].

Some analyses, such as ion chromatography involve extraction of the filter media. However other analyses such as x-ray fluorescence directly analyze the filter without extraction. These analyses require a uniform filter deposit. Similarly, the analysis of organic and elemental carbon is most often done using a small section, or punch from the filter. Again, it is necessary that the filter deposit be uniform.

The SASS sampler is designed to give a uniform filter deposit. The SASS filter support screens are manufactured to the same specifications as those for the Federal Reference Method $PM_{2.5}$ sampler. The FRM screens are specifically designed to avoid the grid patterns that can arise on Teflon™ filters when using coarse support screens.

Table 1.3.
Analytical Detection Limits for Ambient Aerosols Collected with the SASS

Species	Analytical Method	Method Detection Limit[1]	SASS Detection Limit[2] ($\mu g/m^3$)
Mass	Gravimetry	15 µg/filter	1.7
Chloride	Ion chromatography	0.05 µg/mL	0.06
Nitrate	"	0.05 µg/mL	0.06
Sulfate	"	0.05 µg/mL	0.06
Ammonium ion	Auto. Colorimetry	0.05 µg/mL	0.06
Soluble potassium	Atomic Adsorption	0.07 µg/mL	0.08
Organic carbon	Thermal Optical Anal.	0.82 $\mu g/cm^2$	1.07
Elemental carbon	"	0.19 $\mu g/cm^2$	0.25
Al	X-ray fluorescence	0.0025 $\mu g/cm^2$	0.0033
Si	"	0.0014 $\mu g/cm^2$	0.0018
P	"	0.0014 $\mu g/cm^2$	0.0018
Cl	"	0.0012 $\mu g/cm^2$	0.0016
K	"	0.0026 $\mu g/cm^2$	0.0034
Ca	"	0.0015 $\mu g/cm^2$	0.0020
Ti	"	0.0011 $\mu g/cm^2$	0.0014
V	"	0.00073 $\mu g/cm^2$	0.00096
Cr	"	0.00048 $\mu g/cm^2$	0.00063
Mn	"	0.0004 $\mu g/cm^2$	0.00053
Fe	"	0.00038 $\mu g/cm^2$	0.00050
Co	"	0.00022 $\mu g/cm^2$	0.00029
Ni	"	0.00022 $\mu g/cm^2$	0.00029
Cu	"	0.00027 $\mu g/cm^2$	0.00035
Zn	"	0.00027 $\mu g/cm^2$	0.00035
Ga	"	0.00048 $\mu g/cm^2$	0.00063
As	"	0.00039 $\mu g/cm^2$	0.00051
Se	"	0.00031 $\mu g/cm^2$	0.00041
Br	"	0.00025 $\mu g/cm^2$	0.00033
Rb	"	0.00024 $\mu g/cm^2$	0.00032
Sr	"	0.00028 $\mu g/cm^2$	0.00037
Y	"	0.00033 $\mu g/cm^2$	0.00043
Zr	"	0.00042 $\mu g/cm^2$	0.00055
Mo	"	0.00067 $\mu g/cm^2$	0.00088
Ag	"	0.003 $\mu g/cm^2$	0.0039
Cd	"	0.003 $\mu g/cm^2$	0.0039
In	"	0.0034 $\mu g/cm^2$	0.0045
Sn	"	0.0044 $\mu g/cm^2$	0.0058
Sb	"	0.0045 $\mu g/cm^2$	0.0059
Ba	"	0.013 $\mu g/cm^2$	0.017
Hg	"	0.00065 $\mu g/cm^2$	0.00085
Pb	"	0.00076 $\mu g/cm^2$	0.00100

[1] from Chow and Watson (1998)

[2] Assumes 24 hour collection at 6L/min with deposit diameter of 38 mm (11.4 cm^2) or extraction of entire filter in a volume of 10 mL

1.4 Sampler Configuration Options

The SASS is designed to be flexible. Any canister can be configured with just one filter, with two filters, with a denuder and one filter or with a denuder and two filters. The type of denuder and the filter media can be tailored to meet the needs and desires of the sampling program. In this way, it can accommodate new denuder filter methods as they become established.

For sampling nonvolatile particle constituents, denuders are not y needed. Non-volatile components are readily collected by selection of a filter media appropriate to the analysis to be performed, and which does not adsorb gaseous species that could interfere with the measurement. For nonvolatile inorganic species, Teflon™ and quartz filters are usually used.

Semi-volatile constituents are collected using a denuded, adsorbing filter. This is because more volatile particle constituents can be lost during sampling due to evaporation from the filter substrate. Denuder – filter systems use a denuder that removes semi-volatile vapors followed by an adsorbing filter that retains both particle and vapor compounds.

Denuded filter methods have traditionally been used for measuring particle nitrates[12-19]. One method is to pass the air sample through a MgO coated denuder followed by a nylon filter[20]. The MgO coated denuder removes the gas phase nitric acid and other gaseous nitrogen species that can collect on the nylon filter. The particles pass through the denuder and are collected by the nylon filters. The nylon filter adsorbs nitric acid that is formed from the vaporization of the particle nitrate, and thus the nylon filter is able to retain the particle nitrate without vaporization losses. It is also possible to use tandem Teflon™ and nylon filters behind a nitric acid denuder to give inorganic ions and nitrate in the same cassette. However, if samples cannot be retrieved quickly after the end of the sampling period, a separate nylon filter downstream of the denuder may be preferred because of possible losses from the Teflon™ filter after the conclusion of sampling. (Note that the backup nylon filter will capture nitrate lost during sampling, but once sampling stops further volatilization will result in loss in nitrate to the sampler walls.)

For some constituents such as total organic carbon there is no accepted accurate sampling method. The organic compounds in the atmosphere include gaseous organic compounds that are readily adsorbed by the quartz fiber filters required for total carbon analysis[21, 22]. The particle phase also includes semi-volatile compounds that are lost by evaporation from the filter during sampling[23]. The magnitude of these two artifacts appears to be variable. Correction for positive artifacts has been done by sampling with two quartz filters in series, or by sampling with a quartz filter behind the Teflon™ filter. This backup filter is used to correct for the adsorption of gaseous organic compounds on the front quartz filters. However, some have argued that the volatilization of organic compounds during sampling is a larger source of error. Denuder-filter methods[23,] for organic carbon, analogous to that described above for nitrate, is a current area of research. The SASS can be used for organic sampling in any of the configurations described here.

The SASS is provided with one type of denuder, the MgO coated aluminum. The expected configuration for the SASS for most applications is shown in Figure 1.9. This has two Teflon™ filters, one for mass and metals analysis, and one for inorganic ion analysis. The third leg is a MgO-denuded nylon filter is provided for fine particle nitrate measurement and the fourth leg is double quartz for organic and elemental carbon analysis.

Alternative configurations are shown in Figure 1.9. This shows a Teflon™ filter for mass and metals, a denuded Teflon™ nylon filter pair for ions and volatile nitrate, a double quartz filter for organic and elemental carbon, and a denuded double quartz filter for adsorption-corrected organic carbon.

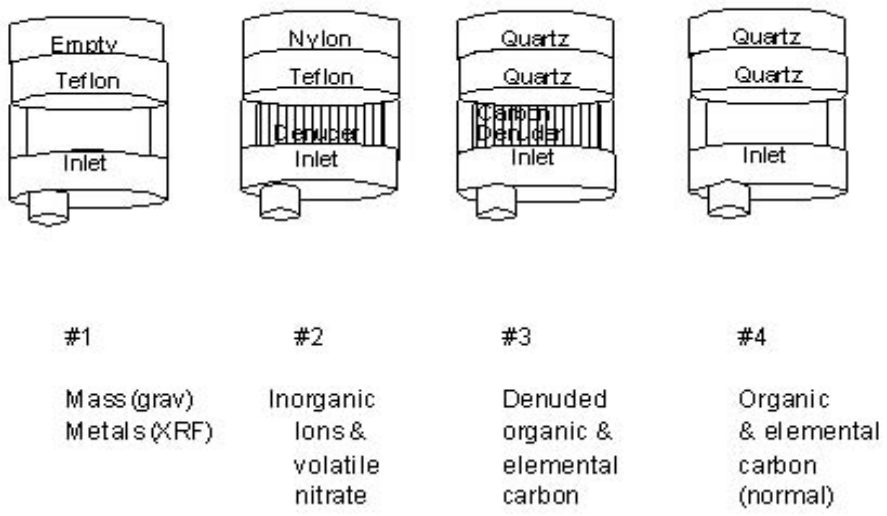


Figure 1.9. Alternate configuration for the SASS canister, using an activated carbon denuder for removal of positive adsorption artifacts for the measurement of particulate organic carbon.

For EPA test configuration, the canisters are configured with canister 1 containing a Teflon filter, with canister 2 containing the MgO denuder and a nylon filter, and the third canister supplied with a quartz filter.

1.5 Sampling Head

The requirement to minimize the temperature differential between ambient temperature and filter (sample) temperature in the sample canister is a prime consideration in the design of the SASS. The solar radiation shield is one of three unique designs with the SASS. The second is the Sharp cut cyclone Inlet (Section 1) and third is the design incorporated features from the field tested “Two Week Sampler” of Aerosol Dynamics used over the past four years in California for the Children’s Epidemology Study. Additionally, the SASS microprocessor firmware and SASS Comm AQ™ Software meets the requirements of the 40CFR Part50 Appendix L. The sampler operates with a clean exhaust diaphragm vacuum pump.

The SASS solar radiation shield has been designed to maintain the sample canisters and filter temperatures to the EPA FRM design requirement of < 5°C above the ambient temperature during and after a sampling event. This temperature control is designed to minimize the loss of semi-volatile materials from the aerosol sample. The SASS is designed to maintain the temperature differential between ambient and sample to within 3° C. The sampling head / solar radiation shield is physically separate from the sampling control and vacuum systems. The shield manufactured from aluminum for low mass. High reflectivity coatings are used on all surfaces. Isolation is included to minimize direct conductive paths upstream of the filters.

The Solar radiation shield is composed of an upper shield, lower shield and terrestrial shield. All three are uniquely designed from Met One's years of experience in measuring ambient temperatures using fan aspirated radiation shields. The large upper shields, flat top plate and second round plate provide primary solar radiation shielding. At the maximum solar input, between mid-morning and late afternoon, the lower shields are almost completely shaded by the primary shielding.

The requirement to minimize the temperature differential between ambient temperature and filter (sample) temperature in the canisters is a prime consideration in the design of the SASS. The solar radiation shield that is provided by the inlet head assembly is one of three unique designs with the SASS. This temperature control is designed to minimize the loss of semi-volatile materials from the aerosol sample.

The terrestrial radiation shield (the bottom flat part of the solar radiation shield assembly) cannot have air circulation across the outside surface as that could impact the ambient particulate sample going into the nozzle and sharp cut cyclone inlet. However, this flat shield prevents bounced radiated heat and light off the sampling deck or ground surface to heat the sampling canisters.

The sample canisters are housed inside the lower shields, mounted from above with a single point of thermal contact located after the filters. The design consists of two concentric shields separated by an air passage to allow the air to flow between the shields and this airflow "scrubs" the surfaces and effectively cools the cassette surfaces. The SASS has a thermistor temperature measurement at the first of the canister locations, as all canisters are used in a common test. For maximum flexibility with the SuperSASS, a thermistor temperature measurement is provided in each of the canister connections immediately after the hardware connection.

To insure the solar radiation shield is operating correctly, ambient air temperature and filter temperature are measured continuously and the logger records data. The air temperature is measured using a passive multi-plate radiation shield and thermistor temperature sensor that is mounted on the sampling pole.

Met One, EPA contractor, and state and local agencies to determine the effects of solar conducted numerous ambient field tests and terrestrial radiation and the temperature difference between ambient and filter temperatures. One site was chosen in a typical North West SLAMS monitoring site in Grants Pass, Oregon. Five days of 24-hour measurements were collected in May of 1998. The maximum solar radiation measured during these tests was 1250 W/m^2, measured with a NIST traceable Eppley™ meter. All data points are averaged over five minutes, built on a second sample. The temperate difference indicated over the five-day test was a maximum of –0.7°C. Arid desert sites like Phoenix indicate the SASS can maintain filter temperatures over a 24 hour sample event to within <2°C above ambient.

2.0 UNPACKING, SITING AND INSTALLATION

2.1 Unpacking

The SASS is shipped in five (5) cardboard boxes. These contain the following:

Box 1: (CONTROL BOX) Size 20”L x 20”W x 12”H Wt = 20 Lbs

Contains: Control unit (PN 8863) & Mounting Hardware
Ambient Temperature Sensor (PN 064-1)
Temperature Shield (PN 5980) and mounting Hardware
Five (5) Sharp Cut Cyclones (PN 8670) w/ SASS
Four (4) Sharp Cut Cyclones (PN 8670) w/ SuperSASS
One (1) MgO Denuder (PN 8382)
RS-232 Cable (PN 3159)

Tools: Kit (PN 8629) Poly bagged together.
One (1) 1/4 x 20 Allen Wrench
One (1) Allen Wrench Kit
One (1) O-Ring Lubricant
Three (3) Hex Head Screws
One (1) Wrench
One (1) Cassette Laboratory Assembly Block
Two (2) Black Tie Wraps

Manuals:
One (1) SuperSASS Operators Manual
One (1) SASSComm Operators Manual and Software

Box 2: (TRIPOD) Size 8” x 8” x 52” Wt = 15 Lbs

Contains: One (1) Tripod (PN 8864)

Box 3: (PUMP BOX) Size 20”L x 20”W x 24” H Wt = 45 Lbs

Contains: One (1) Pump Box and Flow Management System
(PN 8862-1) SASS or (PN 8862-2) SuperSASS

Box 4: (TRANSPORT CASE) Size 18”L x 16”W x 12” H Wt = 18 Lbs

Contains: One (1) Canister Transport Case (PN 8460)
Five (5) Sample Canisters (PN 8370) w/ SASS
Four (4) Sample Canisters (PN 8370) w/ SuperSASS
With Cap plugs™ for Inlet and Outlet of Cassettes

Box 5: (SAMPLING HEAD) Size 25”L x 25”W x 20”H Wt = 15 Lbs

Contains: One (1) Sampling Head and Canister Mounting
Platform (PN 8861-1) SASS or (PN 8861-2) SuperSASS

2.2 Siting

40 CFR Part 58 Regulations and promulgated $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) were revised in 1997. A Chemical Speciation network of fifty (50) $PM_{2.5}$ sites was required to be operational by end of year 1998. The U.S. Environmental Protection Agency anticipates that approximately 300 sites will make a complete national Chemical Speciation network by year 2003.

Note: Use of co-located instruments with carbon vanes, i.e., Hi-Vol, Anderson RAAS, etc can be a source of contamination and steps should be taken to isolate these instruments.

At the time of writing this operating manual two government documents are in draft form, which give specific details to guidance regarding siting, operation and analysis.

DRAFT "Particulate Matter $PM_{2.5}$ Speciation Guidance Document" May 4, 1998 Monitoring and Quality Assurance Group, Emissions, Monitoring, and Analysis Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711

DRAFT "Guideline on Speciated Particulate Monitoring" February 9, 1998 Prepared for Neil Frank & Jim Homolya, Office of Air Quality Planning & Standards (MD-44). U.S. Environmental Protection Agency, Research Triangle Park, NC 27711 Prepared By Judith C. Chow & John G.Watson, Desert Research Institute, P.O. Box 60220, Reno, NV 99506

The USA EPA Web site for more current information can be found at http://www.epa.gov/ttn/amtic

2.3 Tripod

The SASS tripod comes as an assembled item. Upon removal from the shipping container, the operator simply removes the 3 ringed pins from the tripod leg bracket and folds down the three (3) legs of the tripod. The 3 pins are then re-inserted to hold the three legs in position.

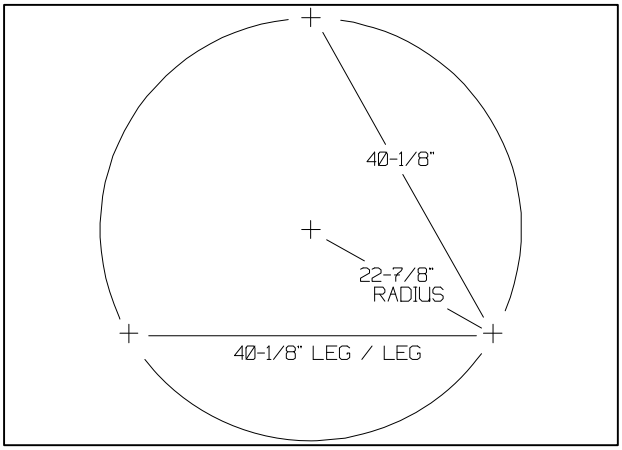


Figure 2.1 Mounting Hole Pattern

CAUTION: Note the tripod and sampling system operate at approximately 72 inches above ground or sampling deck level. It is very important to anchor the tripod with use of commercial hardware to the sampling deck to prevent damage in strong winds or weather.

(Note: Installation Instructions Are Additionally Supplied on Outside of Each Tripod Shipping Carton)

Holes are provided in the tripod feet and commercial hardware can be used to anchor the tripod to the sampling site. Typically, AMS and SLAMS operating sites are made of wood. Use of ¼ Lag Screw mounting is advised, to attach the tripod feet to the sampling platform. If the sampling site is on the ground, it is recommended to use spikes driven through the tripod mounting feet. If cement or other hard material makes up the sampling site surface, commercial hardware must be selected to properly secure the tripod.

2.4 Sampling Head Installation

Note: It is advisable for installation of sampling head to use a short three-step ladder and/or the help of a second person makes assembly easier. The bottom shield must be set in place before any of the socket head cap screws are set in place.

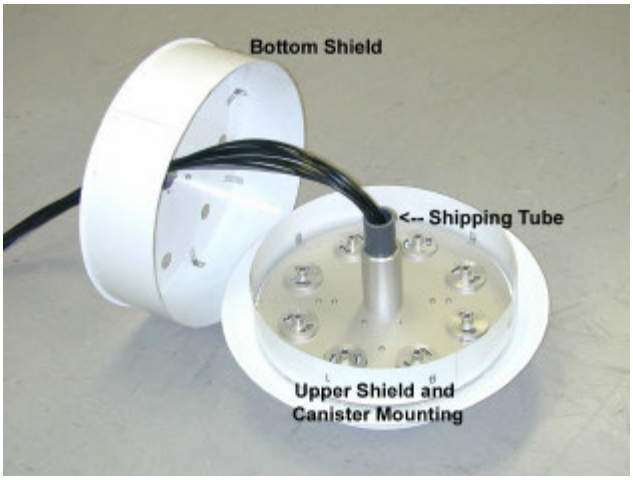


Figure 2.2 Sample Head (Upside Down)

Locate bottom shield. It is in the top portion of the sampling head that is found in the box containing the complete head assembly. (See Figure 2.2) It can easily be identified by the 8 holes in the flat portion. Lift it up off the rest of the sampling head, letting the hose and cable slide through the hub at the center of the shield. It is of mostly sheet metal construction with a hub and tethered pin. Pull the pin from the hub, letting it hang by its chain. Slide the shield down onto top of mast and allow it to rest on the leg weldment. There is a gray PVC shipping tube that will need to be removed from the center of the sampling head assembly. It is used only for aligning the two sections during shipment and is no longer required as part of the installation of the sample head.

Next, install the socket head screws as shown in figure 2.3. Locate the tool kit and plastic bag containing three (3) each 8-32 x 3/16" long socket head cap screws. (An extra screw is provided.)

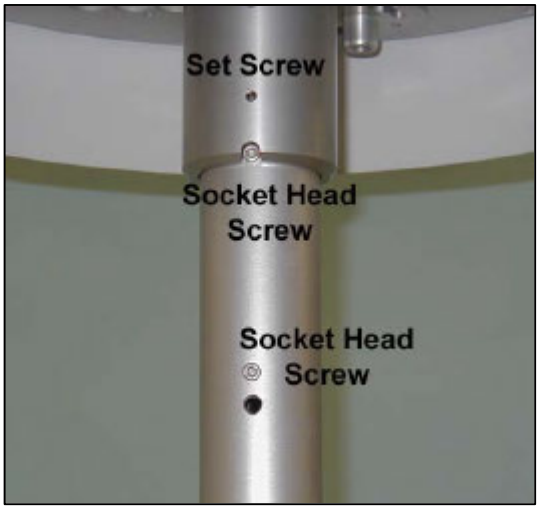


Figure 2.3 Screw Locations

Figure 2.4 Assembled Sample Head

Screws have been treated with thread-locking compound. Use the Allen wrench and install them into the two tapped holes in the top area of the mast. These screws provide upper and lower shield orientation.

Stretch out and unwind the cable with connector and tubing bundle coming from the hub of the upper sampling head. While supporting the sampling head, feed the bundle into the top of the mast and mount the hub onto the mast. Engage the notch in the hub with the topmost screw head to properly align unit. Tighten two (2) setscrews (factory installed in sampling head hub) to secure sampling head to mast.

Note: A bundle of sample flow lines and one (1) electrical cable should be coming out bottom of tripod tube.

Raise bottom shield to stop position, aligning he slot with screw head in mast and pin in place, while installing the next portion of the SASS Unit.

2.5 Control unit & Mounting

The SASS control unit is an all-weather & environmental NEMA rated cabinet. The control unit houses the microprocessor, LCD display, and keypad. The SASS control unit is designed for angle mounting on the tripod so that it can be easily read and operated.

Figure 2.6 Mounting Detail

Figure 2.5 Control Unit Mounting

There is no AC power in the control unit. The AC 110VAC 60 Hz enters the vacuum pump box and a DC power supply is used to operate the control unit. The control unit is provided with two metal mounting brackets and two sets of U-Bolt hardware clamps. It is the first item to be mounted to the mast. Use the supplied wrench or a 7/16” Nut Driver

A set of mounting brackets holds the control unit to the mast just above the top of the tripod legs. Use the two U-Bolts supplied in the hardware package and secures the control unit to the mast. Proper orientation of the control box is with the hinged side of the box facing the left (from the front) and all cable connections are facing the ground or platform in the middle of two legs of the tripod. Once the unit is positioned tighten the U-Bolt hardware clamps using the supplied wrench or by using a 7/16” nut driver.

See Figures 2.5 and 2.6 for mounting details.

2.6 Ambient Temperature Sensor Installation

The SASS includes a passive ambient temperature sensor using a thermistor protected by several round plates. The shield is naturally aspirated by the wind to provide an accurate temperature measurement. This is identical to EPA $PM_{2.5}$ FRM sampler. The ambient temperature sensor includes the Model 5980 temperature shield, Model 064-1 temperature Sensor, tripod mounting hardware and the connecting cable with connectors.

After the control unit is secured to the tripod, the next item is to mount the ambient temperature sensor and shield assembly. Attach the shield and temperature sensor assembly using one (1) U-Bolt and the two 7/16”nuts with washers. The temperature shield is mounted above the lower mounting bracket of the control unit. Place the ambient temperature sensor on the mast with the flat top plate facing up and the cable connector facing the ground. Lower the sensor until the mounting bracket hits the top of the bottom bracket of the control unit. Position the ambient temperature sensor so the shields face the back of tripod. When positioned secure the sensor by tightening the two 7/16” hardware nuts and Washers using the supplied wrench or a nut driver. Typically, it would be about 3 inch above the lower control unit U-bolt. The top of the shield should be about the same level as the top of the control unit box. This will allow the lower shield of the sampling head to be lowered without hitting the top of the temperature shield. See Figures 2.5 and 2.6 for details.

Attach the cable and connector to the ambient temperature sensor from the pump control box. It is impossible to misconnect the cable since the connections are keyed.

2.7 Canister Installation

It will be necessary to install the 2.5-micron sharp cut cyclone (SCC) to the bottom of each filter canisters. A very light coating of silicone grease can be applied to the two O-rings on the cyclone. Use just enough to “wet” the O-rings. The short fitting with the two O-rings is inserted into the hole on the bottom of each canister. It is then rotated until the notched corner of the SCC mount is under the lock screw of the canister.

Figure 2.7 Inserting Canisters

Note: Do not loosen or remove the fixed shoulder bolts that are mounted in the canister. These are locked in place are necessary for proper installations of both the canister and the SCC inlet assembly.

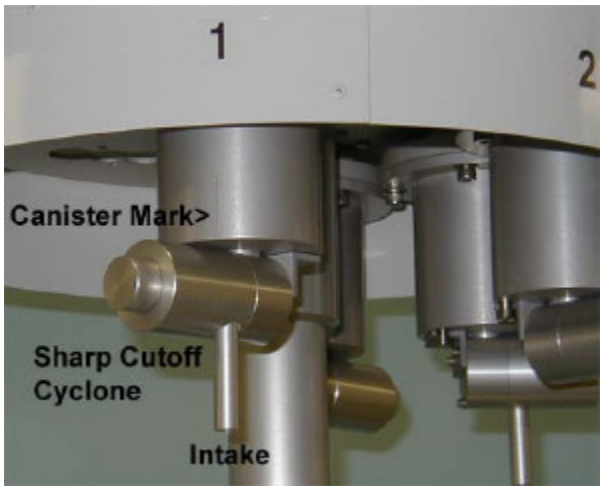


Figure 2.8 Canister Mark

Details on the canisters can be found in Section 1.0 of this manual. The Sampling Head Assembly has mountings for up to eight filter sampling canisters. Around the outside of

the upper shield are labels indicating the location of the sampling canisters. (Note: In some instances during operation, only three or six of the canisters will be installed) Each canister has a pair of mounting shoulder bolt posts and a vacuum connection with O-rings. The posts are slipped into the inlet assembly and the O-ring seal provides an airtight seal to the airflow system. The canister's alignment posts are inserted into the larger holes in the mounting fixture of the Inlet head. Apply a very light coating of silicone grease to the O-rings on the top of the canister. Use only enough to "wet" the O-rings; any additional or excess grease may contaminate other parts in the air path. Push up the canister, and then rotate clockwise (looking up) to the stop and it will lock into place.

Each canister has a mark that should be pointing out and away from the center of the support tripod. This can be seen in Figure 2.8. Once all the canisters are installed in the sampling head, the lower shield can then be up raised up and locked into place. When raising the lower shield, be sure that the slot in the shield must be aligned with the socket head screw. Once in the correct position, the locking pin on the chain can be inserted in place to hold the lower shield assembly in the operating position.

Note: When removing the canisters, keep them in their normal operating position and remove the Sharp cut cyclone. Do not invert the canister when removing the SCC, as any loose material in the cyclone might fall into the canister and contaminate the collection filter. Once removed, cap both ends of the canister with the supplied yellow stoppers. Removing the grit cup, and dumping it out, and then a quick blow of clean air through the cyclone to remove any collected dust can then clean the cyclone.

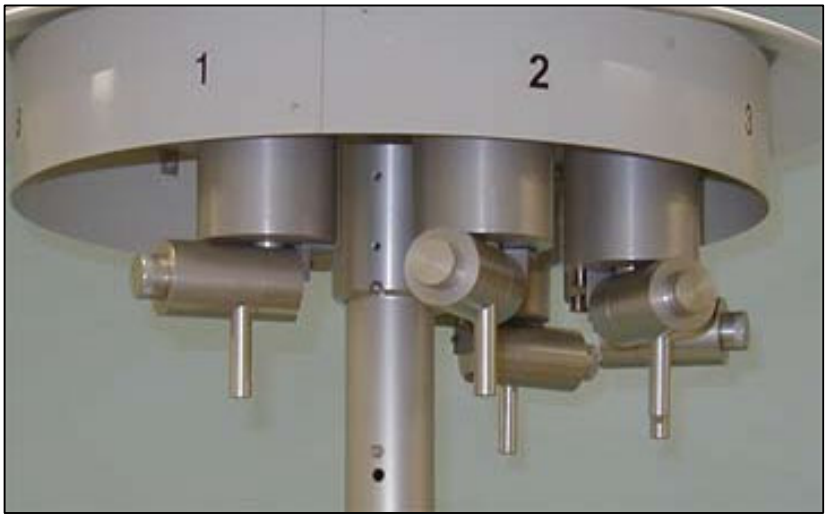


Figure 2.9 Installed Canisters

Note: As part of the EPA project to monitor PM2.5 particulate, canisters, denuders, and canister spare parts are sent to the EPA contractor in charge of filter analysis. They will be cycled around on a regular basis to collect filter data. If the SASS owner chooses, some canisters can be retained for their own use and analysis of collected samples. Typically, in the EPA project, only three canisters are used in each test, at one time in the SASS. All materials for collection of samples, chain of custody, and transport cooler will be provided by the EPA contractor.

2.8 Pump Box Mounting

The dual diaphragm AC vacuum pump is contained in its own environmental shelter isolated from the SASS to prevent vibration, noise, heat and any potential of exhaust contamination. The vacuum pump is a dual head Thomas Co.™ diaphragm vacuum pump mounted with four bolts through the bottom of the cabinet.

The vacuum pump box contains a filter screen under the pump and an aspiration fan on the side. Heat is exhausted from the box by pulling ambient air in the base and through the fan and exhausting on the right. The pump box is mounted on an aluminum framework stand with four ¼" anchoring holes provided in the base. The pump box will be located in a position that is close to the base of the tripod. The pump box is made to sit on the floor or deck of the sampling platform and the pre-drilled holes for securing to the platform. The base can be mounted using ¼" bolts or lag screws. The holes are located on a hole pattern that is set on 10" x 16" dimensions.

AC power supplied to a DC converter powers the entire SASS system. The vacuum pump box contains three cables. One is the 110VAC 60HZ power cable, which is connected to the AC grounded service. The second is a signal cable with a screw type connector that attaches to the ambient temperature sensor. The third cable from the bottom of the pump box connects to the center connector on the bottom of the control unit. Be sure that this cable connection is pushed securely into the mating connector on the control unit. Once inserted rotate the outer ring on the front of the connector to lock it in place on the control unit. A multi-pin connector on the side of the pump box connects to a multi-conductor cable that runs down from the sampling head assembly.

With the inlet head in place, it is then necessary to make the sample line connections. There will be either Five (5) or Eight (8) labeled sample lines, visible below the mast-mounting tube. Pull each individual sample tube out and attach #1 tube to #1 Quick-Disconnect valve connector on the side of the Pump Box. If only three canisters are used with SASS, lines 4 and 5 can be left disconnected and capped. Now, attach the filter canister temperature sensor cable if not already done.

Once all the cables have been connected, some tie wraps can be used to secure the various cables to the support tripod. Be sure that the tie wraps used are the black colored type. The natural or nylon type will degrade in the sunshine, and break after only a short time in the sun.

Figure 2.10 Tubing Installation (SuperSASS)

2.9 System Grounding

To provide electrical hazard protection, a heavy green/yellow ground cable, is attached to the bottom of the pump box. This ground cable provides an electrical hazard ground, and static discharge path. It also provides some protection to the equipment from induced electrical currents that may occur during nearby lightning strikes.

> ***NOTE: Because of the potential for injury and possible loss of life, the operator should not work around the SASS unit during lightning storms or whenever there is the possibility of nearby lightning strikes. In general, the location of the SASS and its association with other similar equipment, accentuates the potential hazard to the user.***

For maximum effectiveness the ground cable should be connected to a nearby earthed ground rod. If a ground rod is not available, a cold water pipe can be used as an alternative. If a water pipe must be used, be sure that a suitable type of compression grounding clamp is attached to the water pipe.

> ***NOTE: If a water pipe is used as a ground, be sure that it is a cold water pipe, and not a gas pipe, or hot water pipe. They do not provide a suitable ground, or have the potential for explosion.***

In addition, it is recommend that one leg of the mounting tripod also be grounded to the same earth ground used to ground the pump box. For maximum effectiveness, a copper cable of AWG # 6 or larger should be used to ground the tripod.

3.0 SETUP AND OPERATING PROCEDURES

3.1 Operational Checkout of System

The SASS system is powered by plugging the male AC power cord into a 115 VAC supply. There is no on/off switch. The pump fan in the pump box should be detected operating and the LCD display of the Control unit should illuminate. The screen of the control unit will start up in the Main Screen as displayed below in Figure 3.1. From this point pressing the push buttons located below the four main screen menu selections can access all other necessary screens.

Note: For a detailed list of all menu selections, see Section 4.0 of this manual.

```
        SASS Speciation Sampler
               V 4.02

       Met One Instruments, Inc
            www.metone.com
                                Transfer
Event     Setup    Calibrate    Data
```

Figure 3.1 Example of Main Screen

Note: Due to ambient temperature the LCD display may be weak or saturated. Adjust contrast using the ✱ key on the Control Box keypad. Continued pressure on the key will lighten or darken the LCD display.

As part of the preliminary setup and checkout of the SASS or SuperSASS, the following process can be used to verify the operation of the unit. Differences between the two units will be indicated. It will also cover the programming of the unit to begin the first test sequence and any additional sequences following the first test. To insure that the system has been correctly assembled, there are no leaks, and that there has been no damage to the SASS use the following procedure.

3.1.1 Temperature, Pressure and Flow Test

From the main screen menu, select the “Calibrate” function. This will take you to the next menu selection identified as the Calibrate Menu. From this menu select the “System Test” item by pressing the F1 key as indicated in the menu. Once the F1 key has been selected the following screen shown in Figure 3.2, with the following options will appear.

```
System Test            MM/DD/YY HH:MM:SS
Ambient P   724 mmHg   Ambient T  24.4 C
   Flow 1    .0 Lpm    Filter 1   24.5 C
   Flow 2    .0 Lpm
   Flow 3    .0 Lpm
   Flow 4    .0 Lpm
   Flow 5    .0 Lpm   Pump:   ON
                     Pump     Exit
```

Figure 3.2a System Test Screen (SASS)

```
System Test            MM/DD/YY HH:MM:SS
Ambient P   724 mmHg   Ambient T  24.4 C
   Flow 1    .0 Lpm    Filter 1   24.5 C
   Flow 2    .0 Lpm    Filter 2   24.3 C
   Flow 3    .0 Lpm    Filter 3   24.3 C
   Flow 4    .0 Lpm    Filter 4  -xx.x C
                      Pump:   ON
Cans                 Pump     Exit
```

Figure 3.2b System Test Screen (SuperSASS)

At this point the current ambient temperature, the current temperature of the filters in the sample head, and the current absolute barometric pressure in mm/Hg will be displayed. The SASS provides a single filter temperature while the SuperSASS includes filter temperatures for each group of four canisters. In addition, the SASS provides flow values for all five canisters with the SuperSASS having flow for a maximum of four canisters. The values for flow on all channels should be at 0.0 LPM. If the values displayed for temperature or barometric pressure are obviously incorrect, check to verify that all connections have been made and the connectors from the pump box are installed. If any problems are found, consult Section 6.0 of this manual for assistance in trouble shooting problems.

If all looks correct, then the button under the menu selection “pump” can be pressed. This will bring up the following caution screen. This is displayed to prevent stopping an event in progress to activate the pump.

```
................Caution................

  Press 'Continue' to STOP the sample
  event and control the pump.



  Cancel                       Continue
```

Figure 3.3 Test Caution Screen

Pressing the “Continue” will activate the pump and you should immediately hear the pump start inside the pump enclosure. The pump should not have been running prior to pressing the “pump” button on the keyboard of the control unit, unless a test event was already in progress. The only exception to this would be if the temperature inside the pump box were below 35 degrees F. Under these conditions, the pump is automatically turned on so that there is no possibility of the pump not starting correctly in cold weather. If the pump was running, pressing the “pump” button will cause the bypass valve in the pump box to de-activate and flow values should now appear on the screen of the control unit. The values for all canisters should be between 6.6 and 6.8 LPM of flow.

If the flow value is far outside this range, then check use the trouble shooting information contained in Section 6.0 of this manual.

3.1.2 Leak Check of System

Use the following procedure described in the revised section 6.2 for System Leak Check .

3.1.3 Calibration of System

When supplied from the factory, the system has been setup and calibrated using NIST traceable standards for measurement of flow, pressure and temperature. It should be ready for operation as supplied, and the operator using this procedure as described in Section 3.1 has verified operation. If a complete calibration is required, see Section 6.0 of this manual for procedures.

3.2 Programming of System

As delivered, either type of SASS will need to be set with the current date and time, as well as some default values for typical operation. This can be done, by selecting the “Setup” button from the Main Screen as shown in Figure 3.1. One selected, the Setup Menu Screen as shown below in Figure 3.4 will appear.

```
Setup Menu
F1: Event Manager
F2: Event Defaults
F3: Clock
F4: Unit ID
F5: Clear Event History
F6: Flow Sensors
                                Exit
```

Figure 3.4 Setup Menu

3.2.1 Setting Date and Time

Pressing the keyboard key “**F3**” will take you to the Clock Setup Screen (See Section 4.3.3) and time at the installed location of the SASS. From the screen menu use the left and right arrow keys to move to the values of MM/DD/YY or HH:mm:ss that need to be changed. Then use the up and down arrow keys at each digit, to change the current values to the current date and time. Once completed, press the “Set” key and the newly entered values will be entered as the new default values. At the point the “Set” key is entered, the new time will be entered. It’s best to set the time to a future time or at the top of the minute, and then enter “Set” when that time occurs.

3.2.2 Setting Default Elapsed Time for Tests

Pressing the keyboard key “**F2**” will take you to the default setup screen, this is used to set up the default value that is used for the total elapsed time for each run of the SASS during the operation and collection of sample material in the installed canisters. This also allows for the selection of a default set of canisters. See section 3.2.3 for a listing of the defined sets of canisters. Factory default set is {1,2, & 3}.

```
Sample Event Defaults
           Event Length: HH:mm
           Canister Set: {1,2,3}




   Save                            Exit
```

Figure 3.5 Default Values Menu

From the Sample Event Defaults Screen (See Section 4.3.2) use the left and right arrow keys to move to the values of HH or mm that need to be changed. Then use the up and down arrow keys to change the current values to the typical value used for all sample collection. Once completed, press the “Save” key and the newly entered values will be entered as the new default values.

3.2.3 Event Manager

SASS includes an Event Manager for the most flexible operation. It is used to program the start time and duration of all test sequences. Each test event or sequence must be pre-programmed into the Event Manager. The Event Manager will maintain a pre-event list, up to four (4) pre-events are allowed. When working with SASS, the events are entered, but the canisters cannot be sequenced, all of them 1 to 5 will be operating at the same time. Unused vacuum lines can be disconnected at the pump box. The SuperSASS allows for sequential programming of the groups of canisters that will be used for each sample event. Twenty-four (24) post events are archived in a circular manner where the oldest is overwritten by the newest addition.

```
Event Manager          MM/DD/YY HH:mm:ss
Start Date/Time    Length  Canisters
MM/DD/YY HH:mm:ss  HH:mm   {1,2,3}
MM/DD/YY HH:mm:ss  HH:mm   {5,6,7}



   Add      Modify    Delete     Exit
```

Figure 3.6 Event Manager

Only active pre-events are listed. They are ordered (top to bottom) by the earliest date and time. Up to four (4) pre-events can be listed. Use the up and down arrows to select an event for modification or deletion. If there are less than 4 pre-programmed events then the Add key will bring up the Add Event screen. Typically as delivered from the factory, there are no pre-programmed events programmed into the Event Manager. The Add key is also used to begin the first event sequence. See Figure 3.6

```
Add Event              MM/DD/YY  HH:mm:ss
                       MM/DD/YY  HH:mm
         Event Start:  MM/DD/YY  HH:mm
        Event Length:            HH:mm
        Canister Set:  {1,2,3}


   Add                 Default    Cancel
```

Figure 3.7 Add Event Screen

Edit the Event Start date and time, Event Length time, and the Canister Set. The canister set is a pick list of defined sets. Use the up down keys to select the specific canister set or use the Default key to select the default set and event length. Even though the canisters cannot be sequenced in the SASS unit, it is necessary to indicate to the control box which canisters are installed and used as part of the sample event. Doing this insures that the correct data is recorded for each flow sensor and canister set. All of the control box screens are dynamically updated; they only show the active canisters as part of the reported data. Typically as part of the EPA test plan, SASS canister set {1,2, & 3} will be used. This is also the default set.

- Defined set for SASS consists of {1}, {1,2}, {1,2,3}, {1,2,3,4} and {1,2,3,4,5}

- Defined sets for SUPER SASS are {1}, {2}, {3}, {4}, {1,2}, {3,4}, {5,6}, {7,8}, {1,2,3}, {5,6,7}, {1,2,3,4}, and {5,6,7,8}.

Press the Add button to add this event to the pre-event list. A successful add will return the user to the Event Manager screen. Edit keys are available to modify or delete the events.

Press the Modify button to view the Modify Event screen.
Press the Delete button to view the Delete Event screen.

3.2.4 Setting ID Value of SASS System

Pressing the keyboard key "**F4**" will take you to the ID Setup Screen (See Section 4.3.4). This screen allows the entry of an ID value for this particular site. Normally site number that was entered at the factory is the serial number of the control unit. If a different ID value is to be used then use the up and down arrow keys at each digit, to change the current values to the new ID value. Once completed, press the "Save" key and the newly entered values will be entered as the new ID.

3.2.5 Clear all Event History

Pressing the keyboard key "**F5**" will clear all event history. This would typically be used to clear all events, or to start up the SASS at a new location. It will bring up a warning screen before allowing the clearing of all event history. (See Section 4.3.5)

Note: This completes the initial setup of required preset values in the unit. The last menu entry for flow sensors is factory set and should not be changed unless there has been a replacement of the flow sensor from a 20 LPM to a 10 LPM Sensor.

3.3 Preparation for Test Sequence

Once the system setup values and the sequence have been entered, the first test sample sequence can begin. Each test sequence will require a new set of canisters properly configured with filters and identified. If the SASS is used as part of the EPA Trends Network Speciation Project, then the pre-loaded canisters will have been loaded with filters and supplied in a protective cooler. Each canister supplied as part of the data collection project, from the EPA will have a specific serial number identified by a bar code; along with a colored dot indicating which position, the canisters are to be installed. (See Table 3.1) Specific information on the setup and installation location of the canisters will be supplied from the third party contractor that is doing the actual filter evaluation and testing. The colored dots are typically supplied from the EPA or the third party contractor. The canisters are supplied less the Sharp Cut Cyclones and they will need to be installed on the canisters before they are installed in the sample head. Typically, only three canisters are used as part of the EPA Trends Network.

The next step is to install the canisters in the appropriate locations, install the lower shield, and setup of the control unit for the correct operating sequence.

Canister Number	Color Code
Canister #1	Green
Canister #2	Red
Canister #3	Orange
Canister #4	Blue

Table 3.1 Canister Color Codes

Note: At the time of printing of this manual, specific color configuration has yet to be determined by the EPA for any changes in color codes for canisters used in sequential sampling systems.

3.3.1 Starting Sample Event

If the sequence has been programmed into the Event Manger in section 3.2.3, the system is ready to start the next test sequence when the start time has been reached. From the main menu on the menu screen, select the Event key selection. This will take you to the menu screen identified as Event Menu as shown below.

```
Event Menu
F1: Current Event Status
F2: Previous Event Summary
F3:
F4: Event Manager
F5:
F6: Historical Event Summary
                                Exit
```

Figure 3.8 Operate Menu

From this screen, select the **F1** Menu Item. This will advance to the Status Menu as shown below.

```
Status: Finished       MM/DD/YY HH:mm:ss
 00       Canister Set: (1,2,3)
          Event Start: MM/DD/YY HH:mm:ss
          Event  Stop: MM/DD/YY HH:mm:ss
          Event Length:         HH:mm:ss


                <<        >>       Exit
```

Figure 3.9 Status Menu (Finished)

The next test will begin at the date and time programmed into the event sequence menu. Once the test has been completed, the status menu will display Finished as the status on the screen. If a sample event is in progress then the Status will be indicated as Sampling as shown in Figure 3.10.

```
Status: Sampling       MM/DD/YY HH:mm:ss
 00       Canister Set: (1,2,3)
          Event Start: MM/DD/YY HH:mm:ss
          Event  Stop: MM/DD/YY HH:mm:ss
              Elapsed:          HH:mm:ss
            Remaining:          HH:mm:ss

              <<        >>       Exit
```

Figure 3.10 Status Menu (Sampling)

3.3.2 Collecting Data After Sample Event

Following the sampling event, the data required for documentation of the results can be done manually or via the RS-232 port on the Control Box. Both methods can be used to provide immediate and archival storage of information. See typical form in Appendix B of this manual.

Using the RS-232 Connection and PC

Located under the control box, the most left hand circular connection is for the RS-232 cable supplied with the SASS Unit (Part Nr 3159). It is a four pin circular connector with a 9-pin RS-232 female (DE-9F) type connection at the other end. Connect the circular connection to the control box, and the 9-pin connector to the laptop PC or to an RS-232 extension cable to a PC Computer. In most applications, RS-232 connections are typically, limited to 50 ft. unless special low loss cables are used. Longer lengths of cable made from some types of wire can cause errors in the data collection process.

Use the SASSComm AQ Software version 4.0.1 (or higher), supplied with the system, to collect the data from either type of SASS. Consult the SASSComm AQ Manual for specific information on data collection via the RS-232 port, or via telephone dial-up modem.

Using the Transfer Module

A small transfer module UX-961 can be used to collect data from the SASS. This is a useful accessory item that is described in Section 6 of this manual. It simply plugs into the SASS Control Box. Using the special RS-232 Cable part nr 3169 supplied with the transfer module. Connect the 9-pin end to the transfer module and the circular 4-pin connector to the RS-232 connection on the control box. **NOTE: The standard RS-232 cable nr 3159 will not work.**

```
     Super SASS Speciation Sampler
                V 4.02

       Met One Instruments, Inc
            www.metone.com
                                Transfer
Event      Setup    Calibrate    Data
```

Figure 3.11 Main Screen

Once connected, select the Transfer Data button from the main control box screen as seen in figure 3.11. This will activate the data transfer of information from the control box to the transfer module. The screen will appear with download information as the data is copied from the control unit to the transfer module. Note: Only one SASS sampler data set can be stored in the transfer module at any one time. Once the data has been removed, the same transfer module can be used to collect data from another SASS System.

Take the transfer module to the PC computer using the SASS Com Software, and follow the procedure for extraction of data from the transfer module. Collected data will be stored in the PC computer where reports can be generated on the results of this sample run. This method will also collect all of the 5-minute data from the data logger of the SASS.

Manual Collection of Data

To fill out the transfer of custody / field data form provided from the vendor that is doing the analysis of the collected canisters; it will be necessary to record the data from the various screens. Select from the main menu the Event screen as shown in Figure 3.8 in this section of the manual. Next, Select the key "**F2**" for Previous Event Summary. This will display the data from the previous event that was most recently completed. Note: When all programmed events are completed, the current event status and the previous event summary will be the same.

Using the << and >> arrow keys under the menu, the remaining status menus can be viewed, to find the additional information required for filling out the forms. Using the right arrow key >>, the first screen is "Current" it displays current values, press the key again and it comes to the screen "5 Min Values" it shows the last 5 minute values that were collected. Now press the >> key once more and it goes to the first of the screens containing the information for the custody/field data form. This is the "Volume Summary" Screen.

```
Volume Summary          MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg    Ambient T –xx.x C
Volume 1  x.xxx m3      Filter 1  –xx.x C
Volume 2  x.xxx m3
Volume 3  x.xxx m3
Volume 4  x.xxx m3
Volume 5  x.xxx m3
              <<         >>       Exit
```

Figure 3.12a Volume Summary Screen (SASS)

In the SASS unit, up to 5 of the recorded volumes will be displayed. The total number will be based on the number of canisters selected for the sample event.

```
Volume Summary          MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg    Ambient T –xx.x C
Volume 5  x.xxx m3      Filter 5  –xx.x C
Volume 6  x.xxx m3      Filter 6  –xx.x C
Volume 7  x.xxx m3      Filter 7  –xx.x C
Volume 8  x.xxx m3      Filter 8  –xx.x C

              <<         >>       Exit
```

Figure 3.12b Volume Summary Screen (Super Sass)

From this screen the volume, data as well as the average values over the previous event can be examined and transferred to the field data form. In the SASS unit, there can be up to 5 flow channels displayed. Press the >> Key again and this will bring up the “CV Summary” Screen as shown below.

```
CV Summary              MM/DD/YY HH:MM:SS
          CV       Mean       Std Dev
 Flow 1       %         Lpm         Lpm
 Flow 2       %         Lpm         Lpm
 Flow 3       %         Lpm         Lpm
 Flow 4       %         Lpm         Lpm

              <<         >>       Exit
```

Figure 3.13 CV Summary Screen

From this screen the CV values, Mean Values as well as the Standard Deviation of the flow measurements taken during the previous event can be examined and transferred to the field data form. Press the >> key again and this will bring up the “Min/Max” Summary Screen as shown below.

```
Min/Max Summary         MM/DD/YY HH:MM:SS
 Ambient T Max       C
           Min       C
Filter 1 T Max       C
           Min       C
 Ambient P Max     mmHg
           Min     mmHg
              <<         >>       Exit
```

Figure 3.14 Min/Max Summary Screen

On SuperSASS, use the Up and Down arrow keys to scroll through the filter canister numbers to select the desired filter temperature. The SASS unit provides only a single filter temperature from canister #1. From this screen the various min/max values, for temperature and pressure that were recorded during the previous event can be examined and transferred to the field data form.

Press the >> key again and this will bring up the “Filter DT Summary” Screen as shown on the next page.

```
Filter dT Summary      MM/DD/YY HH:MM:SS
Max dT
 5 –xx.x C    MM/DD/YY HH:mm:ss
 6 –xx.x C    MM/DD/YY HH:mm:ss
 7 –xx.x C    MM/DD/YY HH:mm:ss


               <<        >>       Exit
```

Figure 3.15 Filter Temperature Summary Screen (Super SASS)

This screen indicates the maximum temperature recorded between the ambient temperature and the filter temperature. The SASS screen, provides only a single MAX dT value for filter canister #1 and the ambient temperature. It also includes the date and time of the maximum value. This value will continue to record even after the event has been completed, so that the value includes any differences that occur before the sample canister is removed.

Press the >> key again and this will bring up the “Warnings” Summary Screen as shown below.

```
Warnings               MM/DD/YY HH:MM:SS
Elapsed Time: YES  HH:mm:ss < 23:00:00
Filter dT
 5   YES    –xx.x C    MM/DD/YY HH:mm:ss
 6   YES    –xx.x C    MM/DD/YY HH:mm:ss
 7   YES    –xx.x C    MM/DD/YY HH:mm:ss

              <<        >>       Exit
```

Figure 3.16 Warnings Screen (Super SASS)

This screen indicates if there were any alarms or warnings, which occurred during the previous test. A “Yes” value indicates that an alarm occurred, the date and time of the event is stored on the screen. These alarm results can be examined and transferred to the field data form. As before, the SASS version of this screen will show only a single filter temperature warning.

Press the >> key again and this will bring up the “Flow Warnings” Summary Screen as shown below.

```
Flow Warnings          MM/DD/YY HH:mm:ss
                 Lpm
   Flow 1: Yes   xx.x MM/DD/YY HH:mm:ss
   Flow 2:  No
   Flow 3:  No
   Flow 4:  No
   Flow 5:  No
              <<        >>       Exit
```

Figure 3.17 Flow Warnings Summary Screen (SASS)

This screen indicates if there were any alarms or warnings, which occurred during the previous test, related to flow measurement. A “Yes” value indicates that an alarm occurred, the date and time of the event is stored on the screen. The SASS screen can display up to 5 separate

flow warnings, while the SuperSASS would have a maximum of 4 flow warning channels. These alarm results can be examined and then are transferred to the field data form. This completes the collection of data results required by the field data form.

Pressing the >> Key again brings up the “Power Interruptions” screen. This screen provides information on power interruptions that may have occurred during the sampling event.

```
Power Interruptions    MM/DD/YY HH:MM:SS

1 MM/DD/YY HH:MM:SS  6 MM/DD/YY HH:MM:SS
2 MM/DD/YY HH:MM:SS  7 MM/DD/YY HH:MM:SS
3 MM/DD/YY HH:MM:SS  8 MM/DD/YY HH:MM:SS
4 MM/DD/YY HH:MM:SS  9 MM/DD/YY HH:MM:SS
5 MM/DD/YY HH:MM:SS  0 MM/DD/YY HH:MM:SS
              <<        >>       Exit
```

Figure 3.18 Power Interruptions Screen

A power interruption event is logged when it lasted for more than 1 minute. A maximum of ten events are logged. If more than ten events occur, the tenth (0) is over written with the most recent.

3.4 Sample QA/QC Procedures

Certain quality control checks must be conducted at the time of sample setup and at monthly or quarterly intervals thereafter. Carry out these checks before making any adjustments to the sampler. Record information about the site, the sampler and the results of scheduled or special (unscheduled) quality control checks on a QA/QC Report Form. This report form originates at the field site, and the site operator should keep the original on file and copies to others. Any actions taken to service or calibrate the SASS sampler, after the check should be recorded in brief on the form and in detail in the field operators notebook.

3.4.1 Date and Time Checks

Conduct these checks monthly or whenever daylight savings time changes occur. Compare the date and time displayed on the sample to the known data and to an accurately set watch. Record date and time check information on the QA/QC data form.

3.4.2 Monthly Leak Check

Performed upon startup, and then monthly, see procedure in Section 6.0 of this manual

3.4.3 Monthly Temperature Check

Performed upon startup and then monthly, check the ambient and filter temperature sensors of the sample by positioning the probe of a certified transfer standard digital thermometer in close proximity to the sample sensors. Allow time to achieve stable readings and record the results in the field notebook and the QA/QC report form. If the sample and control check temperature readings differ by more the +/- 2°C, trouble shoot the system and recheck. If still out of tolerance, conduct a two-point calibration as described in Section 6.0, or replace the faulty sensor.

3.4.4 Quarterly Temperature Check

Performed each calendar quarter, follow the procedure for the calibration of the temperature probe as described in Section 6.0 of this manual. It should be compared against a certified NIST calibrated standard. Should a temperature sensor not maintain its calibration after the monthly or quarterly checks, maintenance and/or replacement of the faulty parts must occur.

3.4.5 Monthly Pressure Check

Compare the ambient barometric pressure readout from the sampler display screen with the reading from a certified transfer standard barometer. If the pressure readings differ by more than +/- 10 mm Hg, perform a calibration of the pressure sensor as described in Section 6.0 of this manual or if necessary replace the faulty sensor.

3.4.6 Quarterly Pressure Check

Performed each calendar quarter, follow the procedure for calibration of the pressure sensor as described in Section 6.0 of this manual. It should be compared to a certified NIST calibrated pressure standard. Should the pressure sensor not maintain its calibration after the monthly or quarterly checks, maintenance and/or replacement of the faulty parts must occur.

3.4.7 Monthly Flow Rate Check

Performed upon startup, and then monthly, see procedure in Section 6.0 of this manual. If the flow deviation exceeds +/- 10% (+/- 0.67 LPM) [24] then troubleshoot the problem to determine the cause of the change.

3.4.8 Quarterly Flow Rate Check

Performed each calendar quarter, follow the procedure for calibration of the flow sensor as described in Section 6.0 of this manual. It should be compared to a certified NIST calibrated flow reference standard. Should the flow sensor not maintain its calibration after the monthly or quarterly checks, maintenance and/or replacement of the faulty parts must occur.

4.0 MICROPROCESSOR MENUS AND SCREENS

Super SASS uses a series of intuitive menus to lead the operator through the setup, calibration, operation and data recall. Review the following section for a complete overview of the menu system.

Super SASS includes an Event Manager for the most flexible operation. An Event Manager will maintain a pre-event list, up to four (4) pre-events are allowed. Twenty-four (24) post events are archived in a circular manner where the oldest is overwritten by the newest addition. User selectable menus are designed to allow automatic timed sample events or manual on and off settings for calibration. Many menus and windows give current sampler information of ambient temperature, filter canister temperature, barometric pressure, sample flow rates and any error messages.

4.1 Main Screen

When the SASS or SuperSASS, is first powered up the user will see the MAIN SCREEN. The version number and system identification, as well as the choices Operate, Setup, Calibrate and Transfer Data are displayed.

Keys directly below the screen are associated with the screen text; these keys are called “soft keys”, because their function changes as the software changes. Keys F1 to F6 are called function keys.

```
      Super SASS Speciation Sampler
                V 4.02

        Met One Instruments, Inc
             www.metone.com
                                 Transfer
Event     Setup     Calibrate     Data
```

Figure 4.1 Main Screen

Event Menu Screen:
The Event menu is used to view all previous data and event results that have occurred. Up to 24 previous events can be stored in the memory of the SASS control box. From the Event menu, either current or previous sample event data can be viewed.

Setup Menu Screen:
Setup Menu is used to program into the control box the time and date of events, set the clock, customize the default menu, set the identification number and clear all event memory.

Calibration Menu Screen:
This menu contains the various calibration screens and test functions.

Transfer Data:
Provides data save menu using the accessory transfer module. It can also be used to verify the transfer of data via the RS-232 port. When communications is active, the transfer information is displayed in this screen.

4.2 Event Menu

From the Main Screen, press the EVENT key. The Event section provides the user with current operating conditions and post event summaries.

The Event menu screens are arranged in a closed circle. Select the major section of choice using the Function Keys and then scroll to other screens listed in the Event Menu using the << and >> arrow keys.

Select your choice by pressing the associated Function Key.

```
Event Menu
F1: Current Event Status
F2: Previous Event Summary
F3:
F4: Event Manager
F5:
F6: Historical Event Summary
                                  Exit
```

Figure 4.2 Event Menu

The event menu provides selections for viewing the results of current and post events.

4.2.1 Current Event Status

By pressing the "**F1**"This particular status screen provides the user with the current operating conditions of the SASS sampler. When a sampling event is in progress, the data available for viewing is the current event data.

From this screen, the operator can access the current event that was most recently completed or the current event that is in progress. During operation of the SASS, there are two variations of the screen label that will appear depending upon the current operational sequence in the event. They are identified in the Status line as **Finished,** and **Sampling.** The Status line values are shown in reverse video on the screens.

```
Status: Finished       MM/DD/YY HH:mm:ss
06        Canister Set: (1,2,3)
          Event Start: MM/DD/YY HH:mm:ss
          Event  Stop: MM/DD/YY HH:mm:ss
          Event Length:         HH:mm:ss


              <<        >>       Exit
```

Figure 4.3 Finished Status Screen

From this screen only, the >> and << arrow hot keys can be used to navigate through the various status and summary screens. The current event number appears under the status label at the left hand top corner of the display screen.

If there is a test in progress, the sampling screen will appear indicating the current status of the event that is currently in progress.

```
Status: Sampling       09/11/00 11:43:22
07         Canister Set: (1,2,3)
          Event Start: 09/11/00 00:00:00
          Event  Stop: 09/11/00 24:00:00
          Elapsed:              11:42:22
          Remaining:            12:17:38

               <<        >>       Exit
```

Figure 4.4 Sampling Status Screen

Menu Item Descriptions:

Soft Key	**Description**
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
Sampling	During this state the line 6 display is: Remaining: HH:mm:ss Where the time displayed is the Event Stop time minus the current time. In other words, the time remaining until the pump is turned OFF and sampling stops. Stays in this state until the current time is greater or equal to the Event Stop time, and then the status is set to the Stopping state.
Finished	During this state Data logging continues.

To view the current data relating to the test that is in progress, the >> key can be used to go to the next status screen

Current Data Screen

This screen shows the current operating conditions of flow, temperature, filter temperature and pressure. The pump status is shown in the lower right of the screen. It will display only those canisters that are installed for the current event. Use the >> key to advance to the next screen.

```
Current                MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg   Ambient T –xx.x C
   Flow 1  xx.x Lpm    Filter 1  –xx.x C
   Flow 2  xx.x Lpm
   Flow 3  xx.x Lpm
   Flow 4  xx.x Lpm
   Flow 5  xx.x Lpm       Pump:   ON
              <<        >>       Exit
```

Figure 4.5a Current Data Screen (SASS)

```
Current                 MM/DD/YY HH:MM:SS
Ambient P   724 mmHg    Ambient T  24.4 C
   Flow 1  xx.x Lpm     Filter 1   24.5 C
   Flow 2  xx.x Lpm     Filter 2   24.3 C
   Flow 3  xx.x Lpm     Filter 3   24.3 C
   Flow 4  xx.x Lpm     Filter 4   24.2 C
                         Pump:   ON
             <<         >>       Exit
```

Figure 4.5b Current Data Screen (SuperSASS)

Average Screen

The Super SASS logs data at the U.S. EPA setting of 5 minutes. In the Average screen, the user can view the last calculated average. Included are the last average time and all data values for the sample: flow, temperature, filter temperature and barometric pressure. These are displayed for the current configuration of canisters being used.

```
5 Min. Values           MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg    Ambient T –xx.x C
   Flow 1  xx.x Lpm     Filter 1  –xx.x C
   Flow 2  xx.x Lpm
   Flow 3  xx.x Lpm
   Flow 4  xx.x Lpm
   Flow 5  xx.x Lpm      Pump:   ON
              <<         >>       Exit
```

Figure 4.6a Average Screen (SASS)

```
5 Min. Values           MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg    Ambient T –xx.x C
   Flow 5  xx.x Lpm     Filter 5  –xx.x C
   Flow 6  xx.x Lpm     Filter 6  –xx.x C
   Flow 7  xx.x Lpm     Filter 7  –xx.x C
   Flow 8  xx.x Lpm     Filter 8  –xx.x C
                         Pump:   ON
              <<         >>       Exit
```

Figure 4.6b Average Screen (SuperSASS)

This screen always displays the 5-minute values from the current event in progress or when there is no event in progress, it is the data for the previous event. This data is not applicable for recording on the post event data report. Be careful that these screens are not confused with the event summary data that should be recorded on the transfer of custody or data result forms.

Menu Item Descriptions

Soft Key	Description
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2

<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
Ambient P	Displays the 5-minute average of barometric pressure for the current event.
Ambient T	Displays the 5-minute average of ambient temperature for the current event.
Flow n-n	Displays the 5-minute average of the flow in Lpm for the current event, the number of flows values displayed will depend upon the number of installed canisters.
Filter n-n	Displays the 5-minute average of the filter temperatures for the current event. There is only a single temperature for the SASS unit, canister #1

The screens shown in figures 4.5 and 4.6 are the two key screens that display data being collected for the event that in progress. Additional screens that can be viewed are described in section 4.2.2

4.2.2 Previous Event Summary Screen

This screen is selected from the event menu in figure 4.2 by using the "F2" key. It is used to show the recorded results of the previous event that has just finished. In some test sequences, the displayed previous event is the same as the current event. This can occur when there is not another event in progress and there is not one scheduled. It should also be noted that only the data results for the number of installed canisters would be displayed in the various screens.

The previous event summary is the primary source of information for the collection of data that is transcribed to the transfer of custody form or other documentation related to the recent event.

The sequence number of the event is listed in the upper left hand corner, just below the status label. The << and >> arrow hot keys are used to sequence through the various screens containing the status, summary and warnings data. The following status screen "finished" is the home display.

```
Status: Finished       MM/DD/YY HH:mm:ss
06          Canister Set: (1,2,3)
          Event Start: MM/DD/YY HH:mm:ss
          Event  Stop: MM/DD/YY HH:mm:ss
          Event Length:         HH:mm:ss


               <<        >>       Exit
```

Figure 4.7 Status Screen

The remainder of the screens that display data results can be viewed by selecting the >> key from the status screen. The first two screens were previously shown in figures 4.5 and 4.6. They are only relevant for the display of current data that is being collected during an event that is in progress. Skip past them to the summary screen, which contains the information that needs to be transcribed to the transfer of custody form as seen in appendix B.

Volume Summary Screen

The volume summary screen has the information about the average pressure, volumes, the ambient temperature as well as filter temperature summary. This screen and the following screens provide information that may be required for chain of custody forms, or other documents used to document the results of the previous sample event. The number of individual items will vary depending upon the number of installed canisters used during each test sequence. Use the >> key to advance to the next screen.

```
Volume Summary          MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg    Ambient T –xx.x C
Volume 1  x.xxx m3      Filter 1  –xx.x C
Volume 2  x.xxx m3
Volume 3  x.xxx m3
Volume 4  x.xxx m3
Volume 5  x.xxx m3
              <<         >>       Exit
```

Figure 4.8a Volume Summary Screen (SASS)

```
Volume Summary          MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg    Ambient T –xx.x C
Volume 5  x.xxx m3      Filter 5  –xx.x C
Volume 6  x.xxx m3      Filter 6  –xx.x C
Volume 7  x.xxx m3      Filter 7  –xx.x C
Volume 8  x.xxx m3      Filter 8  –xx.x C

              <<         >>       Exit
```

Figure 4.8b Volume Summary Screen (SuperSASS)

Menu Item Descriptions

Soft Key	**Description**
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
Ambient P	Displays the average barometric pressure for the event.
Ambient T	Displays the average of ambient temperature for the event.
Volume n-n	Displays the total volume in cubic meters for the event. The number of displayed channels will depend upon the number of installed canisters.
Filter n-n	Displays the average filter temperatures for the event, only a single filter temperature for the SASS unit.

CV Summary Screen

CV is the Coefficient of Variance is equal to the Standard Deviation divided by the Mean times 100. The units are in percent. The number of displayed flow values will vary with the number of installed canisters. To advance to the next screen, use the >> key.

```
CV Summary                MM/DD/YY HH:MM:SS
          CV       Mean       Std Dev
 Flow 1       %         Lpm         Lpm
 Flow 2       %         Lpm         Lpm
 Flow 3       %         Lpm         Lpm


              <<         >>        Exit
```

Figure 4.9 CV Summary Screen

Menu Item Descriptions

Soft Key	Description
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
Flow n-n	Displays the coefficient of variance, the mean and the standard deviation of the flow for the entire event. Only the flows for the installed canisters will be displayed in both SASS and SuperSASS.

Min/Max Summary Screen

The Min/Max Summary screen provides the maximum and minimum values recorded during the previous event. Each indicates the date and time of the occurrence of the maximum and minimum values. In the SASS unit, there is only a single filter temperature max/min value available. Use the >> key to advance to the next screen.

```
Min/Max Summary          MM/DD/YY HH:MM:SS
Ambient T Max   22.4 C   MM/DD/YY HH:MM:SS
          Min   19.5 C   MM/DD/YY HH:MM:SS
Filter 1T Max   23.3 C   MM/DD/YY HH:MM:SS
          Min   19.3 C   MM/DD/YY HH:MM:SS
Ambient P Max  730 mmHg  MM/DD/YY HH:MM:SS
          Min  630 mmHg  MM/DD/YY HH:MM:SS
              <<         >>        Exit
```

Figure 4.10 Min/Max Summary Screen

Use the up/down keys to select the SuperSASS filter canister number to display max/min data.

Menu Item Descriptions

Soft Key	Description
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Up / Down	Use to select the specific canister filter temperature to display. This is only active in the SuperSASS. SASS provides a single temperature max/min value.
Status	**Description**
Ambient T Max/Min	Displays the maximum and minimum values for the ambient temperature and the time and date of occurrence since the beginning of the event.
Filter x T Max/Min	Displays the maximum and minimum values for the filter temperature and the time and date of occurrence since the beginning of the event. Use the up and down arrow keys to select individual canisters.
Ambient P Max/Min	Displays the maximum and minimum values for the barometric pressure and the time and date of occurrence since the beginning of the event.

Filter dT Summary Screen

The filter dT summary screen displays the maximum temperature difference between the ambient temperature and the filter temperature. In addition to recording the maximum temperature difference, it also indicates the date and time of the maximum value. These value will continue to change and will be and indication of the values up to the time the canisters are removed from the SASS. The SASS unit provides a single Max dT value for canister #1, while the SuperSASS provides a Max dT value for each canister used in the sample event.

Use the >> key to advance to the next screen.

```
Filter dT Summary      MM/DD/YY HH:MM:SS
Max dT
 1 –xx.x C    MM/DD/YY HH:mm:ss
 2 –xx.x C    MM/DD/YY HH:mm:ss
 3 –xx.x C    MM/DD/YY HH:mm:ss



              <<         >>       Exit
```

Figure 4.11 Filter dT Summary Screen

Menu Item Descriptions

Soft Key	Description

Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
Max dT	Displays the maximum difference between the ambient temperature and the filter temperature. Includes time and date of occurrence since the beginning of the event.

Warnings Screen

This screen displays any warnings that indicate that the length of the test was out of tolerance or the difference temperature between the ambient and the filter exceeded the preset limit.

A Filter Error display of NO indicates no flow errors. A Filter Error display of YES indicates a filter temperature error that is greater than 5 degrees Celsius from the ambient temperature. On the SASS only a single dT warning would be displayed, for SuperSASS a dT warning can be displayed for each canister used in the sample event.

```
Warnings                MM/DD/YY HH:MM:SS
Elapsed Time: YES  HH:mm:ss < 23:00:00
Filter dT
 1   YES    -xx.x C    MM/DD/YY HH:mm:ss
 2   YES    -xx.x C    MM/DD/YY HH:mm:ss
 3   YES    -xx.x C    MM/DD/YY HH:mm:ss

              <<         >>       Exit
```

Figure 4.12 Warnings Screen

Menu Item Descriptions

Soft Key	**Description**
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
YES - NO	NO indicates that there were no errors, a YES indicates that an error occurred or the dT was exceeded.
Elapsed Time	The elapsed sample time is out of range – less than 23 hours or greater than 25 hours.
Filter dT	Filter temperature differential is out of specifications and it's time and data of occurrence. The filter temperature exceeded the ambient temperature by more than 5° C for more than 30 minutes during either the sampling or post sampling period of operation.

Flow Warnings Screen

The displayed flows for each sample canister are constantly adjusted to the required “actual” volumetric flow based on actual site conditions using the ambient filter temperature and the barometric pressure. In SASS there can be a maximum of 5 flows, while there are 4 for the SuperSASS. The actual number of channels displayed will depend upon the number of canisters used for the sample event.

```
Flow Warnings          MM/DD/YY HH:mm:ss
                  Lpm
   Flow 1: Yes   xx.x MM/DD/YY HH:mm:ss
    Flow 2:  No
    Flow 3:  No
    Flow 4:  No

               <<         >>       Exit
```

Figure 4.13 Flow Warnings Screen

Menu Item Descriptions

Soft Key	Description
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Status	**Description**
YES - NO	NO indicates that there were no errors, a YES indicates that there was a error in flow rate.
Flow 1-8	Sample flow rate out of spec, its value, and its time and date of occurrence. The flow rate exceeded a range of +/- 10 percent of the average flow rate for the sample period for more than 5 minutes.

Power Interruptions Screen

A power interruption event is logged when it lasted for more than 1 minute. A maximum of ten events are logged. If more than ten events occur, the tenth (0) is over written with the most recent. The time and date of each event is logged as part of the power interruptions summary.

```
Power Interruptions     MM/DD/YY HH:MM:SS

1 MM/DD/YY HH:MM:SS   6 MM/DD/YY HH:MM:SS
2 MM/DD/YY HH:MM:SS   7 MM/DD/YY HH:MM:SS
3 MM/DD/YY HH:MM:SS   8 MM/DD/YY HH:MM:SS
4 MM/DD/YY HH:MM:SS   9 MM/DD/YY HH:MM:SS
5 MM/DD/YY HH:MM:SS   0 MM/DD/YY HH:MM:SS
               <<         >>       Exit
```

Figure 4.14 Power Interruptions Screen

This is the last summary screen, pressing the >> key will return to the finished status screen as seen in figure 4.3.

4.2.3 Event Manager Screen

Selecting the event manager screen using the "**F4**" key will go directly to the event manager that is part of the setup menu. This shortcut can be used to view the events currently programmed into the SASS, or to add, modify or delete events from the system. Exiting the event manager will return to the setup screen and does not return to the event menus. See Section 4.3 for details on the using the event manager.

4.2.4 Historical Event Summary Screen

The historical event summary screen allows for viewing of post events. A maximum of 24 post events can be stored in memory before they are over written by a new event. The menu is identical to that of the previous event summary screen as seen in figure 4.7. The key difference is that the event number can be selected from the historical event summary; while in the previous event summary it only shows the most recently completed event. The event number is displayed below the Status label in the upper left hand corner of the screen. The various screens available are the same as described in section 4.2.2, except they are for the selected post event.

```
Status: Finished       MM/DD/YY HH:mm:ss
06          Canister Set: (1,2,3)
          Event Start: MM/DD/YY HH:mm:ss
          Event  Stop: MM/DD/YY HH:mm:ss
          Event Length:         HH:mm:ss


               <<        >>       Exit
```

Figure 4.15 Status Screen

Menu Item Descriptions:

Soft Key	**Description**
Exit	The Exit key when pressed will exit the current menu and return to the event menu screen as seen in Figure 4.2
<< And >>	Selection of these keys step through the various status and summary screens for the current event, or when there are no running events, the just finished event will be displayed.
Up / Down	Use the Up and Down arrow keys to select the event summary to view, the most recent event will always be the starting point. Use the up arrow to go to the next older event.
Status	**Description**
Finished	Indicates that this is a completed event.

4.3 Setup Menu

The setup menu is used to setup the various event, defaults, date and time, the unit ID as well as provide a way to clear from the SASS memory all event history. The setup menu screen shown in figure 4.16 is displayed, when the setup key from the main menu is selected.

```
Setup Menu
F1: Event Manager
F2: Event Defaults
F3: Clock
F4: Unit ID
F5: Clear Event History
F6: Flow Sensors
                                  Exit
```

Figure 4.16 Setup Menu Screen

Use the function keys to access the various menu selections. To return to the main menu, the exit key can be selected.

4.3.1 Event Manager screen

The event manager allows for the programming of the events or test sequences that will be processed by the SASS unit. Up to four events can be programmed to occur at the prescribed date and time. In addition to the date, time and length of the event, the set of canisters that will be used during each event can be programmed. The SASS unit provides only a single set of canisters, typically (1,2, & 3) that can be programmed for future sample events. The SuperSASS allows for sequential sampling, so that a new sample event can begin using an alternate set of canisters while the original canisters are still inplace.

```
Event Manager          MM/DD/YY HH:mm:ss
Start Date/Time    Length  Canisters
MM/DD/YY HH:mm:ss  HH:mm   {1,2,3}
MM/DD/YY HH:mm:ss  HH:mm   {5,6,7}




   Add      Modify    Delete     Exit
```

Figure 4.17 Event Manager Screen

Only active pre-events are listed. They are ordered (top to bottom) by the earliest date and time. Up to four (4) pre-events can be listed. Use the up and down arrows to select an event for modification or deletion. Then use the Modify or Delete action keys to perform the function on the selected event. If there are less than 4 pre-programmed events then the Add key will bring up the Add Event screen.

Menu Item Descriptions

Soft Key	Description
Add	This key is used to add an event to the system
Modify	Once selected an event can be modified using this key selection.

Delete	This key allows for the deletion of an event from the event queue.
Exit	Used to exit the menu to the event manger screen (Figure 4.16)
Up / Down	The arrow keys are used to select an event for modification or deletion.

Add Event Screen

The add event screen is used to add and event to the pre-event list or to enter the first event into the SASS unit. This menu is used to edit the Event Start date and time, Event Length time, and the Canister Set. Current date and time are shown in the upper right hand corner of the screen. While the canister set of the SASS cannot be sequenced, the configuration of the installed canisters for the sample event needs to be indicated. The dynamic nature of the various screens requires that the configuration be defined for the test, so that it can be properly displayed on the screens. Typically as part of the EPA test plan, SASS canister set {1,2 & 3} will be used. This is also the default set. The Canister Set is a pick list of defined sets as shown below.

Defined sets for SASS are:

{1}, {1,2}, {1,2,3}, {1,2,3,4}, {1,2,3,4,5}

Defined sets for Super SASS are:

{1}, {2}, {3}, {4}, {1,2}, {3,4}, {5,6}, {7,8}, {1,2,3}, {5,6,7}, {1,2,3,4}, and {5,6,7,8}.

Press the Add button to add this event to the pre-event list. A successful add will return the user to the Event Manager screen.

```
Add Event              12/14/00  08:34:09
                       MM/DD/YY  HH:mm
         Event Start: 12/15/00  00:00
        Event Length:           24:00
        Canister Set: {1,2,3}


   Add                Default    Cancel
```

Figure 4.18 Add Event Screen

Menu Item Descriptions

Soft Key	**Description**
Add	This key is used to add this event to the pre-event list.
Default	Selection will automatically enter the preset default values as described in figure listed in the section “Event Defaults”
Cancel	This key allows the user to cancel the add function and returns to the event manager screen.
Term	**Description**

Event Start	This is the start date and time for the event. Use arrow keys to move and edit values. Selection of default will automatically enter the default value for this event.
Event Length	This is the length of the event in hours and minutes. Use arrow keys to move and edit the values. Selection of default will automatically enter the default value for this event.
Canister Set	This is the set of canisters to be used during this event. Using the up and down arrow keys to select the set of canisters. See listing above for choices of canisters grouped in sets.

Modify Event Screen

The modify event screen is used to modify an event in the pre-event of the SASS unit. This menu is used to modify the Event Start date and time, Event Length time, and the Canister Set. Current date and time are shown in the upper right hand corner of the screen. The Canister Set is a pick list of defined sets as previously described.

Press the Save button to commit changes to the event. A successful save will return the user to the Event Manager screen.

```
Modify Event          12/14/00  18:23:05
                      MM/DD/YY  HH:mm
         Event Start: 12/15/00  00:00
        Event Length:           24:00
        Canister Set: {1,2,3}


   Save               Default    Cancel
```

Figure 4.19 Modify Event Screen

Menu Item Descriptions

Soft Key	**Description**
Save	This key is used save the modified event to the pre-event list.
Default	Selection will automatically enter the preset default values as described in figure listed in the section “Event Defaults”
Cancel	This key allows the user to cancel the add function and returns to the event manager screen.
Term	**Description**
Event Start	This is the start date and time for the event. Use arrow keys to move and edit values. Selection of default will automatically enter the default value for this event.
Event Length	This is the length of the event in hours and minutes. Use arrow keys to move and edit the values. Selection of default will automatically enter the default value for this event.
Canister Set	This is the set of canisters to be used during this event. Using the up and down arrow keys to select the set of canisters. See listing above for choices of canisters grouped in sets.

Delete Event Screen

If the delete event from the event manager screen is selected, the following caution screen will appear. It is used to warn the operator that they are about to remove an existing sample event. Select the appropriate key to delete the event or the cancel key to return to the events manager screen.

```
................Caution................

Press 'Delete' to remove the selected
sample event.



  Delete                          Cancel
```

Figure 4.20 Delete Event Screen

4.3.2 Event Defaults screen

This menu allows the operator to set default values into the system. These values will be used whenever the default is selected from the add or modify event screens shown in figures 4.18 and 4.19. Defaults are selected for event length and canister set. A list of canister sets can be found in the add events section of figure 4.18. Use the arrow keys to select the value to change. Use Save key to save the default values or the Exit key to leave them as they are.

```
Sample Event Defaults
                            HH:mm
           Event Length:  24:00
           Canister Set: {1,2,3}





   Save                           Exit
```

Figure 4.21 Sample Event Defaults Screen

4.3.3 Clock Setup Screen

The clock screen shows the current date and time setting of the SASS at the upper right of the screen. Using the left and right arrow keys scroll to the settings to be changed, change using the up and down arrows. After setting to the correct date and time press the SET key. Notice that the SASS time is changed to the current settings. It is best to set the new clock time to a future time, and then hit the set key when the new set time has been reached.

```
Clock Setup            12/24/00 11:10:35
      MM/DD/YY
Date: 12/24/00

      HH:mm:ss
Time: 11:30:22

   Set                             Exit
```

Figure 4.22 Clock Setup Screen

4.3.4 Unit ID Screen

The SASS is identified by a station number (ID). This is set by the factory to match the last four digits of the SASS serial number. The ID number marks the retrieved data from the SASS. Data retrieved from multiple samplers are identified by a unique ID number. Every SASS unit has its own ID number, from 0 to 9999. Press the SAVE key to save changes to the Unit ID.

```
Unit ID

Unit ID: 4585




   Save                            Exit
```

Figure 4.23 Unit ID Screen

4.3.5 Clear Event History Screen

The clear event history screen can be used to remove all archived events as well as all logged data that has been collected during the archived events. This function should only be used when all data in the SASS has been collected and archived on other media such as a PC Computer. The clear will delete any current test in progress as well as any events in the event queue. Use this command with caution to prevent the loss of data.

```
................Caution................

Press 'Clear' to erase current and
All archived events and data log data.



  Clear                           Cancel
```

Figure 4.24 Clear Event History Caution Screen

4.3.6 Flow Sensors Screen

Flow sensor types are only changed if a flow sensor must be replaced. Instructions are provided with the flow sensor that provide correct configuration. The SASS can use 2 types of mass flow meters—10 or 20 LPM full scale. Edit to select the appropriate type. This configuration normally done at the factory, but it may become necessary to make a change if a field replacement is of a different type than the original. The SASS will have 5 sensors compared to SuperSASS 4 sensor channels. Press Save to save or Exit to leave the menu.

```
Flow Sensors
Sensor Type
 1  10 LPM FS
 2  10 LPM FS
 3  10 LPM FS
 4  10 LPM FS

   Save                            Exit
```

Figure 4.25 Flow Sensors Screen

4.4 Calibration Menu

This menu contains the calibration and test screen selection. Using the functions keys F1 to F4 the various types of test and calibration sub menus can be found. The system test selection allows for the viewing of physical parameters temperature, and flow on all system channels.

```
Calibrate Menu
F1: System Test
F2: Flow Calibration
F3: Temperature Calibration
F4: Pressure Calibration
F5:
F6:
                                  Exit
```

Figure 4.26 Calibrate Menu

4.4.1 System Test Screen

The system test screen shows all of the measured parameters in real time. Its primary function is to allow testing of the system as part of the preliminary checkout of the SASS. It is also useful for the troubleshooting of the SASS when problems may have been detected or for general maintenance of the unit.

```
System Test            MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg   Ambient T –xx.x C
   Flow 1  xx.x Lpm    Filter 1  –xx.x C
   Flow 2  xx.x Lpm
   Flow 3  xx.x Lpm
   Flow 4  xx.x Lpm
   Flow 5  xx.x Lpm      Pump:   ON
                        Pump     Exit
```

Figure 4.27a System Test Screen (SASS)

```
System Test            MM/DD/YY HH:MM:SS
Ambient P   xxx mmHg   Ambient T –xx.x C
   Flow 5  xx.x Lpm    Filter 5  –xx.x C
   Flow 6  xx.x Lpm    Filter 6  –xx.x C
   Flow 7  xx.x Lpm    Filter 7  –xx.x C
   Flow 8  xx.x Lpm    Filter 8  –xx.x C
                         Pump:   ON
   Cans                 Pump     Exit
```

Figure 4.27b System Test Screen (SuperSASS)

Menu Item Descriptions:

Soft Key	Description
Cans	This key allows the toggling of canister group {1,2,3,4} and group {5,6,7,8} for display on the screen. (SuperSASS Only)
Pump	This key allows the toggling of the pump from OFF to ON

Exit	Exits this menu to the calibrate menu screen
Status	**Description**
Ambient P	The current ambient barometric pressure in mm of Mercury
Ambient T	The current ambient temperature in degrees centigrade.
Flow x	Displays the current numbered canister flow in liters per minute, use Cans to view the alternate canister group.
Filter x	Displays the current numbered canister temperature in degrees centigrade, use Cans to view the alternate canister group. There is only a single filter temperature in the SASS unit.
Pump	Displays the current status of the pump.

4.4.2 Flow Calibration Screen

This menu is the first of the calibration screens that allow for the actual calibration of the SASS system. To perform a calibration of volumetric flow, a reference standard is required. This single point check is made on each individual flow channel. Selection of flow channel is done using the up and down arrow keys to select the number of the channel listed in label Chan.

```
Volumetric Flow Calibration

Chan  SASS   Ref        Type
 (1)    .0   6.7 LPM    10 LPM FS

             Pump: OFF

Calibrate    Pump     Default    Exit
```

Figure 4.28 Volumetric Flow Calibration Screen

Menu Item Descriptions:

Soft Key	**Description**
Calibrate	Set new calibration coefficients into memory. Before pressing this key, the pump should be ON and the desired SASS calibration reference reading entered in Ref.
Pump	This key allows the toggling of the pump from OFF to ON
Default	Restore factory default calibration values.
Exit	Return to the calibrate menu, see figure 4.26.
Term	**Description**
Chan	Flow sensor channel number, use up / down arrow keys to select 1 to 4 or 5
SASS	The current volumetric flow rate of the SASS unit.
Ref	This is the reference reading from the calibration standard being used to calibrate flow for the selected channel. This should be the volumetric flow value or the corrected value to volumetric flow.
Type	Flow sensor type either 10 LPM or 20 LPM full scale value
Pump	Indicates the current pump status, either ON or OFF

4.4.3 Temperature Calibration Screen

This screen provides the calibration screen for the calibration of the temperature monitoring system of SASS. To perform a calibration of temperature, a reference standard for a low value and a high value is required. Typically, the two points consist of a zero centigrade reading using an ice bath, and a high temperature using a high temperature bath with reference thermometer. The up/down keys are used to select the temperature sensor that is to be calibrated. The name in the upper left corner will either be listed as “ambient” for the outside temperature and “filter” for the specific canister temperature (1 to 8). The SASS unit has only a single canister temperature (1) while the SuperSASS has (8). Because this is typically a two-point test, a separate save function key is provided for the low and high temperature values.

```
(x) xxxxxxxx Temperature Calibration

SASS   Pt  Save   Reference
 21.9   1  -30.0  -30.0 C      Save(F1)
        2   50.0  050.0 C      Save(F4)



Calibrate             Default    Exit
```

Figure 4.29 Temperature Calibration Screen

Menu Item Descriptions:

Soft Key	**Description**
Calibrate	Set new calibration coefficients into memory. Before pressing this key, the desired SASS calibration reference reading for points 1 and 2 has been entered in Reference using the F1 and F4 keys.
Default	Restore factory default calibration values.
Exit	Return to the calibrate menu, see figure 4.26.
Save (F1)	Store the current low temperature reference reading to the Pt 1 entry.
Save (F4)	Store the current high temperature reference reading to the Pt 2 entry.
Term	**Description**
(x) xxxxxxx	Used to select the desired temperature channel. (0) Ambient or (1 to 8) for filter temperatures of individual canisters. SASS unit has (0 & 1) only.
SASS	The current measured temperature of the selected SASS temperature channel.
Pt	One point of a two-point calibration. Generally point 1 = low calibration value and point 2= high calibration.
Save	Saved un-scaled SASS temperature device reading associated with the corresponding reference value. Use F1 to save calibration value 1 and F4 to save calibration value 2.
Reference	Enter the low or high calibration value that the temperature probe is currently measuring. Allow sufficient time for the temperature probe and the reference to stabilize.

4.4.4 Pressure Calibration Screen

This screen provides the calibration screen for the calibration of the pressure sensor in the SASS unit. The pressure is used by the flow monitoring system to determine the volumetric flow from the measured mass flow sensors. To perform a calibration of pressure, a reference standard for a low value and a high value is required. Typically, the two points consist of a low reading of 600 mm of Hg and a high reading of 800 mm of Hg.

```
Pressure Calibration

SASS   Pt  Save   Reference
 730    1   735   600 mmHg      Save(F1)
        2   735   735 mmHg      Save(F4)


Calibrate             Default    Exit
```

Figure 4.30 Pressure Calibration Screen

Menu Item Descriptions:

Soft Key	**Description**
Calibrate	Set new calibration coefficients into memory. Before pressing this key, the desired SASS calibration references reading for points 1 and 2 have been entered in Reference using the F1 and F4 keys.
Default	Restore factory default calibration values.
Exit	Return to the calibrate menu, see figure 4.26.
Save (F1)	Store the current un-scaled pressure reading to the Pt 1. Save variable associated with the corresponding reference value.
Save (F4)	Store the current un-scaled pressure reading to the Pt2. Save variable associated with the corresponding reference value.
Term	**Description**
SASS	The current pressure reading of the SASS unit.
Pt	One point of a two-point calibration. Generally point 1 = low calibration value and point 2= high calibration.
Reference	Measured pressure reading of reference device, enter value in range 000 to 999 mm of mercury.
Save	Saved un-scaled SASS pressure device reading associated with the corresponding reference value. Use F1 to save calibration value 1 and F4 to save calibration value 2.

4.5 Transfer Data

This menu once selected from the main screen allows for the transfer of the SASS memory contents into the optional UX-961 Transfer Module. See Figure 5.1 Transfer Module. During direct connection to PC data transfers, the status of the transfer can be viewed when the transfer data screen is selected.

```
XMODEM File Transfer
              Status:
            Received:
           File Size:
              Packet:

 Transfer  Transfer
 History     All                 Exit
```

Figure 4.31 Xmodem File Transfer Screen

Menu Item Descriptions:

Soft Key	**Description**
Transfer History	Transfers all post event sample summaries to the transfer module. This file is approximately 16K bytes in size and transfers in XXX minutes.
Transfer All	Transfers all post event sample summaries as well as 5 minute logger data to the transfer module. This file is approximately 112K bytes in size and transfers in XXX minutes.
Exit	Exits this menu to the main menu screen
Status	**Description**
Status	Indicates status of either “Transmitting” or “Finished”
Received	Indicates the number of xmodem packets that have been received
File Size:	Indicates the files size transferred. (i.e. 114,688 bytes for All Transfer)
Packet	Packet number currently being transferred.

4.6 Error and Warning Screens

There are various screens used to indicate cautions and warnings to the user. These are used to prevent actions that might cause loss of data, or provide warning when an error condition occurs in the SASS unit. The following is a list of the common caution and warnings screens.

Link Down Warning Screen

This screen is displayed when communication has failed between the control box and the pump box. A failure is defined as no communication for more than 10 seconds. This screen will remain on the screen until the continue key is pressed. This error is caused by a number of conditions that can occur during the normal operation of the SASS System. It should be considered a problem when it has a duration that exceeds more than 5 minutes.

Link down warning: displays the date and time the event occurred.
Duration: displays the duration of the event. Press Continue to return to the Home screen.

```
................Warning.................

  Communication link down to pump box!

  Link down: MM\DD\YY  HH:mm:ss
   Duration: HH:mm:ss

 Continue
```

Figure 4.32 Link Down Warning Screen

Test Caution Screen

This caution screen occurs whenever the operator requests that the pump be turned on, when and event is scheduled in the system. It also appears when the pump is running and event and a stop request is made.

```
…..............Caution….............

  Press 'Continue' to STOP the sample
  event and control the pump.



  Cancel                       Continue
```

Figure 4.33 Test Caution Screen

5.0 SAMPLER OPTIONS

5.1 Hand-Held Data Transfer Module

Met One Instruments Model UX-961 is a 12 volt DC self contained RS232 compatible data transfer module that can be carried to the field site by an operator to down-load the data that has been logged from the SASS. The device eliminates the requirement to carry a laptop computer to the field or manually transcribing data to a data sheet. The Module measures 6”L x 3”W x 1”H.

Figure 5.1 Transfer Module

The Data Transfer Module includes all RS-232 Interface cables and connections to interface with the RS-232 connection on the Control Unit. By selecting “Transfer Data” from the main screen menu, the transfer of information from the SASS to the transfer module will start. As data is transferred, the screen will indicate the progress of the transfer.

Once the data has been transferred to the module, it can then be taken to a PC computer where the special power supply and cable connects to the communications port on the computer. The SASSComm AQ Software is used on the PC to prepare reports in a format similar to that used by the EPA FRM Samplers.

5.3 Flow Rate Transfer Standard

Presently there are a number of commercial flow rate calibrators available from commercial manufacturers. Several use a patented “frictionless piston” and others a wet soap-bubble meter device. At present time, Met One believes the wet soap-bubble meter to be most reproducible and accurate, in laboratory conditions. For field use, the BGI, Model Delta Cal provides a single reference device for flow, temperature and pressure. In addition, several companies manufacture other types of transfer standard venturi flow devices. These are very accurate and can be used to calibrate the SASS. Please contact the factory for discussion of an accurate flow measurement device to use to calibrate the SASS. Adjustment of flow rates in the SASS should be consulted with the factory before made in the field.

5.4 Accessory Communications Items

Various accessory communications accessory items such as dial-up auto answer telephone modems, radio modems and cellular devices are available for the SASS. These are all designed to make the collection of data from the control unit easier. Additional information and details can be obtained from Met One Instruments, Inc.

6.0 MAINTENANCE, CALIBRATION, TROUBLESHOOTING

6.1 Maintenance

Very little maintenance is required for the operation of the SASS Sampler System. The following procedures should be followed for reliable continuous operation of the system. Most maintenance involves inspection of components for damage or wear, as well as performing regular checks and calibrations of the system. It is recommended that all maintenance and trouble shooting activities be recorded in the site notebook.

The SASS system contains both electronic and pneumatic components. Historically the vacuum pumps of most ambient air sampling systems require at least annual maintenance. The dual headed Thomas™ diaphragm pump used in the SASS can be removed by the operator from the field and new diaphragms and valves placed into the pump insuring another year of operation without failure.

The O-rings used in the SASS are made from Viton™ rubber. These O-rings should continue to provide a leak free system for several years. However, if leaks are detected during operation or during leak checking, these O-rings could be leaking. It is recommended to replace O-rings every two to three years depending on use and wear. However, they should be inspected on a regular basis

6.1.1 System Cleaning

Each time the system canisters are replaced, or as deemed necessary, the solar radiation shield of the sampler head should be cleaned with a wet cloth or, if required, a dilute soap and water solution. Dirt buildup on the shield can reduce the effectiveness of the reflective surface and cause the temperature to rise inside the shield.

The pump housing should be inspected and cleaned at least every quarter by removing the four screws on the corners and lifting the cover up and out of the way. Using a brush, or a compressed air source, clean the insides of the enclosure and in particular, the screen located below the pump assembly. When completed, replace the cover by tightening down the two screws located on the fan exhaust side first, and then “snug” the two screws on the opposite end of the enclosure.

The control box and cables should be inspected for damage or dirt and dust accumulation. The control box can be cleaned with a wet cloth or if required a dilute soap and water solution. The screen of the control box electronics should only be cleaned with a damp cloth, and no liquids should be allowed to enter the electronics package.

6.1.2 Denuder Replacement

Following the normal test sequence of the EPA Trends network, the MgO denuder will need replacement approximately every three months of operation or as required by the US-EPA. Under the EPA Trends program, the denuders are replaced by the third party vendor performing the analysis of the filters. The third party vendor is replacing filters and denuders in each canister; sufficient denuders should be supplied based on the three months of operation being typical. Details on the coating of the denuder can be found in the Appendix of this manual.

6.1.3 System Inspection

As part of the normal maintenance and operation, the various components of the system should be inspected for wear, damage, and changes in previous operation. Most inspections rely on

visual checks during normal operation of the system. These should be performed each time anything is done to the system.

Each time the canisters are removed, check the O-rings of the canisters and those on the Sharp Cut Cyclone. Each time the cyclones are removed, unscrew the grit cap and dump out any dirt that may have collected as part of a routine maintenance program.

6.2 System Leak Check

The system can easily be checked for air leaks. Leak checks are done from the System Test screen.

```
System Test            01/19/01 15:30:00
Ambient P   735 mmHg   Ambient T  22.5 C
   Flow 1   6.7 Lpm    Filter 1   22.5 C
   Flow 2   6.7 Lpm
   Flow 3   6.7 Lpm
   Flow 4   6.7 Lpm Leak Test:   OFF
   Flow 5   6.7 Lpm      Pump:   ON
             Leak       Pump     Exit
```

System Test Screen (SASS)

```
System Test            01/19/01 15:30:00
Ambient P   735 mmHg   Ambient T  22.5 C
   Flow 1   6.7 Lpm    Filter 1   22.5 C
   Flow 2   6.7 Lpm    Filter 1   22.5 C
   Flow 3   6.7 Lpm    Filter 1   22.5 C
   Flow 4   6.7 Lpm    Filter 1   22.5 C
Leak Test: OFF           Pump:   ON
   Cans      Leak       Pump     Exit
```

System Test Screen (Super SASS)

Before a leak test can be done the flow control valves must be operating at 6.7 LPM (+/- 0.2). Check for this operating point by turning the pump ON and waiting at least 5 to 10 minutes for the 6.7 LPM operating point to be reached (Note: SASS units do not have flow control on channels 4 and 5). Once this operating point has been reached press the `Leak` button to put the unit in leak test mode (Note: The leak test mode turns OFF motor control to the flow control valves).

While the pump is operating and flow values are being displayed on the screen of the control unit, block off the inlet tube of the SCC (Sharp Cut Cyclone) of canister #1 mounted in the sample head. The flow value for Flow 1 should drop to a 0.0 or 0.1 SLM, indicating that there are no detected leaks in the components of the first canister. Continue this procedure for the remaining canisters and make sure the flow drops to a 0.0 or 0.1 SLM. If you are using a SuperSASS, next select the CAN key to switch to the other canister set if they are installed in positions 5 to 8. A flow reading greater than this, on any of the canister channels, indicates

that there is a leak in that portion of the system. Testing individual sections of the system can identify the location of the leak.

1.0 Disconnect the vacuum line from the sample head at the side of the pump box. The flow for that channel should drop to 0.0 SLM. This indicates that the leakage path is between the pump and the sample head.

2.0 Reconnect the vacuum line to the pump box. Remove the canister from the sample head, and block off the vacuum line connection that would have inserted into the canister. One of the yellow cap plugs supplied on the canisters can be used for this. If the flow value drops to 0.0 SLM, then the leakage is either in the connection between this point and the canister or the SCC.

3.0 Remove the SCC from the canister and plug the bottom of the canister with one of the yellow cap plugs. Install the canister in the sample head and examine the flow value. It should drop to 0.0 SLM. It if indicates a leak then the seal between the sample head and the canister is at fault (check to see if the O-rings are in good condition). The other possibility is that the canister is not correctly assembled and a leakage path around the two sections of the canister exists. A 0.0 SLM reading would indicate the problem is in the SCC.

4.0 Replace the SCC on the canister; if the flow channel indicates a leak, then the problem is with the SCC. Verify that the O-ring seals on the SCC are intact and have not been damaged. If they are cut or have any other type of damage, they must be replaced. If the flow reads 0.0 SLM then the problem is fixed, and there is no leakage in the system. The original indication was probably caused by a poor initial connection when the canister or SCC was installed in the sample head.

This now verifies that the vacuum system is in intact and everything is working correctly.

.

6.3 Calibration

The calibration procedure performed in the field for the SASS is flow rate measurement, ambient filter, ambient temperature and barometric pressure measurement. Calibration procedures being adopted by the U.S. Environmental Protection Agency in the Draft document for Quality Assurance of $PM_{2.5}$ samplers should be adopted and used for the SASS.

Using a set of NIST traceable standards, for volumetric flow, barometric pressure and temperature, the SASS Unit can be easily calibrated using the calibration screens in the SASS Control Unit. From the main screen menu select the “Calibrate” key. This action will display the following Utility Menu Screen.

```
Calibrate Menu
F1: System Test
F2: Flow Calibration
F3: Temperature Calibration
F4: Pressure Calibration
F5:
F6:
                                Exit
```

Figure 6.1 Calibrate Menu Screen

6.3.1 Temperature Calibration

From the Utility Menu Screen shown in Figure 6.1, select the **F3** key on the control unit keyboard. This will bring up the Temperature Calibration Screen as shown below. Additional details on the various menu selections can be found in Section 4.4 of this manual.

```
(x) xxxxxxxx Temperature Calibration

SASS   Pt  Save   Reference
 21.9   1     .0  -30.0 C      Save(F1)
        2   22.0  050.0 C      Save(F4)


Calibrate             Default    Exit
```

Figure 6.2 Temperature Calibration Menu

Before beginning it will be necessary to have a reference temperature measurement device that has a calibration traceable to NIST or other approved calibration authority.

One good reference point for the ambient temperature sensor measurement is “ice point” (0°C / 32°F) the second being some elevated temperature above 20° C. During the summer, the local ambient may provide a suitable second temperature for calibration. The ice bath consists of a slurry of distilled water and ice chips that has been stirred to produce a 0°C temperature bath as measured with the reference thermometer. A wide mouth thermos bottle works well for the temperature tests.

From the menu of Figure 6.2, if the menu is not already in the “ambient” temperature measurement mode, use the arrow keys to move the cursor to the upper left hand selection and choose the “ambient” measurement.

The indication under the SASS menu item indicates the current ambient temperature, and this will be used to determine if the system needs to have the calibration changed.

Remove the ambient temperature probe from the shield by removing the three hexagonal nuts that hold the ring in place under the shield.

Now using the ice point bath with the reference thermometer, immerse the sensor portion of the ambient temperature probe 064-1 into the ice mixture. After about 1 minute of time to allow for stabilization, the measured value of SASS Ambient Temperature. The temperature should be within ±2°C of the reference thermometer.

Next using a second thermos bottle with a warm water mixture of approximately 30°C immerse the temperature probe and compare the reference thermometer in the bath with the measured value indicated for SASS Ambient Temperature. The temperature should be within ±2° C of the reference thermometer.

If both measurements are within the temperature tolerance then it is not necessary to calibrate the ambient temperature probe. If the temperature is in excess of the tolerance then use the following procedure to reset the calibration of the ambient temperature probe.

1. Insert the probe in the ice bath with the reference thermometer, and allow several minutes for the measurements to stabilize. It is best to try and stir the bath while both probes are in the ice mixture. When the probes are stable, enter the value measured from the reference thermometer in the top reference window. When completed press **F1** to save this value.
2. Now insert the probe in the heated water mixture and allow time for the probe and the reference thermometer to stabilize. When the probes are stable, enter the value measured from the reference thermometer in the second reference window. When completed press **F4** to save this value.
3. Now press the “Calibrate” key and the new values will be saved in memory of the control unit.
4. This calibrated the temperature probe to the reference thermometer. Re-run the temperature checks previously outlined and verify that at the two measurement points the temperatures are within the ±2° C tolerance. If they are not, then rerun the calibration test one more time.
5. If it fails the test a second, time, there is the possibility that the temperature probe is damaged, and will need to be replaced. If a new probe is installed, be sure to set the replacement probe using the “Default” menu selection. This will return to the original measurement factors.

This same procedure can also be used for the filter temperature measurement, except that for the temperature check, use the local ambient as a single reference point. From the temperature menu, use the arrow keys to change the value from 0 to 1 which will now indicated “Filter” Temperature. Insert a temperature probe into the open hole after canister #1 has been removed. Allow 10 minutes for the temperatures to stabilize, and then compare the reference thermometer with the filter temperature screen. They should be within ±2°C of each other. If the error is greater, then use the procedure outlined in steps 2-5 for this temperature probe. Except that the upper temperature is based on a reference thermometer placed near the filter temperature probe located above the canister. If this is a SuperSASS, continue this same procedure for the remaining 7 filter temperature probes.

6.3.2 Pressure Calibration

From the Utility Menu Screen shown in Figure 6.1, select the **F4** key on the control unit keyboard. This will bring up the Volumetric Flow Calibration Screen as shown below. Additional details on the various menu selections can be found in Section 4.4 of this manual.

```
Pressure Calibration

SASS   Pt  Save   Reference
 730    1     0   000 mmHg      Save(F1)
        2   730   730 mmHg      Save(F4)


Calibrate             Default    Exit
```

Figure 6.3 Pressure Calibration Screen

Comparing the current SASS pressure measurement with a reference barometer can make a preliminary check. The pressure indicated for the SASS should be within ±10 mm Hg of the reference pressure device. If the measurement is in excess of this value, then it may be necessary to re-calibrate the sensor in the SASS using a two-point barometric pressure measurement.

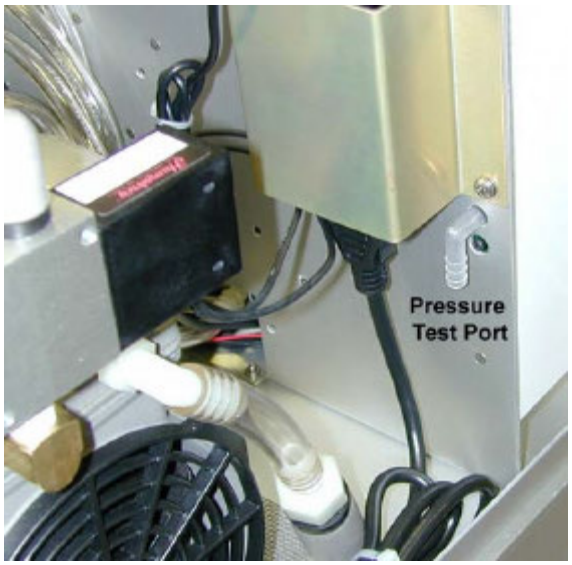


Figure 6.4 Pressure Test Port

To perform a pressure calibration, a few items will be required. This includes a precision barometer or other pressure-monitoring device that has a range of 600 to 800 mm Hg with accuracy in excess of 0.1mm Hg. Located inside the pump enclosure just under the power supply on the center wall on the pump side is a nylon right angle connection that attaches to the pressure transducer. This can be seen in Figure 6.4.

To perform a calibration, two measurement points will be necessary. This can be accomplished by using a syringe, some tubing, a tee, and the precision reference pressure device. See Figure 6.5 for detail of pressure test setup. Connect from the pressure test point to a tee connector using some tubing, one side of the tee goes to the pressure measurement device and the other to the syringe. The size syringe required is dependent upon the length (total air volume) of tubing used to make this test apparatus. The syringe is used to change the pressure inside the tubing from below ambient to above ambient. Adjust the syringe in and out to change the simulated test pressure measured by the reference device and transferred to the sensor inside the SASS. Two typical readings would be 600 and 760 mmHg. First verify that the syringe is able to adjust the simulated barometric pressure to 600 mmHg and 800 mmHg. Adjust the size of the syringe or the lengths of tubing to provide the necessary adjustments.

Once set begin the following sequence to calibrate the internal barometer to the reference standard.

1. Set the simulated pressure value to 600 mmHg as measured from the reference pressure sensor. When the measurement is stable, enter the value measured from the reference in the top reference window. When completed press **F1** to save this value.

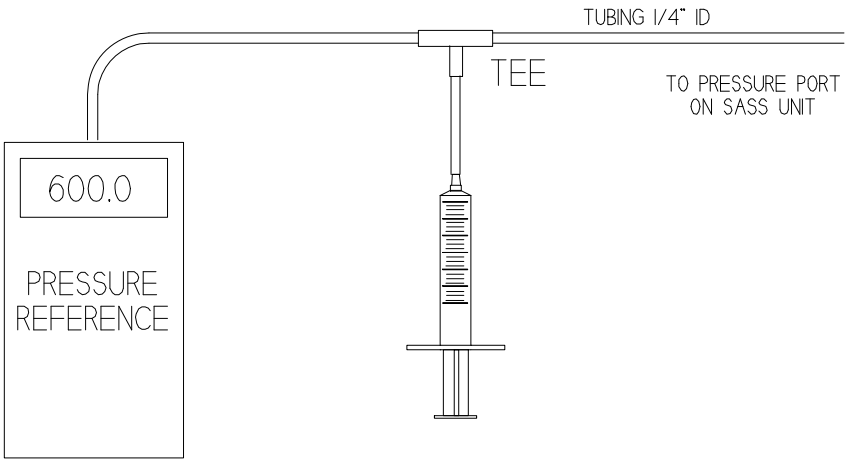


Figure 6.5 Pressure Test Setup

2. Now set the simulated pressure value to 800 mmHg as measured from the reference sensor. When the measurement is stable, enter the value measured from the reference in the second reference window. When completed press **F4** to save this value.

3. Now press the "Calibrate" key and the new values will be saved in memory of the control unit.

4. This calibrated the pressure sensor in the pump box to the reference barometer. Re-run the pressure checks previously outlined and verify that the new measurement is within the ±10 mmHg tolerance. If they are not, then rerun the calibration test one more time.

5. If it fails the test a second, time, there is the possibility that the pressure sensor is damaged, and will need to be replaced. If a new sensor is installed, be sure to set the replacement sensor using the "Default" menu selection. This will return to the original measurement factors.

Remove the test apparatus and log the results in the on site maintenance log.

6.2.3 Flow Calibration

From the Utility Menu Screen shown in Figure 6.1, select the **F2** key on the control unit keyboard. This will bring up the Volumetric Flow Calibration Screen as shown below. Additional details on the various menu selections can be found in Section 4.4 of this manual.

Note: There are only 4 flow channels in the Super SASS

```
Volumetric Flow Calibration

Chan  SASS   Ref        Type
 (1)    .0   6.9 LPM    10 LPM FS

             Pump: OFF

Calibrate    Pump     Default    Exit
```

Figure 6.6 Volumetric Flow Calibration Screen

Before beginning the calibration, it will be necessary to have some type of reference flow device that has a calibration that is traceable to NIST, or some other approved calibration authority. The best type of flow unit to use is one that is a direct reading device that has minimal inline flow restriction. Some of the flow measurement devices can restrict the flow, to a point that it is difficult to measure at the operating flow rate of the system.

Using a flow test device, and any adapter that might be necessary to adapt to the input tube of the SCC, measure the flow at each of the canisters. The SCC inlet adapter part number 8959 can be used. Using the Up/Down key select each of the flow line positions. The SASS has 5 flow monitors while the SuperSASS has 4 flow lines. In the SuperSASS these same four lines are also used by the second set of 4 sample canisters. These keys are used to change the channel being monitored. All measured flows, should be within ±0.67 LPM or ±10%[24] of the reference standard. The channels 4&5 of the SASS are set to ± 0.69 LPM or ±10%[24]. If any value is in excess of this tolerance, entering the value of the reference in the Reference position and then hitting the “Calibrate” key can calibrate the channel. This will enter in the correctly measured value for that channel. Use this same procedure for any other channels that may require recalibration. Record all changes to the system in the onsite logbook.

6.4 Troubleshooting

Since this is a new instrument, Met One Instruments will revise the operation manual to include additional troubleshooting steps and operator information as it becomes available. If your problem is not listed, please contact the Met One factory and ask for SASS Technical Service (541) 471-7111.

PROBLEM(S)	ACTION
Torn or suspect filter catch	1. Inspect filter holder and connections 2. Check sampler pneumatics
Out of specification (+/- 10% of transfer standard)	1. Completely remove flow rate measurement adapter; reconnect and perform flow rate check again. 2. Perform leak test 3. Check flow rate at three points to determine if flow rate problem with slope. 4. Recalibrate flow rate
Leak outside acceptable tolerance	1. Completely remove flow rate measurement adapter; reconnect and perform leak test again. 2. Inspect all seals and o-rings; replace as necessary and perform leak test again. 3. Check sampler with different leak test device.
Consistently low flows during sample runs	1. Check programming of sampler flow rate. 2. Check flow with a flow rate verification filter and determine if actual flow is low.
Out of specification (+/- 4°C of standard)	1. Recalibrate sensor; replace sensor.
Out of specification (+/- 10 mm Hg of standard)	1. Make certain pressure sensors are exposed to the ambient air and are not in direct sunlight. 2. Call local airport or other source of ambient pressure data and compare that pressure to pressure data from monitors sensor; pressure correction may be required. 3. Connect new pressure sensor.
Out of specification (+/- 5 min)	1. Check programming; verify power outages 2. Reset
Sample did not run	1. Check programming 2. Try programming sample run to start while operator is at site; ensure the transport filter is in the unit.
Power Interruptions	1. Check line voltage
Liquid-crystal display pen on, but sample not working.	1. Check to see that plugs are in place and there are no loose connections
Data did not transfer to laptop computer	1. Document key information on sample data sheet. Make sure problem is resolved before data may be overwritten.

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Appendix A

Consumables, Spare Parts, and Maintenance Items.

Description	Met One Part Number
Accessory and Replacement Parts:	
Sharp Cutoff Cyclone, 2.5 Micron, Complete	8670
Filter Canister, includes filter holders, less SCC	8370
47 mm Filter Holder	460128
SCC Intake Tube to Flow Unit Adaptor	8959
Ambient Temperature Probe (Sensor)	064-1
Temperature. Solar Radiation Shield w/mount	5980
Consumables:	
47mm 2 micron Pore Size Teflon Filters (50/pkg)	460137
47mm Glass Fiber Filters (100/pkg)	460138
47mm Quartz Fiber Filters (50/pkg)	460139
47mm 1 micron Pore Size Nylon Filters (100/pkg)	460141
Coated, MgO Denuder with Mounting Ring	8382
Maintenance:	
Pump Service Kit (2 Required) Select Pump Series	
Pump Series 2628	680850
Pump Series 2639	680851
Pump Series 2688	680855
Pump Series 2669	680856
Canister O-Ring Kit	8657
Sharp Cutoff Cyclone O-Ring Kit	8658
Replaceable Spare Parts:	
Muffler, pump by-pass	580293
Muffler, main exhaust	580297
Flow Sensor Unit	8424
AC/DC Power Supply	510645
In-Line Filter Unit (4 per Unit)	580299
Female Quick Connection (Pump Box)	580012
Female Quick Connection SuperSASS (Pump Box)	580010
Male Quick Connection (Tubing End)	580011
¼" OD Black Polyethylene Tubing	960020
3/8" OD Black Tubing	960205
3/8" OD Clear Tygon Tubing	960200
Pump Unit	680832
Flow Control Module	9053
Line Select Solenoid Valve	8893
Pump By-Pass Solenoid	8894
SCC Grit Cap	8664
Fan, Pump Box	590052
15 Amp AC Fuse	590816

Appendix B
Typical Transfer of Custody Form

Q10013M	PM 2.5 STN CUSTODY AND FIELD DATA FORM TRAINING DB FOR TRAINING USE ONLY	c. White (return to lab) c. Yellow (site retains) c. Pink (lab)

A. CUSTODY RECORD (Name, Date) **Bin ID:** B1043Y

1. Laboratory, Out Jim O'Rourke 11/1/99
2. Site, In _____
3. Site, Out _____
4. Lab, In _____

B. SITE AND SAMPLER INFORMATION

1. Site AIRS Code 199901
2. Sampler S/N 100-3
3. Sampler Type SASS
4. Sampler POC 3
5. Site Name EPA/RTP-SASS
6. Intended date of use Thursday, November 04, 1999
7. Date of Sampler set-up _____
8. Operator's name _____

C. SAMPLER CHANNEL COMPONENT

Channel No.	Component ID No.	Component Description
1	Kept at Site	SASS cyclone
1	I1006S	SASS cassette (Teflon filter) (GREEN)
2	Kept at Site	SASS cyclone
2	I1007T	SASS cassette (MgO denuder nylon filter) (RED)
3	Kept at Site	SASS cyclone
3	I1008U	SASS cassette (quartz filter) (ORANGE)

D. START, END, AND RETRIEVAL TIMES

Channel No.	Start date	Start time	End date	End time	Retrieval date	Retrieval time
1						
2						
3						

E. SAMPLER CHANNEL INFORMATION (Post-Sampling)

Channel No.	Run Time	Run Time, Flag	Sample Volume (m3)	Avg. flow (L/min)	Avg. flow CV (L/min)	Avg. ambient T (° C)	Max. ambient T (° C)	Min. ambient T (° C)
1								
2								
3								

Channel No.	Δ T Flag	Avg. Filter T (° C)	Max. Filter T (° C)	Min. Filter T (° C)	Avg. BP (mm Hg)	Max. BP (mm Hg)	Min. BP (mm Hg)
1							
2							
3							

F. Comments _____

Appendix C
Denuder Maintenance

Coated Denuder

Coating:
Met One Instruments recommends to SASS users that the MgO coated aluminum multicell material and coated be provided by Met One. The multicell aluminum material is a sole source manufacturing company and when received in a bulk form it must be cleaned and made ready to coat.

Customers who wish to do their own coating can contact Met One for cut and cleaned multicell material which is pushed into the Denuder sleeve aluminum ring for use in the sampling canister.

Operational life expectancy of the MgO coated aluminum Denuder is six months in an urban airshed like Los Angeles. Re-coating of the material is not practical and therefore not recommended.

The Met One MgO Coating Procedure Follows, however users should consult the factory for improved or updated process.

Note: Laboratory Safety and Personal Protection Procedures Shall be applied.
Use of gloves and a respirator is required.

1. The aluminum multicell material is washed in an ultrasonic bath under an explosive proof fume hood for five minutes using Methanol.
2. Air dry to complete dryness. Use of filtered laboratory air is necessary for quick drying.
3. Pour approximately 150ml of CH3OH into a clean glass beaker
4. Place a #150 mesh Stainless Steel screen over the top opening of the beaker.
5. Using gloves, place MgO power reagent on top of the screen and using a clean spatula press the MgO through the screen into the CH3OH.
6. Mix thoroughly
7. Using gloves, hand dip the multicell material into the slurry by dipping both one side and then the other to thoroughly coat the internal surfaces of the hexagonal cells.
8. Using filtered laboratory air in a hood, rotate the coated multicell material and blow-filtered air over the surface until the MgO starts to dry to the touch. Approximately 1 minute is necessary before it can be set down.
9. Set coated denuder in clean area and let dry 24 hours before packaging or use.

(1) HF; (2) HCl; (3) H_3PO_4; (4) HBr; (5) HNO_3; (6) H_2SO_4

MW: Table 1 CAS: Table 1 RTECS: Table 1

METHOD: 7903, Issue 2 **EVALUATION: FULL** **Issue 1: 15 February 1984**
Issue 2: 15 August 1994

OSHA : Table 1
NIOSH: Table 1
ACGIH: Table 1

PROPERTIES: Table 1

SYNONYMS: (1) hydrofluoric acid; hydrogen fluoride
(2) hydrochloric acid; hydrogen chloride
(3) phosphoric acid; ortho-phosphoric acid; meta-phosphoric acid
(4) hydrobromic acid; hydrogen bromide
(5) nitric acid; aqua fortis
(6) sulfuric acid; oil of vitriol

SAMPLING

SAMPLER: SOLID SORBENT TUBE (washed silica gel, 400 mg/200 mg with glass fiber filter plug)

FLOW RATE: 0.2 to 0.5 L/min

VOL-MIN: 3 L
-MAX: 100 L

SHIPMENT: routine

SAMPLE STABILITY: stable at least 21 days @ 25 °C [1]

BLANKS: 2 to 10 field blanks per set

ACCURACY

RANGE STUDIED: see EVALUATION OF METHOD

BIAS: see EVALUATION OF METHOD

OVERALL PRECISION ($\hat{S}_{rT}$): see EVALUATION OF METHOD

ACCURACY: ± 12 to ± 23%

MEASUREMENT

TECHNIQUE: ION CHROMATOGRAPHY

ANALYTE: F^-, Cl^-, PO_4^{3-}, Br^-, NO_3^-, SO_4^{2-}

DESORPTION: 10 mL 1.7 mM $NaHCO_3$/1.8 mM Na_2CO_3

INJECTION LOOP VOLUME: 50 µL

ELUENT: 1.7 mM $NaHCO_3$/1.8 mM Na_2CO_3; 3 mL/min

COLUMNS: HPIC-AS4A anion separator, HPIC-AG4A guard, anion micro membrane suppressor [2]

CONDUCTIVITY SETTING: 10 µS full scale

RANGE: see EVALUATION OF METHOD

ESTIMATED LOD: see EVALUATION OF METHOD

PRECISION ($\bar{S}_r$): see EVALUATION OF METHOD

APPLICABILITY: The working range is ca. 0.01 to 5 mg/m^3 for a 50-L air sample (see EVALUATION OF METHOD). This method measures the total concentration of six airborne anions. The corresponding acids may be collected on a single sam pler and determined simultaneously. Formic acid has been determined by this method [3].

INTERFERENCES: Particulate salts of all the acids will give a positive interference. Chlorine or hypochlorite ion interfere with chloride determination and bromine interferes with bromide. Silica gel will collect ca. 30% of the free Cl_2 and Br_2 in an atmosphere [4]. Acetate, formate and propionate have elution times similar to F^- and Cl^-. If these anions are present, use a weak eluent (e.g., 5 mM $Na_2B_4O_7$) for greater resolution.

OTHER METHODS: This is P&CAM 339 in a revised format [5]. Alternate methods are 7902 for fluoride and P&CAM 268 for sulfate [6].

REAGENTS:

1. $NaHCO_3$, reagent grade.
2. Na_2CO_3, reagent grade.
3. Distilled, deionized water, filtered through 0.45-µm membrane filter.
4. Eluent: bicarbonate/carbonate buffer solution (1.7 mM $NaHCO_3$/1.8 mM Na_2CO_3). Dissolve 0.5712 g $NaHCO_3$ and 0.7631 g Na_2CO_3 in 4 L filtered deionized water.
5. Calibration stock solutions, 1 mg/mL (as the anion). Dissolve salt in filtered deionized water.
   a. Fluoride: 0.2210 g NaF/100 mL.
   b. Chloride: 0.2103 g KCl/100 mL.
   c. Phosphate: 0.1433 g KH_2PO_4/100 mL.
   d. Bromide: 0.1288 g NaBr/100 mL.
   e. Nitrate: 0.1371 g $NaNO_3$/100 mL.
   f. Sulfate: 0.1814 g K_2SO_4/100 mL.

* See SPECIAL PRECAUTIONS.

EQUIPMENT:

1. Sampler: glass tube, 11 cm x 7-mm OD, containing a 400-mg front section and 200-mg backup section of washed silica gel, flame-sealed ends with plastic caps. Front section is retained with a glass fiber filter plug. Urethane plugs separate and retain the backup section. Tubes are commercially available (Supelco ORBO 53 or equivalent) or may be prepared according to APPENDIX.
2. Personal sampling pump, 0.2 to 0.5 L/min, with flexible connecting tubing.
3. Ion chromatograph, HPIC-AG4A anion separator and HPIC-AG4A anion micro membrane suppressor, conductivity detector, integrator and strip chart recorder.
4. Waterbath: hotplate with beaker of boiling water.
5. Centrifuge tubes, 15-mL, graduated, plastic, with caps.*
6. Syringes, 10-mL, polyethylene with luer tip.
7. Filters, luer tip, with membrane filter, 13-mm, 0.8-µm pore size.
8. Micropipettes, disposable tips.
9. Volumetric flasks, 50- and 100-mL.*
10. Laboratory timer.
11. Bottles, polyethylene, 100-mL.
12. Auto sampler vials (optional).

* Thoroughly clean glassware with mild detergent, rinse thoroughly with deionized water, to minimize anion blank values.

SPECIAL PRECAUTIONS: Acids, particularly HF, are extremely corrosive to skin, eyes, and mucous membranes. HF will attack glass. Plastic labware is recommended.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break ends of sampler immediately before sampling. Attach sampler to personal sampling pump with flexible tubing.
3. Sample at an accurately known flow rate between 0.2 and 0.5 L/min for a total sample size of 3 to 100 L.
   NOTE: Do not exceed 0.3 L/min when sampling for HF.

SAMPLE PREPARATION:

4. Score sampler with a file in front of primary sorbent section.
5. Break sampler at score line. Transfer glass fiber filter plug and front sorbent section to a 15-mL graduated centrifuge tube.

NOTE: Particulate salts of the volatile acids (HCl, HB, HF, and HNO_3), if present in the air sample, will collect on the glass fiber filter plug. To estimate the concentration these salts, analyze the plug separately from the front sorbent section.

6. Place backup sorbent section in separate centrifuge tube. Discard urethane plugs.
7. Add 6 to 8 mL eluent to each centrifuge tube. Heat in boiling waterbath for 10 min.
   NOTE: Eluent used for desorption should be from same batch as the eluent used in the chromatograph to avoid carbonate/bicarbonate peaks near F^- and Cl^-.
8. Allow to cool, dilute to 10.0-mL volume with eluent.
9. Cap the centrifuge tube and shake vigorously.
10. Pour sample into 10-mL plastic syringe fitted with in-line filter.

CALIBRATION AND QUALITY CONTROL:

11. Calibrate daily with at least six working standards covering the range 0.001 to 0.3 mg of each anion per sample.
    a. Add known aliquots of calibration stock solution to eluent in 50-mL volumetric flasks and dilute to the mark.
    b. Store working standards in tightly-capped polyethylene bottles. Prepare fresh working standards weekly.
    c. Analyze working standards together with samples and blanks (steps 12 through 14).
    d. Prepare a calibration graph for each anion [peak height (mm or µS) vs. concentration (µg per sample)].

MEASUREMENT:

12. Set ion chromatograph to conditions given on page 7903-1, according to manufacturer's instructions.
13. Inject 50-µL sample aliquot. For manual operation, inject 2 to 3 mL of sample from filter/syringe to ensure complete rinse of sample loop.
    NOTE: All samples, eluents and water flowing through the IC must be filtered to avoid plugging system valves or columns.
14. Measure peak height.
    NOTE: If sample peak height exceeds linear calibration range, dilute with eluent, reanalyze and apply the appropriate dilution factor in calculations.

CALCULATIONS:

15. Determine the mass, µg, of anion found in the sample front (W_f) and back (W_b) sorbent sections, and in the average media blank front (B_f) and back (B_b) sorbent sections.
16. Calculate concentration, C, of acid in the air volume sampled, V (L):

$$C = \frac{(W_f + W_b - B_f - B_b) \cdot F}{V}, \text{ mg/m}^3.$$

where: F (conversion factor from anion to acid) = 1.053 for HF; 1.028 for HCl; 1.032 for H_3PO_4; 1.012 for HBr; 1.016 for HNO_3; and 1.021 for H_2SO_4.

EVALUATION OF METHOD:

The method was evaluated for hydrochloric, hydrobromic, nitric, phosphoric and sulfuric acids by laboratory generation of mixed acids [1]. Data for the individual analytes are:

Acid	Range Studied (mg/m^3)	Range Studied (µg/sample)	(%)	Measurement Precision ($\bar{S}_r$)	Overall Precision ($\hat{S}_{rT}$)	Accuracy (%)	Estimated LOD [2] (µg per sample)
HF [7]	0.35 - 6	0.5 - 200	0.7	0.053	0.116	±23.4	0.7
HCl [8]	0.14 - 14	0.5 - 200	0.3	0.025	0.059	±11.9	0.6
H_3PO_4 [1]	0.5 - 2	3 - 100	-0.9	0.029	0.096	±19.7	2.0
HBr [1]	2 - 20	3 - 960	2.0	0.056	0.074	±16.5	0.9
HNO_3 [1]	1 - 10	3 - 500	2.0	0.018	0.085	±18.7	0.7
H_2SO_4 [1]	0.5 - 2	3 - 100	2.4	0.028	0.087	±19.4	0.9

The method was field-evaluated at two electroplating facilities using side-by-side silica gel tubes and bubblers. The method was evaluated for hydrofluoric acid in 1983 using the silica gel tubes and impingers [7]. Recovery based on impinger collection was 106% with $\hat{S}_{rT}$ of 0.116. The capacity of the silica gel sampler for HF was 820 µg. This is equivalent to an 8-h sample at two to three times the OSHA PEL. Samples were stable for at least 21 days at 25 °C. Updated analytical columns have been used by NIOSH for analytical sequences [2].

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APPENDIX: SAMPLING TUBE PREPARATION

Silica gel cleaning procedure: Add 500 to 600 mL deionized water, slowly and with stirring, to ca. 200 mL volume of silica gel in 1-L beaker. When exothermal reaction has subsided, heat in boiling waterbath for ca. 30 min with occasional stirring. Decant and rinse four to five times with deionized water. Repeat cleaning procedure and dry overnight in 100 °C oven until free flowing. If blank of silica gel shows impurities upon analysis by ion chromatography, repeat cleaning procedure.

Silica gel tubes: Pack glass tubes, 7-mm OD, 4.8-mm ID, 11 cm long, with 400 mg of 20/40 mesh washed silica gel in front section and 200 mg backup section. Use urethane foam plugs between sorbent sections and at back end. Hold front section in place with 6-mm diameter, 1-mm thick glass fiber filter plug (Gelman 66088).

TABLE 1. GENERAL INFORMATION.

Acid and BP M.W. (°C)	PROPERTIES CAS Sp. Gr. RTECS (liq.)	EXPOSURE LIMITS VP @ 20 °C OSHA kPa (mm Hg)	NIOSH	ACGIH	mg/m^3 = 1 ppm @ NTP	Physical State	MP (°C)
HF 19.5 (20.01)	7664-39-3 0.987 MW7875000	3 ppm >101 (>760)	3 ppm; 6 ppm STEL	C 3 ppm;	0.818	gas	-83.1
HCl -114.8 (36.46)	7647-01-0 -85.0 MW4025000	C 5 ppm 1.194	C 5 ppm >101 (760)	C 5 ppm	1.491	gas	
H_3PO_4 260 (97.99)	7664-38-2 1.7 TB6300000	1 mg/m^3 0.0038 (0.03)	1 mg/m^3;* STEL 3 mg/m^3	1 mg/m^3; STEL 3 mg/m^3	(aerosol)	liquid	21.0
HBr -66.8 (80.92)	10035-10-6 2.16 MW3850000	3 ppm >101 (>760)	C 3 ppm	C 3 ppm	3.31	gas	-88.5
HNO_3 -42.0 (63.01)	7697-37-2 83 QU5775000	2 ppm 1.50	2 ppm; 0.39 (2.9) STEL 4 ppm	2 ppm; STEL 4 ppm	2.58	liquid	
H_2SO_4 290 (98.08)	7664-93-9 1.84 W55600000	1 mg/m^3 <0.0001 (<0.001)	1 mg/m^3*	1 mg/m^3 STEL 3 mg/m^3	(aerosol)	liquid	3.0

*Group I Pesticide

EPA/625/R-96/010a

Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air

Compendium Method IO-3.3

DETERMINATION OF METALS IN AMBIENT PARTICULATE MATTER USING X-RAY FLUORESCENCE (XRF) SPECTROSCOPY

Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

June 1999

Method IO-3.3

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DISCLAIMER

This Compendium has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Method IO-3.3
Determination of Metals in Ambient Particulate Matter Using
X-Ray Fluorescence (XRF) Spectroscopy

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Chapter IO-3
CHEMICAL SPECIES ANALYSIS OF FILTER-COLLECTED SPM

Method IO-3.3
DETERMINATION OF METALS IN AMBIENT PARTICULATE MATTER USING X-RAY FLUORESCENCE (XRF) SPECTROSCOPY

1. Scope

1.1 During a span of more than two decades, the U. S. Environmental Protection Agency (EPA) has developed and applied x-ray fluorescence (XRF) to the analysis of ambient and source aerosols using both energy and wavelength dispersive spectrometers. Inorganic Compendium Method IO-3.3 briefly describes the agency's experience with XRF and informs the reader of its capability in elemental aerosol analysis and attempts to give a brief account of what is involved in its application. The procedures described have been in a continual state of evolution beginning with those in use on a special purpose spectrometer designed by Lawrence Berkeley Laboratory (LBL) and eventually applied to a commercially available instrument manufactured by Kevex. It is for the Kevex spectrometer to which this method applies.

1.2 The area of toxic air pollutants has been the subject of interest and concern for many years. Recently the use of receptor models has resolved the elemental composition of atmospheric aerosol into components related to emission sources. The assessment of human health impacts resulting in major decisions on control actions by Federal, state, and local governments is based on these data. Accurate measures of toxic air pollutants at trace levels is essential to proper assessments.

1.3 Suspended particulate matter (SPM) in air generally is considered to consist of a complex multi-phase system consisting of all airborne solid and low vapor pressure, liquified particles having aerodynamic particle sizes ranging from below 0.01 microns to 100 (0.01 Fm to 100 Fm) microns and larger. Historically, measurement of SPM has concentrated on total suspended particulates (TSP) with no preference to size selection.

1.4 The most commonly used device for sampling TSP in ambient air is the high-volume sampler, which consists essentially of a blower and a filter, and which is usually operated in a standard shelter to collect a 24-hour sample. The sample is weighed to determine concentration of TSP and is usually analyzed chemically to determine concentration of various inorganic compounds. When EPA first regulated TSP, the National Ambient Air Quality Standard (NAAQS) was stated in terms of SPM with aerodynamic particle size of < 100 Fm captured on a filter as defined by the high-volume TSP sampler. Therefore, the high-volume TSP sampler was the reference method. The method is codified in 40CFR50, Appendix B.

1.5 More recently, research on the health effects of TSP in ambient air has focused increasingly on particles that can be inhaled into the respiratory system, i.e., particles of aerodynamic diameter of < 10 Fm. These particles are referred to as PM_{10}. It is now generally recognized that, except for toxic materials, it is this PM_{10} fraction of the total particulate loading that is of major significance in health effects. The reference method for PM_{10} is codified in 40CFR50, Appendix J and specifies a measurement principle based on extracting an ambient air sample with a powered sampler that incorporates inertial separation of PM_{10} size range particles and collection of these particles on a filter for a 24-hour period. Again, the sample is weighed to determine concentration of PM_{10} and is usually analyzed chemically to determine concentration of various inorganic compounds.

1.6 Further research now strongly suggests that atmospheric particles commonly occur in two distinct modes, the fine (< 2.5 µm) mode and the coarse (2.5 to 10.0 Fm) mode. The fine or accumulation mode (also termed the respirable particles) is attributed to growth of particles from the gas phase and subsequent agglomerization, whereas the coarse mode is made up of mechanically abraded or ground particles. Because of their initially gaseous origin, the fine range of particle sizes includes inorganic ions such as sulfate, nitrate, and ammonium as well as combustion-form carbon, organic aerosols, metals, and other combustion products. Coarse particles, on the other hand, normally consist of finely divided minerals such as oxides of aluminum, silicon, iron, calcium, and potassium. Samplers which separate SPM into two size fractions of 0-2.5 µm and 2.5-10 µm are called dichotomous samplers. In 1997, the EPA promulgated a new standard with fine particles. The new $PM_{2.5}$ standard replaced the previously NAAQS for PM_{10}.

1.7 Airborne particulate materials retained on a sampling filter, whether TSP, PM_{10}, $PM_{2.5}$, or dichotomous size fractions, may be examined by a variety of analytical methods. This method describes the procedures for XRF analysis as the analytical technique. The XRF method provides analytical procedures for determining concentration in ng/m^3 for 44 elements that might be captured on typical filter materials used in fine particle or dichotomous sampling devices. With the sample as a thin layer of particles matrix effects substantially disappear so the method is applicable to elemental analysis of a broad range of particulate material. The method applies to energy dispersive XRF analysis of ambient aerosols sampled with fine particle (< 2.5 µm) samplers, dichotomous and VAPS (versatile air pollution sampler) samplers with a 10 µm upper cut point and PM_{10} samples.

1.8 The analysis of ambient aerosol samples captured on filterable material should be performed by a scientist that has been trained in energy dispersive x-ray fluorescence spectroscopy and its associated data processing system. The training should be performed by a scientist with an advance degree in the physical sciences with a minimum of 5 years experience in x-ray spectroscopy.

2. Applicable Documents

2.1 ASTM Documents

- D4096 Application of High Volume Sample Method For Collection and Mass Determination of Airborne Particulate Matter.
- D1356 Definition of Terms Related to Atmospheric Sampling and Analysis.
- D1357 Practice For Planning the Sampling of the Ambient Atmosphere.

2.2 U.S. Government Documents

- U.S. Environmental Protection Agency, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide for Environmental Quality Assurance*, EPA-600/R-94/038a.
- U.S. Environmental Protection Agency, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods (Interim Edition)*, EPA-600/R-94/038b.
- "Reference Method for the Determination of Particulate Matter in the Atmosphere," *Code of Federal Regulations*, 40 *CFR* 50, Appendix B.
- "Reference Method for the Determination of Particulate Matter in the Atmosphere (PM_{10} Method)," *Code of Federal Regulations*, 40 *CFR* 50, Appendix J.
- "1978 Reference Method for the Determination of Lead in Suspended Particulate Matter Collected From Ambient Air." *Federal Register* 43 (194):46262-3.
- *Test Methods for Evaluating Solid Waste, Method 9022*, EPA Laboratory Manual, Vol. 1-A, SW-846.

2.3 Other Documents

- Kevex XRF TOOLBOX II Reference Manual
- Kevex 771-EDX Spectrometer User's Guide and Tutorial

3. Summary of Method

[Note: This method was developed using the Kevex spectrometer. EPA has experience in the use of the Kevex spectrometer associated with various field monitoring programs involving analysis of filterable particulate matter for metals over the last two decades. The use of other manufacturers of x-ray spectrometers should work as well as long as the quality assurance and quality control specifications identified in Sections 12 through 14 of Method 10-3.3 are met. However, modifications to Compendium Method IO-3.3 procedures may be necessary if another commercial x-ray spectrometer is used.]

The method described is x-ray fluorescence applied to PM_{10}, fine (< 2.5 µm) and coarse (2.5-10 µm) aerosols particles captured on membrane filters for research purposes in source apportionment. The samplers which collect these particles are designed to separate particles on their inertial flow characteristics producing size ranges which simplify x-ray analysis. The instrument is a commercially available Kevex EDX-771 energy dispersive x-ray spectrometer which utilizes secondary excitation from selectable targets or fluorescers and is calibrated with thin metal foils and salts for 44 chemical elements. Spectra are acquired by menu-driven procedures and stored for off-line processing. Spectral deconvolution is accomplished by a least squares algorithm which fits stored pure element library spectra and background to the sample spectrum under analysis. X-ray attenuation corrections are tailored to the fine particle layer and the discrete coarse particle fraction. Spectral interferences are corrected by a subtractive coefficient determined during calibration. The detection limits are determined by propagation of errors in which the magnitude of error from all measured quantities is calculated or estimated as appropriate. Data are reported in ng/m^3 for all samples. Comprehensive quality control measures are taken to provide data on a broad range of parameters, excitation conditions and elements.

4. Significance

4.1 The area of toxic air pollutants has been the subject of interest and concern for many years. Recently the use of receptor models has resolved the elemental composition of atmospheric aerosol into components related to emission sources. The assessment of human health impacts resulting in major decisions on control actions by federal, state and local governments are based on these data.

4.2 Inhalable ambient air particulate matter (< 10 µm) can be collected on Teflon® filters by sampling with a dichotomous sampler and analyzed for specific metals by X-ray fluorescence. The dichotomous sampler collects particles in two size ranges - fine (< 2.5 µm) and coarse (2.5-10 µm). The trace element concentrations of each fraction are determined using the nondestructive energy dispersive X-ray fluorescence spectrometer.

4.3 The detectability and sensitivity of specific elements may vary from instrument to instrument depending upon X-ray generator frequency, multichannel analyzer sensitivity, sample interferences, etc.

5. Definitions

[Note: Definitions used in this document are consistent with ASTM Methods. All pertinent abbreviations and symbols are defined within this document at point of use.]

5.1 Accuracy. The agreement between an experimentally determined value and the accepted reference value.

5.2 Attenuation. Reduction of amplitude or change in wave form due to energy dissipation or distance with time.

5.3 Calibration. The process of comparing a standard or instrument with one of greater accuracy (smaller uncertainty) for the purpose of obtaining quantitative estimates of the actual values of the standard being calibrated, the deviation of the actual value from a nominal value, or the difference between the value indicated by an instrument and the actual value.

5.4 10 µm Dichotomous Sampler. An inertial sizing device that collects suspended inhalable particles (< 10 µm) and separates them into coarse (2.5-10 µm) and fine (< 2.5 µm) particle-size fractions.

5.5 Emissions. The total of substances discharged into the air from a stack, vent, or other discrete source.

5.6 Filter. A porous medium for collecting particulate matter.

5.7 Fluorescent X-Rays (Fluorescent Analysis). Characteristic X-rays excited by radiation of wavelength shorter than the corresponding absorption edge.

5.8 Inhalable Particles. Particles with aerodynamic diameters of < 10 µm which are capable of being inhaled into the human lung.

5.9 Interference. An undesired positive or negative output caused by a substance other than the one being measured.

5.10 Precision. The degree of mutual agreement between individual measurements, namely repeatability and reproducibility.

5.11 Standard. A concept that has been established by authority, custom, or agreement to serve as a model or rule in the measurement of quantity or the establishment of a practice or procedure.

5.12 Traceability to NIST. A documented procedure by which a standard is related to a more reliable standard verified by the National Institute of Standards and Technology (NIST).

5.13 Uncertainty. An allowance assigned to a measured value to take into account two major components of error: (1) the systematic error, and (2) the random error attributed to the imprecision of the measurement process.

5.14 Chi-square. A statistic which is a function of the sum of squares of the differences of the fitted and measured spectrum.

5.15 Fluorescer. A secondary target excited by the x-ray source and in turn excites the sample.

5.16 FWHM. Full width at half maximum, a measure of spectral resolution.

5.17 NIST. National Institute of Standards and Technology.

5.18 Shape. The actual shape of a background corrected pulse height spectrum for an element.

5.19 SRMs. Standard reference materials.

5.20 Teflo®. Trade name of a Teflon filter.

5.21 Unknown. A sample submitted for analysis whose elemental concentration is not known.

5.22 XRF. X-ray fluorescence.

6. Description of Spectrometer

The x-ray analyzer is a Kevex EDX-771 energy dispersive spectrometer with a 200 watt rhodium target tube as an excitation source. The machine has multiple modes of excitation including direct, filtered direct, and secondary which utilizes up to 7 targets or fluorescers. To minimize radiation damage to delicate aerosol samples only the secondary mode is used. Table 1 provides a listing of the fluorescers and the elements which they excite associated with energy dispersive spectrometers. Analysis atmospheres are selectable with choices of helium, vacuum or air; helium is used for all targets except Gd where air is employed because it gives a lower background. The detector is cryogenically cooled lithium-drifted silicon with a 5 µm Be window and a resolution of 158 eV at Fe K_{α} and comes with two manually changeable collimators. A 16 position rotating wheel accommodates the samples and provides sample changing.

The machine is operated by procedure files (or programs) written in Kevex's proprietary Job Control Language (JCL) which runs in a Windows 3.1 environment and provides setting of the analytical conditions and data acquisition. Using the JCL language, procedures have been written in-house to perform all the

functions necessary to acquire spectra and to assign to them file names in a structured manner to facilitate future spectral processing. These procedures are invoked in menu form.

7. Caveats

7.1 The type of samplers mentioned in Section 1.7 must be operated in accordance with Inorganic Compendium Method IO-2.2 Sampling for Suspended Particulate Matter in Ambient Air Using a Dichotomous Sampler, or severe errors in x-ray analysis may occur. For example, errors in flow rate will not only give erroneous volumes but will cause a more serious condition of altering the cut points upon which the coarse particle x-ray attenuations are based. If samples are intended for x-ray analysis then the sampling protocol must conform to the constraints inherent within this method. Furthermore, the type of filter on which the sample is collected is very important. In general, thin membrane filters (Teflo® and Nuclepore®) are required so that the background is low and penetration of particles into the matrix of the filter is small. Thick depth filters such as quartz or glass fiber not only have high background but also allow particles to penetrate into the matrix of the filter - a condition which the spectral processing program cannot accommodate.

7.2 Some internal contaminations consisting of Sn, Ni, Cu and Fe are present which sometimes appear in blanks. Routine analysis of blanks with samples will give the magnitude of the correction necessary to compensate for this.

7.3 In general the elements analyzed by the Gd fluorescer have higher detection limits than the other fluorescers (see Table 2). The reason for this is due to limitations in the upper voltage limit of the x-ray tube power supply and the use of rhodium instead of a heavier element such as tungsten as a target material for the x-ray tube. As a secondary consequence of this, there are also higher detection limits for many of the elements below chromium because they overlap the elements analyzed by Gd.

7.4 An inherent problem with a helium atmosphere is the diffusion of He through the detector window causing detector degradation and necessitating replacement. A lifetime of 3 to 4 years is expected.

7.5 Due to an x-ray leak around the anode area of the x-ray tube the head must be shielded with additional lead cladding to prevent unwanted excitation of internal parts. This leak posed no threat to personnel but caused high background when operating at the maximum voltage. The additional shielding proved very effective at improving detection limits.

7.6 Experience with wavelength dispersive spectrometers (WDXRF) has shown good agreement with energy dispersive instruments (EDXRF) over a broad range of elements. In spite of this agreement and the simpler spectral processing requirements of wavelength machines the preference remains with energy dispersive equipment for a variety of reasons. The very low power tubes in EDXRF machines leaves the sample intact and unaffected whereas in WDXRF the high power excitation embrittles the filter itself after 15 - 30 min exposure raising the possibility of altering particle morphology. This is a concern if electron microscopy is considered. Also, the vacuum environment, necessary for WDXRF, causes loss of some volatile materials.

8. Sample Preparation

8.1 Sample preparation begins with the correct operation of the samplers employed. Inorganic Compendium Method IO-2.2, Sampling for Suspended Particulate Matter in Ambient Air Using a Dichotomous Sampler, covering the option of the samplers in the field and subsequent collection of ambient air particles on 37-mm Teflon® filter for XRF analysis. One of the greatest advantages of analyzing aerosols by XRF is that the sample can, in theory, be collected in a manner most advantageous to XRF by sampling for a duration that produces an ideal mass loading on the filter. An approximate maximum target mass is about 100 $\mu g/cm^2$ although much less is often collected in many environments.

8.2 The types of filters used for aerosol sampling are 37-mm or 47-mm Teflo® with a pore size of 2 microns and, if electron microscopy is planned for the coarse fraction, then a 0.6 micron pore size Nuclepore® filter is used. The sample should be collected on the side of the Teflo® filter with the supporting ring to maintain the proper distance between the sample and detector during analysis. A properly collected sample will be a uniform deposit over the entire collection area of at least 25-mm in diameter. Samples which are not uniformly deposited over the whole collection area are not quantitatively analyzable.

8.3 All filter samples received for analysis are removed with tweezers from their container and are checked for any invalidating conditions such as holes, tears, or a non-uniform deposit which would prevent quantitative analysis. If such a condition is found the sample is noted as invalid on the XRF data entry form; data from such samples are not reported. Teflo® filters are easily handled because of the supporting ring, however, Nuclepore® filters must have a supporting ring applied to them (after gravimetric assay) to help maintain their flatness and to securely hold them in the frame. The sample is then placed in a custom-designed commercially available two-part sample frame which snaps together holding the filter securely in place.

9. Spectral Acquisition and Processing

9.1 Spectra are acquired in sets of 15 samples each. Up to 7 spectra are acquired for each sample depending on how many secondary excitation targets are selected. Utilizing all seven fluorescers requires approximately 4 hours machine time for 44 elements analyzed plus atmospheric argon.

9.2 Elemental intensities are determined by spectral deconvolution with a least squares algorithm which utilizes experimentally determined elemental shape functions instead of the mathematical Gaussian function. This approach has been successfully implemented for many years on an earlier machine and is described in Section 15, Citation 10. Since the spectral shape is not a pure Gaussian the experimental shapes are a more realistic representation of a spectrum. In addition to this library of elemental shape spectra there is also a background shape spectrum for each of the types of filters. It is assumed that the background on an unknown sample is due to the filter and not to the sample. (This is one of the reasons for avoiding heavily loaded filters.) The least squares algorithm synthesizes the spectrum of the sample under analysis by taking a linear combination of all the elemental shapes spectra and the background shape spectrum. The coefficients on the linear combination of elemental shapes and background spectra are scaling factors determined by minimizing chi-square thus producing the best fit possible by least square minimization. Values of the chi-square statistic are calculated for each sample and fluorescer to give an indication of the quality of the fit.

9.3 X-ray attenuation corrections are performed as described in Section 15, Citation 10 and are briefly described here. The mass absorption coefficients for the layer of fine particles is based on a typical composition of ambient aerosol particles so the actual x-ray attenuations on a given sample are simply a function of the mass loading. Coarse particle attenuations are more complex in that they are based on x-ray

attenuation by spherical particles with compositions of common crustal minerals with various size distributions. An average attenuation and uncertainty for each coarse particle element is based on this broad range of crustal minerals and is therefore a one-time calculation giving an attenuation factor useable for all subsequent coarse (2.5-10 µm) particle analyses. This treatment assumes low coarse particle loading so that the particles do not shadow one another - yet another reason for assuring that the sample mass loading is not too high. Attenuation corrections on PM_{10} particles are deduced from elemental concentration data from samples taken with collocated PM_{10} and dichotomous samplers.

9.4 The need for interference corrections arises from overlaps that are not deconvoluted by the least squares algorithm. This can best be illustrated by an example: Barium and titanium are analyzed by the gadolinium and iron fluorescers, respectively. The barium L x-rays overlap with the K x-rays of titanium and require an interference correction because the elements analyzed by gadolinium do not include titanium. The interference correction technique is described by Gilfrich in Section 15, Citation 29. The interference coefficient, determined during calibration, represents the fraction of the concentration of an affecting element (barium in the present example) which must be subtracted from the concentration of the affected element concentration (titanium) to compensate for the interference.

9.5 When samples are collected by the dichotomous or other samplers using virtual impaction, an additional correction must be employed because these type of samplers do not perfectly separate the fine and coarse particles. Due to virtual impaction requirements, about 10% of the fine particle mass is deposited on the coarse filter. Therefore, the attenuation corrections used for the particles on the coarse filter "over-correct" the attenuation because of these residual fines on the coarse filter. These effects are compensated for by the flow fraction correction.

10. Data Reporting

[Note: In other Inorganic Compendium methods, the authors have provided detailed examples of calculations involving final metal concentration (in terms of µg/m^3) from filterable materials. However, due to the nature of overlapping spectra which is characteristic of energy dispersive spectormeters, calculations are required to be performed by computer due to the complexity of the deconvolution of the recorded spectra which uses least square algorithm involving experimentally determined elemental shape functions instead of the mathematical Gaussian function. To perform by hand would require second order calculus and considerable time and manpower. Thus, the application of a computer is mandatory to determine elemental intensities and the elemental concentrations by a polynomial fit using a model based on the fundamentals of x-ray physics process (see Section 11 for further explanation).]

The two most important data output files are an ASCII file which contains a recapitulation of the field data and the final sample concentrations in ng/m^3 and a Lotus file with only the sample data. An example printout of a fine/coarse sample pair is shown in Table 3.

The uncertainty reported with each concentration is a 1F (68% confidence level) uncertainty and is determined by propagating the errors given in Section 12. Elements with concentrations below 3 times the uncertainty are flagged with an asterisk (*) on the printed record. If the true elemental concentration is zero then the fitting procedure implies that negative and positive results are equally probable. Therefore, negative numbers may be reported.

11. Calibration

11.1 Calibration is performed only when a change in fluorescers or x-ray tubes or detector is made or a serious malfunction occurs requiring significant repairs. Calibration establishes the elemental sensitivity factors and the magnitude of the interference or overlap coefficients. It takes approximately 2 weeks to complete a calibration.

11.2 Thin film standards are used for calibration because they most closely resemble the layer of particles on a filter. There are two types of calibration standards in use. One type consists of thin films deposited on Nuclepore substrates (Micromatter Co., Eastsound, WA). These standards are available for almost all the elements analyzed ranging in atomic number from 11 (Na) to 82 (Pb) with deposit masses gravimetrically determined to ± 5%. Another type consists of polymer films that contain known amounts of two elements in the form of organo-metallic compounds dissolved in a polymer and are not commercially available but their preparation is described in Section 15, Citation 9. These standards have been prepared for elements with atomic numbers above 21 (titanium and heavier). The same set of standards is used every time the spectrometer is calibrated. The standards are sufficiently durable to last many years, however occasionally one must be replaced due to accidents in handling. Approximately 200 calibration standards for 44 elements are in use (see Table 4.) and the acquisition of their spectra requires several days.

11.3 The background files which are used for background fitting are created at calibration time. Thirty clean Teflo® and Nuclepore® blanks are kept sealed in a plastic bag and are used exclusively for background measurement. After acquiring spectra for all 7 fluorescers the spectra are added together to produce a single spectrum for each fluorescer. Options are available to omit a spectrum from the sum if one shows a contamination. It is these summed spectra that are fitted to the background during spectral processing.

11.4 The shapes standards are thin film standards consisting of ultra pure elemental materials for the purpose of determining the physical shape of the pulse height spectrum. For this purpose it is not necessary for the concentration of the standard to be known - only that it be pure. A slight contaminant in the region of interest in a shape standard can have serious effect on the ability of the least squares fitting algorithm to fit the shapes to the unknown. For this reason the Se and elemental As standards, whose compounds are volatile, are kept in separate plastic bags in a freezer to prevent contamination of other standards; the Au standard, which will slowly amalgamate with atmospheric Hg, is kept in a desiccator. The shape standards are acquired for sufficiently long times to provide a large number of counts in the peaks of interest. It is these elemental shapes spectra that are fitted to the peaks in an unknown sample during spectral processing.

11.5 The spectra from the calibration standards are deconvoluted to get elemental intensities as described in Section 9.2. Using these intensities and the elemental concentration in the standards the sensitivities are determined by a polynomial fit using a model based on the fundamentals of the x-ray physics process as well as measurements on the calibration standards. This approach allows the calculation of sensitivities for elements for which there are poor or no standards such as volatile ones like Se and elemental As well as improving on elements with good standards.

11.6 The overlap coefficients are determined during calibration and represent the extent of interference that exists between overlapping spectral peaks. During calibration an affecting element (barium, to continue with the example of Section 9.4) is measured both at the analyte line peak for barium and at the titanium peak. The coefficient is expressed as the ratio of the concentration of the affected element (titanium) to the

concentration of the affecting element (barium). All elements requiring overlap coefficient determination are calculated in this manner.

12. Detection Limits

The detection limits are determined by propagation of errors. The sources of random error which are considered are: calibration uncertainty (± 5%); long term system stability (± 5%); peak and background counting statistics; uncertainty in attenuation corrections; uncertainty in overlap corrections; uncertainty in flow rate; and uncertainty in coarse fraction due to flow fraction correction (paired samples only). Table 2 outlines typical 1F (68% confidence level) detection limits on a Teflo® blank for fine particles and a Nuclepore® blank for coarse (2.5 µm-10 µm) particles. These detection limits are defined in terms of the uncertainty in the blank. This ignores the effect of other elements which generally is small except for the light elements (potassium and lower) where overlapping spectral lines will increase the detection limit.

[Note: The difference in the detection limits between the two filters in Table 2 is due more to the difference in sensitivity to fine and coarse particles and less to the difference in filter material.]

Higher confidence levels may be chosen for the detection limits by multiplying the 1F limits by 2 for a 2F (or 95% level) or by 3 for 3F (or 99.7% level). To convert the detection limits to more useful units one can use the typical deposit areas for 37-mm and 47-mm diameter filters of 6.5 cm^2 and 12.0 cm^2 respectively.

13. Quality Control

13.1 A comprehensive quality control program is in effect consisting of many measured parameters covering all measurement conditions and automatically produces control charts for all such measurements. All plotted data are normalized to the mean to give a rapid assessment of relative change.

13.2 Run-time quality control gives an indication of instrument performance at the time of data acquisition by measurements on stable qualitative standards. The parameters which are measured and their significance are: peak areas (monitors change in sensitivity), background areas (monitors contamination or background changes), centroid (monitors gain and zero adjustment to insure that spectra are assigned the correct channel), and FWHM, (monitors degradation of the detector resolution). These four parameters are measured for elements ranging from sodium to lead and include atmospheric argon. An example of plots of run-time QC data are illustrated in Figures 1 through 4 and Table 5, for the target and tolerance values for the parameters measured.

13.3 In addition to the run-time quality control procedure the analysis results of Standard Reference Materials SRM1833 and SRM1832 are included in the data reports. These results provide an overall check of the spectral processing program for the elements which are certified in the standards. The sole purpose of the SRMs is to provide a quality control measure; the standards are not used for calibration. Typical results of these SRMs are documented in Tables 6 and 7, and plotted in Figure 5.

13.4 The run-time quality control procedures serve as an indicator of possible emerging problems by flagging deviations greater than 3 tolerance units as defined for each element in Table 5. Persistently increasing trends are investigated to determine their cause(s) before they impact the results of SRM analyses.

13.5 The acceptance criteria of results for the elements certified in the SRMs is that the uncertainty intervals for the analytical results and those of the certified values should overlap each other. If any element fails this then the run of unknowns is repeated. Repeated failures indicate the need for recalibration.

13.6 A value for chi-square is calculated and reported with the data to indicate the quality of the fit. Chi-square values that are much larger than 1.0 indicate a problem in the fitting procedure. Changes in detector resolution or gain in the amplifier produce large values for chi-square; however such changes would be detected by the run-time quality control procedure. Also, large chi-square values can accompany results for heavily loaded filters even though the relative errors are typical. In addition, elements analyzed by the titanium and the iron fluorescers may experience large chi-square values due to interferences from overlapping elements. Chi-square is a more useful measure of goodness-of-fit for the other fluorescers for this reason.

13.7 To acquire more information about fitting problems the fitted spectra can be viewed on the screen or a hard copy printed. Such plots can be compared to the unknown spectra, background spectra, or to the library shape standards to help elucidate the suspected problem. Various statistics such as the correlation coefficient can be calculated on the fitted and measured spectra as a additional measure of the goodness-of-fit. Fitted spectrum superposed on its measured spectrum along with the associated statistics is illustrated in Figure 6.

14. Precision and Accuracy

Precision varies with the element and concentration. At high concentrations (greater than 1 µg/cm²) a precision of 7.1% can be expected for elements analyzed by one fluorescer and 5.0% can be expected for those analyzed by two. Refer to Table 1 for a listing of the elements and the fluorescers which analyze them. Based upon the analysis of NIST SRMs the accuracy is ± 10%.

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TABLE 1. EXAMPLE OF FLUORESCER USAGE

	Fluorescer						
Element	Al	Ti	Fe	Ge	Ag	Zr	Gd
Na	x						
Mg	x						
Al	x						
Si	x						
P	x	x					
S	x	x					
Cl	x	x					
Ar	x	x					
K	x	x					
Ca	x	x					
Sc	x	x					
Ti			x	x			
V			x	x			
Cr			x	x			
Mn				x		x	
Fe				x		x	
Co				x		x	
Ni				x		x	
Cu				x		x	
Zn						x	
Ga						x	
Ge						x	
As						x	
Se						x	
Br						x	
Rb					x	x	
Sr					x		x
Y					x		
Zr					x		x
Mo					x		x
Rh							x
Pd							x
Ag							x
Cd							x
Sn							x
Sb							x
Te							x
I							x
Cs							x
Ba							x
La							x
W					x	x	
Au					x	x	
Hg					x	x	
Pb					x	x	

[Note: The 'x' marks the fluorescers that analyze each element.]

TABLE 2. METHOD DETECTION LIMITS (MDL) FOR TEFLO® AND NUCLEPORE® BLANK FILTERS (1F)

Teflo® - fine element Method Detection Limits (MDL)			Nuclepore® - coarse element Method Detection Limits (MDL)		
	ng/cm^2	ng/m^3[1]		ng/cm^2	ng/m^3[2]
Na	5.3	1.59	Na	17.4	47.12
Mg	3.2	0.96	Mg	7.9	21.34
Al	17.6	5.29	Al	46.7	126.48
Si	8.0	2.41	Si	21.2	50.40
P	2.6	0.78	P	4.1	11.10
S	2.6	0.78	S	6.9	16.56
Cl	4.8	1.44	Cl	5.6	13.44
K	6.3	1.89	K	5.6	15.17
Ca	9.0	2.71	Ca	8.7	23.56
Sc	1.5	0.45	Sc	1.3	3.52
Ti	16.9	5.08	Ti	18.7	42.52
V	5.3	1.59	V	5.5	14.89
Cr	3.0	0.90	Cr	3.0	8.12
Mn	.8	0.24	Mn	.8	2.17
Fe	.7	0.21	Fe	1.0	2.71
Co	.4	0.12	Co	.4	1.08
Ni	.6	0.18	Ni	.7	1.89
Cu	.7	0.21	Cu	.8	2.17
Zn	1.0	0.30	Zn	1.1	2.98
Ga	1.6	0.48	Ga	1.5	4.06
Ge	1.1	0.33	Ge	1.0	2.71
As	.8	0.24	As	.9	2.44
Se	.7	0.21	Se	.6	1.62
Br	.6	0.18	Br	.7	1.89
Rb	.7	0.21	Rb	.7	1.89
Sr	1.1	0.33	Sr	.9	2.44
Y	1.2	0.36	Y	1.1	2.98
Zr	1.2	0.36	Zr	1.1	2.98
Mo	1.6	0.48	Mo	1.5	4.06
Rh	25.9	7.79	Rh	26.5	71.70
Pd	22.9	6.89	Pd	18.7	50.65
Ag	20.2	6.02	Ag	20.3	54.98
Cd	22.0	6.62	Cd	19.2	52.00
Sn	30.5	9.18	Sn	31.5	85.31
Sb	31.4	9.45	Sb	26.7	72.31
Te	26.3	7.91	Te	27.6	66.62
I	35.5	10.68	I	34.4	93.17
Cs	48.9	14.62	Cs	50.9	137.85
Ba	51.8	15.59	Ba	58.3	157.89
La	70.6	2.12	La	68.9	186.60
W	3.4	10.23	W	3.3	8.93
Au	1.7	0.51	Au	1.5	4.06
Hg	1.5	0.45	Hg	1.4	3.79
Pb	1.5	0.45	Pb	1.5	4.06

[1]Based upon dichotomous sampling for 24-hrs. using a 37-mm Teflo® filter at a sampling rate of 0.9 m^3/hr.
[2]Based upon dichotomous sampling for 24-hrs using a 37-mm Nuclepore® filter at a sampling rate of 0.1 m^3/hr.

TABLE 3. DATA REPORT FORMAT FOR A FINE/COARSE PAIRED SAMPLE

KEVEX SUMMARY: ADOBE FLATS URBAN PARTICULATE STUDY

```
SITE           =    ADB
DURATION (MIN) =    714.0       SAMPLE DATE  =  3/20/92 AND 1900 HOURS
FLOW FRAC      = .0869          FLOW (L/MIN) =   37.105 +-  .500
XRF ID         = 999906         XRF ID       = 999956
SAMPLE ID      = T0033          SAMPLE ID    = NU0033
```

FINE, NG/M³				COARSE, NG/M³			
MASS	77912.	+-	1962.	MASS	11347.	+-	812.
*NA	211.9	+-	71.4	*NA	53.3	+-	27.1
MG	564.6	+-	89.4	MG	443.9	+-	40.8
*AL	162.2	+-	74.1	AL	539.9	+-	173.8
SI	213.4	+-	40.4	SI	909.5	+-	232.7
* P	12.1	+-	18.5	* P	-5.5	+-	11.3
S	2653.4	+-	183.7	S	285.7	+-	84.9
CL	1164.4	+-	79.3	*CL	34.8	+-	24.6
K	193.6	+-	13.8	K	63.5	+-	8.9
CA	43.4	+-	5.6	CA	181.7	+-	13.9
*SC	3.6	+-	4.1	*SC	-1.3	+-	2.2
*TI	17.6	+-	6.6	TI	54.7	+-	9.6
* V	4.6	+-	2.3	* V	3.2	+-	1.7
*CR	2.0	+-	1.0	CR	9.8	+-	1.6
MN	10.0	+-	1.4	MN	10.1	+-	1.3
FE	243.7	+-	21.9	FE	783.5	+-	78.2
*CO	2.8	+-	1.8	*CO	4.8	+-	1.7
NI	3.8	+-	1.2	*NI	.3	+-	.6
CU	14.3	+-	1.9	CU	8.8	+-	1.3
ZN	167.5	+-	14.9	ZN	27.6	+-	4.9
*GA	2.4	+-	1.0	*GA	-.0	+-	.4
*GE	3.3	+-	1.3	*GE	.0	+-	.6
AS	24.7	+-	3.6	*AS	1.8	+-	1.2
SE	4.7	+-	.8	*SE	.7	+-	.4
BR	29.0	+-	2.8	BR	7.9	+-	1.1
*RB	1.7	+-	.8	*RB	1.0	+-	.4
SR	2.9	+-	.9	SR	2.2	+-	.5
* Y	12.4	+-	6.1	* Y	3.9	+-	2.9
*ZR	2.9	+-	4.8	*ZR	4.3	+-	2.6
*MO	7.3	+-	4.8	*MO	-3.2	+-	2.2
*RH	.0	+-	3.2	*RH	-1.2	+-	1.6
*PD	-3.6	+-	3.1	*PD	-1.0	+-	1.7
*AG	-6.4	+-	3.4	*AG	1.2	+-	1.9
*CD	8.5	+-	4.5	*CD	-.7	+-	2.2
SN	54.3	+-	9.4	*SN	2.3	+-	3.9
*SB	-1.6	+-	6.4	*SB	-.6	+-	3.3
*TE	2.5	+-	7.5	*TE	-7.2	+-	3.8
* I	25.0	+-	9.6	* I	2.4	+-	4.7
*CS	-4.0	+-	11.2	*CS	12.4	+-	5.9
*BA	-7.7	+-	13.7	BA	25.1	+-	7.4
*LA	-4.8	+-	34.5	*LA	22.6	+-	17.9
* W	-1.1	+-	2.6	* W	1.5	+-	1.3

```
        *AU       -.9 +-     1.8       *AU        .2 +-      .9
        *HG       -.4 +-     1.9       *HG       1.5 +-     1.0
         PB     221.6 +-    19.7        PB      46.0 +-     6.2
* INDICATES THAT THE CONCENTRATION IS BELOW 3 TIMES THE UNCERTAINTY.
  XRF DATE= 04/29/1992  16:35 RBK   (F):  04/29/1992  20:35 RBK   (C)
  SPECTRAL ANALYSIS DATE=  5/20/1992
```

TABLE 4. CALIBRATION STANDARDS AND CONCENTRATIONS

Standard ID	Element	µg/cm²	Standard ID	Element	µg/cm²	Standard ID	Element	µg/cm²	Standard ID	Element	µg/cm²
CaF237	F	18.00	CuS1124	S	31.90	Cr 85	Cr	85.00	RbNO311	Rb	69.00
CaF2 29	F	14.10	CuS58.6	S	16.50	Cr 84	Cr	84.00	RbNO322	Rb	12.90
CaF2 90	F	43.80	CuS57.6	S	13.90	Cr 75	Cr	75.00	RbNO3 a	Rb	24.90
CaF2 91	F	44.30	CuS58.2	S	14.00	Cr 74	Cr	74.00	RbNO3 b	Rb	24.90
CaF2102	F	49.60	NaCl 57	Cl	34.60	Cr 122	Cr	122.00	RbNO3 c	Rb	24.90
CaF2 66	F	32.10	NaCl 87	Cl	52.80	CrCu32a	Cr	9.19	SrF2 57	Sr	39.80
CaF2 28	F	13.60	NaCl446	Cl	27.10	CrCu26g	Cr	8.14	SbSr29z	Sr	4.97
CaF2 33	F	16.10	NaCl715	Cl	43.40	MnZn24b	Mn	8.57	SrF2 50	Sr	34.90
CaF2 39	F	19.00	NaCl497	Cl	30.20	Mn 57	Mn	57.00	SbSr31y	Sr	5.14
CaF2 54	F	26.30	NaCl501	Cl	30.40	Mn 183	Mn	183.00	SrF2137	Sr	95.60
CaF2291	F	14.10	NaCl 51	Cl	31.00	MnZn27x	Mn	9.10	SrF2184	Sr	12.80
CaF2 30	F	14.60	NaCl512	Cl	31.10	Mn 43	Mn	43.00	SrF2 92	Sr	64.20
CaF2 52	F	25.30	NaCl519	Cl	31.50	Mn 46.9	Mn	46.90	SrF2103	Sr	71.80
CaF2 48	F	23.40	KCl 45	Cl	21.40	Mn 44.5	Mn	44.50	YF3 46	Y	28.00
CaF2 45	F	21.90	KCl53.3	Cl	25.40	Mn 46.6	Mn	46.60	ZrCd24c	Zr	9.85
CaF2 36	F	17.50	KCl 70	Cl	33.30	Mn 43.7	Mn	43.70	ZrCd20w	Zr	10.77
CaF2134	F	65.20	KCl 49	Cl	23.30	Mn 69	Mn	69.00	MoO3145	Mo	96.70
CaF2110	F	53.50	KCl48.7	Cl	23.20	FePb37y	Fe	7.72	MoO3106	Mo	70.70
NaCl 57	Na	22.40	KCl47.9	Cl	22.80	Fe 107	Fe	107.00	MoO3110	Mo	73.30
NaCl 87	Na	34.20	KCl 48	Cl	22.80	Fe 127	Fe	127.00	MoO3 59	Mo	39.30
NaCl446	Na	17.60	KCl47.6	Cl	22.60	Fe 46	Fe	46.00	MoO3 54	Mo	36.00
NaCl715	Na	28.10	KCl 45	K	23.60	Fe 88	Fe	88.00	Rh 16	Rh	16.00
NaCl497	Na	19.60	KCl53.3	K	28.00	FePb38y	Fe	7.71	Pd 33	Pd	33.00
NaCl501	Na	19.70	KCl 70	K	36.70	Co 45a	Co	45.00	Pd 198	Pd	198.00
NaCl 51	Na	20.10	KCl 49	K	25.70	Co 45b	Co	45.00	Ag 35	Ag	35.00
NaCl512	Na	20.10	KCl48.7	K	25.50	RbCo29c	Co	7.43	Ag 132	Ag	132.00
NaCl519	Na	20.40	KCl47.9	K	25.10	RbCo25b	Co	7.65	Cd 83	Cd	83.00
Mg 81	Mg	81.00	KCl 48	K	25.20	Ni 54	Ni	54.00	ZrCd20w	Cd	9.15
Mg 41	Mg	41.00	KCl47.6	K	25.00	Ni 88	Ni	88.00	ZrCd24c	Cd	8.38
Mg 41.3	Mg	41.30	CaF2 37	Ca	19.00	NiV 21c	Ni	5.77	Cd 77	Cd	77.00
Mg 43	Mg	43.00	CaF2 29	Ca	14.90	Ni 101	Ni	101.00	Sn 40	Sn	40.00
Mg 43.8	Mg	43.80	CaF2 90	Ca	46.20	Cu 96	Cu	96.00	Sn 185	Sn	185.00
Mg 60.2	Mg	60.20	CaF2 91	Ca	46.70	Cu 104	Cu	104.00	Sn 97a	Sn	97.00
Al 57	Al	57.00	CaF2102	Ca	52.40	Cu 128	Cu	128.00	Sn 97b	Sn	97.00
Al 37.9	Al	37.90	CaF2 66	Ca	33.90	CrCu26g	Cu	7.65	Sn 79	Sn	79.00
Al 37.4	Al	37.40	CaF2 28	Ca	14.40	CrCu32a	Cu	8.63	Sb 194	Sb	194.00
Al 29	Al	29.00	CaF2 33	Ca	16.90	Cu 38	Cu	38.00	Sb 47	Sb	47.00
Al 43.2	Al	43.20	CaF2 39	Ca	20.00	Zn 51	Zn	51.00	Sb 147	Sb	147.00
Al 62	Al	62.00	CaF2 54	Ca	27.20	Zn 125	Zn	125.00	Sb 42	Sb	42.00
Al 75	Al	75.00	CaF2291	Ca	14.90	MnZn27x	Zn	8.46	SbSr29z	Sb	5.01
SiO 46	Si	29.30	CaF2 30	Ca	15.40	MnZn24b	Zn	7.97	SbSr31y	Sb	5.18
SiO 47	Si	29.90	CaF2 52	Ca	26.70	GaP 34	Ga	23.50	Te 53	Te	53.00
SiO 51a	Si	32.50	CaF2 48	Ca	24.60	GaP 40	Ga	27.70	KI 46	I	35.20
SiO 51b	Si	32.50	CaF2 45	Ca	23.10	GaP 70	Ga	48.50	CsBr 53	Cs	33.10
SiO 56	Si	35.70	CaF2 36	Ca	18.50	GaP 105	Ga	72.70	CsBr 54	Cs	33.70
SiO 80	Si	51.00	CaF2134	Ca	68.60	Ge 37	Ge	37.00	CsBr 51	Cs	31.90
SiO27.6	Si	17.60	CaF2110	Ca	56.50	TiGe33d	Ge	6.22	BaF2108	Ba	84.60
SiO46.1	Si	29.40	ScF3 57	Sc	25.10	TiGe29x	Ge	5.94	BaF2 48	Ba	37.60
SiO72.2	Si	46.00	Ti 39	Ti	39.00	Ge 140	Ge	140.00	BaF2 60	Ba	47.00
GaP 34	P	10.50	Ti 95	Ti	95.00	BaAs23y	As	5.60	BaF2 57	Ba	44.70
GaP 40	P	12.30	TiGe33d	Ti	2.46	BaAs36w	As	5.52	BaF2143	Ba	112.00
GaP 70	P	21.50	TiGe29x	Ti	2.36	CsBr 53	Br	19.90	BaF2114	Ba	89.40
GaP 105	P	32.30	V 45	V	45.00	CsBr 54	Br	20.30	BaAs23y	Ba	4.98

TABLE 4. (continued)

Standard ID	Element	µg/cm²	Standard ID	Element	µg/cm²	Standard ID	Element	µg/cm²	Standard ID	Element	µg/cm²
CuS1052	S	30.80	V 53	V	53.00	CsBr 51	Br	19.10	BaAs36w	Ba	4.91
CuS 48	S	13.00	NiV 21c	V	6.64	RbNO346	Rb	26.60	LaF3157	La	111.30
CuS 136	S	33.00	Cr 30	Cr	30.00	RbCo25b	Rb	7.88	LaF3 62	La	44.00
CuS39.6	S	10.20	Cr 53	Cr	53.00	RbCo29c	Rb	7.65			

TABLE 5. TARGET AND TOLERANCE VALUES FOR QC RESULTS

(TARGET VALUES)

FILE: 0:QCBEGTGT FILE: 0:QCENDTGT

STDEL ID	EL	AREA (cts)	CENTROID (keV)	FWHM (ev)	STD ID	EL	AREA (cts)	CENTROID (keV)	FWHM (ev)
1833	Pb	31112.12	10.5449	207.4653	1832	Cu	17548.85	8.0411	174.1389
1833	Zn	31772.52	8.6306	179.6835	1832		5303.84	6.9247	167.1478
1833	Fe	313475.41	6.3935	159.4537	1832	Mn	86202.33	5.8891	154.6347
1833	Ti	216978.09	4.5037	142.4946	1832	Ca	217562.00	3.6847	135.3520
1833	Si	69021.60	1.7322	121.7406	1832	V	99761.96	4.9443	146.1904
1833	K	220344.80	3.3069	132.4137	1832	Al	16562.45	1.4779	119.5793
BLKt	Sn	111.52	0.0000	0.0000	1832	Si	67688.42	1.7319	118.4960
BLKt	Pb	85.82	0.0000	0.0000	1832	Na	10332.21	1.0256	114.4485
BLKt	Cu	497.06	0.0000	0.0000	BLKn	Ba	183.14	0.0000	0.0000
BLKt	Sr	72.92	0.0000	0.0000	BLKn	W	241.42	0.0000	0.0000
BLKt	Ni	648.99	0.0000	0.0000	BLKn	Zn	148.48	0.0000	0.0000
BLKt	Fe	459.10	0.0000	0.0000	BLKn	Sr	83.00	0.0000	0.0000
BLKt	S	266.76	0.0000	0.0000	BLKn	Ni	654.44	0.0000	0.0000
BLKt	Al	396.30	0.0000	0.0000	BLKn	Fe	603.55	0.0000	0.0000
BLKt	Ar	747.74	0.0000	0.0000	BLKn	S	3047.53	0.0000	0.0000
BLKt	Na	120.85	0.0000	0.0000	BLKn	Si	936.48	0.0000	0.0000
BaNa	Na	27711.44	1.0278	107.2698	BLKn	Ar	751.18	0.0000	0.0000
BaNa	Ba	7369.12	32.0701	670.6336	BLKn	Mg	3622.12	0.0000	0.0000
					BaSr	Sr	210871.20	14.1410	227.8625
					BaSr	Ba	7464.85	32.0692	671.0372

(TOLERANCE UNITS in %)

FILE: 0:QCBEGTOL FILE: 0:QCENDTOL

STDEL ID	EL	AREA (cts)	CENTROID (keV)	FWHM (ev)	STD ID	EL	AREA (cts)	CENTROID (keV)	FWHM (ev)
1833	Pb	1.66	0.0313	0.9901	1832	Cu	1.66	0.0104	1.9331
1833	Zn	1.66	0.0131	1.7328	1832	Co	1.70	0.0308	2.4345
1833	Fe	1.66	0.0224	0.9361	1832	Mn	1.66	0.0198	1.3536
1833	Ti	1.66	0.0259	0.9768	1832	Ca	1.66	0.0253	1.1311
1833	Si	1.66	0.0616	1.4120	1832	V	1.66	0.0243	1.1031
1833	K	1.66	0.0323	0.9235	1832	Al	2.02	0.1173	3.3722
BLKt	Sn	12.98	0.0000	0.0000	1832	Si	1.66	0.0481	0.8888
BLKt	Pb	8.93	0.0000	0.0000	1832	Na	1.78	0.1560	1.5333
BLKt	Cu	4.95	0.0000	0.0000	BLKn	Ba	9.92	0.0000	0.0000
BLKt	Sr	17.61	0.0000	0.0000	BLKn	W	8.20	0.0000	0.0000
BLKt	Ni	3.81	0.0000	0.0000	BLKn	Zn	11.45	0.0000	0.0000
BLKt	Fe	7.57	0.0000	0.0000	BLKn	Sr	10.88	0.0000	0.0000
BLKt	S	8.71	0.0000	0.0000	BLKn	Ni	6.55	0.0000	0.0000
BLKt	Al	7.23	0.0000	0.0000	BLKn	Fe	5.63	0.0000	0.0000
BLKt	Ar	17.39	0.0000	0.0000	BLKn	S	2.88	0.0000	0.0000
BLKt	Na	16.00	0.0000	0.0000	BLKn	Si	6.75	0.0000	0.0000
BaNa	N	1.66	0.1103	1.2599	BLKn	Ar	22.14	0.0000	0.0000
BaNa	Ba	2.53	0.0979	3.9782	BLKn	Mg	5.64	0.0000	0.0000
					BaSr	Sr	1.66	0.0073	0.4538
					BaSr	Ba	1.86	0.0279	2.8094

TABLE 6. EXAMPLE PRINTOUT OF SRM 1833

KEVEX SUMMARY: TEFLO® BLANKS LOT #457803 (NEW TUBE)

SITE	=		
DURATION (MIN)	= .0	SAMPLE DATE	= 99/99/99 AND 9999 HOURS
FLOW FRAC	= .0000	FLOW (L/MIN)	= .000 +- .200
XRF ID	= 112141		
SAMPLE ID	= SRM1833		

	FINE, NG/CM^2				NIST CERTIFIED VALUES		
MASS	0.	+-	398.	MASS	15447		
*NA	-801.2	+-	326.4	NA	.0	+-	.0
MG	161.3	+-	18.2	MG	.0	+-	.0
AL	1027.5	+-	102.2	AL	.0	+-	.0
SI	34806.8	+-	3023.4	SI	33366.0	+-	2163.0
P	79.8	+-	19.9	P	.0	+-	.0
*S	-28.2	+-	782.8	S	.0	+-	.0
*CL	-68.6	+-	113.8	CL	.0	+-	.0
K	16734.7	+-	1018.7	K	17147.0	+-	1699.0
*CA	-3.9	+-	61.4	CA	.0	+-	.0
*SC	-17.1	+-	5.4	SC	.0	+-	.0
TI	12852.9	+-	822.1	TI	12821.0	+-	1854.0
*V	46.0	+-	52.2	V	.0	+-	.0
CR	108.2	+-	12.7	CR	.0	+-	.0
MN	13.8	+-	2.9	MN	.0	+-	.0
FE	14332.4	+-	872.4	FE	14212.0	+-	463.0
*CO	-2.6	+-	2.9	CO	.0	+-	.0
NI	62.5	+-	4.6	NI	.0	+-	.0
*CU	3.8	+-	1.5	CU	.0	+-	.0
ZN	3800.9	+-	327.7	ZN	3862.0	+-	309.0
*GA	-30.9	+-	7.7	GA	.0	+-	.0
*GE	5.9	+-	3.6	GE	.0	+-	.0
*AS	5.7	+-	14.6	AS	.0	+-	.0
*SE	-2.0	+-	2.6	SE	.0	+-	.0
*BR	-2.3	+-	2.5	BR	.0	+-	.0
*RB	.5	+-	1.4	RB	.0	+-	.0
*SR	-5.0	+-	2.9	SR	.0	+-	.0
* Y	-2.6	+-	7.5	Y	.0	+-	.0
*ZR	-7.6	+-	3.5	ZR	.0	+-	.0
MO	45.4	+-	5.6	MO	.0	+-	.0
*RH	156.7	+-	69.5	RH	.0	+-	.0
*PD	79.2	+-	67.1	PD	.0	+-	.0
*AG	114.0	+-	69.7	AG	.0	+-	.0

TABLE 6. (continued)

	FINE, NG/CM^2				NIST CERTIFIED VALUES		
*CD	24.7	+ -	66.3	CD	.0	+ -	.0
*SN	-1496.1	+ -	188.1	SN	.0	+ -	.0
*SB	88.2	+ -	96.2	SB	.0	+ -	.0
*TE	240.8	+ -	93.8	TE	.0	+ -	.0
* I	134.8	+ -	107.5	I	.0	+ -	.0
*CS	-209.3	+ -	106.6	CS	.0	+ -	.0
*BA	-5098.1	+ -	517.8	BA	.0	+ -	.0
*LA	-1416.4	+ -	202.2	LA	.0	+ -	.0
W	59.9	+ -	17.6	W	.0	+ -	.0
*AU	8.7	+ -	6.8	AU	.0	+ -	.0
*HG	-30.6	+ -	5.9	HG	.0	+ -	.0
PB	16886.2	+ -	1028.1	PB	16374.0	+ -	772.0

* INDICATES THAT THE CONCENTRATION IS BELOW 3 TIMES THE UNCERTAINTY.
XRF DATE = 28-SEP-93 10:58:37 RBK
SPECTRAL ANALYSIS DATE = 12/14/1993

TABLE 7. EXAMPLE PRINTOUT OF SRM 1832

KEVEX SUMMARY: TEFLO® BLANKS LOT #457803 (NEW TUBE)

SITE	=		
DURATION (MIN)	= .0	SAMPLE DATE	= 99/99/99 AND 9999 HOURS
FLOW FRAC	= .0000	FLOW (L/MIN)	= .000 +- .200
XRF ID	= 112191		
SAMPLE ID	= SRM1832		

FINE, NG/CM^2				NIST CERTIFIED VALUES			
MASS	0.	+-	398.	MASS	16431		
NA	11891.5	+-	1035.0	NA	11173.0	+-	.0
MG	92.2	+-	13.0	MG	.0	+-	.0
AL	15856.5	+-	1373.2	AL	14953.0	+-	986.0
SI	34398.8	+-	2964.2	SI	35491.0	+-	1150.0
P	492.0	+-	32.1	P	.0	+-	.0
S	402.1	+-	27.3	S	.0	+-	.0
CL	156.8	+-	15.9	CL	.0	+-	.0
* K	18.5	+-	18.0	K	.0	+-	.0
CA	20011.7	+-	1218.2	CA	19225.0	+-	1315.0
*SC	-21.8	+-	5.6	SC	.0	+-	.0
*TI	-4.7	+-	130.6	TI	.0	+-	.0
V	4593.6	+-	281.1	V	4272.0	+-	493.0
*CR	7.4	+-	7.3	CR	.0	+-	.0
MN	4959.3	+-	302.4	MN	4437.0	+-	493.0
FE	30.5	+-	3.9	FE	.0	+-	.0
CO	1055.1	+-	64.7	CO	970.0	+-	66.0
*NI	-6.8	+-	1.8	NI	.0	+-	.0
CU	2400.1	+-	146.3	CU	2300.0	+-	164.0
ZN	9.3	+-	2.7	ZN	.0	+-	.0
*GA	2.1	+-	2.1	GA	.0	+-	.0
*GE	.3	+-	2.4	GE	.0	+-	.0
*AS	-3.7	+-	2.2	AS	.0	+-	.0
*SE	1.0	+-	1.2	SE	.0	+-	.0
BR	10.7	+-	1.8	BR	.0	+-	.0
*RB	-.2	+-	.9	RB	.0	+-	.0
*SR	2.8	+-	2.3	SR	.0	+-	.0
* Y	-5.0	+-	1.6	Y	.0	+-	.0
*ZR	-6.5	+-	1.8	ZR	.0	+-	.0
MO	26.8	+-	4.2	MO	.0	+-	.0
*RH	25.2	+-	58.2	RH	.0	+-	.0

TABLE 7. (continued)

	FINE, NG/CM^2				NIST CERTIFIED VALUES		
*PD	-69.0	+ -	54.7	PD	.0	+ -	.0
*AG	151.2	+ -	63.4	AG	.0	+ -	.0
*CD	24.2	+ -	58.2	CD	.0	+ -	.0
*SN	-640.8	+ -	138.6	SN	.0	+ -	.0
*SB	-73.5	+ -	81.3	SB	.0	+ -	.0
*TE	-9.3	+ -	73.9	TE	.0	+ -	.0
* I	-46.6	+ -	91.6	I	.0	+ -	.0
*CS	3.6	+ -	96.7	CS	.0	+ -	.0
*BA	-2352.9	+ -	328.6	BA	.0	+ -	.0
*LA	-509.9	+ -	156.5	LA	.0	+ -	.0
W	40.0	+ -	12.9	W	.0	+ -	.0
*AU	-5.6	+ -	2.5	AU	.0	+ -	.0
*HG	-5.4	+ -	3.0	HG	.0	+ -	.0
*PB	-10.4	+ -	4.2	PB	.0	+ -	.0

* INDICATES THAT THE CONCENTRATION IS BELOW 3 TIMES THE UNCERTAINTY.
XRF DATE = 29-SEP-93 13:27:55 RBK
SPECTRAL ANALYSIS DATE = 12/14/1993

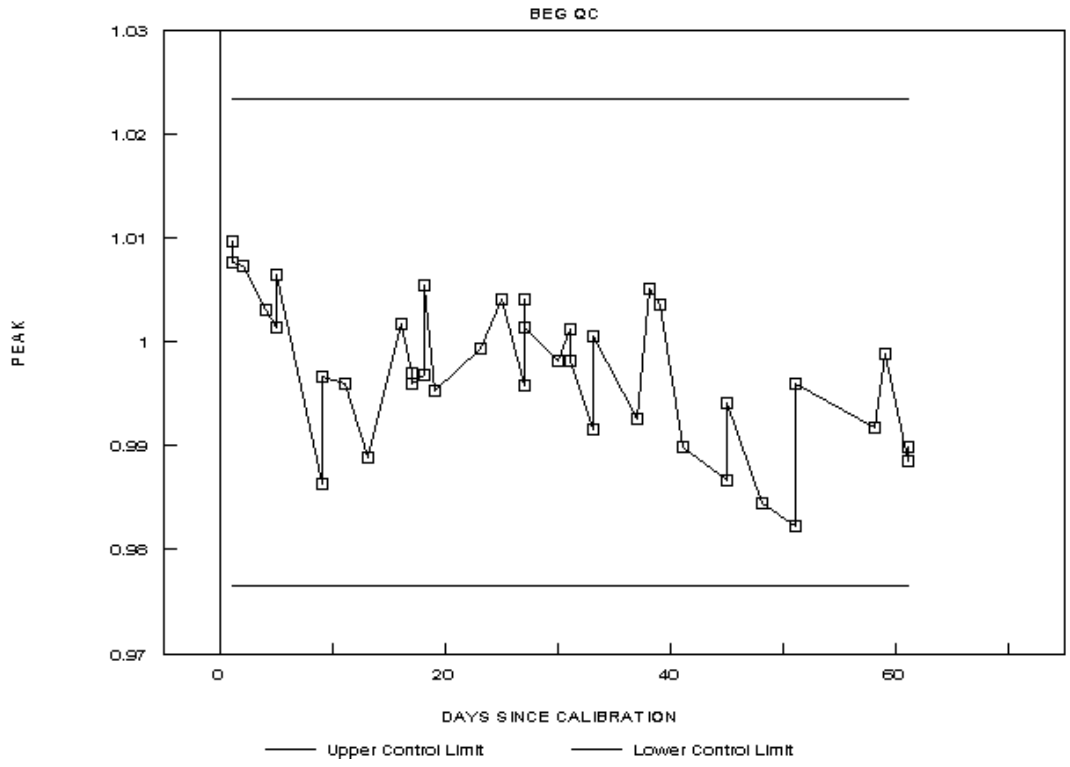

Figure 1. Quality control indicator associated with Fe peak area.

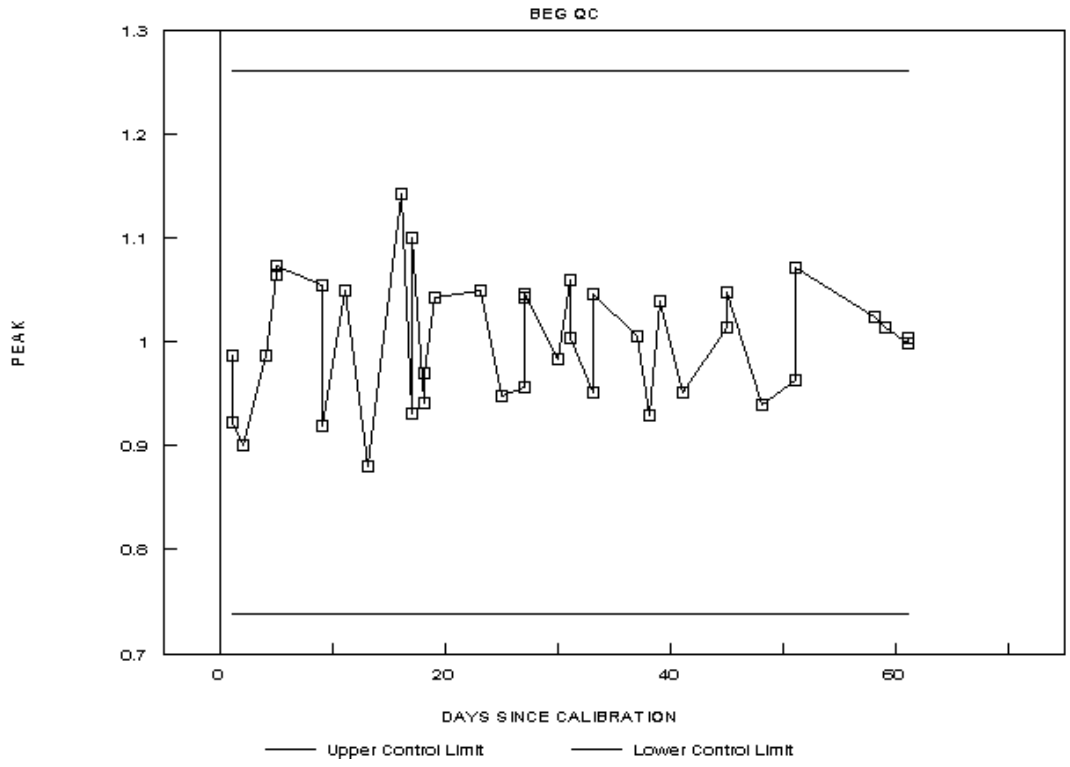

Figure 2. Quality control indicator associated with S background area.

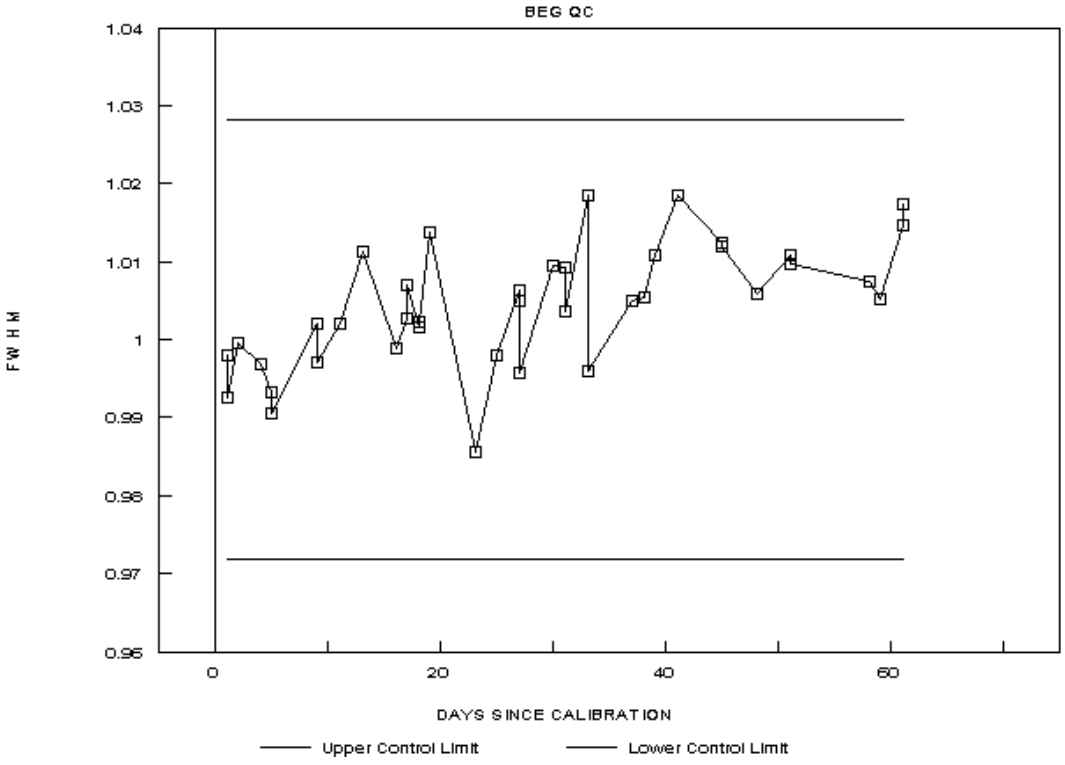

Figure 3. Quality control indicator associated with Fe FWHM.

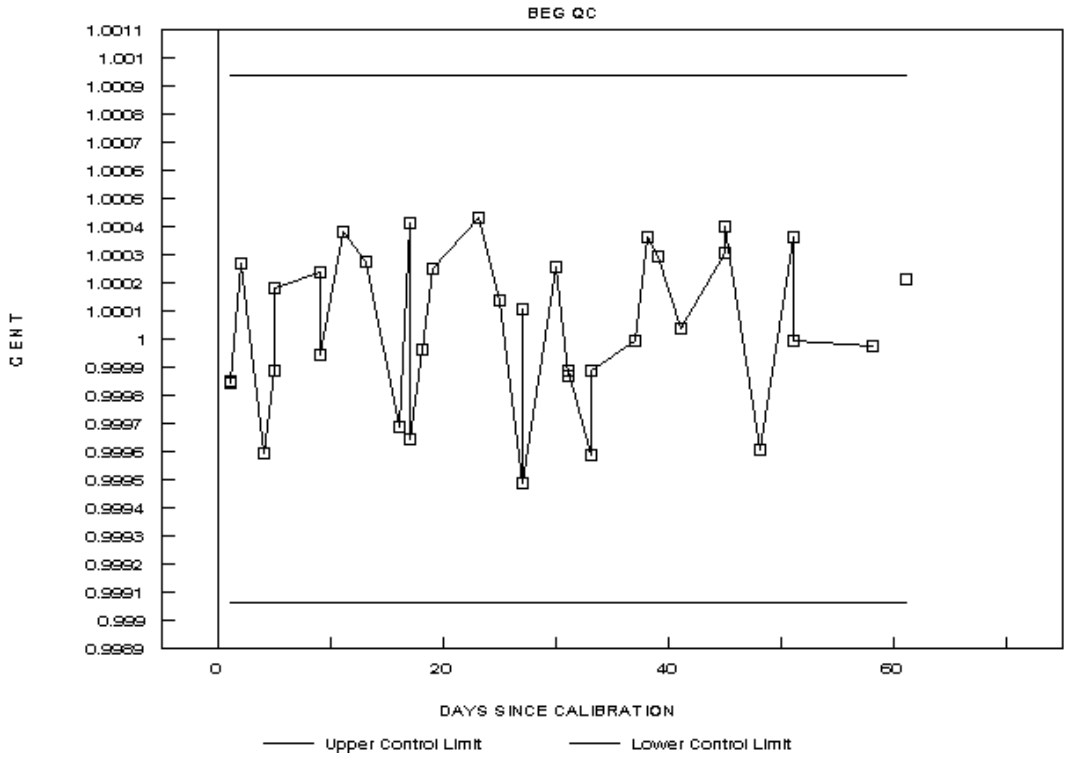

Figure 4. Quality control indicator associated with Pb centroid.

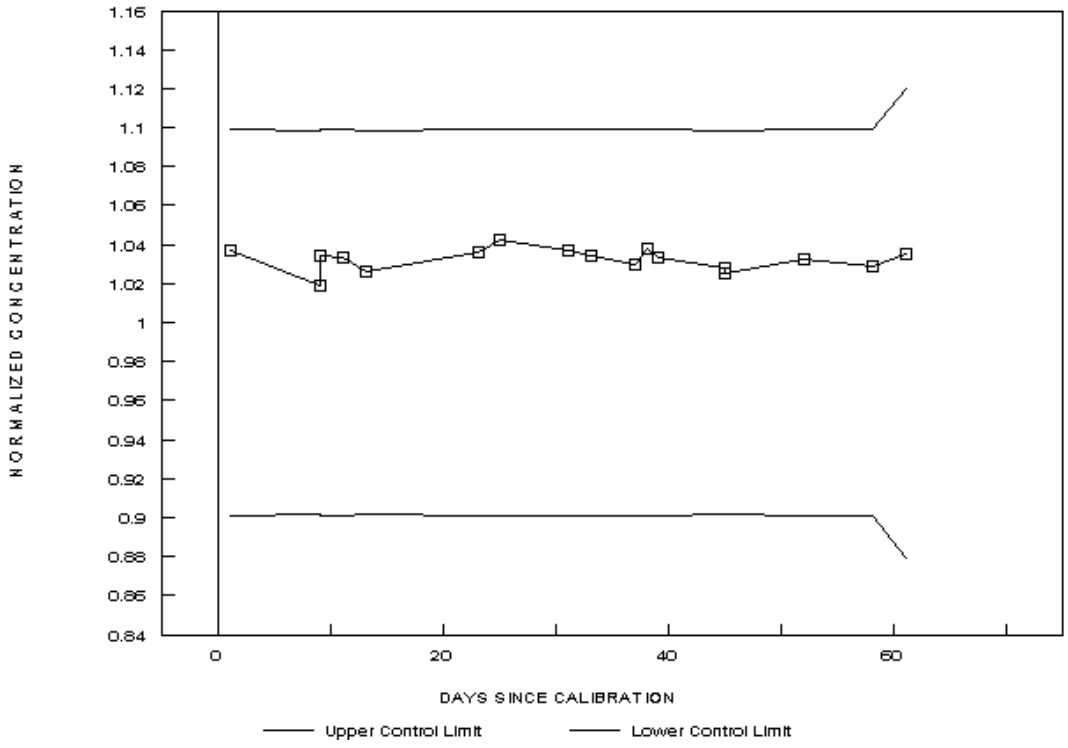

Figure 5. Quality control indicator associated with Pb in SRMs.

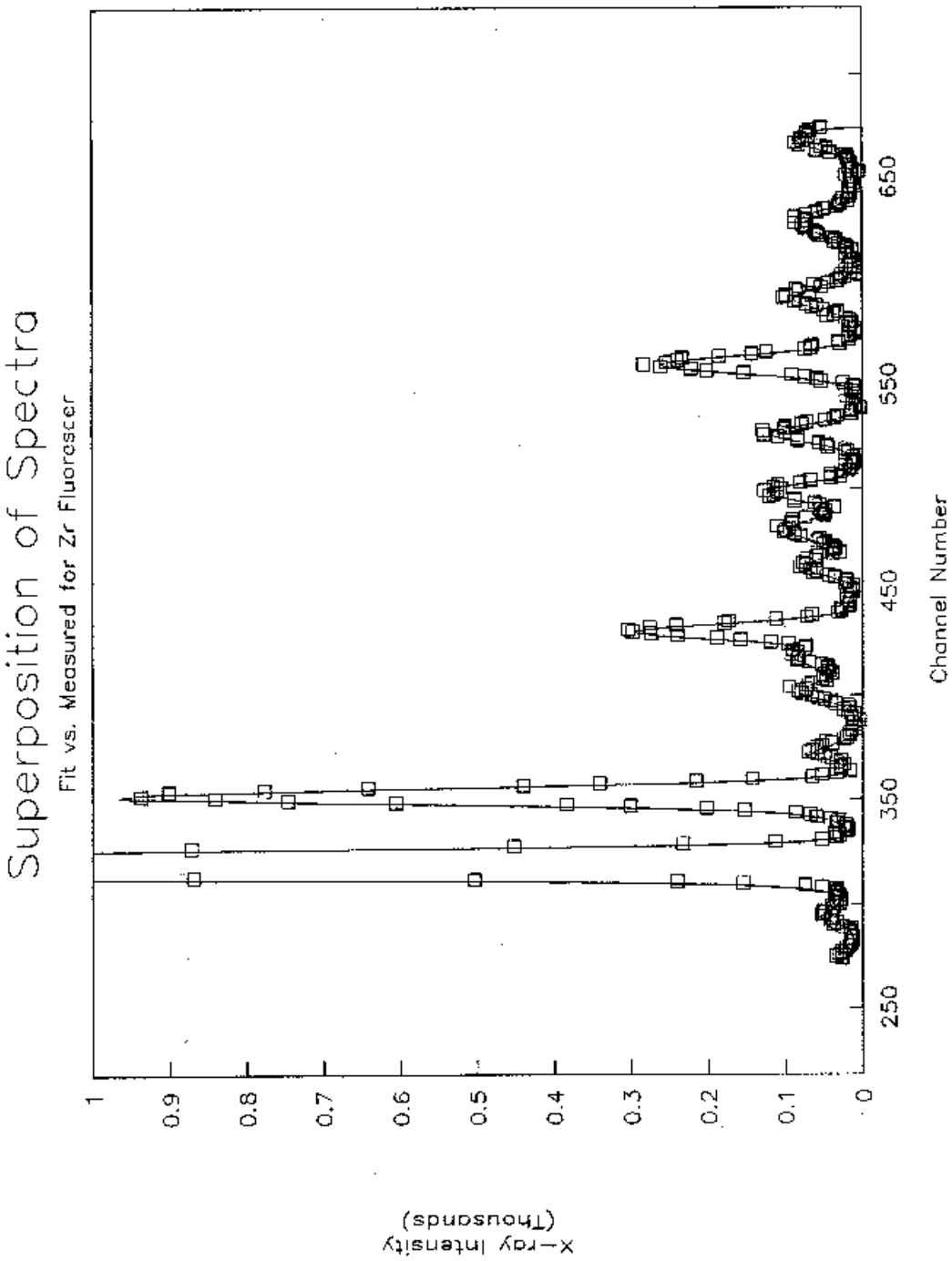

Figure 6. Quality control indicator associated with superposition of fitted and measured spectrum.

DRI STANDARD OPERATING PROCEDURE

DRI Model 2001 Thermal/Optical Carbon Analysis (TOR/TOT) of Aerosol Filter Samples – Method IMPROVE_A

DRI SOP #2-216.1
Revised November 2005

Prepared by:

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1 GENERAL DISCUSSION

1.1 Purpose of Procedure

This standard operating procedure is intended to:

- Provide a basic understanding of the principles of carbon analysis and carbon analyzer operation;
- Describe routine determination of organic, elemental, and carbonate carbon from ambient- and source-filter samples using the *DRI Model 2001 Thermal/Optical Carbon Analyzer*; and
- Detail the concerns and procedures which will ensure a state-of-the-art carbon analysis measurement process.

This procedure will be followed by all analysts at the Environmental Analysis Facility of the Division of Atmospheric Sciences of the Desert Research Institute, Reno, Nevada, USA.

1.2 Measurement Principle

The operation of the DRI Model 2001 Thermal/Optical Carbon Analyzer is based on the preferential oxidation of organic carbon (OC) compounds and elemental carbon (EC) at different temperatures. Its function relies on the fact that organic compounds can be volatilized from the sample deposit in a non-oxidizing helium (He) atmosphere, while elemental carbon must be combusted by an oxidizer. The analyzer operates by: 1) liberating carbon compounds under different temperature and oxidation environments from a small sample punch taken from a quartz-fiber filter; 2) converting these compounds to carbon dioxide (CO_2) by passing the volatilized compounds through an oxidizer (heated manganese dioxide, MnO_2); 3) reducing CO_2 to methane (CH_4) by passing the flow through a methanator (hydrogen-enriched nickel catalyst); and 4) quantifying CH_4 equivalents with a *flame ionization detector* (FID).

The principal function of the optical (laser reflectance and transmittance) component of the analyzer is to correct for pyrolysis charring of OC compounds into EC. Without this correction, the OC fraction of the sample might be underestimated and the EC fraction might include some pyrolyzed OC. The correction for pyrolysis is made by continuously monitoring the filter reflectance and/or transmittance (via a helium-neon laser and a photodetector) throughout an analysis cycle. The reflectance and transmittance, largely dominated by the presence of light absorbing EC, decrease as pyrolysis takes place and increase as light-absorbing carbon is liberated during the latter part of the analysis. By monitoring the reflectance and transmittance,

the portion of the EC peak corresponding to pyrolyzed OC can be accurately assigned to the OC fraction. The correction for the charring conversion of OC to EC is essential for a less-biased measurement of carbon fractions (Johnson et al., 1981). The Thermal Optical Reflectance (TOR) and Thermal Optical Transmittance (TOT) charring corrections are not necessarily the same, owing to charring of organic vapors adsorbed within the quartz fiber filter (Chow et al., 2004; Chen et al., 2004). OC and EC determined by both methods are reported.

Carbonate carbon can be determined by measuring the CO_2 evolved upon acidification of the sample punch before the normal carbon analysis procedure.

Seven temperature fractions, as well as the TOR and TOT charring correction, are individually quantified and reported when the IMPROVE (Chow et al., 1993, 2001) temperature protocol is applied. Values routinely reported include total OC, total EC, total carbon (TC, sum of total OC and total EC), and pyrolized carbon, monitored by both reflectance (OPR) and transmittance (OPT). Depending on the thermal/optical protocol applied for quantification, thermally-derived subfractions of OC and EC, and of carbonate carbon, are reported.

1.3 Measurement Interferences and Their Minimization

Precision of *thermal/optical carbon analysis* depends on the sample temperature in the analysis. Therefore, the correlation between sample temperature and thermocouple temperature should be established and calibrated semiannually so that the thermal protocol can truly reflect the sample temperature during the analysis (Chow et al., 2005). The thermocouple's position in relation to the sample, as well as the different heating properties of the thermocouple and the sample govern the temperature offset. This relationship must be maintained for the temperature calibration to hold. The analyzer must not be used if the sample boat shifts position or becomes loose in its holder (see Figure 2-3) .

Carbonate carbon may bias carbon concentrations if it constitutes more than 5% of total carbon in the ambient or source sample. Carbonate carbon may be measured as either OC or EC depending on the chemical nature of the carbonates and their thermal decomposition temperatures. Acid pretreatment of filter samples can eliminate the carbonate interference (Novakov, 1981, 1982; Rosen et al., 1982). Carbonate carbon has been found at only a few IMPROVE monitoring sites, and then at levels that do not appreciably bias OC and EC concentrations (Chow and Watson, 2002).

The presence of certain minerals in some soils can affect the laser correction for pyrolysis. These minerals change color as the sample punch is heated, generally resulting in a darker

sample. For samples which contain large fractions of resuspended soils, the split between OC and EC should be examined manually.

Some minerals, again predominantly in soil samples or soil-dominated samples, may affect the laser correction by temporarily changing color or changing the surface texture of the deposit residue. Unlike the effect described above, these changes are reversible and temperature-dependent.

Some colored organic compounds can affect the laser correction, causing increased reflectance or decreased transmittance as these compounds are removed. This effect is ascertained by examining the laser response during the organic portion of the analysis. The split between OC and EC should be examined manually if the effect is large.

The presence of certain elements (Na, K, Pb, Mn, V, Cu, Ni, Co, and Cr), existing either as contaminants on the filters (e.g., glass-fiber filters), or as part of the deposit material, has been shown to catalyze the removal of EC at lower temperatures (Lin and Friedlander, 1988). Such catalysis would affect the distribution of carbon peaks during the analysis.

If present in sufficient levels, water vapor, either contained in the deposit or remaining after acidification of the sample punch can shift the FID baseline. To eliminate this effect, allow the sample punch to dry in the analyzer by passing carrier gases over it before starting the analysis.

1.4 Ranges and Typical Values of Measurements

Source-dominated or heavily polluted environments, which would normally have carbon concentrations above the working range of the carbon analyzer, may be sampled and analyzed within the range of the carbon analyzer by increasing the filter deposit area or by decreasing the sampling flow in the field equipment. Deposits that are very black, such that the initial reflectance is close to zero, provide a less precise OC/EC split, because additional blackening due to OC charring is not quantified by the reflected light.

The carbon analyzer can effectively measure between 0.05 and 750 µg carbon/cm^2 for a typical punch size of 0.5 cm^2. The upper limit depends on the particular compounds on the filter and the temperatures at which they evolve. This upper limit may be extended by reducing the punch size or extending analysis times at lower temperature plateaus to avoid an over-range FID signal.

Typical carbon values range between 10 and 100 µg carbon/cm^2 for 24-hour ambient samples. The distribution between OC and EC depends on the particulate source types, ranging from negligible levels of EC (e.g., secondary sulfate) to 80% or more EC (e.g., diesel exhaust).

1.5 Typical Lower Quantifiable Limits, Precision, and Accuracy

The *lower quantifiable limits* (LQLs) of thermal carbon methods depend on the variable carbon content of the blank quartz filters, as well as the analysis method. For better LQLs, the unexposed filters should be pre-fired in an oven at high temperatures for several hours to remove any residual carbon contamination (Fung, 1986; Huntzicker, 1986; Rau, 1986; DRI, 2004). All quartz-fiber filters originating from DRI are pre-inspected for defects such as pinholes or tears. They are then pre-fired for a minimum of four hours at 900 °C and 2% of these are acceptance-tested for blank levels before use in the IMPROVE network. Batches containing filters that fail to pass the preset acceptance levels (1.5 µg OC, 0.5 µg EC, and 2.0 µg TC per cm^2) are not used for sample collection. Average pre-fired blank levels are 0.15 ± 0.15 µg OC/cm^2, 0.00 ± 0.02 µg EC/cm^2, and 0.15 ± 0.15 µg TC/cm^2. Because pre-fired filters can adsorb organic vapors during shipping and storage, the LQL of analysis on a particular set of filters depends on the number of field blanks analyzed and the variability in the results from those blanks. To reduce the risk of contamination during shipping and storage, samples are vacuum-sealed and stored in a freezer.

The *minimum detection limit* (MDL) of the DRI Model 2001 carbon analyzers used for IMPROVE_A protocol is based on the analyses of 214 blank quartz-fiber filters. The MDL is defined as three times the standard deviation of their measured results. They are:

total OC	0.45 µg/cm^2
total EC	0.06 µg/cm^2
TC	0.45 µg/cm^2

Acid-evolved carbonate levels in pre-fired quartz-fiber filters have been shown to be quite variable (0.0-1.0 µg/cm^2) over time. The reaction of ambient CO_2 with alkaline sites on the quartz fibers may be the cause of such variable blank levels. Acceptance testing for carbonate is only performed for special projects that require carbonate analysis.

The precision of carbon analysis has been reported to range from 2-4% (Johnson, 1981). For analysis of actual ambient and source filters, homogeneity of the deposit is most important for reproducible results. For homogeneous deposits containing >5 µg/cm^2 (~10 times MDL) of TC, precision is generally 10% or better; for inhomogeneous deposits replicates may deviate by as much as 30%. The precision of carbonate analysis results is ~10%.

The precision of the laser-dependent split between OC and EC fractions depends upon how rapidly the laser is increasing at the time of the split and whether or not the split falls in the middle of a large carbon peak. Typically, relative laser split times are reproducible within 10 seconds and deviations in calculated splits are <5% of the total measured carbon.

The accuracy of the thermal/optical reflectance method for TC determined by analyzing a known amount of carbon is between 2-6% (Rau, 1986). Precision of the OC/EC split is between 5% and 10%. This precision is also influenced by the filter loading and source type.

1.6 Personnel Responsibilities

Before performing carbon analysis, all analysts in the laboratory should read and understand the entire *Standard Operating Procedure (SOP)*, including routine system calibration, actual analysis, and immediate review of the data as it is produced, in order to correct system problems.

The responsibilities of the laboratory manager or supervisor are: to ensure that the carbon analyses procedures are properly followed; to examine and document all replicate, standard, and blank performance test data; to designate samples for reanalysis; to arrange for maintenance and repair; to maintain the supplies and gases necessary to ensure uninterrupted analysis; and to deliver the analysis results in database format to the project manager within the specified time period.

The *quality assurance* (QA) *officer* of DRI's Division of Atmospheric Sciences is responsible for determining the extent and methods of quality assurance to be applied to each project, to estimate the level of effort involved in this quality assurance, to update this procedure periodically, and to ascertain that these tasks are budgeted and carried out as part of the performance on each contract.

1.7 Definitions for IMPROVE_A Thermal Protocol for Carbon Analysis

The following terms are used in this document:

IMPROVE_A Thermal Protocol:	A thermal protocol is used in carbon analyzers to quantify carbon fractions evolved at different temperature plateaus. The IMPROVE_A thermal protocol derives from the Interagency Monitoring of Protected Visual Environments (IMPROVE) thermal protocol initiated in 1987 (Chow et al., 2005).
Calibration Injection:	The injection of calibration gases, either CO_2 or CH_4, into the

sample stream at the beginning and end of each work day to check instrument performance.

Calibration Peak: The FID peak resulting from the automatic injection of methane calibration gas (CH_4/He) at the end of each analysis run for each sample. All integrated peak areas are divided by the calibration peak area and multiplied by an instrument-specific calibration factor to obtain µg carbon per sample punch.

FID Split Time: The time at which the laser split occurs plus the transit time required for thermally evolved carbon to travel from the sample punch to the FID.

Organic Carbon: Carbon evolved from the filter punch in a He-only (>99.999%) atmosphere at 140, 280, 480 and 580 °C plus pyrolyzed organic carbon. This is the same as Volatile Organic Carbon (VOC) plus high-temperature OC.

Elemental Carbon: Carbon evolved from the filter punch in a 98% He/2% O_2 atmosphere at 580, 740, and 840 °C minus any pyrolyzed OC.

High Temperature OC: Carbon evolved from the filter punch in a He-only atmosphere at 280, 480, and 580 °C plus pyrolyzed organic carbon. This is OC minus the first OC peak (OC1).

High Temperature EC: Carbon evolved from the filter punch in a 98% He/2% O_2 atmosphere at 740 and 840 °C minus any pyrolyzed organic carbon present in these two peaks. This is EC minus the first EC peak (EC1).

Laser Split: The separation between OC and EC, which depends on the laser-measured reflectance and/or transmittance of the filter punch returning to its initial value. At this point all pyrolyzed OC has been removed and EC is beginning to evolve.

Lower Split Time: The time at which the laser-measured reflectance and/or transmittance of the filter punch reaches its initial value minus the precision of the laser signal (currently defined as 10 counts).

Pyrolysis: The conversion of OC compounds to EC due to thermal

decomposition; this may be envisioned as "charring" during the organic portion of the analysis.

OC1: Carbon evolved from the filter punch in a He-only (>99.999%) atmosphere from ambient (~25 °C) to 140 °C.

OC2: Carbon evolved from the filter punch in a He-only (>99.999%) atmosphere from 140 to 280 °C.

OC3: Carbon evolved from the filter punch in a He-only (>99.999%) atmosphere from 280 to 480 °C.

OC4: Carbon evolved from the filter punch in a He-only (>99.999%) atmosphere from 480 to 580 °C.

OP: The carbon evolved from the time that the carrier gas flow is changed from He to 98% He/2% O_2 at 580 °C to the time that the laser-measured filter reflectance (OPR) or transmittance (OPT) reaches its initial value. A negative sign is assigned if the laser split occurs before the introduction of O_2.

EC1: Carbon evolved from the filter punch in a 98% He/2% O_2 atmosphere at 580 °C.

EC2: Carbon evolved from the filter punch in a 98% He/2% O_2 atmosphere from 580 to 740 °C.

EC3: Carbon evolved from the filter punch in a 98% He/2% O_2 atmosphere from 740 to 840 °C.

Regular Split Time: The time at which the laser-measured reflectance and/or transmittance of the filter punch reaches its initial value.

Total Carbon (TC): All carbon evolved from the filter punch between ambient and 840 °C under He and 98% He /2% O_2 atmospheres.

Upper Split Time: The time at which the laser-measured reflectance and/or transmittance of the filter punch reaches its initial value plus the precision of the laser signal (currently defined as 10 counts).

1.8 Related Procedures

Standard Operating Procedures (SOPs), related carbon analysis activities, and other manuals that should be reviewed in conjunction with this document are:

DRI SOP #6-001.1	Shipping and Mailing Procedures.
DRI SOP #6-009.1	Field and Laboratory Safety Procedures. Any SOPs dealing with filter handling and shipping in conjunction with the specific sampling method used.
DRI SOP #2-106.1	Pre-Firing of Quartz Filters for Carbon Analysis.

The DRI Model 2001 Thermal/Optical Carbon Analyzer Owner's Manual, revised 3/2004 (Atmoslytic, Calabasas, CA).

The DRI Model 2001 Thermal/Optical Carbon Analyzer Installation, Operation and Troubleshooting Manual, revised 12/2004 (Atmoslytic, Calabasas, CA).

2 APPARATUS, INSTRUMENTATION, REAGENTS, AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 Description

The components of the DRI Model 2001 Thermal/Optical Carbon Analyzer are depicted in Figures 2-1 through 2-3; the complete gas flow schematic is shown in Figure 2-4. Other details of the configuration of the DRI Model 2001 Thermal/Optical Carbon Analyzer are referred to in the owner's manual. The programmable combustion oven is the heart of the carbon analyzer and includes loading, combustion, and oxidation zones in a single quartz "oven" as depicted in Figure 2-5.

In addition to the DRI Model 2001 thermal/optical analyzer, which is connected to a Pentium 4x compatible computer, the following items are needed for routine carbon analysis:

- Stainless steel punching tool: 5/16-inch diameter, 0.5 cm^2 nominal area for removing small sample punches from quartz filters. This punching tool must be kept clean and sharp. If the punching tool is resharpened, the punch area must be re-verified. Verification is performed by removing 10 punches from a 47-mm quartz-fiber filter (17.35 cm^2); then calculating the punch area [= 17.35 cm^2 x (average weight of 10 punches / original filter weight)]. Further verification can be done by taking a precise measurement of the punching tool.

Figure 2-1. DRI Model 2001 Thermal/Optical Carbon Analyzer

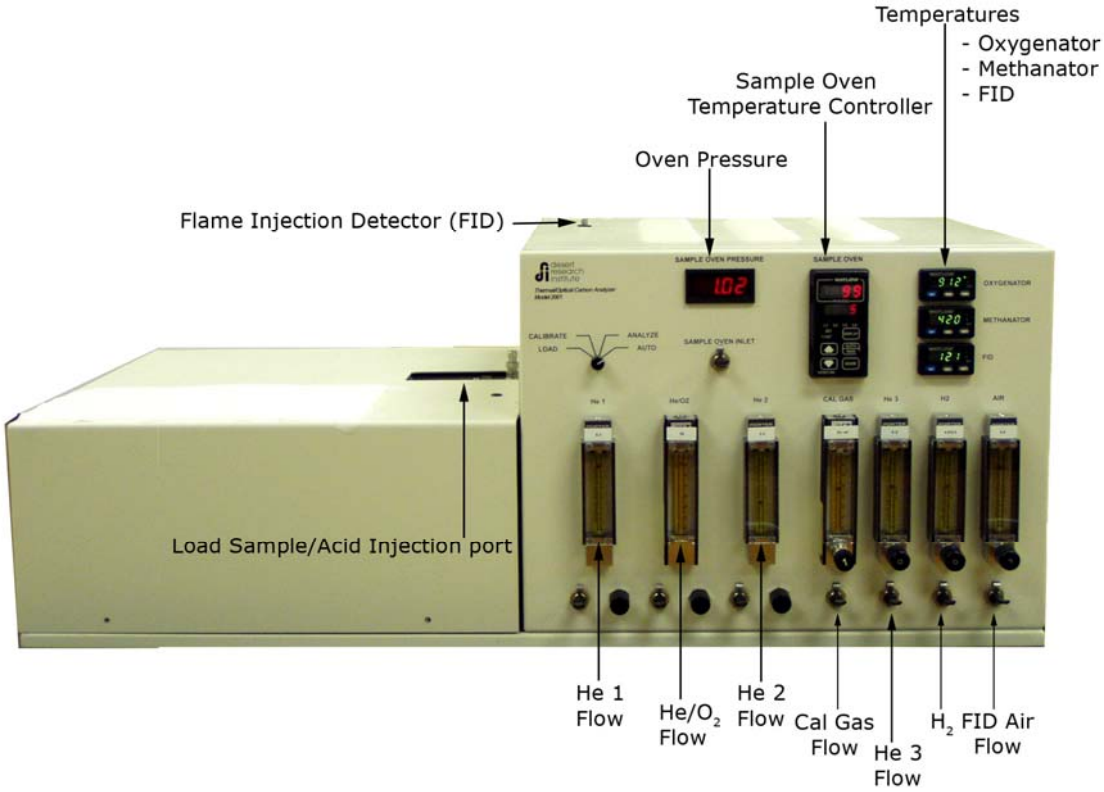


Figure 2-2. DRI Model 2001 Thermal/Optical Carbon Analyzer Schematic Diagram

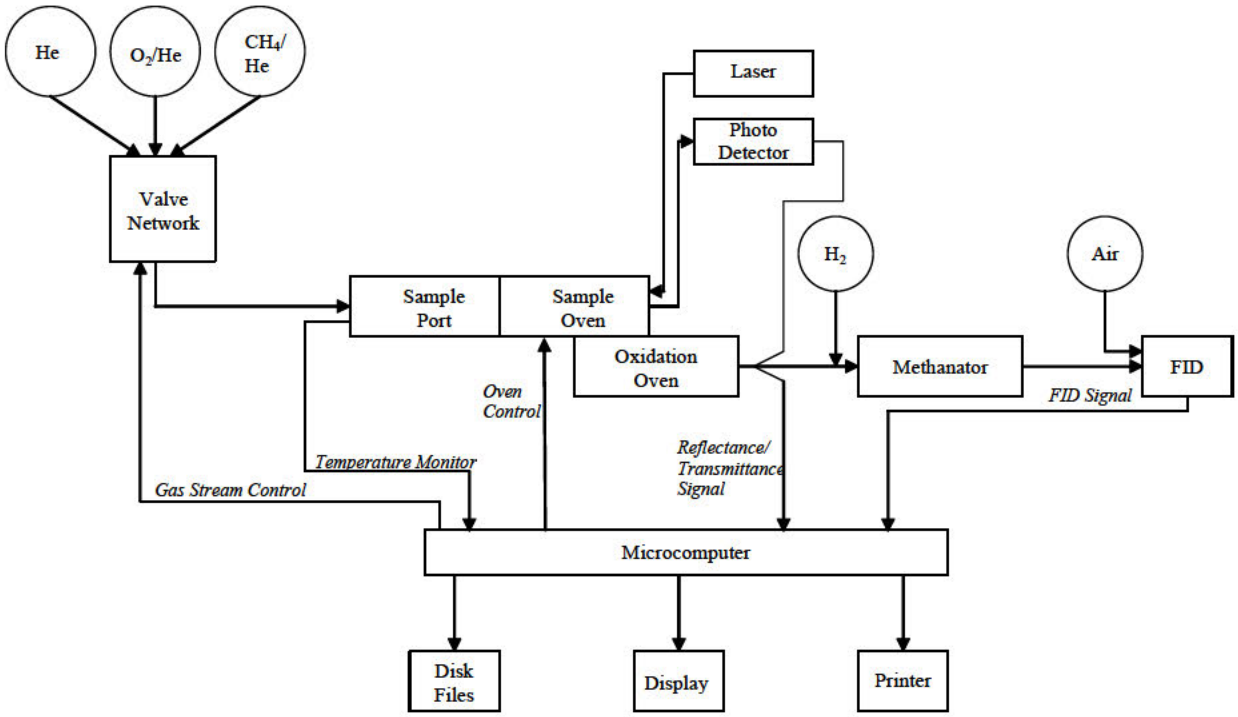
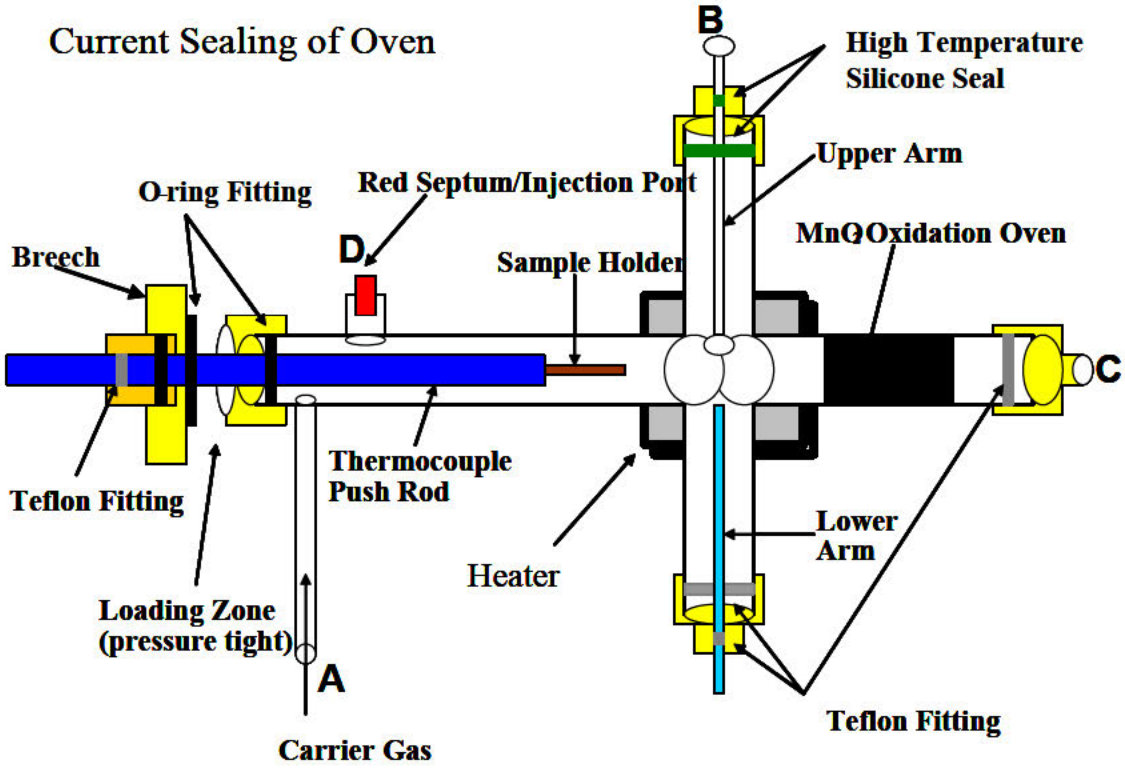


Figure 2-3. DRI Model 2001 Thermal/Optical Carbon Analyzer Sealing Diagram



Note: In the breech, there is a Teflon-reducing ferrule to seal the pushrod thermocouple, plus one O-ring to seal the breech against the inlet (coupler) connector.

Figure 2-4. DRI Model 2001 Thermal/Optical Carbon Analyzer Gas Flow Schematic

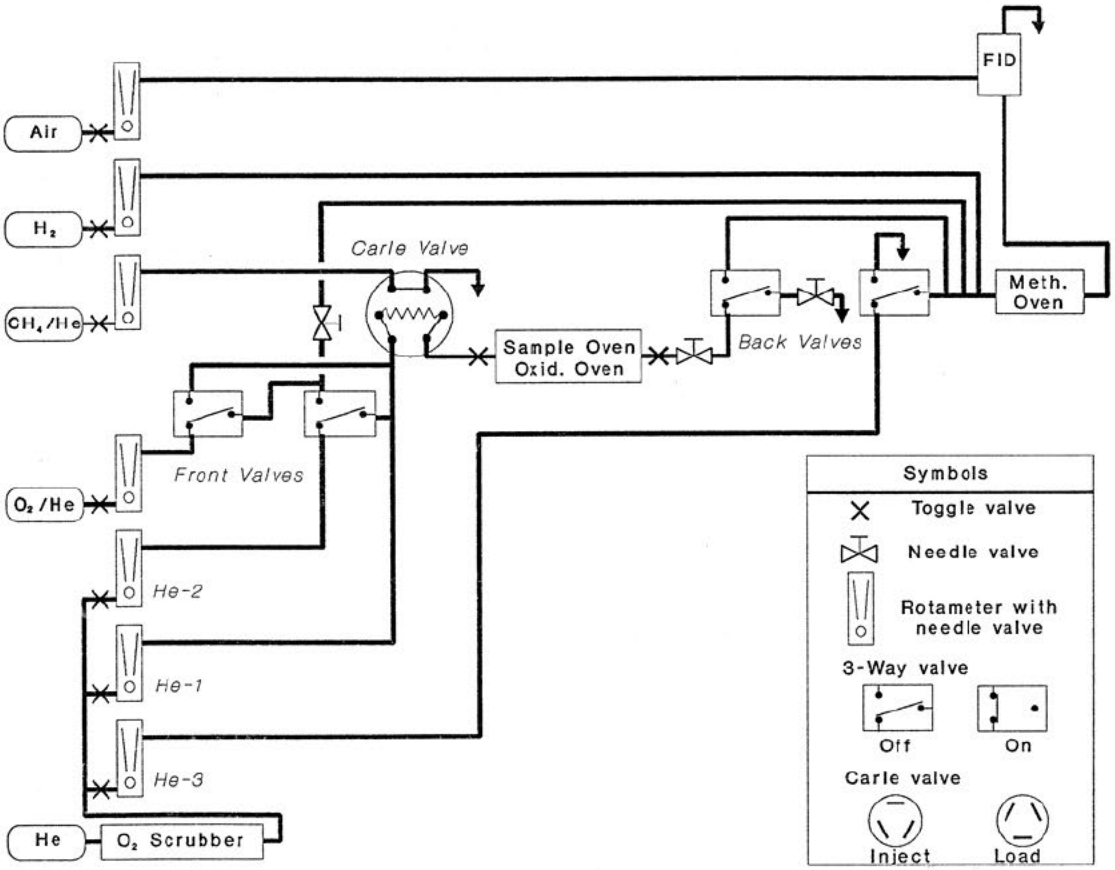
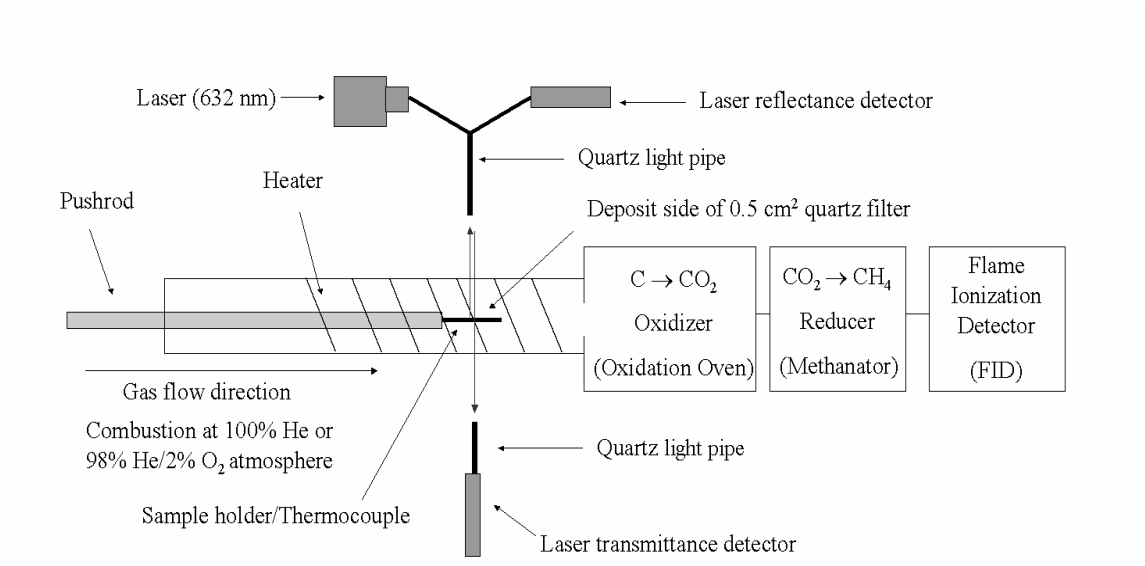


Figure 2-5. DRI Model 2001 Thermal/Optical Carbon Analyzer Combustion Oven



- Syringes: Hamilton Gas-Tight 1000 and 2500 µl syringes for calibration injections; 25 µl syringe for carbonate analysis and for analyzer calibration.
- Quartz filters: Pallflex 2500 QAT-UP (Pall Life Sciences, Ann Arbor, MI) quartz-fiber filter or equivalent.
- Flat-tip tweezers.
- Flat glass plate.
- Logbook/notebook.
- Transparent tape.
- KIMTECH Pure* CL4 Critical Task Wipers and large KimWipes (EX-L).
- Small Styrofoam cooler or refrigerator.
- Blue ice (if using Styrofoam cooler).
- Butane or piezoelectric lighter.
- A copy of *DRICarb.exe* (the analysis program), *Carbon.par* (the analysis parameter file), and Microsoft Access to run *CarbonNetWork.mdb*.

2.1.2 Instrument Characterization

The DRI Model 2001 Thermal/Optical Carbon Analyzer is program-driven and data is stored automatically to the hard drive via a PC-compatible computer processor board. Response times and signal lag times are built into the parameter file that is loaded when the analysis program begins. The program is driven by the thermal protocol. For example, when using the IMPROVE_A protocol, the program will advance to the next temperature or carrier gas mixture once the FID signal returns to its baseline; i.e., after a minimum of 150 seconds at one analysis condition. A maximum time limit (580 seconds) per analysis condition is also established to prevent a slight baseline drift from holding the analyzer in one condition indefinitely. For the *Speciation Trends Network* (STN) thermal protocol, the program advances from one specified temperature plateau to the next temperature or carrier gas mixture when the specified analysis time is reached. Both methods require at least one ~0.5 cm^2 punch per filter and do not require sample pre-treatment. The sample punch is destroyed by both methods.

Operator concerns for correct routine operation of the instrument include the following (refer to Section 4 for more details):

- Verify sample oven pressure reading and specified flow range in the front-panel flow meters.
- DO NOT leave the room until the analysis begins.
- Check the graphical printout after each analysis run to ensure that the: 1) FID (Flame Ionization Detector), 2) temperature, and 3) laser signals are behaving as expected (Section 4.1). Report any anomalies to the lab supervisor immediately.
- The quartz oven is susceptible to breakage. Care should be taken when handling and cleaning.
- Be careful that no fiber from the KIMTECH wiper is left on the sample punch, tweezers, and/or glass plate.

2.1.3 Maintenance

Regular maintenance for the analyzer involves daily checking of compressed gas supplies, cleaning the punching tool and tweezers between each sample with dry KIMTECH, ensuring that the lab is clean, and backing up data files to disc on a daily basis (unless files are automatically backed up to server). Temperature calibrations for the six temperature plateaus (140, 280, 480, 580, 740, and 840 °C) need to be performed semiannually (see details in Section 5). Checks of laser adjustments (physical and electrical) and leaks are made at least monthly. The procedure for leak checks can be found in Section 3.1.2. Additional leak tests are performed with a He leak detector each time a part is replaced, and whenever the analyzer fails the leak check during the daily routine. The system should show no He leaks at the various connections of the quartz cross oven. Since He has high diffusivity, freedom from He leaks will safeguard against O_2 diffusion into the system. These O_2 levels are determined quarterly using a gas chromatography/mass spectrometry (GC/MS) instrument on the analyzer. When a fresh He cylinder is installed, the O_2 level should be checked in one of the analyzers hooked up to the gas line to assure the quality of the gas supply and the condition of the O_2 scrubber. If the *cmdAutoCalibCheck* command is used for calibration, the condition of the catalysts will be indicated and appropriate action can be taken (such as catalyst replacement). All calibrations, repairs, and checks must be recorded in the *Carbon Analyzer Logbook* (Figure 2-7). Flow rates of all operating gases should be checked

and adjusted (if needed) whenever a new quartz oven or methanator is installed or serviced. Additionally, a flow balance should be performed as well.

2.1.4 Spare Parts

The following spare parts must be kept on hand to ensure minimal interruptions in carbon analysis:

- Quartz furnace tube available from the manufacturer (Atmoslytic, Calabasas, CA).
- Quartz rods: 3 mm nominal diameter, optical quality (Atmoslytic, Calabasas, CA), polished for optical clarity with 104 mm (upper arm) and 119 mm (lower arm) lengths. The version of the carbon analyzer manufactured in 2001 uses a 98 mm rod for the upper arm. Measure the old rods for reference.
- Catalyst ovens: Watlow 15.24 cm length, 2.54 cm tube diameter element from the analyzer supplier.
- Quartz boats (Atmoslytic, Calabasas, CA).
- Thermocouple rods: 24.13 cm length by 0.32 cm outside diameter (OD), Type-K ground isolated with Inconel sheath (Omega, Part #TJ36-CAIN-18E-9.5, Stamford, CT). Remove 1 cm of the sheath with a file to obtain the longer tip needed in this application.
- FID flame tips: for Gow-Mac #12-800 FIDs (Gow-Mac, #132-117, Bethlehem, PA).
- Septa: Standard 0.32 cm or 0.64 cm cylindrical (Alltech Associates #6524, Deerfield, IL) for injection ports. Silicon septa 0.25 cm and 1.11 cm for oven seals (Alltech #15427 and #15429, Deerfield, IL).
- 25 µl syringes.
- Replacement needles for syringes (Alltech #7729-06, Deerfield, IL).
- Replacement oxygen/moisture trap (R&D Separations, Model OT3-2, Rancho Cordova, CA).
- Replacement hydrocarbon trap (R&D Separations, Model HT200-4, Rancho Cordova, CA).

- Replacement indicating oxygen trap (Chromatography Research Supplies, Model 202223, Louisville, KY).
- Quartz wool: For repacking the oxidation oven (Alltech Associates, #4033, Deerfield, IL).
- Viton O-rings: Size 013. Two needed for quartz oven tube inlet.
- Teflon ferrules: Parker or Swagelok style 0.64 cm front and back ferrule for the quartz oven tube outlet connections (Swagelock, T-400-SET, Solon, OH). Refer to instrument user manual for specific ferrule sizes.
- Teflon ferrules: 0.32 cm to 0.64 cm (Alltech Associates, #RF-400/200-T, Deerfield, IL), for the thermocouple rod at the inlet breech. Refer to instrument user manual for specific ferrule sizes (style varies by location on analyzer).
- High temperature silicone seals for quartz light rods and connector, prepared by Alltech Associates, #15427 and #15429, Deerfield, IL.
- Heating element for oven (Watlow, #VC401A06A-0000R [90° bend], Columbia, MO).
- Printer paper and toner cartridge.
- Computer CD for backup if not on server backup.

2.1.5 Reagents

The following chemicals should be reagent grade or better:

- Potassium hydrogen phthalate (KHP), for calibration (Fisher Scientific, cat #P-243, CAS 877-24-7, Fairlawn, NJ).
- Sucrose, for calibration use (EM Science, #SX1075-1, Gibbstown, NJ).
- Manganese dioxide (MnO_2), crystalline, as an oxidizer in the oxidation oven (Nurnberg Scientific, #C5162, Portland, OR; Aldrich Chemicals #24344-2, St. Louis, MO; or equivalent).
- Nickelous nitrate [$Ni(NO_3)_2 \cdot 6H_2O$], crystalline, used to prepare the nickel catalyst in the methanator (Fisher Scientific, cat #N62-5000, CAS 13478-00-70, Fairlawn, NJ).

- Chromosorb A, 20/30 mesh, used as a support for nickel catalyst in the methanator (from any chromatography supplier, such as Alltech cat #2-0165). Both nickelous nitrate and Chromosorb A are for preparing the reduction catalyst in the methanator.

- Hydrochloric acid (HCl), 0.4 molar solution, for use in cleaning punch and quartz ovens, and for use in carbonate analysis (Fisher Scientific, cat #A508-212, CAS 7647-01-0, Fairlawn, NJ).

- Hydrofluoric acid (HF), diluted to 15% for removing the white deposits from devitrification (white deposits of SiO_2) on the quartz oven parts (Fisher Scientific, cat #A147-1LB, CAS 7664-39-3, Fairlawn, NJ).

- Nanopure water. (used as described in Section 4.1.3.1).

2.1.6 Gases

The following compressed gases should be ultra-high purity (UHP) grade or better:

- He for a carrier gas, regulated to 15-40 psi with a metal diaphragm regulator. The higher pressure is required due to the pressure drop across the Supelco oxygen scrubber.

- 5% CH_4 by volume in He for calibration injections and calibration peaks; regulated to 10 psi by a metal diaphragm regulator.

- 5% CO_2 by volume in He for calibration injections; regulated to 10 psi by a metal diaphragm regulator.

- 10% O_2 by volume in He as a carrier gas, regulated to 15 psi by a metal diaphragm regulator.

In addition, the following gases are required:

- Hydrogen for the FID flame, regulated to 15 psi with a metal diaphragm regulator.

- Hydrocarbon-free air to supply O_2 to the FID, regulated to 15 psi by a metal diaphragm regulator from a zero air generator.

- Compressed air for pneumatic activation, regulated to ~25 psi.

At least one backup cylinder per gas type should be kept on hand at all times. The 90% He/10% O_2 mixture are typically replaced every four to six weeks; H_2 and He are replaced once a week. All gases are replaced when the cylinder pressure drops below 500 psi. Check the O_2 scrubber and follow the manufacturer's recommendations for scheduling its replacement.

The flow settings on the flow meters (rotameters) are based on an input of 15 psi for He, 90% He/10% O_2, H_2, and FID air. The pneumatic drivers for the breech should have a pressure of ~25 psi to operate effectively (sealing the opening).

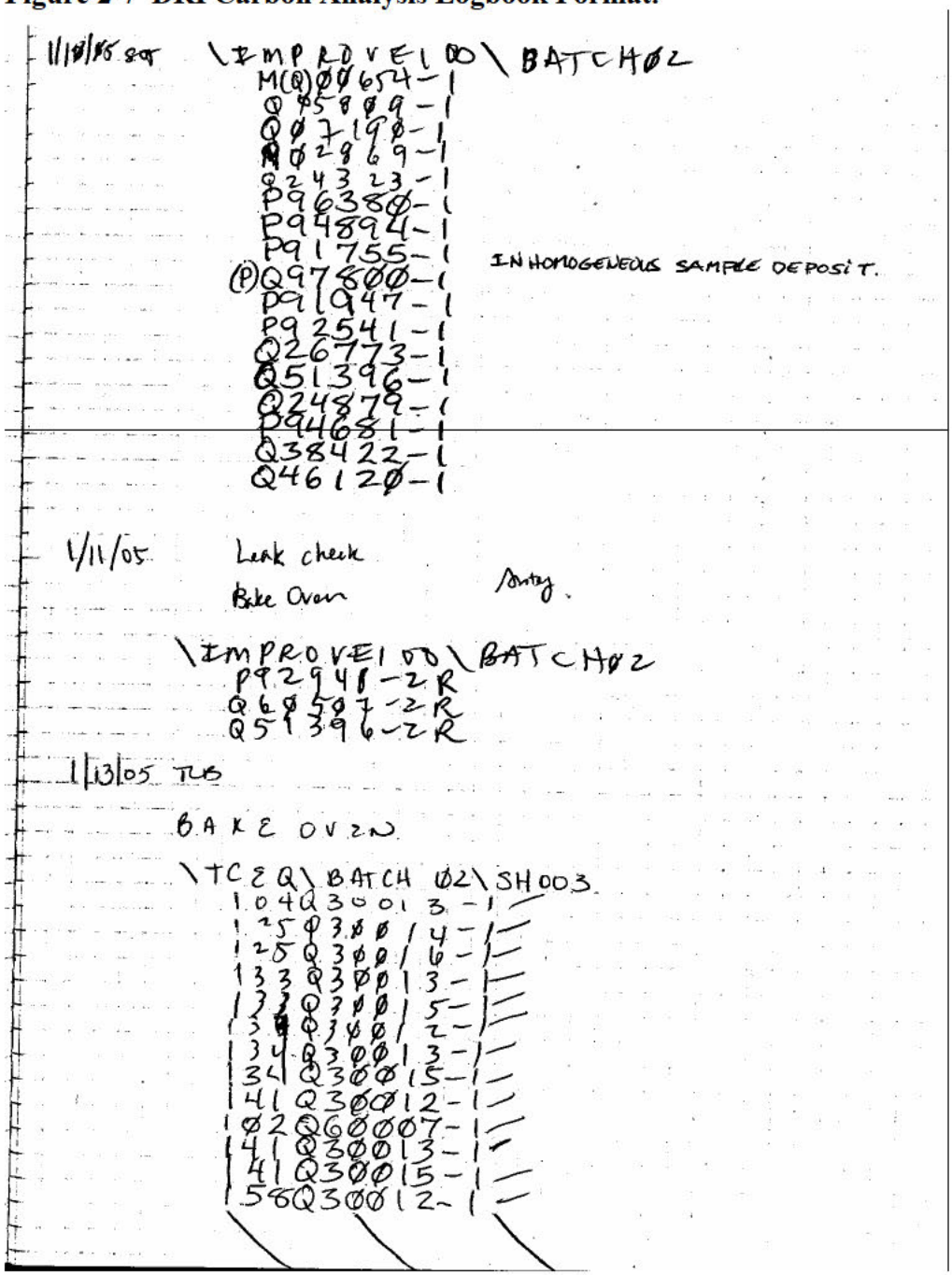
2.1.7 Forms and Paperwork

All samples are logged in upon receipt at the laboratory. A sample analysis list will be prepared by the laboratory supervisor or designated technician indicating which samples will be analyzed, plus any special instructions. Figure 2-6 provides an example of the sample analysis run list. As individual samples are analyzed, entries are made in the *Carbon Analyzer Logbook*, as shown in Figure 2-7.

Figure 2-6. DRI Carbon Sample Analysis Run List.

```
                    IMPROVE NPS B04 - June 2004: Batch G8 Quartz

Date     : Ø8/2Ø/Ø4                        Account: 6300-683-6081

From     : D.Crow

To       :            Carbon Lab

Analysis: OC/EC                          by TOR : 2ØØ samples, data in IMOETG8I.DBF

Sample Overview:

  This analysis list covers samples from the NPS IMPROVE project.  These are 2ØØ
  PM2.5 samples on 25 mm Quartz filters, including no lab blanks and no field
  blanks.  These samples were collected with an Improve sampler.

Analysis Overview:

  Sample deposit area: 3.53 cm2
  Analysis start date: When Ready
  Analysis deadline  :
  Sample location    : Carbon Lab

Analysis Details:

  DO NOT REPLICATE BLANKS OR SECONDARIES! DO NOT FLAG BLANKS!. 'Q' numbers have
  area = 3.53 cm2. 'M' numbers have area = 3.8Ø cm2.

  Carbon analysis data will be stored in the D:\IMPROVE.BØ4\LOTG8 directory.
```

Figure 2-7 DRI Carbon Analysis Logbook Format.



1/10/05 SOT \IMPROVE100\BATCH02
M(Q)00654-1
Q05809-1
Q07190-1
Q02869-1
Q24323-1
P96380-1
P94894-1
P91755-1 INHOMOGENEOUS SAMPLE DEPOSIT.
(P)Q97800-1
P91947-1
P92541-1
Q26773-1
Q51396-1
Q24879-1
P94681-1
Q38422-1
Q46120-1

1/11/05 Leak check
Bake Oven Sorry.

\IMPROVE100\BATCH02
P92948-2R
Q60507-2R
Q51396-2R

1/13/05 TLS

BAKE OVEN

\TCEQ\BATCH 02\SH003
104Q3001 3-1
125Q3001 4-1
125Q3001 6-1
133Q3001 3-1
133Q3001 5-1
134Q3001 2-1
134Q3001 3-1
134Q3001 5-1
141Q3001 2-1
102Q6000 7-1
141Q3001 3-1
141Q3001 5-1
158Q3001 2-1

3 PROCEDURES

3.1 Detailed Procedures

3.1.1 Analyzer Start-Up

If the analyzer is started up for the first time, or after an extended period of non-operation, it will take a period of conditioning to reach a stable system background. At the start, allow all the gases to purge through the system for ~30 minutes before heating the various zones in a stepwise manner. Allow the FID and Line Heaters to reach operating temperatures of 120 °C and 105 °C, respectively, before heating up the oxygenator and methanator. Heat both catalysts at 120 °C for about half an hour, then in ~100 °C increments with ~30 min. hold time until the final temperatures of 912 °C and 420 °C are reached for the oxygenator and methanator, respectively.

The following steps outline analyzer start-up:

- Check all gas cylinder pressures; cylinders with gas pressures less than 500 psi should be replaced before beginning the day's analysis.

- Check that all gas delivery pressures are correct:

Hydrogen (H_2)	15 psi
Helium(He)	15-40 psi (check label on regulator for current setting)
Compressed air	15 psi for FID, 25 psi for breech actuation
O_2/He mix	15 psi
CH_4/He mix	10 psi
CO_2/He mix	10 psi

- Check that the FID is lit by holding a pair of tweezers over the FID exhaust stack and watching for condensation. If the FID is not lit (as immediately after the H_2 or compressed air cylinders are changed), relight the flame by turning the H_2 rotameter to the upper limit (as posted on the flow meter) and holding a butane lighter or match over the FID stack. A soft pop indicates that the flame has been lighted. Verify that the flame remains lit by the tweezers test. Often the flame will not stay lit the first try, especially after the H_2 cylinder is changed and air gets into the gas lines. Return the rotameter to the operation setting after the flame is lit.

- Check and readjust, if necessary, all gas flows at the analyzer. The correct readings are posted on each rotameter. Read through the center of the ball. If drastic adjustments are required on one analyzer, recheck that flows on the other analyzers have not been affected.

- Turn on the computer monitor. Note: the computers are generally left on at all times; only the monitors are turned off when the analyzers are not in use.

- Confirm that the date and time on the computer are correct.

- Wipe the sample tweezers, flat glass plate, and punching tool with clean KIMTECH wiper, taking care not to contact the cleaned surfaces with fingers or other dirty items. Check to make sure that no fibers from the KIMTECH wiper are left on the surfaces.

- Begin the daily entry in the *Carbon Analyzer Logbook*. Entries should follow the format in Figure 2-7.

- Make sure that the printer has enough paper for the day and that the toner cartridge is producing legible text and graphics.

NOTE: When using the carbon analysis software, clicking on the Exit button closes the program. Exiting in the midst of an analysis is not advisable, as the analyzer will revert to the default settings (see settings under Options\Manual); in such a case, a hot thermocouple will retract, possibly damaging the Teflon seal.

If for some reason the program freezes, allow the sample oven to cool to below 200 °C and then close the program and restart *DRICarb.exe*.

3.1.2 Leak Checks

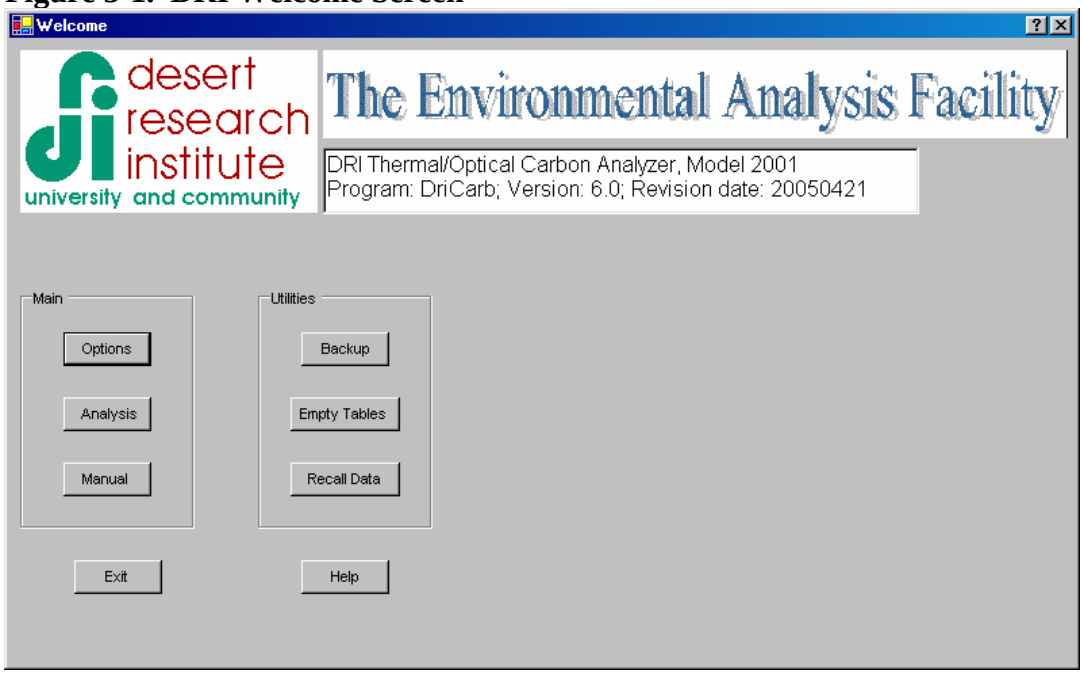
Perform leak checks daily to detect leakage in the sample oven.

3.1.2.1 Manual Leak Check

- To begin the manual leak check, go to C:\CarbonNet, then double click the *DRICarb.exe* program icon to begin the carbon program (or double click the *DRICarb.exe* shortcut on the computer desktop). The DRI welcome screen appears as depicted in Figure 3-1. Verify that the correct version of the software and database are being used. For normal

analysis, the database should be "CarbonNetWorkXX.mdb", where xx is the analyzer number.

Figure 3-1. DRI Welcome Screen



- With the breech closed, flip the oven outlet toggle on the side of the analyzer down (off) and let the sample oven pressure reach ~5 psi. Most systems are working in the ~2.5 psi range, but a leak is easier to detect when the pressure is at ~5 psi. Close the oven inlet toggle, on the front of the analyzer, and watch for a decline in the sample oven pressure. A "leak free" condition is indicated by a steady pressure reading, or a decline of 0.01 psi or less per second (~0.01 ml/sec).

- If the pressure is stable, flip the outlet oven toggle and then the inlet oven toggle back to the on position (up). This is to avoid pressurizing the oven if the inlet toggle is flipped first.

- If the pressure is not stable, use a He leak detector (Alltech, Deerfield, IL) to locate the leak. Check the following items and correct accordingly:

    - All ferrules, fittings and seals.

- Quartz oven.
- All tubing.
- Thermocouple.
- Breech O-ring.

- If the system still leaks, wipe all threads and ferrules with a dry KIMTECH wiper, reassemble, and retry.
- Also, check the breech O-ring to ensure that it sits squarely in the groove and that there is sufficient pressure to close the breech.
- Refer to the carbon analyzer's *Troubleshooting Manual* for additional tips and procedures.

Once the system passes the leak test, make sure that the analyzer's multi-function switch (at the left of the front panel) is set at Auto in order to continue with routine analysis. Allow the system pressure to return to its original value and record this value on the *Daily Analyzer Checklist* shown in Figure 3-2. The pressure should be consistent with previous day's values.

3.1.3 Oven Bake

A daily oven bake is performed to ensure the system is clean before beginning analysis. The oven bake can be performed manually or by using an automated command from the command table. Use the following procedures to do a manual oven bake:

3.1.3.1 Manual Oven Bake

- Select "Manual" from the "Main" submenu. From the "Manual" screen, select "Control" on the drop-down menu list. (Note: analyzer must be in "Auto" mode for the manual control to work.) This will bring up the "Control" screen. Change the "Oven Temperature" field to "1000". Change the "Sample Position" field to "Analyze". Click "Go". This will heat the oven to approximately 950 °C, depending on the instrument's calibration. Exercise caution when working around hot surfaces of the analyzer.
- Repeat until the system is clean. Sample runs or calibrations may then begin.
- System blanks (section 3.1.4.1) are run after the oven bake.

3.1.3.2 Automatic Oven Bake

- From the main welcome screen, select "Analysis".
- Set Type to "Sample" and select *cmdBakeOven* from the drop-down menu in the "Command table" field.
- The project name should be "SAMPLE" and the sample ID should be in the format "CxxYYYYMMDD" where "xx" is the analyzer number (e.g. C0720050715 for analyzer number 7 on July 15, 2005,).
- Set the Run #, Punch area, and Deposit area fields to "1". Click "OK", then "Run".
- Repeat until the system is clean. Sample runs or calibrations may then begin.
- System blanks (Section 3.1.5.1) are run after the autocalibration (Section 4.1.2.1) has been completed and shows an acceptable range.
- The following items should be checked and recorded on the *Daily Analyzer Checklist* shown in Figure 3-2. These values can be obtained by choosing the manual option from the main welcome screen.
    - Reflectance and Transmittance (must be measured with a clean blank filter in the "analyze" position).
        - Reflectance range should be between 1400 and 2000 and consistent with previous days values.
        - Transmittance range should be between 800 and 1300 and consistent with previous days values.
    - System blank values
        - Total carbon must be less than 0.2 ug/cm^2
    - Calibration values
        - Specific to analyzer and must be consistent with previous days values.

Figure 3-2. Daily Analyzer Checklist

Daily Analyzer Check List **CA#:** 7 **Month:** August **2005**

Date	Leak Check/ Op's Init.	System Pressure (T<100°C)	Reflec-tance*	Trans-mittance*	System Blk (TC) in µg	Calibratn OC3 Area	Calibratn EC1 Area	Calibratn LT/RPy Area	Calibratn Peak Area	Comments
8/1 05AM	TLB	2.34	1626	1032	0.06	26499	26019	26231	26180	
8/1 05PM	GHH					26235	26102	25999	26172	
8/2 05AM	SMS	2.34	1621	1041	0.05	26209	25523	25733	25820	
8/2 PM	GHH					26185	25693	26112	26154	
8/3 AM	TLB	2.31	1594	1015	0.10	26138	25514	25729	26115	
8/3 PM	SMS					23776	23030	21866	23262	Calib. low
8/4 AM	TLB	2.33	1590	1011	0.07	26332	26230	26287	26301	
8/4 PM	GHH					26455	26501	26499	26487	
8/5 AM	SMS	2.32	1601	1017	0.11	25998	25878	25799	25907	
8/5 PM	GHH					26101	26058	26011	26100	
8/8 AM	SMS	2.30	1584	1020	0.08	26282	26324	26338	26455	FID out
8/8 PM	GHH					25950	25876	25888	25901	
8/9 AM	TLB	2.31	1581	1021	0.00	26149	26155	26174	26282	
8/9 PM	GHH					25843	25779	25850	25888	
8/10 AM	TLB	2.35	1587	1015	0.03	26111	26114	26156	26200	
8/10 PM	SMS					26099	26178	26210	25975	
8/11 AM	TLB	2.34	1577	1009	0.12	26101	26207	26228	26305	
8/11 PM	GHH					26158	26178	26242	26278	
8/12 AM	SMS	2.33	1572	1005	0.07	25449	25472	25442	25501	
8/12 PM	GHH					25555	25501	25472	25552	
8/15 AM	TLB	2.34	1570	999	0.15	26163	26174	26112	26117	R Low
8/15 PM	SMS					26540	26555	26580	26590	
8/16 AM	TLB	2.31	1575	1001	0.02	25846	25872	25888	25779	
8/16 PM	GHH					25999	25842	25912	25978	Leaking
8/17 AM	TLB	2.32	1572	998	0.01	26152	26178	26165	26118	
8/17 PM	GHH					26185	26112	26202	26282	
8/17 AM	SMS	2.33	1577	1002	0.00	25457	25482	25405	25407	
8/18 PM	GHH					26178	26187	26192	26182	
8/18 AM	TLB	2.31	1567	1011	0.10	25899	25990	25888	25872	System blk high
8/19 PM	SMS					26001	25998	25925	25965	
8/20 AM	TLB	2.30	1571	1003	0.06	26058	26075	26117	26014	
8/20 PM	TLB					25972	25942	25968	25786	

* Test on a blank filter is placed on "Analyze" position.

3.1.4 OC/EC Analysis

Based on the analysis list for the day, retrieve the samples to be analyzed from the sample freezer and place in a Styrofoam cooler with blue ice, or in the analysis room refrigerator.

Routine analysis procedure assumes carbonate will not be measured. For carbonate analysis, refer to Section 3.1.5.2, "Special Analysis".

Always execute the *cmdBakeOven* command to bake the oven before beginning analysis each day (refer to section 3.1.3). This will ensure the system is clean (1.5 µg OC, 0.5 µg EC, and 2.0 µg TC per cm^2). Run a system blank with the IMPROVE_A protocol.

3.1.4.1 Analysis Preparation

- Verify the computer date and time is correct.
- Verify sample oven pressure reading and specified flow ranges in the front-panel flow meters.
- Wipe the flat glass plate, tweezers, and punching tool thoroughly with a dry KIMTECH wiper.
- Based on the analysis list, remove the sample to be analyzed from the Styrofoam cooler or refrigerator.
- Record the filter ID in the analyzer log book (Figure 2-7).
- Open *DRICarb.exe* from the c:\CarbonNet folder or use the desktop "shortcut" to *DRICarb.exe*. Verify correct software version number on the Welcome screen.
- Select "Analysis" from the "Main" submenu of the Welcome form. This will initiate the analysis protocol, as shown in Figure 3-3. You can also select FID ID (typically FID_8) to determine the FID peak sensitivity.
- In the analysis "Setup" form, enter "Sample" for the Type.
- Polarity should default to "Unipolar".

- Fill out the information about the sample, including: Project Name, Batch #, and Sub-batch #.

- Under "Command Table" select *cmdImproveA*.

- Enter the Sample ID number, or place your mouse cursor in the field and use a barcode scanner to read the barcode on the Petri dish.

- Enter the Run #, Punch area and Deposit area for the filter being analyzed.

- Enter technician initials in the "Tech initials" field.

- Select any pre-analysis flags from the drop-down menu in the "Flags" field. A list of valid choices is presented on the screen.

- Visually examine the filter and note any non-uniformity or unusual deposit. Remove it from the Petri slide or Petri dish with tweezers, handling the filter only by the edge. Place the filter on the flat glass plate and remove a sample punch by pushing down gently on the punching tool. Rocking the punching tool slightly will ensure that the punch is completely severed. Try to remove the punch from the edge of the deposit to avoid wasting the filter, while trying to avoid areas of non-uniform deposits.

- Leaving the sample punch in the punching tool, place the punching tool on a clean KIMTECH wiper. Return the filter to the Petri slide or dish, being careful to handle only the filter with the tweezers.

- If this is the first run of the day, or if the analyzer has been cooled down, the analyzer will verbally prompt you to load the punch ("Please load filter analysis"). If the analyzer was previously used, it will cool to 100 °C, then pull the boat back to the calibration position, continue cooling to 50 °C, and pull the boat back to the load position for the next analysis.

3.1.4.2 Loading the Filter Punch

- Use tweezers to remove punch from punch tool and place in analyzer boat.

- Click "OK" on the analysis "Setup" screen. The boat will load to the calibration position and the computer will ask, "Would you like to proceed or would you like to delay

analysis?" Check to make sure a 90-second delay is in the "delay" box. Click "OK" and analysis will begin.

- Wipe the tweezers, flat glass plate, and punching tool with a clean KIMTECH wiper.

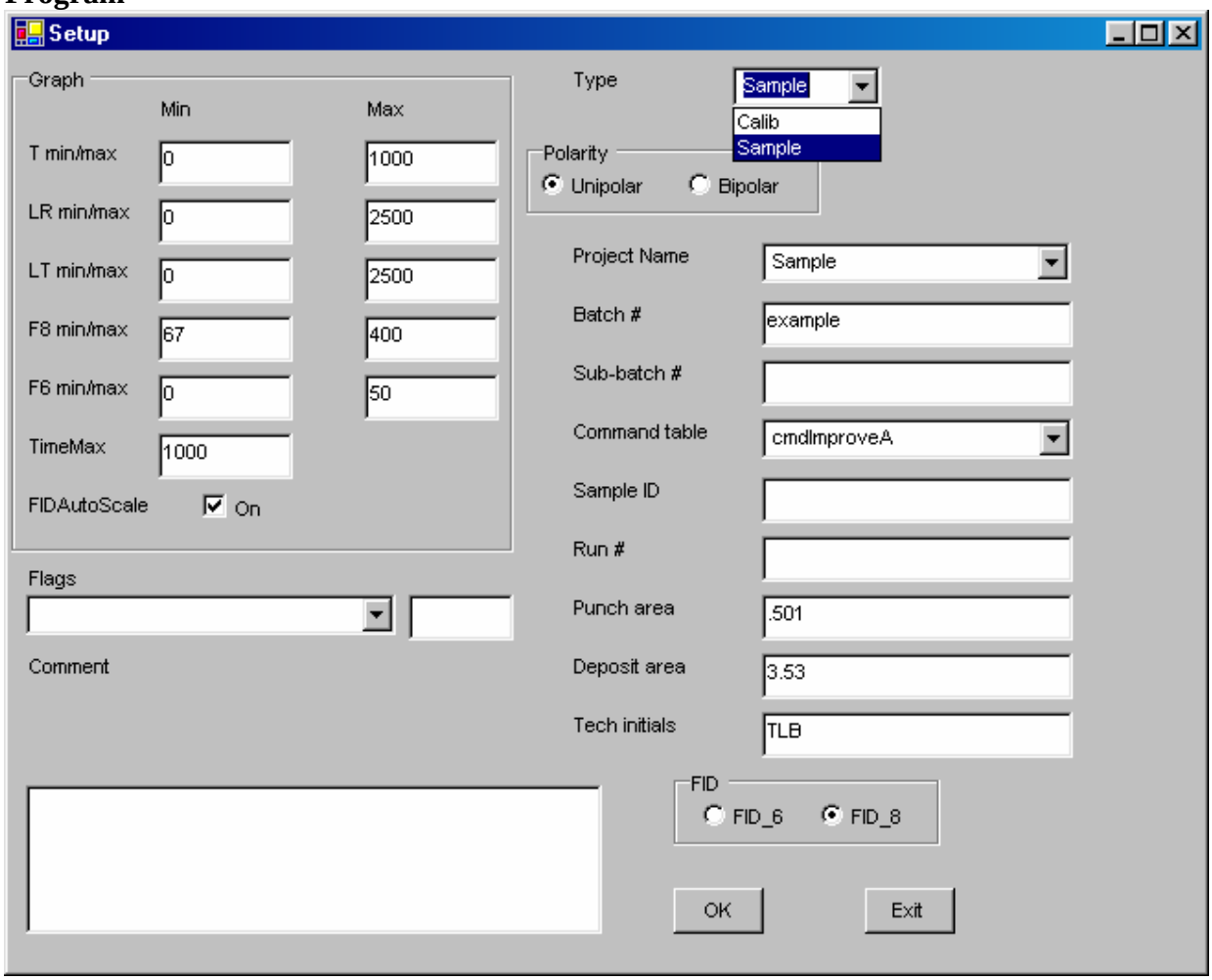
3.1.4.3 Post-Analysis

At the end of each analysis, data is saved to the database, split times are calculated, carbon peaks are integrated, and tabular and graphical printouts are produced. The sample boat will retract to the calibration position when it is sufficiently cooled by the fan (to >100 °C) and will continue to cool until it reaches less than 50 °C.

- Examine the tabular printout (Figure 3-4) to confirm that the calibration peak counts are within specifications (typically 25,000 counts, see Section 4.1).
- Examine the thermogram (Figure 3-5) for proper laser response, temperature profiles, realistic carbon peaks, and the presence of the calibration peak at the end of the analysis.
- Examine the laser signal at the end of the run.
- If a problem is found, register it in the analyzer log book and run list, and notify the lab supervisor immediately.
- If all aspects of the analysis appear correct, select the appropriate analysis flag from the post-analysis form that appears at the end of the run.
- Mark the analysis date on the sample analysis run list.
- Using clean tweezers, remove the punch from the boat and tape it to the thermogram with transparent tape, ensuring that the punch is deposit-side up.

Repeat the above steps for additional analysis runs.

Figure 3-3a. Setup Screen for the DRI Model 2001 Thermal/Optical Carbon Analysis Program



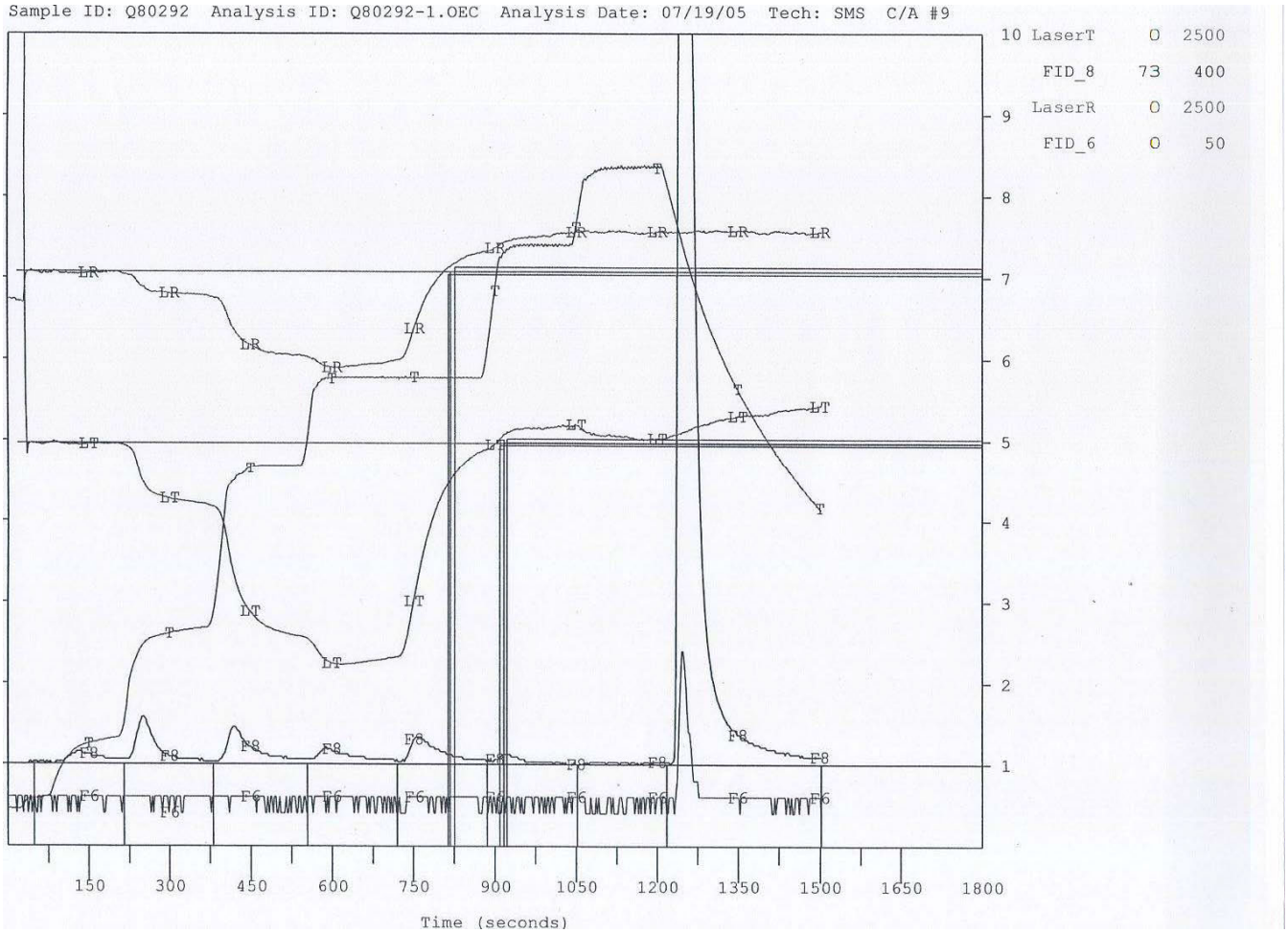
Do not use X to exit in all circumstances. The program will close and rebooting may be necessary.

Figure 3-3b. The Analysis Screen during Sample Analysis for DRI Model 2001 Thermal/Optical Carbon Analysis Program

Figure 3-4. Tabular Printout from DRI Model 2001 Thermal/Optical Carbon Analysis Program

```
Analysis ID      : Q80292-1.OEC
Sample ID        : Q80292
Punch area       :  0.501 cm2
Deposit area     :  3.530 cm2

Analysis Start   : 07/19/05  15:57          Calculation      : 07/19/05  16:28
Analysis Stop    : 07/19/05  16:28
-----------------------------------------------------------------------------
Anal program ver: P6.0  (05/31/05)          Parm file ver    : V0416
Calib. slope     : 21.07 ug C/peak ratio    Baseline time    : 10 sec
Calib. intercept: 00.00 ug C
Reflectance unc.:   010 counts              Transmission unc:   010 counts
Sample transit   : 14 sec
-----------------------------------------------------------------------------
Calibration peak area:   25485 millivolt-seconds
Initial FID baseline :     106   millivolts
Final FID baseline   :     107   millivolts
-----------------------------------------------------------------------------
Laser reflectance initial baseline   :    1768   millivolts
Laser reflectance minimum            :       0   millivolts at     0 sec
Laser reflectance final baseline     :    1894   millivolts
Laser transmittance initial baseline :    1241   millivolts
Laser transmittance minimum          :       0   millivolts at     0 sec
Laser transmittance final baseline   :    1259   millivolts
-----------------------------------------------------------------------------
              Reflect Split Time  Laser                  FID Split Time
  Lower split  :     800 sec          1605 millivolts            814 sec
  Regular split:     804 sec          1606 millivolts            818 sec
  Upper split  :     812 sec          1604 millivolts            826 sec
-----------------------------------------------------------------------------
              Transmit Split Time  Laser                  FID Split Time
  Lower split  :     895 sec           687 millivolts            909 sec
  Regular split:     902 sec           688 millivolts            916 sec
  Upper split  :     908 sec           690 millivolts            922 sec
-----------------------------------------------------------------------------
                      Peak Area                          Carbon
OC1        OC         342  mv-secs     0.56  ug C/cm2     1.99    ug C/filter
OC2        OC         881  mv-secs     1.45  ug C/cm2     5.13    ug C/filter
OC3        OC         871  mv-secs     1.44  ug C/cm2     5.07    ug C/filter
OC4        OC         529  mv-secs     0.87  ug C/cm2     3.08    ug C/filter
EC1        EC         753  mv-secs     1.24  ug C/cm2     4.39    ug C/filter
EC2        EC         178  mv-secs     0.29  ug C/cm2     1.04    ug C/filter
EC3        EC           0  mv-secs     0.00  ug C/cm2      .00    ug C/filter
LRPyMin    Py         579  mv-secs      .96  ug C/cm2     3.37    ug C/filter
LRPyMid    Py         595  mv-secs      .98  ug C/cm2     3.47    ug C/filter
LRPyMax    Py         624  mv-secs     1.03  ug C/cm2     3.63    ug C/filter
LTPyMin    Py         788  mv-secs     1.30  ug C/cm2     4.59    ug C/filter
LTPyMid    Py         811  mv-secs     1.34  ug C/cm2     4.72    ug C/filter
LTPyMax    Py         835  mv-secs     1.38  ug C/cm2     4.86    ug C/filter
*****************************************************************************
```

Figure 3-5. Graphical output from DRI Model 2001 Thermal/Optical Analysis Program



3.1.5 Special Analysis

3.1.5.1 System Blanks

System blanks are run at the beginning of each day. Follow the steps outlined in Section 3.1.3 on oven baking with the following exceptions:

- Go through all the steps for a routine analysis (Section 3.1.4), but when prompted to load filter punch, remove the filter from the previous day and leave the boat empty for the analysis..
- Use project name "Sysblk", Batch # "mm" for the month and Sub-batch # "dd" for the day. Punch area and Deposit area should be "1".
- Use an ID number derived from the current date: e.g., SB071805 for July 18, 2005.
- Calculated carbon concentrations should not be more than 0.2 µg carbon. Values greater than this warrant additional system blanks. Samples may not be analyzed until the system blank is <0.2 µg carbon.

3.1.5.2 Carbonate Analysis

- Enter the Sample ID, Run #, Punch area, and Deposit area. Select *cmdImproveA_Carbonate* from the Command Table drop-down field and start the analysis program.
- Follow the steps under Section 3.1.3 until the sample punch is loaded into the boat. Load sample and click "OK". When asked if you want to delay or continue analysis, click "OK". After 90 seconds the punch automatically centers under the acid injection port. The computer will prompt you to inject the HCl, and then will state "Load syringe" and "XX seconds to acid injection".
- Inject 20 µl of 0.4 M HCl through the septum port to the sample.
- Prior to acidification (approximately 90 seconds elapsed analysis time), flush the 25 µl syringe with 0.4 M hydrochloric acid (HCl) into a waste beaker. When prompted to inject HCl eject 20 µl HCl onto the filter punch, ensuring that the needle bevel is turned toward the punch and that the needle tip is touching the top of the punch.

- When the analysis is underway, flush the syringe with Nanopure water to prevent corrosion of the syringe plunger.

- After analysis, the program will delay any further analysis for 900 seconds to allow the punch to dry.

- After the carbonate analysis is completed, a tabular summary and a copy of the graph will be printed (similar in format to Figures 3-4 and 3-5). Select *cmdImproveA* from the Command Table drop-down field and click "OK". Click "Run" on the analysis Setup screen. The program will automatically cycle into the normal OC/EC analysis, using the same Sample ID. Heat from the oxidation oven will dry the sample in this position (for approximately 15 minutes) without prematurely baking carbon from the sample; the sample temperature should not exceed 42 °C. When the punch is dry proceed with normal OC/EC analysis.

3.1.6 Analyzer Shut-Down

After the final sample for the day is analyzed, shut down the analyzers using the following procedures:

- Leave the last analyzed punch in the boat with the boat positioned in the Calibrate position. This punch will be used as the system blank the following morning and then taped to the corresponding thermogram.

- Perform end-of-the-day calibration gas injection routine, or use *cmdAutoCalibCheck* command, and record the calibration peak counts. Any values outside the expected ranges should be investigated and rerun. Because low values from the end-of-day calibration could potentially invalidate the entire day's runs, any deviation from the accepted ranges must be noted and the cause identified. Notify the lab supervisor.

- Leave the *DRICarb.exe* software open.

- If desired, He-1, Cal Gas, He-2, and Air may be turned off with the toggle valves to conserve gases. However, all other gases should be left on as long as the oxygenator and methanator are heated.

- Place all of the day's printouts, including calibration data in a file folder labeled with the date and analyzer number. Place on the lab supervisor's desk for Level I validation (Section 6.5).

- Leave the computers and analyzers on overnight unless the potential for power outages or surges exists. Turn off the monitors overnight.

- Make a final check of the gas cylinder pressures to ensure that gas flow, especially the compressed air, will continue until someone will be available to check them again.

- Move the samples and blue ice in the Styrofoam cooler or refrigerator back into the sample storage freezer and verify that the freezer is completely closed.

- If the 25 or 50 µl syringe was used for carbonate analysis, thoroughly rinse the syringe with distilled water and tightly cap all solutions. Store solutions in the refrigerator. Freezer storage may cause crystallization.

- Lock the carbon analysis room.

3.2 Abbreviated Procedures

3.2.1 Analyzer Start-Up

- Check pressures and delivery pressures in all gas cylinders.

- Check that all FIDs are lit by holding a pair of tweezers over the FID exhaust stack and watching for condensation. Relight if necessary.

- Check all gas flows at the analyzer; readjust if necessary.

- Turn on the computer monitor.

- Confirm that the date and time on the computer are correct.

- Execute the *DRICarb.exe* either from the shortcut on the computer desktop or from C:\CarbonNet\.

- Confirm that the printers have enough paper for the day and that the toner cartridge is producing legible text and graphics.

- Wipe the sample tweezers, flat glass plate, and punching tool with a clean KIMTECH wiper.
- Begin the daily entry in the *Carbon Analyzer Logbook*.
- Bake the oven for 10 minutes, or bake during leak test.
- Perform a leak test, involving isolating the oven and operating the Carle valve.
- Execute the *cmdAutoCalibCheck* command to verify the analyzer's performance.
- Retrieve the samples to be analyzed from the sample freezer.
- Complete *Daily Analyzer Check Sheet* posted on each analyzer.

3.2.2 Leak Checks and Oven Baking

- Use manual option to set temperature to 900 °C and let analyzer reach this temperature.
- With breech closed, flip oven outlet toggle to the off position and let sample oven pressure reach ~5 psi.
- Flip the oven inlet toggle to the off position and watch for a decline in the sample oven pressure. If system is leak free, the pressure will remain stable.
- If the system is not stable, use a He leak detector to locate the leak; disassemble and reassemble the port fitting if necessary and check the O-ring for correct placement and pressure.
- When system is stable, flip both the inlet and outlet oven toggles back to the on position.
- An oven bake can also be executed without a leak check by selecting *cmdBakeOven* from the drop-down menu in the Command table.
- Update the *Daily Analyzer Checklist* and verify values are within expected range.

3.2.3 OC/EC Analysis

3.2.3.1 Analysis Preparation

- Clean the tweezers, flat glass plate, and punching tool with dry KIMTECH wiper.
- Based on the analysis list, remove the sample to be analyzed from the Styrofoam cooler or refrigerator. Verify the sample ID against the analysis list.
- Remove a sample punch from the filter.
- Record the Sample ID in the analyzer logbook, along with any comments on the condition of the deposit or any other conditions which might affect analysis results.

3.2.3.2 Loading the Filter Punch

- Begin the analysis by clicking on "Analysis" in the Welcome window and inputting the Sample ID, Run #, Punch area, and Deposit area.
- After the boat has cooled to 50 °C or less, remove the previously analyzed sample punch and load the current sample punch.
- Clean the tweezers, flat glass plate, and punching tool with a dry KIMTECH wiper.
- Replace the Petri slide or Petri dish containing the filter into the Styrofoam cooler or refrigerator.
- Upon analysis completion, use a small piece of transparent tape to attach the sample punch to its thermogram, ensuring that the deposit side is facing up.
- At the end of the analysis, the push rod will automatically be pulled back to the Calibrate position to begin cooling.

3.2.3.3 Post Analysis

- Examine the thermogram for proper laser response, temperature profiles, realistic carbon peaks, and the presence of the calibration peak at the end of the analysis. Examine the tabular printout to confirm that the calibration peak counts are within specifications (see Section 4.1). Finally, examine the laser signal at the end of the run.

Indicate successful analyses on the sample analysis list by recording the date. Notify the lab supervisor of any problems and record them in the log book and on the run list.

- Repeat the above steps for additional samples.

3.2.4 Special Analysis

3.2.4.1 System Blanks

- Go through all the steps for a normal analysis, but do not remove the punch from the previous analysis. Proceed with the routine analysis.
- Use project name "Sysblk", Batch # "mm" for the month and Sub-batch # "dd" for the day. Punch area and Deposit area should be "1".
- Calculated carbon concentrations from the system blank should not be more that 0.2 µg carbon. Values greater than this warrant an additional system blank or oven bake.

3.2.4.2 Carbonate Analysis

- Follow the steps under Routine OC/EC Analysis until the sample punch is loaded into the boat.
- Enter the Sample ID, Run #, Punch area, and Filter area.
- When prompted for injection, eject 20 µl 0.4 M HCl onto the filter punch.
- Flush the syringe with Nanopure water between samples.
- Continue the normal OC/EC analysis when the carbonate cycle is complete.

3.2.5 Analyzer Shut-Down:

- Leave the last analyzed punch in the boat with the boat positioned in the Calibrate position. This punch will be used as the system blank the following morning and then taped to the corresponding thermogram.

- Execute the *cmdAutoCalibCheck* command to verify the analyzer's performance.
- When the analysis is complete, record the calibration peak counts and calculated injection calibration in the logbook. Any values outside the ranges defined in Section 4.1 should be investigated and rerun.
- Backup the day's data files to disk, if not automatically backed up on a server.
- Remove the printouts and attach them to a file folder labeled with the date and analyzer number. Place on the lab supervisor's desk.
- Turn off the computer monitors.
- Make a final check of the gas cylinder pressures.
- Move the samples and blue ice in the Styrofoam cooler or refrigerator back into the sample storage freezer and verify that the freezer is completely closed.
- If the 25 µl syringe was used for carbonate analysis, thoroughly rinse the syringe with Nanopure water and tightly cap all solutions. Store at 4 °C.
- Lock the carbon analysis room.

4 QUANTIFICATION

4.1 Instrument Calibration

The calibration procedures for the carbon analyzers are of three types: 1) the end-of-run calibration peak; 2) the routine beginning and end-of-day calibration injections of He/CH_4 and He/CO_2 (you can also use the auto calibration check using the *cmdAutoCalibCheck* command); and 3) full instrument calibration, performed every six months, using KHP, sucrose, and the two calibration gases.

4.1.1 End-of-Run Calibrations (Description)

The end-of-run calibration consists of a set quantity of He/CH_4 calibration gas which is automatically injected by the carbon program. All FID readings during the analysis run are normalized to this peak to minimize the effects of FID performance and electronic drift over time. The end-of-run calibration occurs automatically at the end of each analysis run and

requires no operator intervention. The integrated calibration peak counts should be checked by the operator immediately after each run to confirm that the analyzer is operating satisfactorily. Calibration peak area counts should be greater than 20,000. Check daily records to compare and determine analyzer performance and stability.

4.1.2 Routine Calibrations (Description)

Routine calibrations must be performed at the beginning and end of each day, either manually or by using the automated routine calibration command (*cmdAutoCalibCheck*) in the *CarbonNetWork* database Command table.

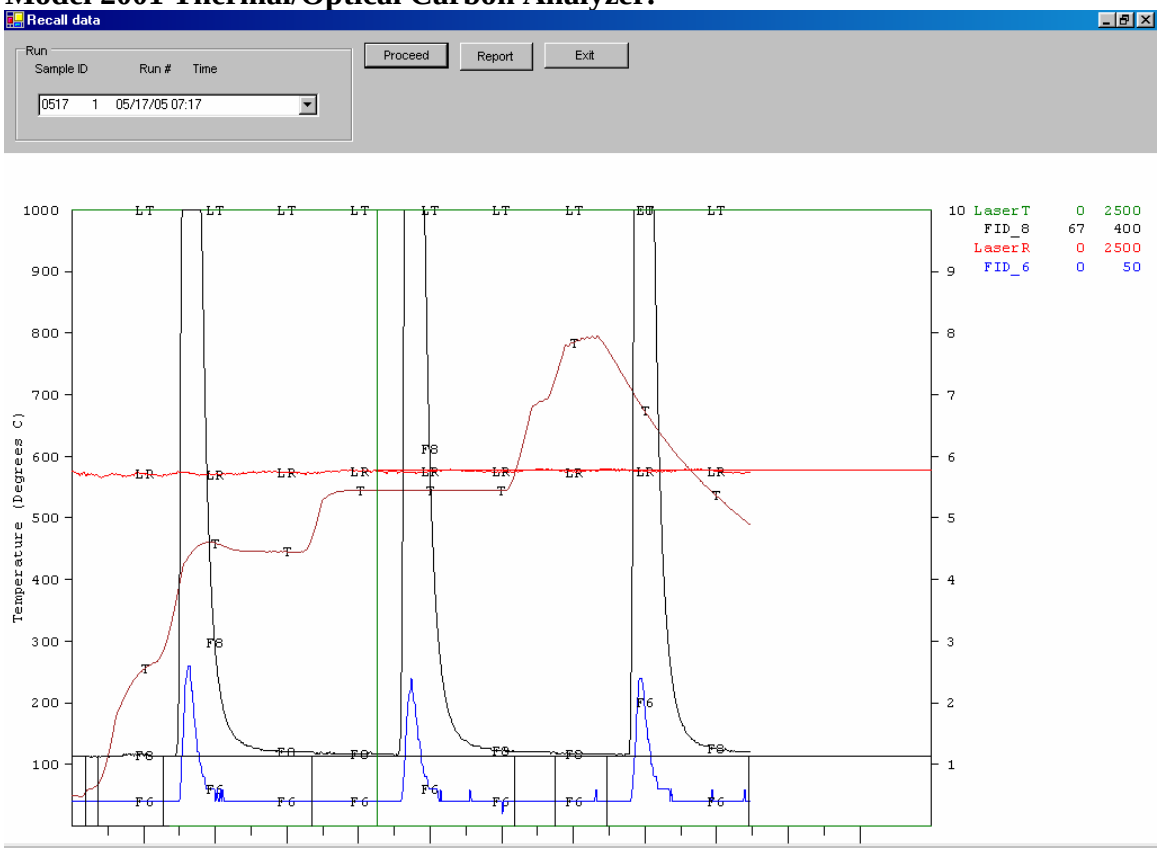
4.1.2.1 Automated Routine Calibration (Description & Instructions)

The automated calibration uses the Carle valve to inject the methane standard once in a He-only atmosphere, once in a He/O_2 atmosphere, and finally, the normal calibration peak at the end of analysis. The three peaks should have identical peak areas if the catalysts are in good condition and the calibration factor holds (See Figure 4-1). Use the following steps to perform this automated calibration:

- From the *DRICarb.exe* Welcome screen, select “Analysis” from the “Main” submenu.
- Set Type to “SAMPLE” and select *cmdAutoCalibCheck* from the drop-down menu in the “Command table” field.
- The project name should be “Calib”, the Batch # should be “0” and the sample ID should be in the format “CxxYYYYMMDD” where “xx” is the analyzer number (e.g. C0720050710 for analyzer number 7, run on July 10, 2005).
- Set the Run # (“1” for first calibration of the day and “2” for second calibration of the day, etc.). Enter “1” in the Punch area, and Deposit area fields. Click on “OK” and then click “Run”.
- Review the thermogram and record these values in the logbook as shown in Figure 2-7. The three calibration peak counts (OC3, EC1, LtPyMid) should be above 20,000 and should be almost identical in area (and within 10% of the “Calibration Peak Area” value show on the tabular printouts). Check the average C value for the calibration gas against those posted on each carbon analyzer.

- Whenever the MnO_2 or Ni catalyst is replaced, an automated routine calibration should be run to confirm that the previous calibration curve holds.

Figure 4-1. Calibration thermogram from the *cmdAutoCalibCheck* command of the DRI Model 2001 Thermal/Optical Carbon Analyzer.



4.1.2.2 Manual Routine Calibration (Instructions)

- From the *DRICarb.exe* Welcome screen, select "Analysis" from the "Main" submenu.

- Set Type to "CALIB" and select *cmdCalib-HeO$_2$* (for example) from the drop-down menu in the "Command table" field.

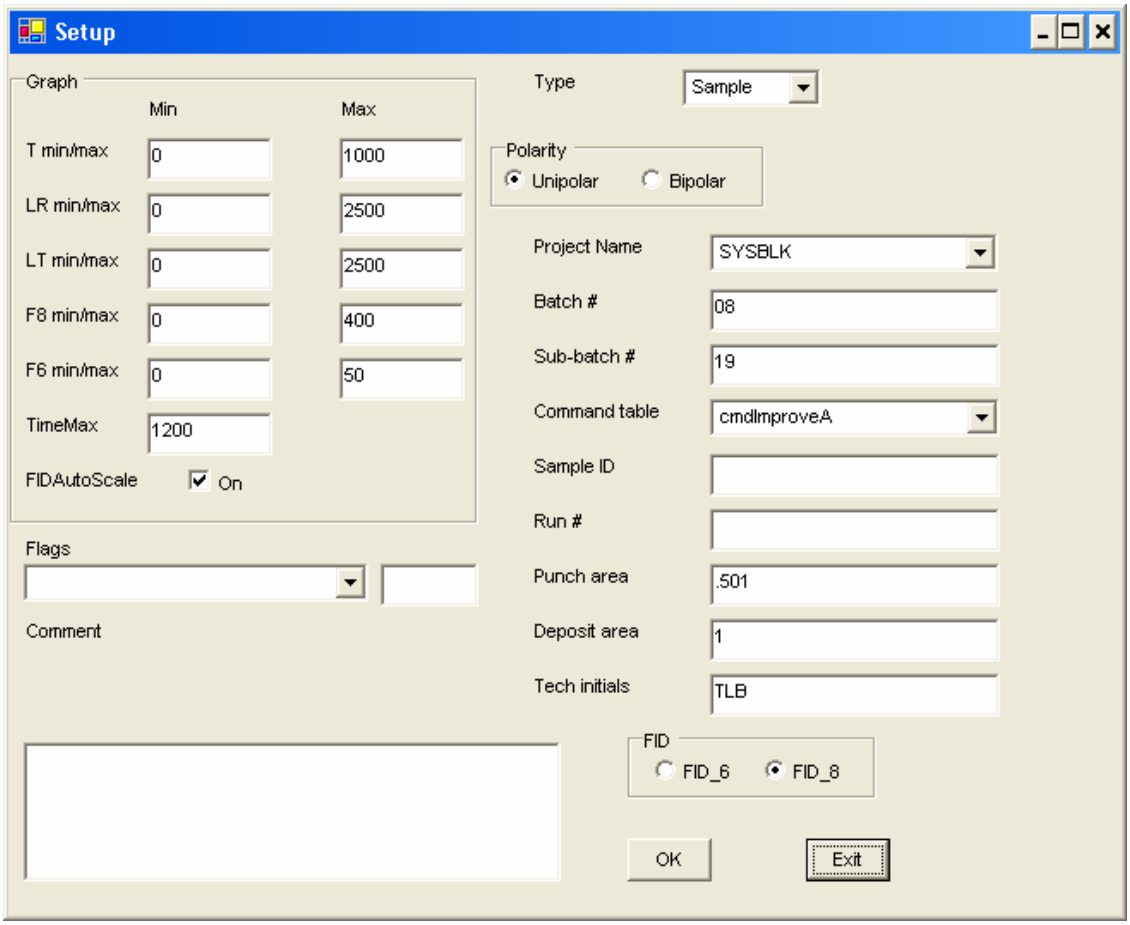
- A project name is not required. The sample ID should be in the format "MIxYYYYMMDD" for CH_4 injection or "CIxYYYYMMDD" for CO_2 injection where x is the analyzer number (e.g. MI720050710 for a CH_4 injection on analyzer number 7, run on July 10, 2005).

- Set the Run # ("1" for first calibration of the day and "2" for second calibration of the day, etc.). Enter "1" in the Punch area, and Deposit area fields. Click on "OK" and then click "Run".

- Select the atmosphere for calibration under the "Cal Gas" (either CH_4 or CO_2) menu and select the proper "Carrier Gas" (either HeO_2 or He; HeO_2 for beginning of day and HE only for end of day). These should be alternated with the calibration gas. Verify the command table matches the options selected.

- Choose "OK" to proceed with the analysis, or "Exit" to leave the program. The analysis will start with the following screen as shown in Figure 4-2. You will note that the top portion contains all the information in the analysis Setup screen. The bottom half will display the thermogram when the run is initiated.

Figure 4-2. Carbon analyzer Analysis Setup screen



- Start a run by clicking on "Run". After the computer states, "Please load gas syringe", flush the gas syringe with the calibration gas at least three times and then load it with the calibration gas. The computer will then state, the "Time remaining until load - XX seconds" and then "Inject calibration gas". Follow the verbal instructions to inject the calibration gas through the septum.

- Calibration gas injections should be in the following ranges for 100 µl gas:

Manual Injection	Lower Allowable Limit	Upper Allowable Limit
CH_4	20.36 µg carbon [1*]	22.50 µg carbon [1*]
CO_2	20.28 µg carbon [2*]	22.41 µg carbon [2*]
Final Calibration Peak	20,000	--

[1] Calculated in a real laboratory environment. For a 5.12% CH_4 standard at 646 mm Hg at 24 °C, actual mass of methane is 21.43 µg carbon.

[2] Calculated in a real laboratory environment. For a 5.10% CO_2 standard at 646 mm Hg at 24 °C, actual mass of carbon dioxide is 21.34 µg carbon.

* Lower Allowable Limit equals to 5% lower than the actual mass; Upper Allowable Limit equals to 5% higher than the actual mass. Limits should be adjusted according to the real laboratory environment.

- Note: Each time the MnO_2 or Ni catalyst is replaced, the instrument calibration should be checked to confirm that the previous calibration curve holds. This can be done by running two points from the six CH_4/He calibration volumes and two points from the six CO_2/He volumes used in the full calibration.

4.1.3 Full Calibration (Description)

Full instrument calibration, performed semi-annually, establishes the calibration slope used in converting counts to µg of carbon, as explained in the next section. Instrument calibration involves spiking pre-fired quartz punches with 5.0 to 20.0 µl of the 1800 ppm KHP and sucrose solutions (Section 4.1) and injecting 100 to 1500 µl of the CO_2 and CH_4 gases.

Four types of standards are used to calibrate the carbon analyzers: 5% nominal CH_4 in He, 5% nominal CO_2 in He, KHP, and sucrose. Only the calibration gases are used on a daily basis as analyzer performance monitors. KHP and sucrose are used in conjunction with CH_4 and CO_2 semiannually to establish the calibration curve of each analyzer.

4.1.3.1 Preparation, Ranges and Traceability of Standards

The calibration is done by injection of a known volume of the standard to yield a calibration curve of peak area ratio of injected carbon: CH_4 (internal standard) versus µg of carbon injected (Internal Standard Calibration Method). For the best accuracy, the temperature and pressure at

the time of analysis need to be taken into account. For a 100% CH_4 or CO_2 standard at 760 mm Hg at 20 °C, each microliter = 0.499 µg carbon. For a 5% standard, it will be 0.02495 µg carbon/µl at standard temperature and pressure (STP; 20 °C, 760 mm Hg). The Ideal Gas Law should be used to correct for the temperature and pressure of the laboratory.

$$\text{Acutal}\,\mu\text{g C per}\,\mu\text{L} = \left(\frac{\text{Pa}}{760}\right)\left(\frac{1}{(\text{T} + 273.15)}\right)\left(\frac{1}{0.08206}\right) \times \%\text{ of cal gas} \times 12$$

where Pa is pressure in mmHg, T is ambient temperature.

The calibration gases are traceable to NIST standards. The calibration gases are assayed for exact concentrations by the gas supplier; the assay value is obtained from the tag on the cylinders and is typically determined by gas chromatography (GC).

To prepare an 1800 ppm standard, the KHP is dried at 110 °C for two hours before dispensing. Transfer 0.3826 g of KHP into a glass 100 ml volumetric flask after the KHP has come to room temperature inside a desiccator. The weight of KHP used must be recorded. Dilute to volume with 0.4 M concentrated hydrochloric acid (HCl) and 99.6 ml Nanopure water. Mix the KHP thoroughly. Store this solution in a refrigerator until it is used for calibration purposes. This solution is good for 40 days. Label the flask with the chemical name, the date of preparation, the name of the chemist preparing the solution, and the exact concentration. The concentration, nominally 1800 ppm carbon, is calculated by:

$$\text{Actual}\,\mu\text{gC per}\,\mu\text{L} = \left(\frac{\text{weight of KHP used in}\,\mu\text{g}}{\text{vol of solution prep in}\,\mu\text{l}}\right)\left(\frac{\text{no of carbon in KHP} \times 12}{\text{MW of KHP}}\right)$$

$$= \left(\frac{\text{weight of KHP used}}{100\text{ ml}}\right)\left(\frac{8 \times 12}{204.23}\right)\left(\frac{10^{-3}\text{ ml}}{\mu\text{l}}\right)\left(\frac{10^{6}\,\mu\text{g}}{\text{g}}\right)$$

The nominal 1800 ppm sucrose solution is prepared by transferring 0.428 µg of sucrose into a glass 100 ml volumetric flask. Dilute to volume with acidified Nanopure water (see blank solution preparation instructions below). Mix the sucrose thoroughly. Store this solution in a refrigerator until it is used for calibration purposes. This solution is good for 40 days. Label the flask with the chemical name, the date of preparation, the name of the chemist preparing the solution, and the exact concentration. The concentration is calculated by:

$$\text{Actual}\,\mu\text{gC per}\,\mu\text{L} = \left(\frac{\text{weight of sucrose used in}\,\mu\text{g}}{\text{vol of solution prep in}\,\mu\text{l}}\right)\left(\frac{\text{no of carbon in sucrose}\times 12}{\text{MW of sucrose}}\right)$$

$$= \left(\frac{\text{weight of sucrose used in}\,\mu\text{g}}{100\ \text{ml}}\right)\left(\frac{12\times 12}{342.31}\right)\left(\frac{10^{-3}\ \text{ml}}{\mu\text{l}}\right)\left(\frac{10^{6}\ \mu\text{g}}{\text{g}}\right)$$

To prepare a blank solution, add 0.4 ml of concentrated HCl to a glass 100 ml volumetric flask and dilute to volume with Nanopure water. This acidified Nanopure water is made fresh each time a 1800 ppm KHP stock solution is prepared.

No primary standards (NIST-traceable) currently exist for carbon analysis. Ideally, such standards should include a range of organic compounds from low- to high-molecular weights and with varying degrees of susceptibility to pyrolysis, as well as EC and carbonate compounds. Currently, KHP, sucrose, and the two calibration gases are used at DRI for calibration and system audit purposes.

4.1.3.2 Calculating Calibration Slope

The calibration slopes derived from the two gases and the KHP- and sucrose-spiked filter punches are averaged together to yield a single calibration slope for a given analyzer. This slope represents the response of the entire analyzer to generic carbon compounds and includes the efficiencies of the oxidation and methanator zones and the sensitivity of the FID. Note that the current calibration procedure is based only on TC, as no routine procedure exists to check the accuracy of the OC/EC split. An example of the spreadsheet is shown in Figure 4-3.

Figure 4-3. Example of calibration summary worksheet used to determine calibration slope.

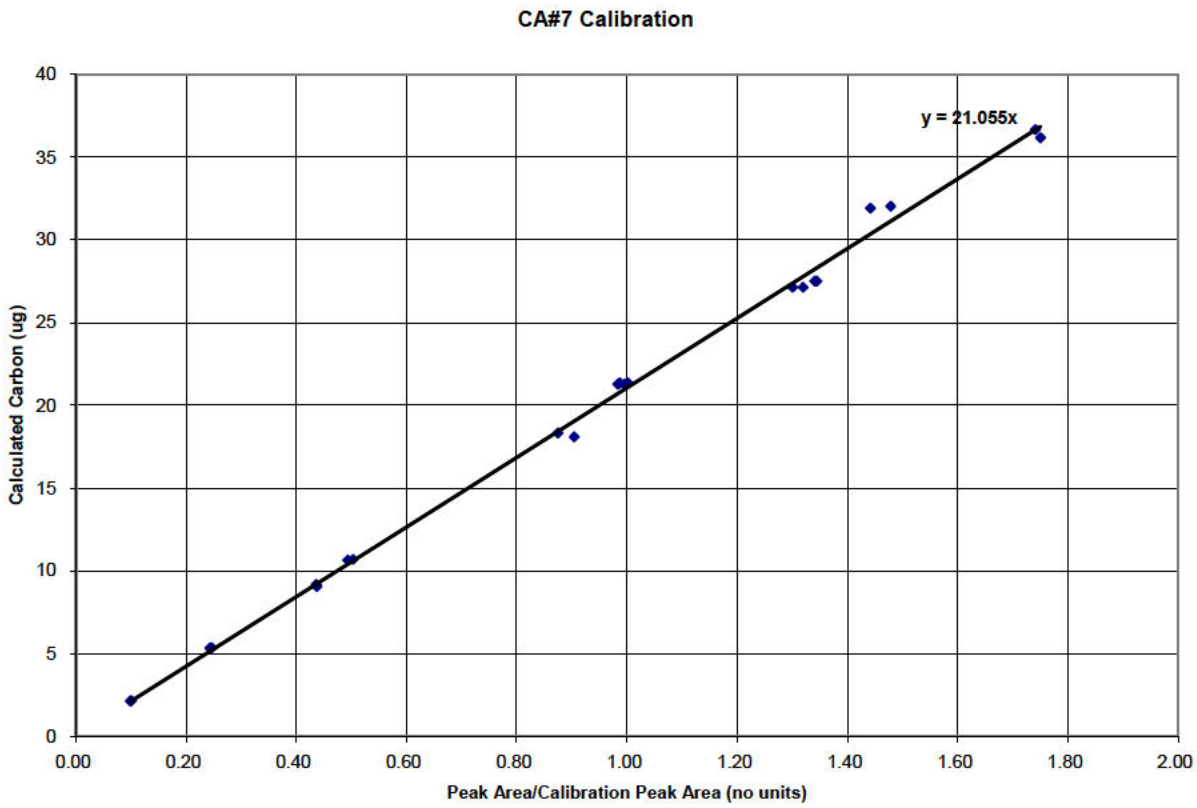
Calibration Standard	Run #	volume (µL)	C in CH_4/He (µg)	Injection Peak Counts	Calibration Peak Counts	Injection/ Calibration	Slope
CH4	MI0719-3	100	2.14	2531	25076	0.1009	21.16
CH4	MI0719-4	250	5.34	6171	24962	0.2472	21.60
CH4	MI0719-5	500	10.68	12563	24977	0.5030	21.23
CH4	MI0719-6	1000	21.36	24589	24907	0.9872	21.63
CH4	MI0719-7	1000	21.36	25164	25120	1.0018	21.32
CH4	MI0719-11	1500	32.03	37275	25207	1.4788	21.66
CO2	CI0508-2	100	2.13	2488	25135	0.0990	21.49
CO2	CI0508-3	250	5.32	6066	24932	0.2433	21.86
CO2	CI0508-4	500	10.64	12294	24918	0.4934	21.56
CO2	CI0508-5	1000	21.27	24531	24942	0.9835	21.63
CO2	CI0508-6	1000	21.27	25123	25221	0.9961	21.36
CO2	CI0508-9	1500	31.91	36300	25172	1.4421	22.13
SUC	SUC5-2	5	9.04	11266	25753	0.4375	20.67
SUC	SUC10	10	18.09	22904	25320	0.9046	20.00
SUC	SUC15-1	15	27.13	33168	25130	1.3199	20.56
SUC	SUC15-2	15	27.13	32668	25114	1.3008	20.86
SUC	SUC20	20	36.18	44168	25230	1.7506	20.67
KHP	KHP5-2	5	9.17	10968	25143	0.4362	21.01
KHP	KHP10	10	18.33	22160	25335	0.8747	20.96
KHP	KHP15-1	15	27.50	33042	24571	1.3448	20.45
KHP	KHP15-2	15	27.50	33165	24730	1.3411	20.50
KHP	KHP20	20	36.66	43276	24853	1.7413	21.06

Slope: 21.05 Scatter: 0.1619 Correlation: 0.99857

4.1.3.3 Typical Accuracy of Calibration Standards

The accuracy of the calibration standards is primarily limited by the accuracy of the calibration gas assays, the accuracy of the preparation of the KHP and sucrose solutions, and the technician's injection technique. The calibration slopes determined by these four compounds historically differ by less than 5% on a given analyzer if sufficient care is taken during the calibration procedure (Section 4.1). Figure 4-4 shows an example of plotted calibration curves.

Figure 4-4. Example DRI Carbon Analyzer Calibration Curves.



4.1.3.4 Data Treatment for Calibration Data

- Calibration values are plotted as actual µg carbon vs. the ratio of the integrated sample peak counts to the calibration peak counts (Figure 4-1). Obvious outliers are identified and rerun. Linear regression is performed on each set of calibration data (separate calculations for KHP, sucrose, CH_4/He, and CO_2/He). The slope (m) is calculated from:

$$\left(m = \frac{\sum (y_i \, x_i)}{\sum (x_i^{\,2})} \right)$$

The standard deviation (s) is calculated by:

$$\sigma = \sqrt{\frac{1}{n-1}\frac{\sum (y_i - mx_i)^2}{\sum x_i^{\,2}}}$$

where:

$$x_i = \frac{(\text{injected carbon peak area})}{(\text{calibration peak area})}$$

and:

$$y_i = \text{calculated carbon in spiked filter or manual injection } (\mu g)$$

- Note that this is a special form of the regression formula which ensures that the curve passes through the origin.
- The resulting slope is compared to previous calibration results. New values should be no more than ±10% different than previous calibrations if no major analyzer changes have been made. If variation is >10%, calibration must be redone to verify values.
- The new slope for each analyzer (derived from combined CH_4, KHP, and sucrose data) is placed into the *Carbon.par* file for each analyzer; this file contains analyzer parameters which are read into the Carbon program when it is first started. The date and version number in the *Carbon.par* file is also updated.
- Calibration data and plots are retained in file folders in the file cabinet with raw analysis data.

4.1.3.5 Calculations

The conversion of integrated peak counts to µg of carbon for each peak in the thermogram is performed by the computer at the end of the analysis program. For reference purposes, the calculation is:

$$\text{peak } \mu\text{g C/punch} =$$

$$(\text{integrated peak counts above baseline})(\text{calibration slope})/(\text{internal calibration n counts})$$

For IMPROVE_A thermal protocol, the peaks reported are: four organic peaks (OC1, OC2, OC3, and OC4) corresponding to 140, 280, 480, and 580 °C in He atmosphere, respectively; three elemental carbon peaks (EC1, EC2, and EC3) corresponding to 580 °C after the introduction of O_2, 740, and 840 °C, respectively; and three pyrolyzed organic carbon peaks (Lower, Regular, and Upper Splits) by reflectance and transmittance, corresponding to the peaks after the introduction of O_2 and before the Lower Split Time, Regular Split Time, and the Upper Split Time, respectively, for the reflectance and transmittance optical charring correction (see Section 1.7 and Figure 3-4). The EC reported includes pyrolyzed carbon.

Carbon values per punch are converted to µg C/cm^2 by:

$$\mu\text{g C/cm}^2 = \frac{(\mu\text{gC/punch})}{(\text{puncharea})}$$

Finally, carbon values are converted to µg C/filter by:

$$\mu\text{gC/filter} = (\mu\text{gC/cm}^2)(\text{filterdepositarea})$$

Precision calculations are performed as the data is merged into the final database (Section 5.5).

4.2 Instrument Calibration Instructions

4.2.1 Full Gas Calibration

- To perform the full calibration, select "Analysis" from the Main menu of the *DRICarb.exe* program Welcome screen.

- Choose "CALIB" under the "Type" drop down menu. In the Command table drop-down, select *cmdCalib-He* (for example). Fill out the Sample ID, Run #, and Tech Initials fields. The sample ID should be in the format, "MIxYYYYMMDD_zzz" (where "MI" is for CH_4 injection; use "CI" for CO_2 injection; x is for the analyzer number and zzz is the volume of gas injected). You can also select FID ID (typically FID_8) to determine the FID peak area and make comments and flag the analysis from this screen before the analysis starts.

- Select the atmosphere for calibration under the "Cal Gas" menu and select the proper "Carrier Gas". Verify the command table matches the options selected.

- Enter the technician initials in the "Tech initials" field.

- Choose "OK" to run the analysis, or "Exit" to leave the program. The analysis will start with the screen as shown in Figure 3-3. You will note that the top portion contains all the information in the Setup screen. The bottom half will display the thermogram when the run is initiated.

- Start a run by clicking on the Run command button. After the computer states "Please load gas syringe" flush the gas syringe with the calibration gas at least three times and then load it with the calibration gas. Time remaining until load will be stated, and then "Inject calibration gas". Inject the gas through the septum. Hold the plunger down with needle still inside septum for 10 seconds, or until peak appears.

- The CO_2 and CH_4 calibrations are run using the "Calibration" options from the main menu. The following volumes are injected:

  - 100 µl CO_2 gas (use 1000 µl syringe)
  - 250 µl CO_2 gas (use 1000 µl syringe)
  - 500 µl CO_2 gas (use 1000 µl syringe)

- 1000 µl CO_2 gas (do once with 1000 µl syringe and once with 2500 µl syringe)
- 1500 µl CO_2 gas (do with 2500 µl syringe)
- Repeat for CH_4

- Record these calibration values in the logbook as in Figure 2-7.
- The integrated peak counts are extracted manually from the tabular printouts and entered into the spreadsheet which is used to determine the final calibration. The total peak is calculated by adding the peak area from OC1, OC2, OC3, and OC4, as well as EC1, EC2, and EC3. Pyrolysis counts are not included in the total.

4.2.2 Full Sucrose and KHP Calibrations

- To perform the full calibration, select "Analysis" from the Main menu of the *DRICarb.exe* program Welcome screen.
- Choose "Calib" under the "Type" drop down menu. Complete the information about the sample, including: Project Name, Batch #, and Sub-batch #. The Project Name should be "CALIB" and the Batch # should be "SUKHPCAL".
- A clean blank quartz punch is baked in the analyzer oven at 900 °C for 10 minutes using *cmdBakeOven* from the Command Table.
- After baking the quartz punch, change to *cmdImproveA* under Command Table.
- Perform system blank before running KHP or sucrose.
- Enter the Sample ID number or place your mouse cursor in the field. The sample ID should be in the format, "SUxYYYYmmdd_zzz" (where "SU" is for sucrose spiking; use "KHP" for KHP spiking; x is the analyzer number and zzz is the volume [05, 10, 15, or 20 µl]). You can also select FID ID (typically FID_8) to determine the FID peak area and make comments and flag the analysis from this screen before the analysis starts.
- Enter the Run #; the Punch area and Deposit area should be "1" for the filter being analyzed.
- Enter technician initials in the "Tech initials" field.

- After the punch has cooled to less than 50 °C, the KHP or sucrose solution (prepared as described in Section 4.1.3.1 and kept at room temperature) is injected onto the punch using a 25 µl syringe. The following volumes are used:

  - 5 µl KHP and sucrose solution
  - 10 µl KHP and sucrose solution
  - 15 µl KHP and sucrose solution (do twice)
  - 20 µl KHP and sucrose solution
  - no injection (as a system blank; see Section 3.1.5.1)
  - 20 µl acidified Nanopure water only (check of background level of Nanopure water)

- Flush the syringe at least three times with the calibration solution before taking up the volume for injection. Pump the syringe plunger to remove any trapped bubbles.

- Slowly spike the solution in the center of quartz punch and wash the syringe with Nanopure after use. If the solution is spiked too quickly it will bead up and run off the punch.

- Click "OK" on the analysis "Setup" screen. The boat will load to the calibration position.

- The computer will ask, "Would you like to proceed or would you like to delay analysis?" Enter the length of time in seconds you wish to delay the beginning of the analysis in the Delay box. This is used to purge dry a filter disc that has been deposited with an aliquot of KHP or sucrose standard solution, or when the sample is acidified for carbonate removal. In general, allow ~1 minute of purge time for every µl of solution deposited (e.g., 5 µl=300s, 10µl=600s, 15µl=900s and 20µl=1200s). Click "OK" and analysis will begin.

- Allow the punch to dry thoroughly; the punch will turn from translucent to opaque as it dries. The punch must be dry to avoid water vapor effects on the FID and the laser reflectance and transmittance signals. Select the *cmdImproveA* option from the analysis menu to start.

- The integrated peak counts for all seven temperature fractions for the sample and calibration peaks are recorded. The total peak is calculated by adding the peak area from OC1, OC2, OC3, and OC4, as well as EC1, EC2, and EC3. Pyrolysis counts are not included in the total.

5 TEMPERATURE CALIBRATIONS

Temperature calibrations are performed semiannually on all instruments to verify that the sample temperature is as accurate as possible.

5.1 Temperature Indicators

Since it is not possible to sense the temperature of the sample directly, materials were sought that: 1) could be placed where the sample would normally be located, and 2) would cause sharp reactions when known temperatures were achieved. Quick-drying temperature-indicating liquids of different melting points, Tempilaqº G (Tempil, Inc., South Plainfield, NJ, USA), were used as temperature indicators in muffle furnaces. A Tempilaqº G set contains long-chain hydrocarbons suspended in an organic solvent, which change their appearance at 44 specific temperatures spanning 80-100 °C. The accuracy of Tempilaq° G is certified within ±1% of its designated temperature and is traceable to the National Institute of Standards and Technology (NIST). Tempilaqº G is bottled in liquid form and dries quickly to a dull, opaque film when applied to a surface. As the surface is heated to the designated temperature, the film liquefies and is accompanied by a change of appearance that can be optically monitored to determine sample temperature.

5.1.1 Standard Preparation

Temperature calibration requires two pre-fired quartz-fiber filter (#2500 QAT-UP, Pall Life Sciences, Ann Arbor, MI) punches (0.3 cm^2 and 0.5 cm^2 for DRI analyzer) and a clean matching-sized quartz disk (Continental Glass Engineering, Burbank, CA). Quartz-fiber filter punches are sliced in half with a filter-slicing device (Fung et al., 2004). A thin layer of Tempilaqº G (25 µL) is uniformly applied to the quartz disk surface with a 0.1 ml Eppendorf graduated Combitip (Brinkman Instruments Inc., Westbury, NY), and, before drying, is immediately covered with a sliced filter punch. For cost savings, a glass, instead of quartz, disk can be used for Temiplaqº G at temperatures less than 520 °C. Higher temperatures require the quartz disc to prevent melting. The disc sandwich (i.e., temperature standard) is then loaded on a sample holder for analysis. The mass of applied Tempilaqº G is determined gravimetrically to ensure its mass is ~10%.

5.1.2 Temperature Program

After insertion of the temperature standard into the analyzer, the temperature is slowly (2 °C/min) ramped across a 50 °C range containing the specified Tempilaq° G melting point. This slow ramping creates a quasi-equilibrium condition that allows the phase transition point to be resolved. When the specified temperature is reached, the Tempilaqº G liquefies, causing a sharp change in reflectance and transmittance.

Figure 5-1 demonstrates the thermocouple temperature, reflectance, and transmittance as a function of thermal analysis time. In the example provided, the reflectance and transmittance remained relatively flat until the temperature approaches its specified value of 184 °C. Figure 5-2 compares the time series of reflectance, transmittance, and their respective first- and second-order derivatives. The second-order derivative (change in the slope) recorded the inflection point of reflectance or transmittance that provided the best indication of the attainment of the designated temperature. Thermocouple temperature at this critical point was recorded as "measured" temperature. The temperature deviation (ΔT) between the sample and the thermocouple temperatures is determined by comparing the rated Tempilaqº G temperature with this measured value (Chow et al., 2005).

In the Model 2001, the reflectance-based method generally gave a lower liquefying temperature than the transmittance-based method, within ±2 ºC. Given the uncertainty in the Tempilaqº G temperature rating of ±1%, calibrations based on the two optical methods were considered to be equivalent; therefore, their means were used. Among temperature indicators that achieve an adequate signal/noise ratio, temperature indicators of 140, 280, 480, 580, 740, and 840 °C were chosen for IMPROVE_A protocol temperature calibration (Chow et al., 2005).

Figure 5-1. Temperature ramping with a Tempilaq° G temperature indicator rated at 184 °C. Also shown are reflectance and transmittance of the temperature indicator (if available). The vertical dashed line indicates the achievement of the rated temperature.

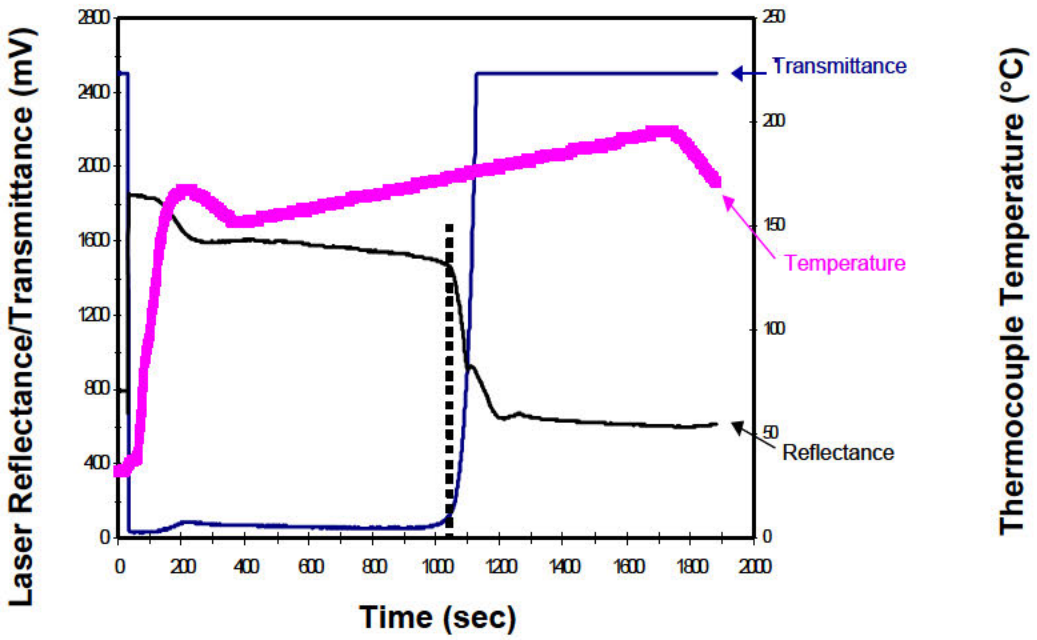
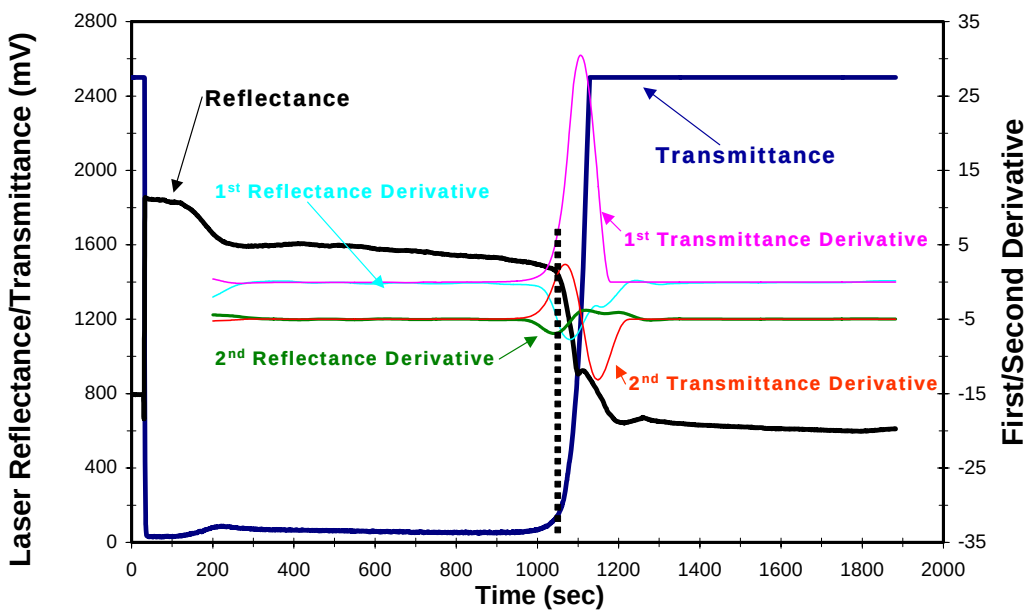


Figure 5-2. Reflectance and transmittance measurements and their first and second derivatives over time with a Tempilaqº G temperature indicator rated at 184 °C (Figure 5-1). The vertical dashed line indicates the achievement of the rated target temperature.



(Tempilaq's melting point 184 ± 2 ºC)

6 QUALITY CONTROL

6.1 Performance Testing

System blanks are performed at the beginning of each day to confirm the system is not introducing bias in the carbon results and to confirm that the laser signal is not temperature-dependent. Contamination is potentially due to:

- Operator practices, such as improper cleaning of tweezers and punch.

- Teflon particles on the push rod getting into the heated zone of the quartz oven.
- Sample boat contamination.
- Contamination of the carrier gas.
- Fibers left on the punch tool or on the flat glass plate during cleaning.
- Contamination from field operator.
- Contamination from normal use of analyzer.

A temperature-dependent laser signal is potentially due to:

- Physical coupling of the push rod to the boat during the run.
- Boat movement due to loose boat holder.
- A quartz rod (laser light pipe) ready for replacement. As quartz is heated to high temperatures, devitrification (white deposits of SiO_2) occurs that leads to a decrease in the laser intensity. The end surface becomes frosty. The bottom light pipe also receives droppings of quartz particles from filter discs during analysis. Thus, the bottom light pipe will deteriorate faster than the upper light pipe. Microscopic cracks in the quartz rod will increase internal reflectance of the laser light; as the number of these cracks multiply, the effect of temperature on these cracks, and thus on the reflectance, becomes an interference in the laser signal.

As described in Section 4.1, the calibration peak at the end of each analysis run serves as a regular standard; the integrated area under the calibration peak serves as a measure of analyzer performance. In addition, the daily injections of two calibration gases further serve as standards. Primary standards in the form of NIST-traceable spiked filter punches do not exist. The *cmdAutoCalibCheck* command check allows the condition of the catalysts to be monitored and verified.

6.2 Reproducibility Testing

Replicates of analyzed samples are performed at the rate of one per group of ten samples. The replicate is selected randomly and run immediately after a group of ten is completed. It is run on a randomly selected analyzer (it can be the same or a separate analyzer as the original). This practice provides a better indication of potential differences if samples are analyzed by different laboratories. The $\mu g/cm^2$ values for OC, EC and TC are compared with the original run. The values should fall into the following criteria:

Range	**Criteria**
OC, EC & TC < 10 $\mu g/cm^2$	< ±1.0 $\mu g/cm^2$
OC and TC $\geq$ 10 $\mu g/cm^2$	< 10 % of average of the 2 values
EC $\geq$ 10 $\mu g/cm^2$	< 20 % of average of the 2 values

Notice that the criteria converge at 10 $\mu g/cm^2$. Replicates which do not fall within the above criteria must be investigated for analyzer or sample anomalies. Analyzer anomalies include poor response (as reflected in the calibration peak areas) or poor laser signals affecting the splits between OC and EC. Typical sample anomalies include inhomogeneous deposits or contamination during analysis or from the field sampling location. Inconsistent replicates for which a reason cannot be found must be rerun again.

When samples are analyzed with an automated sample loader, the sample chamber tray will be set up such that the loader number six location will be a replicate of the first sample, the 12th location a standard spike of sucrose or KHP, and the 18th location a replicate of the sample in loader position.

6.3 Control Charts and Procedures

Control charts are updated at the beginning of each month. These charts include a month of calibration data and are posted in the carbon room until the end of the month, after which they are filed with the raw analysis results.

The control chart gives a plot of calibration peak counts as percent deviation from a historical mean versus date. Instances where the calibration peak area deviates by more than 10% from the historical mean must be investigated and the cause must be corrected. The historical mean covers results from the previous three months and is updated either quarterly, when the CH_4

calibration gas is changed, when the catalysts are renewed, or when extensive repairs are performed.

6.4 Analysis Flags

During Level I validation (see Section 6.5), unusual conditions of the deposit or analysis problems are noted on the analysis printouts. Errors in pre-analysis data entry (e.g., in filter ID, punch size, deposit area) are corrected.

Flags are applied to the Access file created from the analysis results (see Section 6.5). The analysis flags commonly used are presented in Table 6-1. Note that all results flagged with "v" must include a description of the reason for invalidating the sample in the remarks field.

Table 6-1. Common DRI Analysis Flags

Flag	Description
b1	Field blank
b2	Lab blank
b3	Blank of undetermined type
b6	Transport blank
f1	Filter damaged, outside of analysis area
f2	Filter damaged, inside analysis area
i1	Inhomogeneous filter deposit
i3	Deposit falling off (usually occurs on heavily loaded samples)
i4	Abnormal deposit area, possible air leakage during sampling
m2	Non-white sample punch after analysis
j	Possible air leakage during sampling
r1	First replicate on same analyzer
r2	Second replicate on same analyzer
r3	Third replicate on same analyzer
r5	Replicate on different analyzer
v	Sample void

6.5 Data Validation and Feedback

6.5.1 Daily Validation

Level I validation is performed by manually checking the tabular and thermogram printouts the day after the analysis is performed. The laboratory supervisor or a designated technician is responsible for checking the data. The following items are checked on the tabular data (Figure 6-1):

- The filter ID is correct and Punch #.
- For calibration runs, the tabular and thermogram printouts are checked to make sure the catalysts are operating at required level.
- The analysis date and time is correct.
- The punch area is correct; errors in entry require that the calculated carbon concentrations be recalculated.
- The deposit area is correct; errors in entry require that the calculated carbon concentrations be recalculated by hand.
- The calibration peak area is in the correct range (Section 4.1).
- The initial and the final FID baseline readings are within three counts of each other; excessive FID baseline drift is a cause for re-analysis. NOTE: Some very heavily loaded filters will have an FID baseline drift greater than three counts no matter which carbon analyzer the sample is run on; typically a FID baseline drift greater than three counts signals either a problem with the run or with the carbon analyzer.
- The lower laser split time and the upper laser split time are within 10 seconds of each other. If the times differ by more than 10 seconds, check that the lower split OC and upper split OC differ by no more than 5%. OC values which differ by more than 5%, unless due to a small change in laser signal resulting from an extremely clean or very dark sample, requires re-analysis.

Calculated carbon values for calibration injection runs are within 10% of the current mean value for the injected gas type on that analyzer.

Acceptance runs for pre-fired quartz filters result in <1.5 $\mu g/cm^2$ OC, <0.5 $\mu g/cm^2$ EC, and <2.0 $\mu g/cm^2$ TC for IMPROVE_A thermal protocol. Filters which exceed these levels must be re-fired.

Items which are found to be okay are underlined in red. Items which have problems are circled in red.

Figure 6-1. Tabular Output from the DRI Thermal/Optical Carbon Analyzer

```
                          CARBON ANALYSIS RESULTS
Analyzer #6                                                   Technician: LAC
-------------------------------------------------------------------------------

Analysis ID      : Q17289-2.OEC
Sample ID        : Q17289
Punch area       :  0.506 cm2
Deposit area     :  3.530 cm2

Analysis Start  : 12/22/03  14:52        Calculation     : 10/21/04  11:59
Analysis Stop   : 12/22/03  15:09
-------------------------------------------------------------------------------
Anal program ver: P6.0  (02/20/03)       Parm file ver   : V0302
Calib. slope    : 20.27 ug C/peak ratio  Baseline time   : 11 sec
Calib. intercept: 00.00 ug C
Reflectance unc.:   010 counts           Transmission unc:   010 counts
Sample transit  : 18 sec
-------------------------------------------------------------------------------
Calibration peak area:   25078 millivolt-seconds
Initial FID baseline :     100   millivolts
Final FID baseline   :     101   millivolts
-------------------------------------------------------------------------------
Laser reflectance initial baseline   :    1291   millivolts
Laser reflectance minimum            :     884   millivolts at   192 sec
Laser reflectance final baseline     :    1589   millivolts
Laser transmittance initial baseline :     315   millivolts
Laser transmittance minimum          :      60   millivolts at   201 sec
Laser transmittance final baseline   :     427   millivolts
-------------------------------------------------------------------------------
              Reflect Split Time  Laser                FID Split Time
  Lower split  :     277 sec          1681 millivolts          295 sec
  Regular split:     278 sec          1681 millivolts          296 sec
  Upper split  :     279 sec          1683 millivolts          297 sec
-------------------------------------------------------------------------------
              Transmit Split Time  Laser                FID Split Time
  Lower split  :     311 sec           501 millivolts          329 sec
  Regular split:     315 sec           500 millivolts          333 sec
  Upper split  :     320 sec           501 millivolts          338 sec
-------------------------------------------------------------------------------
                      Peak Area                        Carbon
OC1        OC        2184  mv-secs     3.49  ug C/cm2    12.32    ug C/filter
OC2        OC        2156  mv-secs     3.44  ug C/cm2    12.15    ug C/filter
OC3        OC        1808  mv-secs     2.89  ug C/cm2    10.19    ug C/filter
OC4        OC        2704  mv-secs     4.32  ug C/cm2    15.25    ug C/filter
OC5        OC          20  mv-secs     0.03  ug C/cm2      .11    ug C/filter
EC1        EC         112  mv-secs     0.18  ug C/cm2      .63    ug C/filter
EC2        EC          90  mv-secs     0.14  ug C/cm2      .51    ug C/filter
EC3        EC         115  mv-secs     0.18  ug C/cm2      .65    ug C/filter
EC4        EC          94  mv-secs     0.15  ug C/cm2      .53    ug C/filter
EC5        EC           0  mv-secs     0.00  ug C/cm2      .00    ug C/filter
LRPyMin    Py        -759  mv-secs    -1.21  ug C/cm2    -4.28    ug C/filter
LRPyMid    Py        -732  mv-secs    -1.17  ug C/cm2    -4.13    ug C/filter
LRPyMax    Py        -707  mv-secs    -1.13  ug C/cm2    -3.98    ug C/filter
LTPyMin    Py        -182  mv-secs     -.29  ug C/cm2    -1.02    ug C/filter
LTPyMid    Py        -151  mv-secs     -.24  ug C/cm2     -.85    ug C/filter
LTPyMax    Py        -123  mv-secs     -.20  ug C/cm2     -.69    ug C/filter

*******************************************************************************
```

The thermograms are checked for the following (Figure 3-5):

- The initial FID baseline is flat, indicating that the analyzer has been thoroughly purged before analysis began.

- The final FID baseline prior to the calibration peak is within three milliVolts of the initial FID baseline; excessive drift is cause for reanalysis.

- The laser reflectance signal during the first two minutes, prior to sample introduction to the “Analysis” position, appears near the bottom of the graph and shifts position once the sample is in the “Analysis” position. The transmittance signal will be out-of-scale until the sample is in the “Analysis” position.

- The laser signal should dip below the initial laser line until O_2 is introduced, at which point the signal should rise steeply. (For most samples, charring does occur). High temperature soot samples may not show this characteristic.

- The temperature readings reflect stable and smooth temperatures at each level and quick transitions between levels.

- Problems or deviations from normal should be circled in red. If the sample punch taped to the thermogram is not white, it is also circled.

If examination of the tabular and thermogram printouts results in a decision that a sample should be reanalyzed, write "Rerun" in red on the printouts and prepare a re-analysis list. This list should be posted immediately after the validation is complete, and those samples should be rerun as soon as they can be conveniently fit into the current day's analyses.

Evidence of persistent analyzer problems must be resolved, either by physically examining the analyzer or reviewing the problems with the analyzer operator.

6.5.1.1 Validation of Final Data File

The following steps are followed to create an Excel file containing carbon data and to perform Level "I" validation on it:

- Each analyzer will have an Access database containing all of the raw carbon data.
- A query is used to generate the project data in $\mu g/cm^2$ or µg/filter and a validation report is then generated from this query.
- The output of the Access query is saved as an Excel file for data validation and processing. The MS Excel file naming convention calls for a name in the following format:

  xxOETnnt.xls

  where:

  xx is the two-character project identifier

  OET stands for organic/elemental carbon

  nn is the two-digit batch number (generally used to distinguish between different projects for the same client or between sampling quarters for an extended project)

  t stands for the sample type based on sampler technology:
  - A Agricultural burn emissions dilution sampler
  - C Combination particle/gaseous sampler
  - D Dichotomous sampler for $PM_{2.5}$, PM_{coarse}, and PM_{10}
  - G Gaseous
  - H High-volume sampler
  - I IMPROVE/NPS sampler
  - P MiniVol Sampler
  - Q Audit samples
  - R Resuspension chamber
  - S Sequential filter sampler (SFS)
  - W Wet Deposition
  - X Unknown
  - Y Y-sampler (DRI source sampler)

- The final MS Excel file name is specified on the analysis list posted in the carbon room.

- Begin validation by matching the filters listed on the analysis list with the filters listed on the MS Excel printout. There must be at least one entry on the printout for every filter listed on the analysis list.

- Flag field and lab blanks while the list is being reviewed by placing "b1", "b2", "b3", or "b6" in the second column of the printout. Because the MS Excel printout is sorted by ID number, replicates and reruns will be grouped together.

- Indicate missing data by writing the missing filter ID in the margin with an arrow drawn to the appropriate place of insertion. Scan the printout for unusual IDs which may have been mistyped or misread by the scanner during analysis. Generally, these will appear at the beginning or end of the printout, due to the sorting process. Make sure that all samples listed on a rerun list appear on the printout.

- Resolve all missing data. Scan the deposit area column for incorrect entries. Circle the incorrect entries to ensure that corrected values replace those currently in the database.

- Scan the filter IDs for multiple entries of ID numbers. Under normal conditions, the only times multiple entries should occur are reruns and replicates. All multiple entries must be flagged to indicate the reason for their existence.

- Scan for missing runs. The most common example is the first run being aborted or lost for some reason, and the only entry in the MS Excel file is the second run. An entry for the first run must be inserted, flagged as invalid, and labeled as to the reason it was invalid. All punches taken from the filters MUST be accounted for and documented in the file.

- Pull the analysis folders and go through the analysis summaries and thermograms one by one. At this time, resolve all circled items and all missing flags.

    - Determine if analyses flagged by the operator are legitimate. These flags are determined by the operator at the end of the analysis run (Section 6.4) and are defined in Table 6-2.

    - If the temporary flag is not warranted, draw a line through the flag to indicate that it should be removed.

    - If the sample should be rerun, add it to a rerun list.

- If the analysis has some anomaly, but still appears to be legitimate, either flag or add notes to the comments field as appropriate.
- Analysis flags are defined in Section 6.4.
- All samples flagged as invalid must have an entry in the comments field to describe the reason that the sample is invalid. Typical notes and comments are presented in Table 6-3.

- Scan the OC and EC columns looking for unusually high or low values. At this time make sure that the field blanks and/or lab blanks are all close to one another. Circle any possible outliers for further investigation.

- Compare replicates against original run. The values should meet the following criteria:

Range	**Criteria**
OC, EC & TC < 10 $\mu g/cm^2$	< ±1.0 $\mu g/cm^2$
OC and TC $\geq$ 10 $\mu g/cm^2$	< 10 % of average of the 2 values
EC $\geq$ 10 $\mu g/cm^2$	< 20 % of average of the 2 values

- Check the OC/TC ratio. Typically it should not be less than 0.65. Circle any possible outliers for further investigation.

- Scan for records where EC is greater than OC. These may require additional investigation, depending on loading and sample source. Circle records for further investigation.

- Scan blanks for OC being greater than 3.95*deposit area and for EC greater than the deposit area. Rerun any unusually high blanks.

- Compare primary and secondary filters for validity. Secondary filters should have OC and EC measurements less than the corresponding primary filter. Secondary filters should have EC less than or equal to 3.8. OC should be less than or equal to 18. Circle any records that require further investigation.

- All operator-generated flags must be either converted to standard analysis flags (Table 6-1) or removed. The flags in Table 6-2 are temporary flags only and are not recognized as legitimate analysis flags at DRI.

- After all thermograms have been reviewed and all possible reruns have been identified, post the rerun list in the carbon room and have the reruns done as soon as possible.

- Review the data from the reruns, looking for inconsistencies. Confirm that the reasons for the rerun have been addressed. Mark the printout with the new values for manual insertion into the MS Excel file. Previous runs must be flagged as invalid or the reruns flagged as replicates.

- Finally, all comments, flags, insertions, and other changes made to the printout are entered into the MS Excel file. After all changes are made, generate a new printout. Label the new printout with the file name and printout date. Forward a copy of the printout and the MS Excel file on disk to the person putting the final report together.

Table 6-2. DRI Carbon Analysis Temporary Flags

Flag	Description
EI	Error in sample ID
EA	Error in sample deposit area
ST	Suspect temperature profile
SF	Suspect FID signal
SL	Suspect laser signal
Mi	Miscellaneous problem
m2	Non-white sample punch after analysis
v	Invalid run
r	Replicate
b	Blank
i	Inhomogeneous
f	Filter media damaged
g	Sample deposit damaged
d	Sample dropped
n	Foreign substance on filter
w	Sample wet

Table 6-3. DRI Carbon Analysis Validation Comments

Comments	Description
"Anomalous laser"	Despite good initial laser, laser signal drifted above initial laser signal before dropping (typical of auto emissions).
"Operator error"	Used with "v" flag; operator exited program unexpectedly.
"Analyzer malfunction"	Used with "v" flag; analyzer malfunction or problem beyond the control of the operator such as plugged FID, broken oven heater, etc.
"Poor replicate"	Replicate is outside the normal criteria, but no reason can be found for the discrepancy.
"Poor initial laser"	Used with "v" flag; severe coupling or boat not pushed in time for calculation of initial laser signal.
"Potential contamination"	Used with "v" flag; rerun of sample yields lower values or different peaks. Typically used with blanks or reruns of replicates.
“Power failure”	Used with "v" flag; power surge or power failure.

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