BEFORE THE ENVIRONMENTAL APPEALS BOARD
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

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In re:	)
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Shell Gulf of Mexico, Inc.	)
Permit No. R10OCS/PSD-AK-09-01	)
	)
and	)
	)
Shell Offshore, Inc.	)
Permit No. R10OCS/PSD-AK-2010-01	)
	)
	)

EXHIBITS IN SUPPORT OF PETITION FOR REVIEW

NATURAL RESOURCES DEFENSE COUNCIL, NATIVE VILLAGE OF POINT HOPE, RESISTING ENVIRONMENTAL DESTRUCTION ON INDIGENOUS LANDS (REDOIL), ALASKA WILDERNESS LEAGUE, AUDUBON ALASKA, CENTER FOR BIOLOGICAL DIVERSITY, NORTHERN ALASKA ENVIRONMENTAL CENTER, OCEAN CONSERVANCY, OCEANA, PACIFIC ENVIRONMENT, and SIERRA CLUB

In order to detect a major failure of the CDPF control devices, EPA is also proposing a visible emissions (opacity) limit in addition to the PM emission limit described above. EPA proposes that visible emissions from the engines, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

4.4.4 PM BACT for the Diesel-Fired Boilers (FD-21 to FD-22)

<u>Step 2 – Eliminate technically infeasible control options</u>

No PM controls were found in the RBLC or CA-BACT search for small boilers. [15] Although it may be theoretically possible to design an ESP or a fabric filter for the small boilers on the Discoverer, one factor limiting the application of a fabric filter or an ESP on these boilers is that more than 50 percent of the PM from diesel fired boilers is condensable PM which would not be collected in a fabric filter or ESP at normal exhaust gas temperatures. As shown in Appendix A, the PM emissions for each boiler are 0.38 ton per year. Based on these factors, EPA considers a fabric filter or an ESP to be technically infeasible for control of PM from the boilers on the Discoverer. The use of ultra-low sulfur fuel for combustion will minimize the sulfate fraction of the PM emissions.

<u>Step 3 – Rank the remaining technologies by control effectiveness</u>

The only technically feasible PM control option for the two boilers (FD-21 and FD-22) is good combustion practices.

<u>Step 4 – Evaluate the most effective control based on a case-by-case consideration of energy, environmental, and economic impacts</u>

Since the top control option from Step 3 (good combustion practices) is proposed as BACT, this step is not required.

<u>Step 5 – Select PM BACT for the Diesel-Fired Boilers</u>

EPA is proposing that good combustion practices represent BACT for PM for the diesel-fired boilers on the Discoverer. Good combustion practice for PM control essentially consists of operating and maintaining the boilers according to the manufacturer's recommendations to maximize fuel efficiency and minimize emissions. More specifically, EPA proposes the following good combustion practices, in addition to the emission limit set forth below, as BACT for the diesel-fired boilers on the Discoverer:.

- Operating personnel must be trained to identify signs of improper operation and maintenance, including visible plumes, and instructed to report these to the maintenance specialist,

[15] These control technologies are not found in practice because of the high cost of such control technology and the very small potential reduction in PM emissions.

• At least one full-time equipment maintenance specialist must be on board at all times during drilling activities,

• Each emission unit must be inspected by the maintenance specialist at least once a week for proper operation and maintenance consistent with the manufacturer's recommendations,

• The operation and maintenance manual provided by the manufacturer for each emission unit must be maintained on board the Discoverer at all times,

• The manufacturer's recommended operation and scheduled maintenance procedures must be followed for each emission unit.

EPA proposes that the permit include a condition requiring the permittee to follow the good combustion practices listed above.

EPA proposes that an emission limit representative of PM BACT for the boilers is 0.0235 pounds per million Btu (lb/MMBtu). This emission limit was derived from the emission rate and boiler size information provided in Appendix A.

In order to detect a major operating problem with the boilers, EPA is also proposing a visible emissions (opacity) limit in addition to the PM limit described above. EPA proposes that visible emissions from the boilers, excluding condensed water vapor, shall not reduce visibility through the exhaust effluent more than 20 percent averaged over any six consecutive minutes.

4.4.5 PM BACT for the Incinerator (FD-23)

<u>Step 2 – Eliminate technically infeasible control options</u>

Based on review of the RBLC and CA-BACT, the available control technologies for the Discoverer's incinerator (FD-23) are an ESP and good combustion practices. The incinerator listed in the RBLC with an ESP was rated at 350 tons per day (29,167 lb/hr), which is over 100 times the size of the incinerator on the Discoverer. Communication with TeamTec, the manufacturer of the incinerator on the Discoverer, indicated that they were not aware of any control technologies that have been installed on this model of incinerator for control of any of the pollutants including PM (Shell 2/23/09 Rev. App., Appendix F, Footnote 39, pages 105 to 112).

By letter to EPA dated December 13, 2009, Shell provided a study conducted by GI Development LLC to evaluate PM control options for the incinerator (Shell 12/13/09 Supp. App.). The GI Development LLC study evaluated a dry ESP, a wet ESP, a venturi scrubber and a ceramic fiber baghouse.

<u>Step 3 – Rank the remaining technologies by control effectiveness</u>

1. Ceramic fabric baghouse – 99 percent control
2. Venturi scrubber – 90 percent control

3. Dry ESP – 75 percent control at the quoted size
4. Wet ESP – 75 percent control at the quoted size
5. Good combustion practices.

Step 4 – Evaluate the most effective control based on a case-by-case consideration of energy, environmental, and economic impacts

The cost effectiveness value for the ceramic fiber baghouse based on a capital equipment cost of $230,000 was calculated to be $65,986/ton of PM removed. The high cost effectiveness value was due to both the high capital cost and the relatively low amount of potential PM removed (about 0.5 ton/year). This cost effectiveness value is higher than EPA considers reasonable for a BACT determination. Therefore, the ceramic fabric baghouse control device was eliminated from consideration in the BACT process.

The cost effectiveness value for the venturi scrubber based on a capital equipment cost of $150,000 was calculated to be $49,490/ton of PM removed. The high cost effectiveness value was due to both the high capital cost and the relatively low amount of potential PM removed (about 0.5 ton/year). This cost effectiveness value is higher than EPA considers reasonable for a BACT determination. Therefore, the venturi scrubber control device was eliminated from consideration in the BACT process.

Since both the dry and the wet ESP control devices have a higher capital cost ($420,000 and $175,000 respectively) and a lower PM control percentage than the venturi scrubber, the cost effectiveness values for either ESP is greater than for the venturi scrubber. Therefore, the dry and wet ESP control devices were eliminated from consideration in the BACT process.

The remaining control option is good combustion practices.

Step 5 – Select PM BACT for the Incinerator

Good combustion practices are determined to represent BACT for PM for the incinerator. Good combustion practice for PM control essentially consists of operating and maintaining the incinerator according to the manufacturer's recommendations to maximize fuel efficiency and minimize emissions. More specifically, good combustion practices for the incinerator consist of the following:

- Operating personnel must be trained to identify signs of improper operation and maintenance, including visible plumes, and instructed to report these to the maintenance specialist,

- At least one full-time equipment maintenance specialist must be on board at all times during drilling activities,

- Each emission unit must be inspected by the maintenance specialist at least once a week for proper operation and maintenance consistent with the manufacturer's recommendations,

• The operation and maintenance manual provided by the manufacturer for each emission unit must be maintained on board the Discoverer at all times,

• The manufacturer's recommended scheduled operation and maintenance procedures must be followed for each emission unit.

EPA proposes that the permit include a condition requiring the permittee to follow the good combustion practices listed above.

In order to minimize emissions of PM, EPA proposes that the permit require that Shell 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 PM emission limit representative of BACT for the incinerator is 8.20 pounds of PM_{10} per ton of waste burned and 7.00 pounds of $PM_{2.5}$ per ton of waste burned. These emission limits are identical to the emission factors presented in the emission inventory in Appendix A.

4.5 CO and VOC BACT Analysis

Technology used to control CO emissions from combustion sources, including internal combustion engines, also provides control of volatile organic compound (VOC) emissions. Therefore, the following BACT analysis addresses CO and VOC control in combination.

Step 1 – Identify all available control technologies

The available CO and VOC control technologies for the Discoverer's engines, boilers, and incinerator were determined from searches performed on the RBLC and the CA-BACT. The search conditions and a summary of the resulting control technologies are provided in Table 4-7 of the permit application. Crankcase ventilation gases from the diesel engines contain some VOC. CCV eliminates emissions from crankcase blow-by by directing these gases back to the intake manifold of the engine so they can be combusted.

The available CO and VOC combustion control technologies for diesel IC engines identified in the RBLC and CA-BACT are OxyCat and Tier 2 or Tier 3 diesel engine standards. OxyCat reduces CO/VOC emission through catalytic oxidation of these combustible gases. The OxyCat control system proposed for the generator diesel IC engines (and discussed in the Section 4.4.1 above) will provide an overall control efficiency of 80 percent for CO and approximately 70 percent for VOC according to D.E.C. Marine, the OxyCat vendor for the Discoverer's generator diesel IC engines (Shell 2/23/09 Rev. App., Appendix F, Footnote 1, pages 6 & 7). Diesel engines designed to meet Tier 2 or Tier 3 emission standards typically employ a combination of advanced combustion technology and catalytic oxidation. Although not listed in the RBLC or CA-BACT, a CDPF reduces CO and VOC emissions through catalytic oxidation with an overall control efficiency of 90% for both pollutants (Air Sciences 4/27/09).

Regardless of the technology applied to achieve BACT, the control option must result in an emission rate no less stringent than an applicable NSPS emission rate, if any NSPS standard for that pollutant is applicable to the source. 40 C.F.R. § 52.21(b)(12)(definition of BACT). EPA has promulgated exhaust emission standards for stationary IC engines under the NSPS Subpart IIII which specifies that engine manufacturers must certify their 2007 and later engines to the applicable emission standard for new nonroad engines in 40 C.F.R. § 89.112 (and several other sections). 40C.F.R. § 60.4201(a). Engines designed to meet Tier 2 or Tier 3 PM emission standards typically employ a combination of low PM emitting engine designs and DPF or CDPF. For diesel IC engines manufactured to meet the Tier 3 emission standards such as the three 540 hp MLC compressor engines (FD-9 to FD-11) and the 250 hp Logging Unit Winch engine (FD-19), the applicable CO emission standard is 3.5 grams per kilowatt hour (g/kW-hr). 40 C.F.R. § 89.112(a) Table 1. The VOC emission limit for Tier 3 engines is expressed as a combined value with NO_x (4.0 g/kW-hr).

No CO or VOC control technologies were found in the RBLC and CA-BACT searches for diesel-fired boilers less than or equal to 100 MMBtu/hr or for incinerators, nor are any CO or VOC control technologies found in practice for existing small boilers or incinerators. Therefore, good combustion practice is the only available control technology for consideration in this analysis for the diesel-fired boilers and the incinerator.

4.5.1 CO and VOC BACT for the Generator Diesel IC Engines (FD-1 to FD-6)

<u>Step 2 – Eliminate technically infeasible control options</u>

The available control technologies for the generator diesel IC engines are OxyCat, CDPF, Tier 2 or Tier 3 level controls, and CCV. Tier 2 or Tier 3 level controls are intrinsic to the original engine design; and, therefore, are not considered technically feasibility since they are not part of the design of the Discoverer's existing Caterpillar D399 diesel engines.

As discussed above in Section 4.4.1, the primary difference between an OxyCat system and a CDPF is that the OxyCat system is constructed with an open flow catalyst matrix. In contrast, the CDPF is constructed with a catalyst matrix where the inlet channels of the catalyst matrix are plugged at the downstream end, forcing the exhaust gases to flow through the pores of the catalyst matrix and out the adjacent channels, which are plugged at the inlet end of the matrix. Because of this design difference, a CDPF achieves a higher percentage reduction of PM emissions but approximately the same percentage reduction for VOC and CO as compared to an OxyCat system, although at the expense of a higher pressure drop across the catalyst matrix.

As also discussed above, the higher pressure drop of the CDPF is of concern because, as described in Section 4.3.1, the generator diesel IC engines will be equipped with the SCR system for NO_x control. The SCR catalyst imposes a backpressure on the engines due to the pressure drop required to move the exhaust gases through the SCR catalyst matrix. Adding the additional pressure drop associated with a CDPF could result in an excessive backpressure on the engines. D.E.C. Marine addressed the possibility of designing a CDPF to be used with the SCR system (Shell 2/23/09 Rev. App., Appendix F, Footnote 41, page 113). Since a CDPF has not been included with their SCR systems in the past, a feasibility study would have to be conducted before final design. Several considerations would have to be addressed including the additional cross-sectional area needed for the CDPF catalyst matrix (perhaps as much as 50% larger than for an OxyCat matrix), the temperature profiles to determine how well the captured soot would be oxidized in the CDPF, the increased backpressure imposed and the manual cleaning frequency (or filter element exchange) required to keep the backpressure within specifications. D.E.C. Marine states that they are not aware of any applications of CDPF systems on older heavy duty marine engines without modern electronic controlled fuel injection. Since CDPF systems are not commercially available in combination with SCR systems for diesel engines such as the Discoverer's generator diesel IC engines, EPA believes that CDPF systems are technically infeasible for this specific application.[16]

<u>Step 3 – Rank the remaining technologies by control effectiveness</u>

The remaining technically feasible controls for the generator diesel IC engines include OxyCat and good combustion practices for control of exhaust gas emissions.

<u>Step 4 – Evaluate the most effective control based on a case-by-case consideration of energy, environmental, and economic impacts</u>

The most efficient available technology is an OxyCat system with estimated control efficiency of 80% for CO and 70% for VOC. The design proposed by D.E.C. Marine incorporates oxidation catalyst downstream of the SCR catalyst in the same converter shell, which results in a more compact and economical system than having separate devices. The OxyCat system is expected to reduce CO emissions to <0.179 g/kW-hr and VOC emissions to <0.0229 g/kW-hr.

In addition to the exhaust gases from the engine, the diesel generator engines produce emissions from the crankcase, which must be vented to prevent pressure buildup from combustion gases that escape around the piston rings during the combustion stroke. As discussed above in Section 4.4.1, EPA is proposing that CCV represents BACT for PM. Installation of CCV will also control CO and VOC emissions by recycling them back to the intake manifold so that they can be combusted.

<u>Step 5 – Select CO and VOC BACT for the Generator Diesel IC Engines</u>

EPA proposes that BACT for CO and VOC for the generator diesel IC engines is an emission limit of 0.1790 g/kW-hr for CO and 0.0230 g/kW-hr for VOC based on the use of OxyCat technology.

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[16] Even if a CDPF was technologically feasible in this specific application, Shell estimated the cost effectiveness of a CDPF for the generator engines and found the cost effectiveness values to be in the $20,000 to $30,000 per ton of PM removed (see Appendix C of Shell 2/23/09 Rev. App. for the detailed cost calculations). Using a similar cost effectiveness calculation procedure, EPA estimated that the cost effectiveness value for a CDPF to control CO and VOC was approximately $40,000 per ton of CO and VOC removed. These cost effectiveness values exceed what EPA believes is representative of BACT for these engines.

4.5.2 CO and VOC BACT for the Compressor Diesel IC Engines (FD- 9 to FD-11) and the Logging Unit Winch Engine (FD-19) (all Tier 3 Engines)

Step 2 – Eliminate technically infeasible control options

Shell proposed that engines meeting the Tier 3 emission standards represent BACT. However, there is no technical reason why add-on controls can not be considered for Tier 3 engines. The available control technologies for the Tier 3 diesel IC engines include CDPF, OxyCat, and good combustion practices. CCV is included as an inherent feature of the Tier 3 engines.

Step 3 – Rank the remaining technologies by control effectiveness

The technically feasible control technologies for the smaller diesel engines are ranked by control effectiveness:

1. CDPF – 80% control for CO and VOC
2. OxyCat – 47% control for CO and VOC
3. Good combustion practices

Step 4 – Evaluate the most effective control based on a case-by-case consideration of energy, environmental, and economic impacts

On December 22, 2009, Shell submitted CO cost effectiveness calculations for CDPF and Oxy Cat controls for the compressor engines and the Logging Unit Winch engine (Environ 212/22/09). The cost effectiveness value for a CDPF for each of the compressor engines was calculated to be $9,848/ton of CO removed. The cost effectiveness value for an OxyCat for each of the compressor engines was calculated to be $4,323/ton of CO removed. The cost effectiveness values were calculated assuming the baseline emission rate was equal to the Tier 3 CO engine standard of 3.5 g/kW-hr. Since the cost effectiveness value for the CDPF was near the high end of the range that EPA considers reasonable, the incremental cost effectiveness value between an OxyCat and a CDPF was evaluated to determine whether the additional cost to move from an OxyCat to a CDPF for the compressor engines was justified. The incremental cost effectiveness value was calculated to be $17,700/ton of CO removed. Because the incremental cost effectiveness value between an OxyCat and a CDPF is so large, EPA proposes that an OxyCat is representative of BACT for the compressor engines.

In the December 22, 2009 analysis, the cost effectiveness values for a CDPF and an OxyCat for the Logging Unit Winch engine were calculated (Environ 12/22/09). The cost effectiveness value for a CDPF for the Logging Unit Winch engine was calculated to be $3,329/ton of CO removed, a cost effectiveness value that EPA considers reasonable. Therefore, EPA proposes that a CDPF is representative of BACT for the Logging Unit Winch engine.

Step 5 – Select CO/VOC BACT for the Compressor and Logging Unit Winch Diesel IC Engines

EPA proposes that BACT for CO from the compressor diesel IC engines is an emission limit of 1.86 g/kW-hr based on the use of an OxyCat. EPA proposes that BACT for CO from the Logging Unit Winch diesel IC engine is an emission limit of 0.70 g/kW-hr based on the use of a

CDPF. For these Tier 3 engines, the VOC emissions are included in determining compliance with the NO_x emission limit described in Section 4.3.2.

The use of an OxyCat on the compressor engines and a CDPF on the Logging Unit Winch engine will concurrently reduce PM emissions by 50 percent and 85 percent, respectively. Therefore, EPA proposes to reduce the PM emission limits for the Tier 3 engines to 0.10 g/kW-hr for the compressor engines and 0.03 g/kW-hr for the Logging Unit Winch engine.

According to the information from CleanAIR Systems, a CDPF vendor, the CDPF must be operated at temperatures greater than 300ºC (572ºF) for a certain percentage of the operating time for proper filter regeneration using low sulfur fuel. Therefore, EPA proposes to include in the permit a condition requiring monitoring of the temperature of the engine exhaust gas at the inlet of the CDPF.

4.5.3 CO and VOC BACT for the Smaller Diesel IC Engines (FD-12 to FD-18 and FD-20)

<u>Step 2 – Eliminate technically infeasible control options</u>

The available control technologies for the smaller diesel IC engines include CDPF, OxyCat, Tier 2 or Tier 3 engine standards, CCV and good combustion practices. Tier 2 or Tier 3 engine standards are intrinsic to the original engine design and are not technically feasible for the smaller, existing diesel IC engines on the Discoverer.

<u>Step 3 – Rank the remaining technologies by control effectiveness</u>

The technically feasible control technologies for the smaller diesel engines are ranked by control effectiveness:

1. CDPF – 90 percent control for CO and VOC
2. OxyCat – 80 percent control for CO and 70 percent control for VOC
3. Good combustion practices

<u>Step 4 – Evaluate the most effective control based on a case-by-case consideration of energy, environmental, and economic impacts</u>

Shell proposed to use CDPF, the top control option, for all of the smaller diesel IC engines that are not Tier 3 engines. Therefore, no further analysis is required.

<u>Step 5 – Select CO/VOC BACT for the Smaller Diesel Engines</u>

EPA proposes that BACT for CO and VOC is the emission limits shown in Table 4-3 below based on the use of CDPF. The CO and VOC emissions limits are based on a 90% reduction of uncontrolled emissions from the engines.

Table 4-3 - CO and VOC Emission Limits for the Smaller Diesel IC Engines

Emission Unit Number and Engine Name	VOC Emission Limit (g/kW-hr)	CO Emission Limit (g/kW-hr)
FD-12 & 13, HPU Engines	0.20	0.40
FD-14 & 15, Deck Crane Engines	0.0640	0.220
FD-16 & 17, Cementing Unit Engines	0.20	0.40
FD-18 Cementing Unit Engine	0.270	0.880
FD-20, Logging Unit Generator Engine	0.750	0.550

According to the information from CleanAIR Systems, a CDPF vendor, the CDPF must be operated at temperatures greater than 300ºC (572ºF) for a certain percentage of the operating time for proper filter regeneration using low sulfur fuel. Therefore, EPA proposes to include in the permit a condition requiring monitoring of the temperature of the engine exhaust gas at the inlet of the CDPF.

In addition to the exhaust gases from the engine, the smaller diesel IC engines produce emissions from the crankcase, which must be ventilated to prevent pressure buildup from combustion gases that escape around the piston rings during the combustion stroke. EPA believes that CCV represents BACT for PM. Installation of CCV will also control CO and VOC emissions by recycling them back to the intake manifold so that they can be combusted.

4.5.4 CO and VOC BACT for the Diesel-Fired Boilers (FD-21 to FD-22) and the Incinerator (FD 23)

Step 2 – Eliminate technically infeasible control options

No CO or VOC controls were found in the RBLC or CA-BACT searches for small boilers and incinerators. As shown in Appendix A, the CO and VOC emissions for each boiler are 1.25 tons per year and 0.02 tons per year, respectively. Similarly, the CO and VOC emissions for the incinerator are 1.69 tons per year and 0.16 tons per year, respectively.

Step 3 – Rank the remaining technologies by control effectiveness

The only technically feasible CO and VOC control option for the two boilers (FD-21 and FD-22) and the incinerator (FD-23) is good combustion practices.

Step 4 – Evaluate the most effective control based on a case-by-case consideration of energy, environmental, and economic impacts

Since the only control option from Step 3 (good combustion practices) is proposed as BACT, this step is not required.

Step 5 – Select CO and VOC BACT for the Diesel-Fired Boilers and the Incinerator

EPA proposes that good combustion practices represent BACT for CO and VOC for the diesel-fired boilers and the incinerator. Good combustion practice for CO and VOC control essentially consists of operating and maintaining the boilers and the incinerator according to the manufacturer's recommendations to maximize fuel efficiency and minimize emissions. More specifically, good combustion practices for the boilers and the incinerator consist of the following:

- Operating personnel must be trained to identify signs of improper operation and maintenance, including visible plumes, and instructed to report these to the maintenance specialist,

- At least one full-time equipment maintenance specialist must be on board at all times during drilling activities,

- Each emission unit must be inspected by the maintenance specialist at least once a week for proper operation and maintenance consistent with the manufacturer's recommendations,

- The operation and maintenance manual provided by the manufacturer for each emission unit must be maintained on board the Discoverer at all times,

- The manufacturer's recommended operation and scheduled maintenance procedures must be followed for each emission unit.

EPA proposes that the permit include a condition requiring the permittee to follow the good combustion practices listed above.

EPA proposes that the emission limits shown in Table 4-4 below are representative of CO and VOC BACT for the boilers and the incinerator. The emission limits for the boilers are derived from the emission rate and boiler capacity information in the emission inventory in Appendix A. The emission limits for the incinerator are identical to the emission factors for the incinerator from the emission inventory in Appendix A.

Table 4-4 - CO and VOC Emission Limits for the Boilers and the Incinerator

Emission Unit	VOC Emission Limit	CO Emission Limit
Boilers (FD-21 & 22)	0.00140 lb/MMBtu	0.0770 lb/MMBtu
Incinerator (FD-23	3.0 lb/ton of waste burned	31.0 lb/ton of waste burned

4.6 BACT for the Drilling Mud De-gassing Operation (FD-32)

In the letter to EPA dated December 13, 2009, Shell provided additional explanation for the VOC estimate from de-gassing of drilling mud that was originally provided in its May 4, 2009 submission to EPA (Shell 12/13/09 Supp. App.). The VOC emission estimate based on the possibility of drilling a maximum of four wells per year was 128 pounds of VOC per year.

Drilling mud is used to lubricate and carry away heat from the drill bit and to transport drill cuttings to the surface. When the drill passes through a hydrocarbon zone, hydrocarbons in the drill cuttings are carried to the surface (the deck of the Discoverer) with the mud. The mud is directed to the "ditch", then the shakers and then to the mud pit. These pieces of equipment are exposed to the atmosphere and any trapped gases such as hydrocarbons, water vapor or carbon dioxide flash out of the mud. If high concentrations of hydrocarbons from the mud are detected, the mud it diverted to a mud separator where gases flashed from the mud are directed through a 10 inch diameter pipe and vented at the top of the drilling derrick as a safety precaution to prevent exposure to workers and to keep the potentially explosive gases away from ignition sources.

To control all VOC emissions from mud degassing, the mud-handling system would need to be redesigned to collect gas from both the open mud processing areas and from the mud gas separator. The gas collection system would need to be designed to handle a gas volumetric flow rate up to 500 cubic feet per minute associated with emergency and unexpected releases, but normally would process very small gas flows. With such a variable flow rate, condensers, carbon adsorption or routing the gases to the air intake of an on-board combustion device would not be technically feasible. A flare is the only VOC control device that is capable of handling this type of gas service.

In Attachment D of the December 13, 2009 letter to EPA, Shell provided cost information for a flare based on information from the EPA Air Pollution Cost Control Manual (Shell 12/13/09 Supp. App). The annualized cost for a small flare (2 inch diameter nozzle) from Table 2.13 of the EPA Air Pollution Cost Control Manual was $61,800. This annualized cost value is likely an underestimate of the cost as applied to Shell's operation since it was for an on-land flare which is less expensive to construct compared to an on-ship flare system and was based on 2002 dollars. However, using the annualized cost of $61,800, the cost effectiveness value for controlling 128 pounds of VOC per year was calculated to be $965,625/ton of VOC removed (assuming 100 percent destruction of the VOC in the flare). A cost effectiveness value of this magnitude is much higher than EPA considers reasonable for a BACT determination. Therefore, EPA proposes that BACT for the mud de-gassing operation on the Discoverer is the use of the existing equipment.

4.7 BACT for the Supply Vessel at Discoverer (FD-31)

Aside from the supply vessel, the vessels in the Associated Fleet will not be physically attached to the Discover, and therefore will not be part of the OCS source and not subject to the BACT requirement. The supply vessel will be part of the OCS source and thus subject to BACT only for the relatively short period of time it will be tied to the Discoverer. Shell estimated a maximum of eight resupply events per year. When the supplies are delivered to the Discoverer, the supply vessel would be attached to the Discoverer for a maximum of 12 hours with one generator diesel engine of less than 300 horsepower operating. The maximum time a supply vessel would be attached to the Discoverer and thus considered part of the "OCS source" would be 96 hours for the drilling season. The estimated emissions from the supply vessel while tied to the Discoverer based on the maximum time of 96 hours are shown in Appendix A. The largest value is 0.43 tons per year for NO_x. The estimated emissions in units of tons per year for all other pollutants are smaller: 0.09 for CO; 0.03 for PM; 0.03 for VOC; and 0.0002 for SO_2. Because of the very small emission reduction potential and the short time period over which any control technology would be amortized, EPA believes that installation of any additional control technology on the supply vessels would not be cost effective. In the December 11, 2009 supplement to the BACT analysis, Shell provided cost effectiveness calculations for several control alternatives that could be applied to the generator engine on the supply vessel (Environ 12/11/09). In all cases the calculated cost effectiveness values were much greater than EPA considers reasonable for BACT determinations. For example, the calculated cost effectiveness values for the supply vessel generator engine were approximately: $187,000/ton of PM for a CDPF; $114,000/ton of PM for an OxyCat; and $228,000/ton of PM for a DPF. These cost effectiveness values are much greater that EPA considers reasonable within the context of a BACT determination. Thus, EPA proposes that BACT for the supply vessel is no additional add-on controls. Shell has agreed, and the permit proposes, that Shell use ultra-low sulfur diesel fuel in all vessels in the Associated Fleet, including the supply vessel to assure attainment of the NAAQS and compliance with increment.

4.8 Reference Test Methods

This section describes the reference test methods EPA is proposing for the emission limits discussed above.

EPA is proposing that BACT for SO_2 is the use of ultra-low sulfur diesel fuel (≤0.0015% by weight). A representative fuel sample for sulfur analysis must be collected by one of the methods identified in 40 C.F.R. § 80.330(b). Any test method for determining the sulfur content of diesel fuel must satisfy the EPA approval process contained in 40 C.F.R. § 80.585(a) and the precision and accuracy requirements of 40 C.F.R. § 80.584. As an alternative, the sulfur content of the diesel fuel may be determined using ASTM D 5453-09. The permit specifies the frequency of the required testing, which is discussed in Section 3. The testing requirement can also be met by obtaining a certification from the fuel supplier that the fuel meets the sulfur specification based on testing using the methods described above.

EPA proposes that all other emission limits be based on the average of three one hour test runs, with the arithmetic average of the three runs compared to the applicable emission limit.

NO_x emissions shall be measured using EPA Method 7E. EPA Method 7E is the performance test method required by a number of EPA NSPS for sources similar to those on the Discoverer such as steam generating units, gas turbines and large stationary IC engines.

CO shall be measured using EPA Method 10. EPA Method 10 is the performance test method required by the EPA NSPS for petroleum refinery fluid catalytic cracking units which typically include a boiler fueled by off-gas containing CO.

Ammonia emissions shall be measured using Conditional Test Method 027 (CTM-027) or CTM-038.

Except for the incinerator, $PM_{2.5,}$ PM_{10} and $PM_{2.5}$ emissions shall be measured using EPA Method 201/201A and Other Test Method 28 (OTM 28). Once proposed revisions to EPA Method 202 are finalized, see 56 Fed. Reg. 12970 (March 25, 2009), the permit requires the use of EPA Method 202 in place of OTM 28 to measure condensable particulate matter.

For the incinerator only, $PM_{2.5}$ emissions shall be measured using OTM 27 and OTM 28 until EPA finalizes the pending revisions proposed in 56 Fed. Reg. 12970 (March 25, 2009), at which time $PM_{2.5}$ emissions from the incinerator will be measured using the revised EPA Methods 201/201A and 202.

For opacity standards, EPA is proposing EPA Method 9 (40 C.F.R. Part 60, Appendix A) as the reference test method for opacity standards with numerical limits for point sources, with an averaging period of six minutes and an observation interval of 15 seconds.

EPA Methods 1, 2, 3A, 3B, 4 and 19 shall be used as needed to convert the measured NO_x, PM, PM_{10}, $PM_{2.5}$ and CO emissions into units of the emission limits in the permit. The EPA Methods identified in this section can be found in 40 C.F.R. Part 60, Appendix A, in 40 C.F.R. Part 51, Appendix M or on the EPA Emission Measurement Center webpage http://www.epa.gov/ttn/emc/. Permit Condition B.7.11contains procedures for Shell to request and for EPA to approve alternatives to or deviations from the referenced test methods.

emissions from Shell's exploration operations to the formation of ozone in the region is expected to be small. For these reasons, EPA believes that emissions from Shell's exploration operations will not cause or contribute to a violation of the NAAQS for ozone.

5.2.8 Results of NAAQS Demonstration

All of the modeled operating scenarios for the Discoverer and its Associated Fleet resulted in predicted total concentration impacts, including existing background data, below the level of the NAAQS. Table 5-12 summarizes the highest predicted and total impacts for the POS #1 and its alternatives. The levels range from a low of 3.1% of the annual SO_2 NAAQS to a high of 84.0% of the 24-hour $PM_{2.5}$ NAAQS. In addition, Table 5-13 shows the predicted total concentration impacts at Point Lay and Wainwright, the two nearest villages to Shell's leases in Lease Sale 193. In these villages, the total predicted impacts for SO_2, NO_x, and CO are less than 10% of their respective NAAQS and the total predicted impacts for PM_{10} and $PM_{2.5}$ are less than 78% of their respective NAAQS. Thus, the modeling demonstrates that emissions associated with the proposed permit are not expected to cause or contribute to a violation of the applicable NAAQS.

Table 5-12 – Maximum Predicted Impacts on NAAQS and PSD Class II Increments from POS #1 and Alternatives

Pollutant	Averaging Period	Concentration (ug/m^3)			PSD Class II Increment (ug/m^3)	Percent Increment	NAAQS (ug/m^3)	Percent NAAQS
		Total No Background	Back ground	Total th Background				
NO_2 [2]	Annual	18.2	2.0	20.2	25	72.8%	100	20.2%
$PM_{2.5}$	24-Hour	18.4	11	29.4	*	---	35	84.0%
	Annual	1.3	2.8	4.1	*	---	15	27.3%
PM_{10}	24-Hour	19.4	91	110.4	30	64.7%	150	73.6%
	Annual	1.4	15.0	16.4	17	8.2%	---	---
SO_2	3-Hour	68.8	17	85.8	512	13.4%	1,300	6.6%
	24-Hour	26.8	10	36.8	91	29.5%	365	10.1%
	Annual	2.0	0.5	2.5	20	10%	80	3.1%
CO	1-Hour	396.6	1050	1446.6	*	---	40,000	3.6%
	8-Hour	356.9	941	1297.9	*	---	10,000	13.0%

Reference: Shell 9/17/09 Supp. App.; Environ 12/2/09)
*EPA has not promulgated increments for $PM_{2.5}$ or CO

Table 5-13 – Predicted Impacts on NAAQS from POS #1 and Alternatives at Wainwright and Point Lay

Pollutant	Averaging Period	Concentration (ug/m^3) Max. Modeled [1] Wainwright	Point Lay	Background	Wainwright Total with Background	Point Lay Total with Background	NAAQS	Percent NAAQS Wainwright	Percent NAAQ Point Lay
NO_2	Annual	1.7	1.8	2.0	3.7	3.8	100	3.7%	3.8%
$PM_{2.5}$	24-Hour	2.6	2.7	23	25.6	25.7	35	73.1%	73.4%
	Annual	0.2	0.2	3.3	3.5	3.5	15	23.3%	23.3%
PM_{10}	24-Hour	2.8	3.0	114	116.8	117.0	150	77.9%	78.0%
	Annual	0.2	0.2	15.8	16.0	16.0	---	---	---
SO_2	3-Hour	7.3	7.8	17	24.3	24.8	1,300	1.9%	1.9%
	24-Hour	4.1	4.4	10	14.1	14.4	365	3.9%	3.9%
	Annual	0.3	0.3	0.5	0.8	0.8	80	1.0%	1.0%
CO	1-Hour	34.1	36.4	1050	1084.1	1086.4	40,000	2.7%	2.7%
	8-Hour	30.6	32.7	941	971.6	973.7	10,000	9.7%	9.7%

Reference: Shell 9/17/09 Supp. App.

[1] The nearest villages to Shell's Chukchi leases are Wainwright (~110 km away) and Point Lay (~100 km away)

5.2.9 Results of Increment Demonstration

All of the modeled operating scenarios for the Discoverer and its Associated Fleet resulted in predicted concentration impacts below the Class II increments. Table 5-12 above also shows the predicted maximum concentrations for POS #1 and its alternatives as compared to the PSD increments for Class II areas.

As also shown in Table 5-14 below, predicted impacts for the Class II increments in Point Lay and Wainwright are significantly lower, less than 5% for all $SO_{2,}$ increments and the 24-hour PM_{10} increment and less than 10% for the annual NO_x increment and the 24-hour PM_{10} increment.

Table 5-14 – Predicted Impacts on PSD Class II Increments from POS #1 and Alternatives at Wainwright and Point Lay

Pollutant	Averaging Period	Concentration (g/m³)				
		Max. Modeled [1]		Class II Increment	Wainwright Percent Increment	Point Lay Percent Increment
		Wainwright	Point Lay			
NO_2	Annual	1.7	1.8	25	6.8%	7.2%
PM_{10}	24-Hour	2.8	3.0	30	9.3%	10.0%
	Annual	0.2	0.2	17	1.2%	1.2%
SO_2	3-Hour	7.3	7.8	512	1.4%	1.5%
	24-Hour	4.1	4.4	91	4.5%	4.8%
	Annual	0.3	0.3	20	1.5%	1.5%

Reference: Shell 9/17/09 Supp. App

[1] The nearest villages to Shell's Chukchi leases are Wainwright (~110 km away) and Point Lay (~100 km away)

The nearest Class I area is Denali National Park located about 950-kilometers from the Shell lease blocks in Lease Sale 193. Based on the distance and the amount of emissions, the National Park Service did not request Class I area quality increment analysis for Denali National Park (Notar 8/5/09).

5.2.10 Conclusions

An ambient air quality impact analysis was performed using conservative modeling assumptions to demonstrate compliance with NAAQS and air quality increments at over water and over land locations. These assumptions include the use of screening meteorology and the upper end scaling factors to derive other averaging period concentrations from the 1-hour model prediction, and the use of a volume source height based on a D stability and 20 meter per second wind speed. From an engineering perspective, the modeling analysis also took into consideration the application of emission limits and the requirements reflecting Best Available Control Technology, and other limits in the permit that restrict operation and location of the Discoverer, ice breaker fleet, oil spill response fleet and/or supply vessel.

Based on the conservative modeling assumptions and the predicted SO_2, NO_2, CO, PM_{10}, and $PM_{2.5}$ concentration impacts for the primary and secondary operating scenarios, EPA has concluded that Shell's exploratory drilling project is expected to comply with the applicable NAAQS and Class II area air quality increments.

5.3 Additional Impacts Analysis

As discussed above, 40 C.F.R. § 52.21(o) requires additional impact analyses, which must include an analysis of the impairment to visibility, soils and vegetation that would occur as a result of the proposed source modification, or that would occur as a result of any commercial, residential, industrial and other growth associated with the source modification. 40 C.F.R. § 52.21(p) has additional requirements for mandatory federal Class I areas.

APPENDIX A (Revised January 5, 2010)

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Potential to Emit Emission Inventory

Summary of Annual Emissions

Frontier Discoverer Sources

			Potential to Emit (tons/year)						
Unit ID	**Description**	**Make/Model**	**CO**	**NO_x**	**$PM_{2.5}$**	**PM_{10}**	**SO_2**	**VOC**	**Lead**
FD-1	Generator Engine	Caterpillar D399	0.56	1.55	0.40	0.40	0.02	0.08	4.04E-04
FD-2	Generator Engine	Caterpillar D399	0.56	1.55	0.40	0.40	0.02	0.08	4.04E-04
FD-3	Generator Engine	Caterpillar D399	0.56	1.55	0.40	0.40	0.02	0.08	4.04E-04
FD-4	Generator Engine	Caterpillar D399	0.56	1.55	0.40	0.40	0.02	0.08	4.04E-04
FD-5	Generator Engine	Caterpillar D399	0.56	1.55	0.40	0.40	0.02	0.08	4.04E-04
FD-6	Generator Engine	Caterpillar D399	0.56	1.55	0.40	0.40	0.02	0.08	4.04E-04
FD-7[1]	Propulsion Engine	MI / 6UEC65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FD-8	Emergency Generator	Caterpillar 3304	4.30E-02	7.82E-02	1.54E-02	1.54E-02	3.51E-05	8.16E-03	6.38E-07
FD-9-11[2]	MLC Compressor	Caterpillar C-15	2.50	5.37	0.13	0.13	8.63E-03	5.37	1.57E-04
FD-12-13[3, 4]	HPU Engine	Detroit/8V71	0.25	8.18	0.16	0.16	4.71E-03	0.12	8.56E-05
FD-14-15[5]	Deck Cranes	Caterpillar D343	0.20	9.50	0.07	0.07	6.76E-03	0.06	1.23E-04
FD-16-20[6]	Cementing Units and Logging Winches	Various	0.66	11.84	0.29	0.29	5.71E-03	3.01	1.04E-04
FD-21	Heat Boiler	Clayton 200 Boiler	1.25	3.23	0.38	0.38	2.56E-02	0.02	1.45E-04
FD-22	Heat Boiler	Clayton 200 Boiler	1.25	3.23	0.38	0.38	2.56E-02	0.02	1.45E-04
FD-23	Incinerator	TeamTec GS500C	0.39	0.06	0.09	0.10	0.03	0.04	2.68E-03
FD-24-30[7]	Fuel Tanks	NA						0.01	
FD-31	Supply Ship at Discoverer	NA	0.09	0.43	0.03	0.03	1.56E-04	0.03	2.85E-06
FD-32[8]	Drilling Mud System	NA						0.06	
FD-33[9]	Shallow Gas Diverter System	NA						0.00	
Sub-Total Emissions from Frontier Discoverer			10.00	51.23	3.95	3.96	0.23	9.23	0.01

Associated Fleets

	Potential to Emit (tons/year)						
Description	**CO**	**NO_x**	**$PM_{2.5}$**	**PM_{10}**	**SO_2**	**VOC**	**Lead**
Ice Management Fleet - Generic							
Ice Breaker # 1	160.50	849.88	33.60	38.43	0.65	35.87	3.74E-02
Ice Breaker #2	237.17	71.19	11.15	11.79	0.68	27.69	3.73E-02
Resupply Ship - Generic	0.56	4.24	0.26	0.32	1.13E-03	0.10	2.06E-05
OSR Fleet - Generic							
Nanuq - Main Ship	39.14	172.35	1.86	2.51	0.39	13.59	2.81E-02
Oil Spill Response, Kvichak No. 1, 2 and 3 Work Boats	1.72	39.39	0.78	0.78	0.04	0.80	7.51E-04
Sub-Total Emissions from Fleets	439.08	1,137.04	47.64	53.82	1.76	78.05	0.10
TOTAL PROJECT EMISSIONS	449.08	1188.27	51.58	57.78	1.99	87.28	0.11

Notes

1 Propulsion engine is not used when Discoverer is an OCS Source
2 Combined use of all 3 MLC Compressor engines are limited by an aggregate fuel usage limit.
3 Combined use of both HPU are limited by an aggregate fuel usage limit.
4 PTE of HPU Units and Incinerator are based on maximum use of that emission unit in accordance with alternative operating scenarios.
5 Combined use of both deck cranes are limited by an aggregate fuel usage limit.
6 Combined use of all five cementing unit and logging winch engines are limited by an aggregate fuel usage limit.
7 Tanks calculations and software outputs are listed separately but are summarized in this table.
8 Drilling mud system calculations are listed separately but are summarized in this table.
9 Shallow gas diverter system is not expected to be used as part of planned operations

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Criteria Pollutant Potential to Emit Emission Inventory

Emissions Unit:	FD-1-6	Generator Engine
Make/Model[1]:	Caterpillar D399, SCAC, 1200 rpm	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	1,325	hp
Maximum Operating Level[5]:	941	hp
Maximum Hourly Fuel Use[3,5]:	367	lbs/hour
Control Equipment:	SCR for NOx, catalytic oxidation for CO, VOC, PM_{10} and $PM_{2.5}$	

Emissions are on a per-engine basis

Pollutant	Emission Factors[4]	Emission Factor Units	Maximum Hours of Operation		Control Efficiency[6]	Potential to Emit			Potential to Emit in g/sec		
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
CO	882.7	g/hr	24	4032	0.8	0.28	6.72	0.56	0.035	0.035	0.016
NO_x	0.5	g/kW-h	24	4032		0.77	18.48	1.55	0.097	0.097	0.045
$PM_{2.5}$	251.2	g/hr	24	4032	0.5	0.20	4.8	0.40	0.025	0.025	0.012
PM_{10}	251.2	g/hr	24	4032	0.5	0.20	4.8	0.40	0.025	0.025	0.012
SO_2	0.000030	lb/lb fuel	24	4032		1.10E-02	0.26	2.00E-02	1.39E-03	1.36E-03	5.75E-04
VOC	75.5	g/hr	24	4032	0.7	0.04	0.96	0.08	5.04E-03	5.04E-03	2.30E-03
Lead	0.000029	lb/MMBtu	24	4032		2.00E-04	4.81E-03	4.04E-04	2.52E-05	2.52E-05	1.16E-05

Emissions Factor References

CO	From Caterpillar, See permit application dated 2-23-2009, Appendix B, page 28
NO_x	From 10-9-2008 D.E.C. Marine letter to Shell. See permit application dated February 23, 2009, Appendix F, page 6
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	From Caterpillar, See permit application dated February 23, 2009, Appendix B, page 28
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	VOC emissions data from Caterpillar, See permit application dated February 23, 2009, Appendix B, page 28
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Engine specification per 4/6/2009 and 4/9/2009 e-mails from Air Sciences (Rodger Steen) to EPA (Pat Nair)
2 Engine rating per 4/6/2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
3 Fuel usage from Caterpillar, See permit application dated February 23, 2009, Appendix B, page 28
237.5 g/kW-hr converted based on engine rating, and watts/hp and g/lb conversions
4 All emission factors are uncontrolled except for NOx, which reflects guaranteed emission rate.
5 Owner requested limit per Shell's *Response to EPA R10 March 11, 2009, Letter of Incompleteness*, dated 5/18/2009: 71% load
6 Control efficiency is based on use of oxidation catalyst. NOx emission factor already reflects controlled emission rate.

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Criteria Pollutant Emission Inventory

Emissions Unit:	FD-8	Emergency Generator Engine
Make/Model[1]:	Caterpillar 3304	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	131	hp
Maximum Hourly Fuel Use[3]:	49	lbs/hour
Control Equipment:	None	

Emissions are on a per-engine basis.

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation[4]		Control Efficiency	Potential to Emit			Potential to Emit in g/sec		
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
CO	6.2	g/hp-hr	2.00	48		1.79	3.58	4.30E-02	0.226	0.019	1.24E-03
NO_x	11.28	g/hp-hr	2.00	48		3.26	6.52	7.82E-02	0.411	0.034	2.25E-03
$PM_{2.5}$	2.21	g/hp-hr	2.00	48		0.64	1.28	1.54E-02	0.081	0.007	4.42E-04
PM_{10}	2.21	g/hp-hr	2.00	48		0.64	1.28	1.54E-02	0.081	0.007	4.42E-04
SO_2	0.000030	lb/lb fuel	2.00	48		1.46E-03	2.93E-03	3.51E-05	1.84E-04	1.54E-05	1.01E-06
VOC	1.163	g/hp-hr	2.00	48		0.34	0.68	8.16E-03	4.28E-02	3.57E-03	2.35E-04
Lead	0.000029	lb/MMBtu	2.00	48		2.66E-05	5.32E-05	6.38E-07	3.35E-06	2.79E-07	1.84E-08

Emissions Factor References

CO	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34-36, max of Cat engine tests
NO_x	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34-36, max of Cat engine tests
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34-36, max of Cat engine tests
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34-36, max of Cat engine tests
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Engine specification per permit application dated 2/23/2009, Appendix B, page 1
2 Engine rating per permit application dated 2/23/2009, Appendix B, page 1
3 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr converted based on engine rating, fuel density and fuel heat content
4 Operation is restricted to 120 minutes of operation per day and 48 hours per year per Shell request dated 9/17/2009

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Criteria Pollutant Emission Inventory

Emissions Unit:	FD-9-11	MLC Compressor
Make/Model[1]:	Caterpillar C-15	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	540	hp
Maximum Hourly Fuel Use[3]:	190	lbs/hour
Control Equipment:	Tier 3 engines	

Hourly and daily emissions are on a per-engine basis. Annual emissions are for all three MLC compressor engines in aggregate.

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation[4, 5] Daily (hrs)	Maximum Operation[4, 5] Annual (gal)	Control Efficiency[6]	Potential to Emit Hourly, lb/hr	Potential to Emit Daily, lb/day	Potential to Emit Annual, tpy	Potential to Emit in g/sec One-Hour	Potential to Emit in g/sec 24-Hour	Potential to Emit in g/sec 365-Day
CO	1.86	g/kW-h	24	81,346		1.65	39.6	2.50	0.208	0.208	0.072
NO_x	4.0	g/kW-h	24	81,346		3.55	85.2	5.37	0.447	0.447	0.154
$PM_{2.5}$	0.2	g/kW-h	24	81,346	0.5	0.1	2.4	0.13	0.013	0.013	0.004
PM_{10}	0.2	g/kW-h	24	81,346	0.5	0.1	2.4	0.13	0.013	0.013	0.004
SO_2	0.000030	lb/lb fuel	24	81,346		5.71E-03	0.14	8.63E-03	7.19E-04	7.35E-04	2.48E-04
VOC	4.0	g/kW-h	24	81,346		3.55	85.2	5.37	4.47E-01	4.47E-01	1.54E-01
Lead	0.000029	lb/MMBtu	24	81,346		1.04E-04	2.49E-03	1.57E-04	1.31E-05	1.31E-05	4.52E-06

Emissions Factor References

CO	Controlled emission factor from EPA BACT analysis (OxyCat as BACT).
NO_x	From Tier 3 emission limit in 40 CFR 89.112 (Limit is for NOx and NMHC, in aggregate)
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	Assumed to be the same as PM from Tier 3 emission limit in 40 CFR 89.112 and use of OxyCAT
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Tier 3 emission limit in 40 CFR 89.112 (Limit is for NOx and NMHC, in aggregate)
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Engine specification per permit application dated February 23, 2009, Appendix B, page 1
2 Engine rating per permit application dated February 23, 2009, Appendix B, page 1
3 Fuel usage from Caterpillar LEHW7443-00, 2008
26.9 gal/hr and then converted based on fuel density
4 Daily maximum operation is based on hours of operation
5 Annual maximum operation is based on fuel usage for all three engines: 81,346 gallons
6 Control efficiency is based on use of oxidation catalyst. CO emission factor already reflects controlled emission rate.

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Criteria Pollutant Emission Inventory

Emissions Unit:	FD-12-13	HPU Engine
Make/Model[1]:	Detroit 8V-71	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	250	hp
Maximum Hourly Fuel Use[3]:	104	lbs/hour
Control Equipment:	Clean Air Systems PERMIT™ Filter for control of CO, $PM_{2.5}$, PM_{10} and VOC	

Hourly emissions are on a per-engine basis. Daily and annual emissions are for both HPU engines in aggregate.

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation[6, 7] Daily (gal)	Annual[8] (gal)	Control Efficiency[4, 5]	Potential to Emit Hourly, lb/hr	Daily[7], lb/day	Annual[7], tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
Base Case Scenario									**Base Case Scenario**		
CO	2.99	g/hp-hr	0	44,338	0.9	0	0	0.25	0	0	0.007
NO_x	9.81	g/hp-hr	0	44338		0	0	8.18	0	0	0.235
$PM_{2.5}$	1.26	g/hp-hr	0	44338	0.85	0	0	0.16	0	0	0.005
PM_{10}	1.26	g/hp-hr	0	44338	0.85	0	0	0.16	0	0	0.005
SO_2	0.000030	lb/lb fuel	0	44338		0	0	4.71E-03	0	0	1.354E-04
VOC	1.48	g/hp-hr	0	44338	0.9	0	0	0.12	0	0	3.452E-03
Lead	0.000029	lb/MMBtu	0	44338		0	0	8.56E-05	0	0	2.462E-06
Alternative Scenario #1									**Alternative Scenario #1**		
CO	2.99	g/hp-hr	352	44,338	0.9	0.16	3.96	0.25	0.02	0.021	0.007
NO_x	9.81	g/hp-hr	352	44,338		5.41	129.76	8.18	0.682	0.681	0.235
$PM_{2.5}$	1.26	g/hp-hr	352	44,338	0.85	0.10	2.50	0.16	0.013	0.013	0.005
PM_{10}	1.26	g/hp-hr	352	44,338	0.85	0.10	2.50	0.16	0.013	0.013	0.005
SO_2	0.000030	lb/lb fuel	352	44,338		3.11E-03	7.47E-02	4.71E-03	3.92E-04	3.92E-04	1.35E-04
VOC	1.48	g/hp-hr	352	44,338	0.9	0.08	1.96	0.12	1.01E-02	1.03E-02	3.45E-03
Lead	0.000029	lb/MMBtu	352	44,338		5.66E-05	1.36E-03	8.56E-05	7.13E-06	7.13E-06	2.46E-06
Alternative Scenario #2									**Alternative Scenario #2**		
CO	2.99	g/hp-hr	704	44,338	0.9	0.16	7.91	0.25	0.02	0.042	0.007
NO_x	9.81	g/hp-hr	704	44,338		5.41	259.53	8.18	0.682	1.363	0.235
$PM_{2.5}$	1.26	g/hp-hr	704	44,338	0.85	0.10	5.00	0.16	0.013	0.026	0.005
PM_{10}	1.26	g/hp-hr	704	44,338	0.85	0.10	5.00	0.16	0.013	0.026	0.005
SO_2	0.000030	lb/lb fuel	704	44,338		3.11E-03	0.15	4.71E-03	3.92E-04	7.87E-04	1.35E-04
VOC	1.48	g/hp-hr	704	44,338	0.9	0.08	3.92	0.12	1.01E-02	2.06E-02	3.45E-03
Lead	0.000029	lb/MMBtu	704	44,338		5.66E-05	2.72E-03	8.56E-05	7.13E-06	1.43E-05	2.46E-06

Emissions Factor References

CO	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35, max of 2 tests
NO_x	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35, max of 4 tests
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, 2-34 and 2-35, max of 4 tests (PM emis.)
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35, max of 2 tests
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Engine specification per permit application dated February 23, 2009, Appendix B, page 1
2 Engine rating per permit application dated February 23, 2009, Appendix B, page 1
3 Fuel usage per permit application dated February 23, 2009, Appendix B, page 34
0.415 lb/hp-hr
4 PM10 control efficiency based on California Air Resources Board, Verification of Diesel Emission Control Strategies, March 12, 2009 (website April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
5 CO and VOC control efficiency from April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
6 Daily maximum operation and operating scenarios are based on Shell's submittal dated 9/17/2009
7 Daily and annual maximum fuel usage is for both engines, in aggregate: 44,338 gallons
8 Annual maximum fuel usage limit is for all operating scenarios in aggregate.

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-14-15	Deck Cranes
Make/Model[1]:	Caterpillar D343	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	365	hp
Maximum Hourly Fuel Use[3]:	20.76	gallons/hour
Control Equipment:	Clean Air Systems PERMIT™ Filter for control of CO, $PM_{2.5}$, PM_{10} and VOC	

Hourly and daily emissions are on a per-engine basis. Annual emissions are for both deck cranes in aggregate.

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation[6, 8]		Control Efficiency[4, 5]	Potential to Emit			Potential to Emit in g/sec		
			Daily (hrs)	Annual (gal)[8]		Hourly, lb/hr	Daily, lb/day	Annual[8], tpy	One-Hour	24-Hour	365-Day
CO	593.6	g/hr	24	63,661	0.9	0.13	3.12	0.20	0.016	0.016	0.006
NO_x	2810.9	g/hr	24	63,661		6.2	148.80	9.50	0.781	0.781	0.273
$PM_{2.5}$	129.8	g/hr	24	63,661	0.85	0.04	0.96	0.07	0.005	0.005	0.002
PM_{10}	129.8	g/hr	24	63,661	0.85	0.04	0.96	0.07	0.005	0.005	0.002
SO_2	0.000030	lb/lb fuel	24	63,661		4.41E-03	0.11	6.76E-03	5.55E-04	5.55E-04	1.94E-04
VOC	172.6	g/hr	24	63,661	0.9	0.04	0.96	0.06	5.04E-03	5.04E-03	1.68E-03
Lead	0.000029	lb/MMBtu	24	63,661		8.01E-05	1.92E-03	1.23E-04	1.01E-05	1.01E-05	3.53E-06

Emissions Factor References

CO	From Caterpillar, See attachment to e-mail dated April 6, 2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair)[7]
NO_x	From Caterpillar, See attachment to e-mail dated April 6, 2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair)[7]
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	From Caterpillar, See attachment to e-mail dated April 6, 2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair)[7]
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Caterpillar, See attachment to e-mail dated April 6, 2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair)[7]
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59	g/lb
2,000	lbs/ton
745.7	watts/hp
7.076	lbs/gal
133,098	Btu/gal

Footnotes/Assumptions

1 Engine specification per permit application dated February 23, 2009, Appendix B, page 1
2 Engine rating per permit application dated February 23, 2009, Appendix B, page 1
3 From Caterpillar, See attachment to e-mail dated April 6, 2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair)[4]
244.8 g/kW-hr converted based on engine rating, and watts/hp and g/lb conversions
4 PM10 control efficiency based on California Air Resources Board, Verification of Diesel Emission Control Strategies, March 12, 2009 (website April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
5 CO and VOC control efficiency from April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
6 Maximum operation per season is based on an owner requested limit of: 63661 gallons
Per Shell *Response to EPA R10 March 11, 2009 Letter of Incompleteness*, Attachment D, Page 3, dated 5/18/2009
7 As exact engine specification was not available, value used was highest of similarly rated engine configuration
8 Annual fuel usage and annual emissions are for both crane engines aggregated.

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-16-17	Cementing Unit
Make/Model[1]:	Detroit 8V-71N	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	335	hp
Maximum Hourly Fuel Use[3]:	139	lbs/hour
Control Equipment:	Clean Air Systems PERMIT™ Filter for control of CO, $PM_{2.5}$, PM_{10} and VOC	

Emissions are on a per engine basis at 100% load

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation[6] Daily	Maximum Hours of Operation[6] Annual	Control Efficiency[4, 5]	Potential to Emit[6] Hourly, lb/hr	Potential to Emit[6] Daily, lb/day	Potential to Emit[6] Annual, tpy	Potential to Emit in g/sec One-Hour
CO	2.99	g/hp-hr			0.9	0.22			0.028
NO_x	9.81	g/hp-hr				7.25			0.913
$PM_{2.5}$	1.26	g/hp-hr			0.85	0.14			0.018
PM_{10}	1.26	g/hp-hr			0.85	0.14			0.018
SO_2	0.000030	lb/lb fuel				4.17E-03			5.26E-04
VOC	1.48	g/hp-hr			0.9	0.11			1.39E-02
Lead	0.000029	lb/MMBtu				7.58E-05			9.56E-06

Emissions Factor References

CO From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35, max of 2 tests
NO_x From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35, max of 4 tests
$PM_{2.5}$ PM2.5 emissions assumed to be same as PM10 emissions
PM_{10} From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, 2-34 and 2-35, max of 4 tests (PM emis.)
SO_2 Sulfur content of fuel: 0.000015 by weight
VOC From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35, max of 2 tests
Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Engine specification per permit application dated February 23, 2009, Appendix B, page 1
2 Engine rating per permit application dated February 23, 2009, Appendix B, page 1
3 Fuel usage per permit application dated February 23, 2009, Appendix B, page 34
0.415 lb/hp-hr
4 PM10 control efficiency based on California Air Resources Board, Verification of Diesel Emission Control Strategies, March 12, 2009 (website
April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
5 CO and VOC control efficiency from April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
6 See page 11 for daily and annual emissions

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-18	Cementing Unit
Make/Model[1]:	GM 3-71	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	147	hp
Maximum Hourly Fuel Use[3]:	61	lbs/hour
Control Equipment:	Clean Air Systems PERMIT™ Filter for control of CO, $PM_{2.5}$, PM_{10} and VOC	

Emissions are on a per-engine basis.

Pollutant	Emission Factors[6]	Emission Factor Units	Maximum Hours of Operation[7]		Control Efficiency[4, 5]	Potential to Emit[7]			Potential to Emit in g/sec
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour
CO	6.55	g/hp-hr			0.9	0.21			0.026
NO_x	11.72	g/hp-hr				3.8			0.479
$PM_{2.5}$	1.92	g/hp-hr			0.85	0.09			0.011
PM_{10}	1.92	g/hp-hr			0.85	0.09			0.011
SO_2	0.000030	lb/lb fuel				1.83E-03			2.31E-04
VOC	2.01	g/hp-hr			0.9	0.07			8.82E-03
Lead	0.000029	lb/MMBtu				3.33E-05			4.19E-06

Emissions Factor References

CO	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35[6]
NO_x	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35[6]
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35[6] (PM emissions)
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35[6]
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59	g/lb
2,000	lbs/ton
7.076	lbs/gal
133,098	Btu/gal

Footnotes/Assumptions

1 Engine specification per permit application dated February 23, 2009, Appendix B, page 1
2 Engine rating per permit application dated February 23, 2009, Appendix B, page 1
3 Fuel usage per permit application dated February 23, 2009, Appendix B, page 34
0.415 lb/hp-hr
4 PM10 control efficiency based on California Air Resources Board, Verification of Diesel Emission Control Strategies, March 12, 2009 (website
April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
5 CO and VOC control efficiency from April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
6 The 71 series engines were a product of the Detroit Diesel Engine Division of General Motors
This engine is a 3-cylinder version of this family of engine - see 4/9/2009 e-mail from Air Sciences (Sabrina Pryor) to EPA (Pat Nair)
For this emission inventory, emission factors used are the highest for a 71 series engine
7 See page 11 for daily and annual emissions

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-19	Logging Winch
Make/Model[1]:	Caterpillar C7	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	250	hp
Maximum Hourly Fuel Use[3]:	93	lbs/hour
Control Equipment:	None	

Emissions are on a per-engine basis.

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation[4]		Control Efficiency[5]	Potential to Emit[4]			Potential to Emit in g/sec
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour
CO	3.5	g/kW-h			0.8	0.29			0.037
NO_x	4.0	g/kW-h				1.64			0.207
$PM_{2.5}$	0.2	g/kW-h			0.85	0.01			0.001
PM_{10}	0.2	g/kW-h			0.85	0.01			0.001
SO_2	0.000030	lb/lb fuel				2.79E-03			3.52E-04
VOC	4.0	g/kW-h				1.64			2.07E-01
Lead	0.000029	lb/MMBtu				5.08E-05			6.39E-06

Emissions Factor References

CO	From Tier 3 emission limit in 40 CFR 89.112
NO_x	From Tier 3 emission limit in 40 CFR 89.112 (Limit is for NOx and NMHC, in aggregate)
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	Assumed to be the same as PM from Tier 3 emission limit in 40 CFR 89.112
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Tier 3 emission limit in 40 CFR 89.112 (Limit is for NOx and NMHC, in aggregate)
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Engine specification per 12/10/2009 e-mail and attachment from Air Sciences (Rodger Steen) to EPA (Pat Nair).
2 Engine rating per 12/10/2009 e-mail and attachment from Air Sciences (Rodger Steen) to EPA (Pat Nair).
3 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr
4 See page 11 for daily and annual emissions
5 Control efficiency is based on use of CDPF

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-20	Logging Winch	
Make/Model[1]:	John Deere PE4020TF270D		
Fuel:	Liquid distillate, #1 or #2		
Rating[2]:	35	hp	converted from
Maximum Hourly Fuel Use[3]:	13.0	lbs/hour	
Control Equipment:	Clean Air Systems PERMIT™ Filter for control of CO, $PM_{2.5}$, PM_{10} and VOC		

Emissions are on a per-engine basis.

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation[7]		Control Efficiency[4, 5]	Potential to Emit[7]			Potential to Emit in g/sec
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour
CO	5.5	g/kW-hr			0.9	0.03			0.004
NO_x	7.5	g/kW-hr				0.43			0.054
$PM_{2.5}$	0.60	g/kW-hr			0.85	0.01			0.001
PM_{10}	0.60	g/kW-hr			0.85	0.01			0.001
SO_2	0.000030	lb/lb fuel				3.91E-04			4.92E-05
VOC	7.5	g/kW-hr			0.9	0.04			5.04E-03
Lead	0.000029	lb/MMBtu				7.11E-06			8.95E-07

Emissions Factor References

CO	From Tier 2 emission limit in 40 CFR 89.112
NO_x	From Tier 2 emission limit in 40 CFR 89.112
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	Assumed to be the same as PM from Tier 2 emission limit in 40 CFR 89.112
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	From Tier 2 emission limit in 40 CFR 89.112
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59	g/lb
2,000	lbs/ton
745.7	watts/hp
7.076	lbs/gal
133,098	Btu/gal

Footnotes/Assumptions

1 Engine specification per 12/10/2009 e-mail and attachment from Air Sciences (Rodger Steen) to EPA (Pat Nair).
2 Engine rating per 12/10/2009 e-mail and attachment from Air Sciences (Rodger Steen) to EPA (Pat Nair).
3 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr
4 PM10 control efficiency based on California Air Resources Board, Verification of Diesel Emission Control Strategies, March 12, 2009 (website April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
5 CO and VOC control efficiency from April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)
7 See page 11 for daily and annual emissions

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-16-20 Cementing Units and Logging Winches
Make/Model:	See pages A-7 - A-10 for details
Fuel:	Liquid distillate, #1 or #2
Rating:	See pages A-7 - A-10 for details
Control Equipment:	Clean Air Systems PERMIT™ Filter for control of CO, $PM_{2.5}$, PM_{10} and VOC on all engines except FD-19

Emissions are for all cementing unit and logging winch engines in aggregate.

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation[1]		Control Efficiency[3]	Potential to Emit[2]			Potential to Emit in g/sec	
			Daily (gal)	Annual (gal)		Hourly, lb/hr	Daily, lb/day	Annual, tpy	24-Hour	365-Day
CO	0.66	g/hp-hr	320	53,760		[redacted]	7.88	0.66	0.041	0.019
NO_x	11.72	g/hp-hr	320	53,760		[redacted]	140.98	11.84	0.74	0.341
$PM_{2.5}$	0.288	g/hp-hr	320	53,760		[redacted]	3.46	0.29	0.018	0.008
PM_{10}	0.288	g/hp-hr	320	53,760		[redacted]	3.46	0.29	0.018	0.008
SO_2	0.000030	lb/lb	320	53,760		[redacted]	0.07	5.71E-03	3.57E-04	1.64E-04
VOC	2.98	g/hp-hr	320	53,760		[redacted]	35.85	3.01	1.88E-01	8.66E-02
Lead	0.000029	lb/MMBtu	320	53,760		[redacted]	1.24E-03	1.04E-04	6.48E-06	2.98E-06

Emissions Factor References

CO	Maximum emission factor from all cementing unit and logging winch engines - see Reference Table 2, page 25
NO_x	Maximum emission factor from all cementing unit and logging winch engines - see Reference Table 2, page 25
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions
PM_{10}	Maximum emission factor from all cementing unit and logging winch engines - see Reference Table 2, page 25
SO_2	Sulfur content of fuel: 0.000015 by weight
VOC	Maximum emission factor from all cementing unit and logging winch engines - see Reference Table 2, page 25
Lead	Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal
0.415 lb/hp-hr Fuel usage is minimum of values for five engines (FD16-20)

Footnotes/Assumptions

1 Daily fuel usage is per applicant request dated 9/17/2009: 320 gallons per day
2 Emissions are for all cementing unit and logging winch engines in aggregate.
3 Emission factors used on this page are controlled (either CDPF or Tier3)

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-21-22	Heat Boilers
Make/Model[1]:	Clayton 200	
Fuel:	Liquid distillate, #1 or #2	
Rating[2]:	7.97	MMBtu/hr
Maximum Hourly Fuel Use[3]:	424	lbs/hour
Control Equipment:	None	

Emissions are on a per-boiler basis at 100% load

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation		Control Efficiency	Potential to Emit			Potential to Emit in g/sec		
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
CO	14.8	lbs/day	24	4,032		0.62	14.8	1.25	0.078	0.078	0.036
NO_x	38.50	lbs/day	24	4,032		1.6	38.50	3.23	0.202	0.202	0.093
$PM_{2.5}$	4.50	lbs/day	24	4,032		0.19	4.50	0.38	0.024	0.024	0.011
PM_{10}	4.50	lbs/day	24	4,032		0.19	4.50	0.38	0.024	0.024	0.011
SO_2	0.000030	lb/lb fuel	24	4,032		1.27E-02	0.31	2.56E-02	1.60E-03	1.63E-03	7.37E-04
VOC	0.27	lbs/day	24	4,032		0.01	0.27	0.02	1.26E-03	1.42E-03	5.75E-04
Lead	0.000009	lb/MMBtu	24	4,032		7.17E-05	1.72E-03	1.45E-04	9.04E-06	9.04E-06	4.16E-06

Emissions Factor References

CO	From Clayton. See permit application dated 2-23-2009, Appendix B, page 29		
NO_x	From Clayton. See permit application dated 2-23-2009, Appendix B, page 29		
$PM_{2.5}$	PM2.5 emissions assumed to be same as PM10 emissions		
PM_{10}	From Clayton. See permit application dated 2-23-2009, Appendix B, page 29		
SO_2	Sulfur content of fuel:	0.000015	by weight
VOC	From Clayton. See permit application dated 2-23-2009, Appendix B, page 29		
Lead	AP-42, Table 1.3-10		

Conversions Used

2,000 lbs/ton
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Boiler specification per permit application dated February 23, 2009, Appendix B, page 1
2 Boiler rating per permit application dated February 23, 2009, Appendix B, page 1
3 Fuel usage converted based on boiler rating, fuel density and fuel heat content.

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Emissions Unit:	FD-23	Incinerator		
Make/Model[1]:	TeamTec GS500C			
Fuel[2]:	Waste material			
Rating[3]:	276	lbs/hour	converted from	125 kg/hr
Control Equipment:	None			

Hourly emissions are for one incinerator at 100% load

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation, lbs of Waste[4] Daily	Maximum Operation, lbs of Waste[4] Annual[5]	Control Efficiency	Potential to Emit Hourly, lb/hr	Potential to Emit Daily, lb/day	Potential to Emit Annual, tpy	Potential to Emit in g/sec One-Hour	Potential to Emit in g/sec 24-Hour	Potential to Emit in g/sec 365-Day
Base Case Scenario											
CO	31	lbs/ton	1300	50,400		4.28	20.15	0.39	0.539	0.106	0.011
NO_x	5	lbs/ton	1300	50,400		0.69	3.25	0.06	0.087	0.017	0.002
$PM_{2.5}$	7.00	lbs/ton	1300	50,400		0.97	4.55	0.09	0.122	0.024	0.003
PM_{10}	8.2	lbs/ton	1300	50,400		1.13	5.33	0.10	0.143	0.028	0.003
SO_2	2.5	lbs/ton	1300	50,400		0.35	1.63	0.03	4.35E-02	8.53E-03	9.06E-04
VOC	3	lbs/ton	1300	50,400		0.41	1.95	0.04	5.22E-02	1.02E-02	1.09E-03
Lead	0.213	lbs/ton	1300	50,400		0.03	0.14	2.68E-03	3.70E-03	7.27E-04	7.72E-05
Alternative Scenario #1											
CO	31	lbs/ton	800	50,400		4.28	12.40	0.39	0.539	0.065	0.011
NO_x	5	lbs/ton	800	50,400		0.69	2.00	0.06	0.087	0.01	0.002
$PM_{2.5}$	7.00	lbs/ton	800	50,400		0.97	2.80	0.09	0.122	0.015	0.003
PM_{10}	8.2	lbs/ton	800	50,400		1.13	3.28	0.10	0.143	0.017	0.003
SO_2	2.5	lbs/ton	800	50,400		0.35	1.00	0.03	4.35E-02	5.25E-03	9.06E-04
VOC	3	lbs/ton	800	50,400		0.41	1.20	0.04	5.22E-02	6.30E-03	1.09E-03
Lead	0.213	lbs/ton	800	50,400		0.03	0.09	2.68E-03	3.70E-03	4.47E-04	7.72E-05
Alternative Scenario #2											
CO	31	lbs/ton	300	50,400		4.28	4.65	0.39	0.539	0.024	0.011
NO_x	5	lbs/ton	300	50,400		0.69	0.75	0.06	0.087	0.004	0.002
$PM_{2.5}$	7.00	lbs/ton	300	50,400		0.97	1.05	0.09	0.122	0.006	0.003
PM_{10}	8.2	lbs/ton	300	50,400		1.13	1.23	0.10	0.143	0.006	0.003
SO_2	2.5	lbs/ton	300	50,400		0.35	0.38	0.03	4.35E-02	1.97E-03	9.06E-04
VOC	3	lbs/ton	300	50,400		0.41	0.45	0.04	5.22E-02	2.36E-03	1.09E-03
Lead	0.213	lbs/ton	300	50,400		0.03	0.03	2.68E-03	3.70E-03	1.68E-04	7.72E-05

Emissions Factor References

CO	AP-42 Table 2.2-1, multiple hearth
NO_x	AP-42 Table 2.2-1, multiple hearth
$PM_{2.5}$	Owner requested limit per Shell 5/18/2009 *Response to EPA R10 March 11, 2009, Letter of Incompleteness*, Attachment D, Page 3
PM_{10}	Owner requested limit per Shell 5/18/2009 *Response to EPA R10 March 11, 2009, Letter of Incompleteness*, Attachment D, Page 3
SO_2	Owner requested limit per Shell 5/18/2009 *Response to EPA R10 March 11, 2009, Letter of Incompleteness*, Attachment D, Page 3
VOC	AP-42 Table 2.1-12, industrial/commercial multi-chamber
Lead	AP-42 Table 2.1-2, mass burn and modular excess air

Conversions Used

453.59 g/lb
2,000 lbs/ton

Footnotes/Assumptions

1 Incinerator specification per permit application dated February 23, 2009, Appendix B, page 1
2 Incinerator can burn municipal wate or sewage - emission factors are maximum for these two waste feeds
3 Incinerator rating per permit application dated February 23, 2009, Appendix F, page 16
4 Daily and annual usage limits, and alternative scenarios are based on owner requested limits per Shell request dated 9/17/2009
5 Annual maximum waste incinerated is for all operating scenarios in aggregate, and is based on an av 300 lbs/day

Shell Offshore Inc.
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Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Fleet Unit: FD-31 Supply Ship at Discoverer
Fuel: Liquid distillate, #1 or #2

Equipment Type: Internal Combustion Engine
Rating[1]: 292 hp

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation[2]		Control Efficiency	Potential to Emit			Potential to Emit in g/sec		
			Daily	Annual		Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
CO	0.95	lb/MMBtu	12	96		1.94	23.30	0.09	0.245	0.122	2.68E-03
NO_x	4.41	lb/MMBtu	12	96		9.01	108.17	0.43	1.136	0.568	1.24E-02
$PM_{2.5}$	0.31	lb/MMBtu	12	96		0.63	7.60	0.03	0.080	0.040	8.75E-04
PM_{10}	0.31	lb/MMBtu	12	96		0.63	7.60	0.03	0.080	0.040	8.75E-04
SO_2	0.000030	lb/lb fuel	12	96		3.26E-03	0.04	1.56E-04	0.000	0	4.50E-06
VOC	0.35	lb/MMBtu	12	96		0.72	8.58	0.03	0.090	0.045	9.88E-04
Lead	0.000029	lb/MMBtu	12	96		5.93E-05	7.11E-04	2.85E-06	7.47E-06	3.73E-06	8.18E-08

Emissions Factor References
CO, NO_x, $PM_{2.5}$, PM_{10}, VOC From AP-42, Section 3.3, Table 3.3-1
SO_2 Based on fuel sulfur content: 0.000015 by weight
Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions
1 Equipment population and rating based on vessel Jim Kilabuk per permit application dated February 23, 2009, Appendix B, page 15
2 Owner requested limits per e-mail and attachment of 5/22/2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair):
Propulsion engines not operated while berthed at Frontier Discoverer
Equivalent to only one generator to be operated - total hp: 292 hp
Brake specific fuel consumption (from AP-42): 7000 Btu/hp-hr
3 Sulfur content of fuel: 0.0019 by weight

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Fleet Unit:	Ice Breaker #1		
Fuel:	Liquid distillate, #1 or #2, and waste materials for incinerator		
Equipment Type:	Internal Combustion Engines		
Aggregate Rating, Propulsion Engines[1]:	28400	hp	
Max. Aggregate Limit, Propulsion Engines[2]:	22720	hp	
Aggregate Rating, Generation Engines[1]:	2800	hp	
Max. Aggregate Limit, All Engines[2]:	19,030	kW	mechanical kW
Max. Aggregate Limit, All Engines[3]:	17,508	kWe	electrical kW

			Maximum Operation (kWe-hr)			Potential to Emit[3]			Potential to Emit in g/sec		
Pollutant	**Emission Factors**	**Emission Factor Units**	**Daily**	**Annual**	**Control Efficiency**	**Hourly, lb/hr**	**Daily, lb/day**	**Annual, tpy**	**One-Hour**	**24-Hour**	**365-Day**
CO	3.35	g/kW-hr	420,188	28,233,704		140.36	3,368.64	113.17	17.685	17.685	3.256
NO_x	5.876	lb/MMBtu	420,188	28,233,704		1049.69	25,192.53	846.38	132.258	132.258	24.347
$PM_{2.5}$	0.22	lb/MMBtu	420,188	28,233,704		39.30	943.22	31.69	4.952	4.952	0.912
PM_{10}	0.249	lb/MMBtu	420,188	28,233,704		44.48	1067.55	35.87	5.605	5.605	1.032
SO_2	0.000030	lb/lb	420,188	28,233,704		0.28	6.84	0.23	0.036	0.036	0.007
VOC	0.60	g/kW-hr	420,188	28,233,704		25.17	604.15	20.30	3.172	3.172	0.584
Lead	2.90E-05	lb/MMBtu	420,188	28,233,704		5.18E-03	0.12	4.18E-03	6.53E-04	6.53E-04	1.20E-04

Emissions Factor References

CO, VOC From maximum of AP-42, Section 3.4, Table 3.4-1 or IVL and Lloyd's data from Verification of Ship Emission Estimates with Monitoring Measurements to Improve Inventory Modeling, Final Report Prepared for California Air Resource Board, by James J. Corbett, 23 November 2004 - see page 25

NOx Emission factors relied upon by Shell in 9/17/2009 submittal to establish annual, owner-requested emission limits

$PM_{2.5}$, PM_{10} Emission factors relied upon by Shell in 9/17/2009 submittal to establish daily, owner-requested emission limits

SO_2 Based on fuel sulfur content: 0.000015 by weight

Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Aggregate Rating, Heat Boiler(s)[1]:	10.00	MMBtu/hr
Maximum Hourly Fuel Use[5]:	75	gallons/hour

			Maximum Hours of Operation			Potential to Emit			Potential to Emit in g/sec		
Pollutant	**Emission Factors**	**Emission Factor Units**	**Daily**	**Annual**	**Control Efficiency**	**Hourly, lb/hr**	**Daily, lb/day**	**Annual, tpy**	**One-Hour**	**24-Hour**	**365-Day**
CO	5	$lb/10^3$ gal	24	4,032		3.76E-01	9.02	0.76	0.047	0.047	0.022
NO_x	20.00	$lb/10^3$ gal	24	4,032		1.50E+00	36.06	3.03	0.189	0.189	0.087
$PM_{2.5}$	3.30	$lb/10^3$ gal	24	4,032		2.48E-01	5.95	0.50	0.031	0.031	0.014
PM_{10}	3.30	$lb/10^3$ gal	24	4,032		2.48E-01	5.95	0.50	0.031	0.031	0.014
SO_2	0.213	$lb/10^3$ gal	24	4,032		1.60E-02	0.38	0.03	2.02E-03	2.02E-03	9.28E-04
VOC	0.34	$lb/10^3$ gal	24	4,032		2.55E-02	0.61	0.05	3.22E-03	3.22E-03	1.48E-03
Lead	0.000009	lb/MMBtu	24	4,032		9.00E-05	0.00	1.81E-04	1.13E-05	1.13E-05	5.22E-06

Emissions Factor References

CO, NOx AP-42 Table 1.3-1, boilers < 100 MMBtu/hr

$PM_{2.5}$ Assumed to be same as for PM_{10}

PM_{10} AP-42 Table 1.3-1 (filterable for PM) and AP-42 Table 1.3-2 (total condensible)

SO_2 AP-42 Table 1.3-1, boilers < 100 MMBtu/hr a Sulfur content of fuel: 0.000015 by weight

VOC AP-42 Table 1.3-3, commercial boilers

Lead AP-42, Table 1.3-10

Equipment Type:	Incinerator		
Aggregate Rating[1]:	154.00	lb/hr	Emissions are for all incinerators on board the vessel

			Maximum Hours of Operation			Potential to Emit			Potential to Emit in g/sec		
Pollutant	**Emission Factors**	**Emission Factor Units**	**Daily**	**Annual**	**Control Efficiency**	**Hourly, lb/hr**	**Daily, lb/day**	**Annual, tpy**	**One-Hour**	**24-Hour**	**365-Day**
CO	300	lbs/ton	24	4032		23.10	554.40	46.57	2.911	2.911	1.34
NO_x	3	lbs/ton	24	4032		0.23	5.54	0.47	0.029	0.029	0.014
$PM_{2.5}$	9.1	lbs/ton	24	4032		0.70	16.82	1.41	0.088	0.088	0.041
PM_{10}	13.3	lbs/ton	24	4032		1.02	24.58	2.06	0.129	0.129	0.059
SO_2	2.5	lbs/ton	24	4032		0.19	4.62	0.39	0.024	0.024	0.011
VOC	100	lbs/ton	24	4032		7.70	184.80	15.52	0.97	0.97	0.446
Lead	0.213	lbs/ton	24	4032		1.64E-02	3.94E-01	3.31E-02	2.07E-03	2.07E-03	9.51E-04

Emissions Factor References

CO, NOx, SO_2, VOC AP-42 Table 2.1-12, maximum of values for industrial/commercial and domestic single chamber

$PM_{2.5}$, PM_{10}: Owner requested limits per 5/14/2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair).

Lead AP-42, Maximum of uncontrolled values in Table 2.1-2, 2.1-8

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Criteria Pollutant Emission Inventory

Fleet Unit: Ice Breaker #1
(CONTINUED)

Total Emissions for Icebreaker #1

Potential to Emit			Potential to Emit in g/sec		
Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
163.84	3932.06	160.50	20.643	20.643	4.617
1051.42	25234.14	849.88	132.476	132.476	24.448
40.25	965.99	33.60	5.071	5.071	0.967
45.75	1098.08	38.43	5.765	5.765	1.105
0.49	11.84	0.65	0.062	0.062	0.019
32.90	789.56	35.87	4.145	4.145	1.032
0.02	0.52	3.74E-02	2.73E-03	2.73E-03	1.08E-03

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Maximum equipment ratings per e-mail and attachments of 5/14/2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair):

Propulsion engines:	28400 hp at maximum	80%	load
Generator engines:	2800 hp		
Boilers:	10 MMBtu/hr		
Incinerator:	154 lb/hr		

2 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr converted based on aggregate engine rating, and fuel density and heat content

3 Minimum generator efficiency based on conservative data from Shell submittal to EPA dated 11/23/2009 (pages 6 - 7):
Engine minimum generator efficiency: 92%

4 Owner requested limits:

PM2.5 hourly emissions limit:	42.2	lbs
PM10 hourly emissions limit:	48.0	lbs

Shell Offshore Inc.
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Criteria Pollutant Emission Inventory

Fleet Unit: Ice Breaker #2 - Tor Viking Scenario
Fuel: Liquid distillate, #1 or #2, and waste materials for incinerator

Equipment Type: Internal Combustion Engines
Aggregate Rating, Propulsion Engines[1]: 17660 hp
Max. Aggregate Limit, Propulsion Engines[2]: 14128 hp
Aggregate Rating, Generation Engines[1]: 2336 hp
Max. Aggregate Limit, All Engines[2]: 12,277 kW mechanical kW
Max. Aggregate Limit, All Engines[3]: 11,786 kWe electrical kW

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (kWe-hr) Daily	Maximum Operation (kWe-hr) Annual	Control Efficiency	Potential to Emit[4] Hourly, lb/hr	Potential to Emit[4] Daily, lb/day	Potential to Emit[4] Annual, tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
CO	3.35	g/kW-hr	282,867	18,058,216		90.55	2173.25	69.37	11.409	11.409	1.996
NO_x	0.106	lb/gal	282,867	18,058,216		91.78	2202.82	70.31	11.565	11.565	2.023
$PM_{2.5}$	0.0573	lb/MMBtu	282,867	18,058,216		6.60	158.49	5.06	0.832	0.832	0.146
PM_{10}	0.0573	lb/MMBtu	282,867	18,058,216		6.60	158.49	5.06	0.832	0.832	0.146
SO_2	0.000030	lb/lb	282,867	18,058,216		0.18	4.41	0.14	0.023	0.023	0.004
VOC	0.60	g/kW-hr	282,867	18,058,216		16.24	389.76	12.44	2.046	2.046	0.358
Lead	2.90E-05	lb/MMBtu	282,867	18,058,216		3.34E-03	0.08	2.56E-03	4.21E-04	4.21E-04	7.37E-05

Emissions Factor References
CO, VOC From maximum of AP-42, Section 3.4, Table 3.4-1 or IVL and Lloyd's data from Verification of Ship Emission Estimates with Monitoring Measurements to Improve Inventory Modeling, Final Report Prepared for California Air Resource Board, by James J. Corbett, 23 November 2004 - see page 25
NOx Emission factors relied upon by Shell per 1/05/2010 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair) to establish annual, owner-requested emission limits
$PM_{2.5}$ Owner requested limits per 11/23/2009 submittal from Shell
PM_{10} Owner requested limits per 11/23/2009 submittal from Shell
SO_2 Based on fuel sulfur content: 0.000015 by weight
Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Aggregate Rating, Heat Boiler(s)[1]: 1.37 MMBtu/hr
Maximum Hourly Fuel Use[5]: 10 gallons/hour

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation Daily	Maximum Hours of Operation Annual	Control Efficiency	Potential to Emit Hourly, lb/hr	Potential to Emit Daily, lb/day	Potential to Emit Annual, tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
CO	5	$lb/10^3$ gal	24	4,032		5.15E-02	1.24	0.10	0.006	0.006	0.003
NO_x	20.00	$lb/10^3$ gal	24	4,032		0.21	4.94	0.42	0.026	0.026	0.012
$PM_{2.5}$	3.30	$lb/10^3$ gal	24	4,032		0.03	0.82	0.07	0.004	0.004	0.002
PM_{10}	3.30	$lb/10^3$ gal	24	4,032		0.03	0.82	0.07	0.004	0.004	0.002
SO_2	0.213	$lb/10^3$ gal	24	4,032		2.19E-03	0.05	4.42E-03	2.76E-04	2.76E-04	1.27E-04
VOC	0.34	$lb/10^3$ gal	24	4,032		3.50E-03	0.08	0.01	4.41E-04	4.41E-04	2.03E-04
Lead	0.000009	lb/MMBtu	24	4,032		1.23E-05	2.96E-04	2.49E-05	1.55E-06	1.55E-06	7.15E-07

Emissions Factor References
CO, NOx AP-42 Table 1.3-1, boilers < 100 MMBtu/hr
$PM_{2.5}$ Assumed to be same as for PM_{10}
PM_{10} AP-42 Table 1.3-1 (filterable for PM) and AP-42 Table 1.3-2 (total condensible)
SO_2 AP-42 Table 1.3-1, boilers < 100 MMBtu/hr a Sulfur content of fuel: 0.000015 by weight
VOC AP-42 Table 1.3-3, commercial boilers
Lead AP-42, Table 1.3-10

Equipment Type: Incinerator
Aggregate Rating[1]: 151.23 lb/hr Emissions are for all incinerators on board the vessel

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation Daily	Maximum Hours of Operation Annual	Control Efficiency	Potential to Emit Hourly, lb/hr	Potential to Emit Daily, lb/day	Potential to Emit Annual, tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
CO	300	lbs/ton	24	4032		22.68	544.43	45.73	2.858	2.858	1.315
NO_x	3	lbs/ton	24	4032		0.23	5.44	0.46	0.029	0.029	0.013
$PM_{2.5}$	9.1	lbs/ton	24	4032		0.69	16.51	1.39	0.087	0.087	0.04
PM_{10}	13.3	lbs/ton	24	4032		1.01	24.14	2.03	0.127	0.127	0.058
SO_2	2.5	lbs/ton	24	4032		0.19	4.54	0.38	0.024	0.024	0.011
VOC	100	lbs/ton	24	4032		7.56	181.48	15.24	0.953	0.953	0.438
Lead	0.213	lbs/ton	24	4032		1.61E-02	3.87E-01	3.25E-02	2.03E-03	2.03E-03	9.34E-04

Emissions Factor References
CO, NOx, SO_2, VOC AP-42 Table 2.1-12, maximum of values for industrial/commercial and domestic single chamber
$PM_{2.5}$, PM_{10}: Owner requested limits per 5/14/2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair).
Lead AP-42, Maximum of uncontrolled values in Table 2.1-2, 2.1-8

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Criteria Pollutant Emission Inventory

Fleet Unit: Ice Breaker #2 - Tor Viking Scenario
(CONTINUED)

Total Emissions for Tor Viking

Potential to Emit			Potential to Emit in g/sec		
Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
113.29	2718.91	115.20	14.274	14.274	3.314
92.22	2213.20	71.19	11.619	11.619	2.048
7.33	175.82	6.52	0.923	0.923	0.187
7.64	183.44	7.16	0.963	0.963	0.206
0.38	9.00	0.53	0.047	0.047	0.015
23.81	571.32	27.69	2.999	2.999	0.796
1.95E-02	0.47	3.51E-02	2.45E-03	2.45E-03	1.01E-03

Maximum Emissions for Icebreaker#2 (max of Tor Viking and Hull

Potential to Emit			Potential to Emit in g/sec		
Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
234.48	5627.51	237.17	29.544	29.544	6.822
92.22	2213.20	71.19	11.619	11.619	2.048
11.37	272.87	11.15	1.433	1.433	0.321
11.69	280.49	11.79	1.473	1.473	0.339
0.51	12.19	0.68	0.064	0.064	0.019
23.81	571.32	27.69	2.999	2.999	0.796
2.14E-02	0.51	3.73E-02	2.69E-03	2.69E-03	1.07E-03

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Maximum equipment ratings per Shell submittal to EPA dated 9/17/2009:
Propulsion engines: 17660 hp at maximum
Non-propulsion Generator engines: 2336 hp
Boilers: 1.37 MMBtu/hr
Incinerator: 151.23 lb/hr
2 Maximum operating limit Shell submittal to EPA dated 9/17/2009 (Attachment A, page 23):
Propulsion engines, in aggregate: 80%
3 Minimum generator efficiency based on MaK engine specs per Shell submittal to EPA dated 11/23/2009 (Attachment B, page 14):
Propulsion engine minimum generator efficiency: 96%
4 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr converted based on aggregate engine rating, and fuel density and heat content

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Chukchi Sea Exploration Drilling Program
Criteria Pollutant Emission Inventory

Fleet Unit: Ice Breaker #2 - Hull 247
Fuel: Liquid distillate, #1 or #2, and waste materials for incinerator

Equipment Type: Internal Combustion Engines
Aggregate Rating, Propulsion Engines[1]: 24000 kW mechanical kW
Max. Aggregate Limit, Propulsion Engines[2]: 19200 kW mechanical kW
Max. Aggregate Limit, Propulsion Engines[3]: 17664 kWe electrical kW

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (kWe-hr) Daily	Maximum Operation (kWe-hr) Annual	Control Efficiency	Potential to Emit[4] Hourly, lb/hr	Potential to Emit[4] Daily, lb/day	Potential to Emit[4] Annual, tpy	Potential to Emit in g/sec One-Hour	Potential to Emit in g/sec 24-Hour	Potential to Emit in g/sec 365-Day
CO	5.0	g/kW-hr	423,936	31,904,074		211.64	5,079.48	191.13	26.667	26.667	5.498
NO_x	1.8	g/kW-hr	423,936	31,904,074		76.19	1,828.61	68.81	9.6	9.6	1.979
$PM_{2.5}$	0.25	g/kW-hr	423,936	31,904,074		10.58	253.97	9.56	1.333	1.333	0.275
PM_{10}	0.25	g/kW-hr	423,936	31,904,074		10.58	253.97	9.56	1.333	1.333	0.275
SO_2	0.000012	lb/hp-hr	423,936	31,904,074		0.31	7.50	0.28	0.039	0.039	0.008
VOC	0.19	g/kW-hr	423,936	31,904,074		8.04	193.02	7.26	1.013	1.013	0.209
Lead	2.90E-05	lb/MMBtu	423,936	31,904,074		5.23E-03	0.13	4.72E-03	6.59E-04	6.59E-04	1.36E-04

Emissions Factor References

CO, NO_x, PM, VOC Marine engine emission limits in 40 CFR 1042.101 (engines of at least 700 kW). All HC assumed to be VOC
Owner requested annual NOx limits per 9/17/2009 submittal from Shell
$PM_{2.5}$, PM_{10} $PM_{2.5}$ and PM_{10} emission factors assumed to be same as PM
SO_2 AP-42 Table 3.4-1 and Sulfur content of fuel: 0.000015 by weight
Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Aggregate Rating, Heat Boiler(s)[1]: 4.00 MMBtu/hr
Maximum Hourly Fuel Use[6]: 30 gallons/hour

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation Daily	Maximum Hours of Operation Annual	Control Efficiency	Potential to Emit Hourly, lb/hr	Potential to Emit Daily, lb/day	Potential to Emit Annual, tpy	Potential to Emit in g/sec One-Hour	Potential to Emit in g/sec 24-Hour	Potential to Emit in g/sec 365-Day
CO	5	$lb/10^3$ gal	24	4,032		0.15	3.6	0.30	0.019	0.019	0.009
NO_x	20.00	$lb/10^3$ gal	24	4,032		0.60	14.43	1.21	0.076	0.076	0.035
$PM_{2.5}$	3.30	$lb/10^3$ gal	24	4,032		0.10	2.38	0.20	0.012	0.012	0.006
PM_{10}	3.30	$lb/10^3$ gal	24	4,032		0.10	2.38	0.20	0.012	0.012	0.006
SO_2	0.213	$lb/10^3$ gal	24	4,032		6.40E-03	0.15	0.01	8.07E-04	8.07E-04	3.71E-04
VOC	0.34	$lb/10^3$ gal	24	4,032		0.01	0.25	0.02	1.29E-03	1.29E-03	5.93E-04
Lead	0.000009	lb/MMBtu	24	4,032		3.60E-05	8.64E-04	7.26E-05	4.54E-06	4.54E-06	2.09E-06

Emissions Factor References

CO, NOx AP-42 Table 1.3-1, boilers < 100 MMBtu/hr
$PM_{2.5}$ Assumed to be same as for PM_{10}
PM_{10} AP-42 Table 1.3-1 (filterable for PM) and AP-42 Table 1.3-2 (total condensible)
SO_2 AP-42 Table 1.3-1, boilers < 100 MMBtu/hr a Sulfur content of fuel: 0.000015 by weight
VOC AP-42 Table 1.3-3, commercial boilers
Lead AP-42, Table 1.3-10

Equipment Type: Incinerator
Aggregate Rating[1]: 151.23 lb/hr Emissions are for all incinerators on board the vessel

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation Daily	Maximum Hours of Operation Annual	Control Efficiency	Potential to Emit Hourly, lb/hr	Potential to Emit Daily, lb/day	Potential to Emit Annual, tpy	Potential to Emit in g/sec One-Hour	Potential to Emit in g/sec 24-Hour	Potential to Emit in g/sec 365-Day
CO	300	lbs/ton	24	4032		22.68	544.43	45.73	2.858	2.858	1.315
NO_x	3	lbs/ton	24	4032		0.23	5.44	0.46	0.029	0.029	0.013
$PM_{2.5}$	9.1	lbs/ton	24	4032		0.69	16.51	1.39	0.087	0.087	0.04
PM_{10}	13.3	lbs/ton	24	4032		1.01	24.14	2.03	0.127	0.127	0.058
SO_2	2.5	lbs/ton	24	4032		0.19	4.54	0.38	0.024	0.024	0.011
VOC	100	lbs/ton	24	4032		7.56	181.48	15.24	0.953	0.953	0.438
Lead	0.213	lbs/ton	24	4032		1.61E-02	3.87E-01	3.25E-02	2.03E-03	2.03E-03	9.34E-04

Emissions Factor References

CO, NOx, SO_2, VOC AP-42 Table 2.1-12, maximum of values for industrial/commercial and domestic single chamber
$PM_{2.5}$, PM_{10}: Owner requested limits per 5/14/2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair).
Lead AP-42, Maximum of uncontrolled values in Table 2.1-2, 2.1-8

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Fleet Unit: Ice Breaker #2 - Hull 247
(CONTINUED)

Total Emissions for Hull 247

Potential to Emit			Potential to Emit in g/sec		
Hourly, lb/hr	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
234.48	5627.51	237.17	29.544	29.544	6.822
77.02	1848.48	70.48	9.704	9.704	2.027
11.37	272.87	11.15	1.433	1.433	0.321
11.69	280.49	11.79	1.473	1.473	0.339
0.51	12.19	0.68	0.064	0.064	0.019
15.61	374.74	22.52	1.967	1.967	0.648
2.14E-02	0.51	3.73E-02	2.69E-03	2.69E-03	1.07E-03

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Maximum equipment ratings per Shell submittal to EPA dated 9/17/2009 (Attachment A, page 23):
Propulsion engines: 24000 kW mechanical
Non-propulsion Generator engines: 0 hp
Boilers: 4 MMBtu/hr
Incinerator: 151.23 lb/hr
2 Maximum operating limit Shell submittal to EPA dated 9/17/2009 (Attachment A, page 23):
Propulsion engines, in aggrega 80%
3 Minimum generator efficiency based on Shell submittal to EPA dated 11/23/2009:
Propulsion engine minimum generator efficiency: 92%
4 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr
5 Shell has requested an annual NOx limit of 58.39 tpy per 9/17/2009 submittal
6 Fuel usage converted based on boiler rating and fuel heat content.

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Fleet Unit:	Supply Ship - Generic
Fuel:	Liquid distillate, #1 or #2
Equipment Type:	Internal Combustion Engines
Aggregate Rating[1]:	7784 hp
Owner Requested Limit (Daily, Annual)[2]:	6344 hp — Emissions are for all engines in aggregate.
Maximum Hourly Fuel Use[2]:	334 gallons/hour

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation[4]		Control Efficiency	Potential to Emit			Potential to Emit in g/sec		
			Daily	Annual		Hourly, lb/hr[1]	Daily, lb/day	Annual, tpy	One-Hour	24-Hour	365-Day
CO	3.35	g/kW-hr	4	32		34.89	139.57	0.56	4.396	0.733	0.016
NO_x	25.40	g/kW-hr	4	32		264.92	1059.68	4.24	33.379	5.563	0.122
$PM_{2.5}$	1.54	g/kW-hr	4	32		16.06	64.25	0.26	2.024	0.337	0.007
PM_{10}	1.92	g/kW-hr	4	32		20.02	80.10	0.32	2.523	0.421	0.009
SO_2	0.000030	lb/lb	4	32		0.07	0.28	1.13E-03	0.009	0.001	0
VOC	0.60	g/kW-hr	4	32		6.26	25.03	0.10	0.788	0.131	0.003
Lead	0.000029	lb/MMBtu	4	32		1.29E-03	5.16E-03	2.06E-05	1.62E-04	2.71E-05	5.93E-07

Emissions Factor References

All pollutants except lead From maximum of AP-42, Section 3.4, Table 3.4-1 or IVL and Lloyd's data from Verification of Ship Emission Estimates with Monitoring Measurements to Improve Inventory Modeling, Final Report Prepared for California Air Resource Board, by James J. Corbett, 23 November 2004 - see page 25

SO_2 Sulfur content of fuel: 0.000015 by weight

Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Equipment population and rating based on vessel Jim Kilabuk per permit application dated February 23, 2009, Appendix B, page 15

Propulsion Engines:	7200 hp
Both generators:	584 hp
Bow thrusters not used:	0 hp
	7784 hp

2 Owner requested limits per e-mail and attachments of 5/14/2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair) and 5/27/2009 phone call between Air Sciences (Rodger Steen) and EPA (Pat Nair):

Propulsion Engines limited to 2 engines at no more than 80% load, i.e.	5760 hp
Both generators at full load - total hp:	584 hp
Bow thrusters not used:	0 hp

3 Brake specific fuel combustion from AP-42: 7000 Btu/hp-hr

4 Owner requested limits per e-mail and attachments of 5/14/2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair): based on a 4-hour round trip from the 25-mile distance to the Discoverer and 8 annual trips

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Fleet Unit: Oil Spill Response Main Ship - Nanuq
Fuel: Liquid distillate, #1 or #2, and waste materials for incinerator

Equipment Type: Propulsion Engines - Caterpillar 3608 Internal Combustion Engines
Aggregate Rating[1]: 5420 kW

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (gallons)[2] Daily	Annual	Control Efficiency[5, 6]	Potential to Emit Hourly, lb/hr[3]	Daily, lb/day	Annual, tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
CO	0.73	g/kW-hr	3,000	504,000	0.9	0.87	7.57	0.64	0.11	0.04	0.018
NO_x	13.62	g/kW-hr	3,000	504,000		162.70	1412.02	118.61	20.5	7.413	3.412
$PM_{2.5}$	0.17	g/kW-hr	3,000	504,000	0.85	0.30	2.64	0.22	0.038	0.014	0.006
PM_{10}	0.17	g/kW-hr	3,000	504,000	0.85	0.30	2.64	0.22	0.038	0.014	0.006
SO_2[2,4]	0.000030	lb/lb fuel	3,000	504,000		0.07	0.64	0.05	0.009	0.003	0.00
VOC	0.99	g/kW-hr	3,000	504,000	0.9	1.18	10.27	0.86	0.149	0.054	0.025
Lead	0.000029	lb/MMBtu	3,000	504,000		1.33E-03	1.16E-02	9.73E-04	1.68E-04	6.08E-05	2.80E-05

Emissions Factor References
CO, NO_x, $PM_{2.5}$, PM_{10}, VOC Permit application dated February 23, 2009, Appendix B, page 51
NOx NOx emission factor was converted from NO to NO2, ra 1.53
SO_2 Sulfur content of fuel: 0.000015 by weight
Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Equipment Type: Non-Propulsion Generator Engines
Aggregate Rating[1]: 2570 hp
Owner Requested Limit (Daily, Annual)[2]: 800 gal/day

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (gallons)[2] Daily	Annual	Control Efficiency[5, 6]	Potential to Emit Hourly, lb/hr	Daily, lb/day	Annual, tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
CO	3.35	g/kW-hr	800	134,400	0.9	1.41	8.37	0.70	0.178	0.044	0.02
NO_x	25.40	g/kW-hr	800	134,400		107.32	635.21	53.36	13.522	3.335	1.535
$PM_{2.5}$	1.54	g/kW-hr	800	134,400	0.85	0.98	5.78	0.49	0.123	0.03	0.014
PM_{10}	1.92	g/kW-hr	800	134,400	0.85	1.22	7.20	0.60	0.153	0.038	0.017
SO_2	0.000030	lb/lb fuel	800	134,400		2.87E-02	1.70E-01	1.43E-02	0.004	0.001	0.00
VOC	0.60	g/kW-hr	800	134,400	0.9	0.25	1.50	0.13	0.032	0.008	0.004
Lead	0.000029	lb/MMBtu	800	134,400		5.22E-04	3.09E-03	2.59E-04	6.57E-05	1.62E-05	7.46E-06

Emissions Factor References
All pollutants except lead and SO_2 From maximum of AP-42, Section 3.4, Table 3.4-1 or IVL and Lloyd's data from
Verification of Ship Emission Estimates with Monitoring Measurements to Improve Inventory Modeling, Final Report
Prepared for California Air Resource Board, by James J. Corbett, 23 November 2004 - see page 25
SO_2 Sulfur content of fuel: 0.000015 by weight
Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Equipment Type: Incinerator
Aggregate Rating[1]: 125.00 lb/hr Emissions are for all incinerators on board the vessel

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation Daily	Annual	Control Efficiency	Potential to Emit Hourly, lb/hr	Daily, lb/day	Annual, tpy	Potential to Emit in g/sec One-Hour	24-Hour	365-Day
CO	300	lbs/ton	24	4,032		18.75	450.00	37.80	2.362	2.362	1.087
NO_x	3	lbs/ton	24	4,032		0.19	4.50	0.38	0.024	0.024	0.011
$PM_{2.5}$	9.1	lbs/ton	24	4,032		0.57	13.65	1.15	0.072	0.072	0.033
PM_{10}	13.3	lbs/ton	24	4,032		0.83	19.95	1.68	0.105	0.105	0.048
SO_2	2.5	lbs/ton	24	4,032		0.16	3.75	0.32	0.02	0.02	0.01
VOC	100	lbs/ton	24	4,032		6.25	150.00	12.60	0.787	0.787	0.362
Lead	0.213	lbs/ton	24	4,032		0.01	0.32	2.68E-02	1.68E-03	1.68E-03	7.72E-04

Emissions Factor References
CO, NOx, SO_2, VOC AP-42 Table 2.1-12, maximum of values for industrial/commercial and domestic single chamber
$PM_{2.5}$, PM_{10} Owner requested limits e-mail and attachments of 5/14/2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair).
Lead AP-42, Maximum of uncontrolled values in Table 2.1-2, 2.1-8

Conversions Used
453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

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Fleet Unit: Oil Spill Response Main Ship - Nanuq
(CONTINUED)

Footnotes/Assumptions

1 Equipment population, rating and usage based on vessel Nanuq per permit application dated February 23, 2009, Appendix B, page 16
Hourly emissions are based on the aggregate rating of all equipment on board except for the emergency generator

2 Owner requested limits per e-mail and attachments of 5/14/2009 from Air Sciences (Rodger Steen) to EPA (Pat Nair), and Shell's updated request dated 9/17/2009:

Propulsion Engines expected to not exceed (in aggregate):	47000	kW-hr/day
Maximum fuel usage:	3000	gal/day
Generator usage expected to not exceed (in aggregate):	11,350	kW-hr/day
Maximum fuel usage:	800	gal/day

3 Fuel usage per permit application dated 2/23/2009, Appendix B, page 51 204.7 g/kW-hr

4 Fuel usage from AP-42, Section 3.3, brake specific fuel consumption from footnote c to Table 3.3.1
7000 Btu/hp-hr converted based on aggregate engine rating, and fuel density and heat content

5 PM10 control efficiency based on California Air Resources Board, Verification of Diesel Emission Control Strategies, 3/12/2009 (website), April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems, transmitted by April 27, 2009 e-mail from Air Sciences (Rodger Steen) to EPA (Pat Nair)

6 CO and VOC control efficiency from April 24, 2009 letter from CleanAIR Systems and April 20, 2007 quote from CleanAIR Systems,

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Fleet Unit: Oil Spill Response, Kvichak 34-foot No. 1, 2 and 3 Work Boats (three)
Fuel: Liquid distillate, #1 or #2

Equipment Type: Internal Combustion Engines - propulsion
Make/Model[1]: Cummins QSB
Aggregate Rating[1]: 1800 hp Emissions are for all Cummins QSB engines

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation: Daily	Maximum Hours of Operation: Annual	Control Efficiency	Potential to Emit: Hourly, lb/hr	Potential to Emit: Daily, lb/day	Potential to Emit: Annual, tpy	Potential to Emit in g/sec: One-Hour	Potential to Emit in g/sec: 24-Hour	Potential to Emit in g/sec: 365-Day
CO	0.155	g/hp-hr	24	4,032		0.62	15	1.24	0.078	0.078	0.036
NO_x	4.644	g/hp-hr	24	4,032		18.43	442	37.15	2.322	2.322	1.069
$PM_{2.5}$	0.077	g/hp-hr	24	4,032		0.31	7	0.62	0.039	0.039	0.018
PM_{10}	0.077	g/hp-hr	24	4,032		0.31	7	0.62	0.039	0.039	0.018
SO_2	0.000030	lb/lb fuel	24	4,032		0.02	0	0.04	0.003	0.003	0.001
VOC	0.078	g/hp-hr	24	4,032		0.31	7	0.62	0.039	0.039	0.018
Lead	0.000029	lb/MMBtu	24	4,032		3.65E-04	0.01	7.37E-04	4.60E-05	4.604E-05	2.12E-05

Emissions Factor References

CO, NO_x, $PM_{2.5}$, PM_{10}, VOC From permit application dated February 23, 2009, Appendix B, page 64
PM2.5 and PM10 emissions assumed to be same as PM emissions

Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Equipment Type: Internal Combustion Engines - generators
Aggregate Rating[1]: 36 hp Emissions are for all generator engines

Pollutant	Emission Factors	Emission Factor Units	Maximum Hours of Operation: Daily	Maximum Hours of Operation: Annual	Control Efficiency	Potential to Emit: Hourly, lb/hr	Potential to Emit: Daily, lb/day	Potential to Emit: Annual, tpy	Potential to Emit in g/sec: One-Hour	Potential to Emit in g/sec: 24-Hour	Potential to Emit in g/sec: 365-Day
CO	0.95	lb/MMBtu	24	4,032		0.24	6	0.48	0.03	0.03	0.014
NO_x	4.410	lb/MMBtu	24	4,032		1.11	27	2.24	0.14	0.14	0.064
$PM_{2.5}$	0.31	lb/MMBtu	24	4,032		0.08	2	0.16	0.01	0.01	0.005
PM_{10}	0.31	lb/MMBtu	24	4,032		0.08	2	0.16	0.01	0.01	0.005
SO_2	0.000030	lb/lb fuel	24	4,032		4.02E-04	1.00E-02	8.10E-04	0	0	0
VOC	0.35	lb/MMBtu	24	4,032		0.09	2	0.18	0.011	0.011	0.005
Lead	0.000029	lb/MMBtu	24	4,032		7.31E-06	1.75E-04	1.47E-05	9.21E-07	9.208E-07	4.24E-07

Emissions Factor References

CO, NO_x, $PM_{2.5}$, PM_{10}, VOC From AP-42, Section 3.3, Table 3.3-1

Lead Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds, EPA-454/R-98-006, May 1998, page 5-45

Conversions Used

453.59 g/lb
2,000 lbs/ton
745.7 watts/hp
7.076 lbs/gal
133,098 Btu/gal

Footnotes/Assumptions

1 Equipment population, rating and usage based on 3 work boats per permit application dated February 23, 2009, Appendix B, pages 16, 67 - Each of three identical Kvichak 34-foot boats has two 305 hp propulsion engines and a 12 hp generator
2 7000 Btu/hp-hr converted based on aggregate engine rating, and fuel density and heat content
3 Sulfur content of fuel: 0.000015 by weight

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Reference Table 1
Fuel Properties for Distillate Fuel Used on All Emission Units on the Discoverer

Fuel heat value:	133,098	Btu/gal	Keiser, Ronald email to Chris Tengco, 01/26/09, see permit application dated February 23, 2009, Appendix F, page 27.		
Fuel density:	847.9	kg/m^3	SCANRAFF-Vladimir Ignatjuk Certificate of Quality. 09/19/04.		
	7.076	lbs/gal	converted based on	453.59 g/lb	and
				264.17 gal/m^3	

Reference Table 2
Comparison of Controlled Emission Factors for Cementing Units and Logging Winches

Pollutant	Detroit 8V71N Emission Factors cont. (g/hp-hr)	Detroit 3V-71 Emission Factors cont. (g/hp-hr)	John Deere Emission Factors, cont. (g/kW-hr)	John Deere Emission Factors, cont. (g/hp-hr)	Caterpillar C7 Emission Factors, cont. (g/kW-hr)	Caterpillar C7 Emission Factors, uncont. (g/hp-hr)	Maximum Emission Factor	Emission Factor Units
CO	0.299	0.66	0.55	0.41	0.70	0.52	0.66	g/hp-hr
NO_x	9.81	11.72	7.5	5.59	4.0	2.98	11.72	g/hp-hr
$PM_{2.5}$	0.19	0.29	0.09	0.07	0.03	0.02	0.29	g/hp-hr
PM_{10}	0.19	0.29	0.09	0.07	0.03	0.02	0.29	g/hp-hr
VOC	0.148	0.20	0.75	0.56	4.0	2.98	2.98	g/hp-hr

SO_2 emissions not compared as they are based on mass balance

Reference Table 3
Comparison of Emission Factors for Marine Engines

Pollutant	AP-42 Section 3.4 lb/hp-hr	g/kW-hr	IVL g/kW-hr	Lloyd's g/kW-hr	Maximum EF g/kW-hr
CO	5.50E-03	3.35	1.4	1.6	3.35
NO_x [5]	0.056	25.40	18.1	17	25.40
$PM_{2.5}$	0.00056	0.34	1.54		1.54
PM_{10}	0.00058	0.35	1.92	1.5	1.92
SO_2 [5]	1.2135E-05	0.01	0	0.798	0.80
VOC	0.000705	0.43	0.6	0.5	0.60

Reference Table 4
Comparison of Emission Factors for
Marine Engines and External Combustion

Pollutant	Marine Engine EF g/kW-hr	Marine Engine EF[1] $lb/10^3$ gal	AP_42 Section 1.3 Tables 1 to 3 $lb/10^3$ gal	Maximum EF $lb/10^3$ gal
CO	3.35	104.58	5	104.58
NO_x [5]	25.40	794.01	20.00	794.01
$PM_{2.5}$	1.54	48.14	3.30	48.14
PM_{10}	1.92	60.02	3.30	60.02
SO_2 [5]	0.80	24.94	26.98	26.98
VOC	0.60	18.76	0.34	18.76

1 Conversions based on 745.7 watts/hp
453.59 g/lb
Brake specific fuel consumption: 7000 Btu/hp-hr