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

In re:	)
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

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Beaufort 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] Daily	Maximum Hours of Operation[7] Annual	Control Efficiency[4, 5]	Potential to Emit[7] Hourly, lb/hr	Potential to Emit[7] Daily, lb/day	Potential to Emit[7] Annual, tpy	Potential to Emit in g/sec One-Hour	
										g/kW-hr
CO	6.55	g/hp-hr			0.9	0.21			0.026	0.87836
NO_x	11.72	g/hp-hr				3.8			0.479	15.7165
$PM_{2.5}$	1.92	g/hp-hr			0.85	0.09			0.011	0.38621
PM_{10}	1.92	g/hp-hr			0.85	0.09			0.011	0.38621
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	0.26954
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
NO_x From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35
$PM_{2.5}$ $PM_{2.5}$ emissions assumed to be same as PM_{10} emissions
PM_{10} From Health Assessment Document for Diesel Engine Exhaust, EPA/600/8-90/057F, May 2002, pages 2-34 and 2-35 (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
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 01-18-10, Appendix A, page 7
2 Engine rating per permit application dated 01-18-10, Appendix A, page 7
3 Fuel usage permit application dated 01-18-10, Appendix A, page 7
0.415 lb/hp-hr
4 PM_{10} 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 Beaufort 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] Daily	Maximum Hours of Operation[4] Annual	Control Efficiency[5]	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	
										g/kW-hr
CO	3.5	g/kW-h			0.8	0.29			0.037	0.7
NO_x	4.0	g/kW-h				1.64			0.207	4
$PM_{2.5}$	0.2	g/kW-h			0.85	0.01			0.001	0.03
PM_{10}	0.2	g/kW-h			0.85	0.01			0.001	0.03
SO_2	0.000030	lb/lb fuel				2.79E-03			3.52E-04	
VOC	4.0	g/kW-h				1.64			2.07E-01	4
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)
$PM_{2.5}$	$PM_{2.5}$ emissions assumed to be same as PM_{10} 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 permit application dated 01-18-10, Appendix A, page 8
2 Engine rating per permit application dated 01-18-10, Appendix A, page 8
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 Beaufort 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] Daily	Maximum Hours of Operation[7] Annual	Control Efficiency[4, 5]	Potential to Emit[7] Hourly, lb/hr	Potential to Emit[7] Daily, lb/day	Potential to Emit[7] Annual, tpy	Potential to Emit in g/sec One-Hour	
										g/kW-hr
CO	5.5	g/kW-hr			0.9	0.03			0.004	0.55
NO_x	7.5	g/kW-hr				0.43			0.054	7.5
$PM_{2.5}$	0.60	g/kW-hr			0.85	0.01			0.001	0.09
PM_{10}	0.60	g/kW-hr			0.85	0.01			0.001	0.09
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	0.75
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
$PM_{2.5}$ $PM_{2.5}$ emissions assumed to be same as PM_{10} 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 permit application dated 01-18-10, Appendix A, page 9
2 Engine rating per permit application dated 01-18-10, Appendix A, page 9
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 PM_{10} 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 Beaufort 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			7.88	0.66	0.041	0.019
NO_x	11.72	g/hp-hr	320	53,760			140.98	11.84	0.74	0.341
$PM_{2.5}$	0.288	g/hp-hr	320	53,760			3.46	0.29	0.018	0.008
PM_{10}	0.288	g/hp-hr	320	53,760			3.46	0.29	0.018	0.008
SO_2	0.000030	lb/lb	320	53,760			0.07	5.71E-03	3.57E-04	1.64E-04
VOC	2.98	g/hp-hr	320	53,760			35.85	3.01	1.88E-01	8.66E-02
Lead	0.000029	lb/MMBtu	320	53,760			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
$PM_{2.5}$	$PM_{2.5}$ emissions assumed to be same as PM_{10} 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 Beaufort 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	lb/MMBtu
CO	14.8	lbs/day	24	4,032		0.62	14.8	1.25	0.078	0.078	0.036	0.07779
NO_x	38.50	lbs/day	24	4,032		1.6	38.50	3.23	0.202	0.202	0.093	0.20075
$PM_{2.5}$	4.50	lbs/day	24	4,032		0.19	4.50	0.38	0.024	0.024	0.011	0.02384
PM_{10}	4.50	lbs/day	24	4,032		0.19	4.50	0.38	0.024	0.024	0.011	0.02384
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	0.00125
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
$PM_{2.5}$	$PM_{2.5}$ emissions assumed to be same as PM_{10} 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 01-18-10, Appendix A, page 10
2 Boiler rating per permit application dated 01-18-10, Appendix A, page 10
3 Fuel usage converted based on boiler rating, fuel density and fuel heat content.

Shell Offshore Inc.
OCS/PSD Permit for
Frontier Discoverer Beaufort 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									**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									**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									**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 permit application dated 01-18-10
PM_{10} Owner requested limit per Shell permit application dated 01-18-10
SO_2 Owner requested limit per Shell permit application dated 01-18-10
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 01-18-10, Appendix A, page 11
2 Incinerator can burn municipal wate or sewage - emission factors are maximum for these two waste feeds
3 Incinerator rating per permit application dated 01-18-10, Appendix A, page 11
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.
OCS/PSD Permit for
Frontier Discoverer Beaufort 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 01-18-10 Appendix A, page 17
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 Beaufort 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

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (kWe-hr) Daily	Maximum Operation (kWe-hr) Annual	Control Efficiency	Potential to Emit[3] Hourly, lb/hr	Potential to Emit[3] Daily, lb/day	Potential to Emit[3] 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	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 01-18-10 permit application, Appendix A, page 17
$PM_{2.5}$, PM_{10} Emission factors relied upon by Shell in 01-18-10 permit application, Appendix A, page 17
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

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		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

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		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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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:

$PM_{2.5}$ hourly emissions limit:	42.2	lbs
PM_{10} hourly emissions limit:	48.0	lbs

42.71826
48.3493

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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	Potential to Emit in g/sec 24-Hour	Potential to Emit in g/sec 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
NO_X 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
$PM_{2.5}$ Emission factors relied upon by Shell in 01-18-10 permit application, Appendix A, page 18
PM_{10} Emission factors relied upon by Shell in 01-18-10 permit application, Appendix A, page 18
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	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		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	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 - 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 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
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

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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

70.48

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 permit Application, Appendix A, page 16 based on a 4-hour round trip from the 25-mile distance to the Discoverer and 8 annual trips

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

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	Maximum Operation (gallons)[2] Annual	Control Efficiency[5, 6]	Potential to Emit Hourly, lb/hr[3]	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	0.73	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 NO_X emission factor was converted from NO to NO_2, ratio 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	Maximum Operation (gallons)[2] Annual	Control Efficiency[5, 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	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	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	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

Footnotes/Assumptions

1 Equipment population, rating and usage based on vessel Nanuq per permit application dated 01/18/10 Appendix A, page 17
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 PM_{10} 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,

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

Fleet Unit: Oil Spill Response Main Ship - Point Barrow Tug
Fuel: Liquid distillate, #1 or #2

Equipment Type: Propulsion Engines - Caterpillar 3512 Internal Combustion Engines
Aggregate Rating[1]: 2100 hp[2] 1566 kw

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (gallons)[2] Daily	Maximum Operation (gallons)[2] Annual	Control Efficiency[5, 6]	Potential to Emit Hourly, lb/hr[3]	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	0.73	g/kW-hr	2,399	403,032		2.52	60.54	5.09	0.318	0.318	0.146
NO_X	13.62	g/kW-hr	2,399	403,032		47.01	1129.15	94.85	5.923	5.928	2.728
$PM_{2.5}$	0.17	g/kW-hr	2,399	403,032		0.59	14.10	1.18	0.074	0.074	0.034
PM_{10}	0.17	g/kW-hr	2,399	403,032		0.59	14.10	1.18	0.074	0.074	0.034
SO_2[2,4]	0.000030	lb/lb fuel	2,399	403,032		0.02	0.51	0.04	0.003	0.003	0.00
VOC	0.99	g/kW-hr	2,399	403,032		3.42	82.10	6.90	0.431	0.431	0.198
Lead	0.000029	lb/MMBtu	2,399	403,032		3.85E-04	9.26E-03	7.78E-04	4.86E-05	4.86E-05	2.24E-05

Fleet Unit: Oil Spill Response Main Ships - Point Barrow Tug and Arctic Endeavor Barge
Fuel: Liquid distillate, #1 or #2

Equipment Type: Non-Propulsion Generator Engines
Aggregate Rating[1]: 856 hp[3] 638 kw Emissions are for all generator units combined

Pollutant	Emission Factors	Emission Factor Units	Maximum Operation (gallons)[2] Daily	Maximum Operation (gallons)[2] Annual	Control Efficiency[5, 6]	Potential to Emit Hourly, lb/hr[3]	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	3.34	g/kW-hr	1,080	181,440		4.70	112.76	9.47	0.592	0.592	0.272
NO_X	25.40	g/kW-hr	1,080	181,440		35.74	857.50	72.03	4.504	4.502	2.072
$PM_{2.5}$	1.54	g/kW-hr	1,080	181,440		2.17	51.99	4.37	0.273	0.273	0.126
PM_{10}	1.92	g/kW-hr	1,080	181,440		2.70	64.82	5.44	0.34	0.34	0.157
SO_2[2,4]	0.000030	lb/lb fuel	1,080	181,440		0.01	0.23	0.02	0.001	0.001	0.00
VOC	0.60	g/kW-hr	1,080	181,440		0.84	20.26	1.70	0.106	0.106	0.049
Lead	0.000029	lb/MMBtu	1,080	181,440		1.74E-04	4.17E-03	3.50E-04	2.19E-05	2.19E-05	1.01E-05

1 Equipment population, rating and usage based on the permit application dated 01/18/10 Appendix A, and 01-20-10 email with Attachment from Environ (Kirk Winges) to EPA (Natasha Greaves)
2 The Point Barrow Tug has two 1050 hp propulsion engines and two 150 hp generators.
3 The Arctic Endeavor has one 350 hp crane, one 30 hp light plant, one 126 hp generator, and one 50 hp anchor guide.

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
0.7457 kw/hp

Shell Offshore Inc.
OCS/PSD Permit for
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Criteria Pollutant Emission Inventory

Fleet Unit: Oil Spill Response, Kvichak 34-foot No. 1, 2 (two) and 47-foot Work Boats
Fuel: Liquid distillate, #1 or #2

Equipment Type: Internal Combustion Engines - propulsion
Make/Model[1]: Cummins QSB
Aggregate Rating[1]: 2600 hp Emissions are for all Cummins QSB engines

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	0.155	g/hp-hr	24	4,032		0.89	21	1.79	0.112	0.112	0.051
NO_x	4.644	g/hp-hr	24	4,032		26.62	639	53.67	3.354	3.354	1.544
$PM_{2.5}$	0.077	g/hp-hr	24	4,032		0.44	11	0.89	0.056	0.056	0.026
PM_{10}	0.077	g/hp-hr	24	4,032		0.44	11	0.89	0.056	0.056	0.026
SO_2	0.000030	lb/lb fuel	24	4,032		0.03	1	0.06	0.004	0.004	0.002
VOC	0.078	g/hp-hr	24	4,032		0.45	11	0.90	0.056	0.056	0.026
Lead	0.000029	lb/MMBtu	24	4,032		5.28E-04	0.01	1.06E-03	6.65E-05	6.65E-05	3.06E-05

Emissions Factor References
CO, NO_x, $PM_{2.5}$, PM_{10}, VOC From permit application dated 01-18-10, Appendix A page 17 and 01-20-10 email with Attachment from Environ (Kirk to EPA (Natasha Greaves)
$PM_{2.5}$ and PM_{10} 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]: 33 hp Emissions are for all generator engines

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	0.95	lb/MMBtu	24	4,032		0.22	5	0.44	0.028	0.028	0.013
NO_x	4.410	lb/MMBtu	24	4,032		1.02	24	2.05	0.128	0.128	0.059
$PM_{2.5}$	0.31	lb/MMBtu	24	4,032		0.07	2	0.14	0.009	0.009	0.004
PM_{10}	0.31	lb/MMBtu	24	4,032		0.07	2	0.14	0.009	0.009	0.004
SO_2	0.000030	lb/lb fuel	24	4,032		3.68E-04	1.00E-02	7.43E-04	0	0	0
VOC	0.35	lb/MMBtu	24	4,032		0.08	2	0.16	0.01	0.01	0.005
Lead	0.000029	lb/MMBtu	24	4,032		6.70E-06	1.61E-04	1.35E-05	8.44E-07	8.441E-07	3.88E-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 01-18-10, Appendix A, pages 17- Each of three identical Kvichak 34-foot boats has two 305 hp propulsion engines and a 12 hp generator The Rozema Skimmer has two 700 hp propulsion engines and a 9 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

‹ Winges)

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Criteria Pollutant Emission Inventory

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