APPENDIX H: AMORCO MARINE TERMINAL EMISSIONS CALCULATIONS METHODOLOGY

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AMORCO MARINE TERMINAL EMISSIONS CALCULATIONS BACKGROUND

Emissions of criteria pollutants and greenhouse gases (GHG) from ocean going vessels (OGV) were calculated in accordance with methods prescribed by the BAAQMD in Tesoro's Title V Operating Permit (the Permit) which includes Facilities #B2758 – Golden Eagle Refinery and #B2759 - Amorco Marine Oil Terminal. These methods appear in Condition 878 and Appendix B of the operating permit which are provided as Attachment A.

The methods prescribed in The Permit for calculating emissions from OGVs provide the following calculation parameters:

- tanker fuel usage rates;
- diesel fuel used during barge unloading;
- tug usages;
- fuel combustion emission factors; and
- hydrocarbon emission factors from onloading of crude oil, ballast or products.

The last item in the above list is not applicable for the Amorco Terminal since no onloading occurs at this location.

Data from the tanker fuel usage rate table (volume/hr) was multiplied by the time (hr) to calculate the total amount of fuel used. Activities were divided into four categories:

- transit to and from the terminal
- maneuvering in the vicinity of the terminal
- hoteling; and
- boiler operation during unloading.

In addition, two (2) tug boats were assumed to operate in conjunction with each vessel for a total operating time of eight (8) hours per tug boat in accordance with the tug usages provided in the The Permit. Time in each activity was based on a starting point approximately 11 miles west of the Golden Gate Bridge until the vessel was at berth. A total of ten (10) hours was assumed for the roundtrip to and from the starting point west of the Golden Gate Bridge. Six (6) hours was assumed for the transit time and four (4) hours was assumed for the maneuvering time. Hoteling duration was assumed to be 20 hours.

As noted above, tanker fuel use rates were provided in the The Permit. Tug fuel use rates were obtained from the "*Port of Los Angeles Baseline Emission Inventory – 2001*" prepared by Starcrest Consulting Group, LLC (Attachment B). The section on Page 153 of this document entitled *Assist Tugboats* notes "*The average hourly fuel consumption for assist tugboats was 39 gallons per hour.*" This is approximately equal to one (1) barrel (42 gallons) per hour. The calculations used for this analysis conservatively assumed three (3) barrels per hour to account for variance in tugboats and low load factors.

Provided as Attachment C is a spreadsheet entitled, "Ships & Tugs – BAAQMD Prescribed Methodology" which contains the emission factors from The Permit data along with the hourly activity data used to calculate criteria pollutant emissions. The Permit does not specify $PM_{2.5}$ emission factors, therefore factors were obtained from the May 2011 California Air Resources Board Planning and Technical Support Division document entitled "*Emissions Estimation Methodology for Ocean-Going Vessels.*" (The CARB Guidance - Attachment D). Tug-specific

$PM_{2.5}$ emission factors are not provided in The CARB Guidance, therefore to calculate these emissions the ship transit $PM_{2.5}$ emissions are scaled proportionally to the ratio of ship transit-to-tug-transit PM_{10} emissions. The volume of fuel consumed is multiplied by the criteria pollutant emission factors to determine overall emissions. The spreadsheet shows the results for a single ship along with the 2008 baseline and future cases.

GHG emission factors are not provided in The Permit. GHG emission factors in grams pollutant per kW-hr for CO_2 and CH_4 were taken from Tables II-6 through II-9 from The CARB Guidance. Table II-10 in the same document provided fuel consumption rates by fuel type in grams fuel/kW-hr. The fuel consumption rates were used in combination with the emission factors to develop emission factors in terms of grams pollutant/gram fuel. This enabled the use of consistent fuel consumption data for the GHG and criteria pollutant calculations. Emission factors for N_2O were taken from "*The Port of Long Beach Air Emissions Inventory – 2011*" (Attachment B). Tables 2.6, 2.11, and 2.15 contain the N_2O emissions data for propulsion engines, auxiliary engines, and boilers, respectively, in grams/kW-hr. Table 2.17 contains a correction factor for N_2O emissions when burning marine diesel oil (MDO). This factor of 0.94 was applied to the calculated emissions. The table also notes that the emissions of CO_2 and CH_4 have a correction factor of 1.00.

Provided as Attachment E is a spreadsheet entitled, "GHG Based on Fuel from BAAQMD Method" which contains the emission factors and fuel consumption factors from The CARB Guidance along with the fuel consumed (consistent with criteria pollutant calculations). The amount of fuel consumed is multiplied by the GHG emission factors to determine overall emissions. Separate emission factors are identified for CO_2, CH_4, and N_2O. The individual results are multiplied by the GHG potency factors to develop an overall CO_2 equivalent (CO_2e) value. As with criteria pollutants, the spreadsheet shows the results for a single ship along with the 2008 baseline and future cases.

Criteria pollutants outside of indirect emissions from ocean going vessels will remain below the cap set in The Permit. Any actual increase in stationary source emissions would be minor and primarily result from throughput increases in the storage tanks. Other emissions sources at the Amorco Terminal such as fugitive components are included in the cap and will not increase.
GHG emissions from the stationary sources were increased by scaling up the total baseline emissions proportional to the projected increases in the number of ocean going vessels. This is a conservative assumption since only tank throughput emissions would increase.

Attachment A

Title V Operating Permit Excerpts

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Bay Area Air Quality Management District

939 Ellis Street
San Francisco, CA 94109
(415) 771-6000

Final

MAJOR FACILITY REVIEW PERMIT

Issued To:

Tesoro Refining and Marketing Company
Facility #B2758 & Facility #B2759

Facility Addresses:

Facility #B2758
Golden Eagle Refinery
150 Solano Way
Martinez, CA 94553

Facility #B2759
Amorco Terminal
1750 Marina Vista Way
Martinez, CA 94553

Mailing Address:
Golden Eagle Refinery, 150 Solano Way
Martinez, CA 94533

Responsible Official
William Bodnar
Vice President and General Manager

(925) 228-1220

Facility Contact
Matthew Marusich
Environmental Manager

(925) 228-1220

Type of Facility: **Petroleum Refining**
Primary SIC: 2911
Product: Refined Petroleum Products

BAAQMD Engineering Division Contact:
Arthur P. Valla

ISSUED BY THE BAY AREA AIR QUALITY MANAGEMENT DISTRICT

Signed by Jeff McKay for Jack P. Broadbent
Jack P. Broadbent, Executive Officer/Air Pollution Control Officer

June 28, 2011
Date

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VI. Permit Conditions

Condition 878

S100 Avon Wharf Loading Berth No. 1

1. When calculating hydrocarbon emissions from vessel or barge loading, the Permittee/Owner/Operator shall use the emission factors presented in condition number 5 of condition ID #878. (basis: cumulative increase)

2. Permittee/Owner/Operator shall install and maintain a Pressure Recorder/Controller in the vapor recovery system to provide a permanent record of pressure during the loading of vessels. These records shall be maintained for a minimum of 5 years. (basis: cumulative increase)

3. Not less frequently than every six months, Permittee/Owner/Operator shall conduct tests to assess leakage from all relief valves that vent to atmosphere in the marine vapor recovery system on a semi-annual basis.

   Permittee/Owner/Operator shall ensure that the testing and record keeping are done in compliance with Regulation 8, Rule 18.

   (basis: cumulative increase, Regulation 8-18)

4. If leakage is detected during the loading of a vessel, or if the vapor recovery system is shutdown for any period of time during loading, or if a relief valve in the recovery system vents to atmosphere during loading, Permittee/Owner/Operator shall use the "Non-Vapor Recovery" emission factors in condition number 5 of condition ID #878 to calculate emissions from the entire loading operation. Credit for vapor recovery may be given for a portion of a vessel loading operation, provided that Permittee/Owner/Operator can provide documentation to the satisfaction of the APCO that credit is appropriate, as determined by the APCO.
   (basis: cumulative increase)

5. DATA FOR DETERMINING EMISSIONS FROM MARINE ACTIVITY

   Described herein are the following lists of fuel usage rates and emission factors for calculating marine activity emissions

Part B-1 Tanker Fuel Usage Rates

Part B-2 Diesel Fuel Used During Barge Unloading

Part B-3 Tug Usages

VI. Permit Conditions

Part B-4 Fuel Combustion Emission Factors

Part B-5 Hydrocarbon Emissions from Onloading of Crude Oil, Ballast or Products

The methodology, assumptions, and procedures to be used in calculating the emissions shall be consistent with those set forth in Permittee/Owner/Operator's submittal entitled, "Procedures for Determining Emissions from Marine Activity," dated 10/30/81.

Calculated emissions shall be reported in units of short tons (2,000 lbs avoir dupois) rounded to three (3) significant figures.

PART B-1: TANKER FUEL RATES

Tanker Deadweight Tonnage (10000 tons)	(A) Fuel Use OilDiesel	(B) Main Engine Type	(C) Engine Fuel Type	(D) Engine Fuel Use (bbl/hr)	(D) Unloading Rate (bbl/hr)	Hoteling Boiler Fuel Use For Unloading (bbl/hr)	Hoteling Fuel Use (bbl/hr)
< 2	ST	F	5.0	6,000	7.0	1	0
	MT	D	2.5	6,000	7.0	1	1
2 to < 3	ST	F	8.1	8,000	9.5	1	0
	MT	D	5.6	8,000	9.5	1	1
3 to < 4	ST	F	9.4	10,000	11.5	1	0
	MT	D	6.9	10,000	11.5	1	1
4 to < 5	ST	F	10.9	12,000	13.5	1	0
	MT	D	8.1	12,000	13.5	1	1
5 to < 6	ST	F	13.1	14,000	15.5	1	0
	MT	D	8.4	14,000	15.5	1	1
6 to < 8	ST	F	15.0	15,000	16.0	2	0
	MT	D	9.4	15,000	16.0	2	2
8 to < 10	ST	F	18.1	16,000	17.0	2	0
	MT	D	10.9	16,000	17.0	2	2

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10 to < 14	ST	F	20.0	17,000	17.5	2 0
MT	D	13.1	17,000	17.5	2	2
14 to < 18	ST	F	21.6	18,000	18.5	2 0
MT	D	15.6	18,000	18.5	2	2
≥ 18	ST	F	22.5	19,000	19.5	3 0
MT	D	19.1	19,000	19.5	3	3

Explanation of abbreviations for PART B-1:

Column A ST = steamship (steam boilers and turbines)
MT = motorship (internal combustion engines)
Column B F = fuel oil (not diesel fuel)
D = diesel oil
Column C BBL/hr = barrels per hour of fuel use during transit (at 50% of full steaming)
Column D During unloading of oil or ballast, steamships and motorships use fuel oil (F) for boilers/turbines which drive the unloading pumps

PART B-2: DIESEL FUEL USED DURING BARGE UNLOADING*

barge unloading rate (bbl/hr)	diesel fuel usage (bbl/hr)
2,000	2.3
2,200	2.4
2,500	2.9
3,500	4.1
8,000	9.5
10,000	11.5
13,000	13.5

* Based on internal combustion engines driving the unloading pumps on the barges using the same kind of diesel as the tugs (i.e., 0.50 wt% sulfur and API gravity of 35)

PART B-3: TUG USAGES

One tug for assisting tankers of < 50,000 DWT size, for a total transit time of four hours per tanker call at docks.

Two tugs for assisting tankers of > 50,000 DWT size, for a total transit time of four hours each tug per tanker call at docks.

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One tug for transporting barges or lighters, for a total transit time of ten hours per each barge/lighter call at docks.

Thus, for each call below:	Total tug transit hour
Tanker of < 50,000	4
Tanker of ≥ 50,000	8
Product shipment barge	10
Crude oil lighter	10

PART B-4: FUEL COMBUSTION EMISSION FACTORS
(pounds / 1,000 gallons of fuel burned *)

Boiler In Steamships:	Fuel Type	*POC	*SO_2	*NOx	*CO	*PM_{10}
during transit	F	3.10	315.3	48.2	2.62	19.0
during hoteling	F	3.10	315.3	20.9	2.62	19.0
during unloading	F	3.10	315.3	48.2	2.62	19.0

Internal Combustion Engines In Motorships:	Fuel Type	*POC	*SO_2	*NOx	*CO	*PM_{10}
during transit	D	32.8	70.1	367.0	56.9	20.0
during hoteling	D	32.8	70.1	367.0	56.9	20.0

Internal Combustion Engines in Motorships > or = 100,000 DWT:	Fuel Type	*POC	*SO_2	*NOx	*CO	*PM_{10}
during transit	D	32.8	210.3	367.0	56.9	20.0
during hoteling	D	32.8	210.3	367.0	56.9	20.0

Boilers In Motorships:	Fuel Type	*POC	*SO_2	*NOx	*CO	*PM_{10}
during transit	F	3.10	315.3	20.9	2.62	19.0
during hoteling	F	3.10	315.3	48.2	2.62	19.0

Internal Combustion (IC): Engines In Tugs:	Fuel Type	*POC	*SO_2	*NOx	*CO	*PM_{10}
during transit	TD	13.0	70.1	571.2	56.9	25.0
IC engines driving barge unloading pumps	TD	13.0	70.1	571.2	56.9	25.0

(PM-10 factor of 25 lb/1000 gallons also applies to internal combustion engines driving barge unloading pumps)

Explanation of abbreviations for PART B-4:
Fuel Type
F = fuel oil or residuum sulfur @ ≤ 2.0 wt%; nitrogen @ ≤ 0.43 wt%; API gravity 18

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D	= marine diesel	sulfur @ ≤ 0.5 wt%; nitrogen @ ≤ 0.08 wt%; API gravity 35
TD	= tug diesel	sulfur @ ≤ 0.5 wt; API gravity @ 35

PART B-5: HYDROCARBON EMISSIONS FROM ONLOADING OF CRUDE OIL, BALLAST OR PRODUCTS

COMMODITY ONLOADED	Non-Vapor Recovery POC Emissions (lb/1,000 gallons)	Vapor Recovery POC Emissions (lb/1,000 gallons)
Crude Oil:		
Barges	1.7	0.034
Vessels	1.0	0.02
Ballast: (unsegregated***)		
Crude	0.7	0.014
Gasoline	1.6	0.032
Gasoline:		
Barges	4.0	0.08
Vessels	2.4	0.048
Turbine Fuel (Jet Fuel)	0.005	0.0001
Diesel Oil, Gas Oil, Conversion Feed, Cutter Stock, Catalytic Cracker Charge HDN Charge, Stove Oil, Solvents, Lubestocks, Middle Distillate Oil	0.005	0.0001
Fuel Oil, Heavy Fuel Oil, Low Sulfur Oil, Bunkers IFO, LSFO, Residuum, Carbon Black, Purchased Cut Back Tar, Asphalt	4.0 E-05	8.0 E-07

*** The volume of unsegregated ballast taken on by a ship which has offloaded cargo is determined by the following equation:

$$B = 7.5 \times MDWT \times (0.35 - B_{segregated}/100)$$

Explanation of abbreviations for PART B-5:
B = the volume of ballast into dirty cargo tanks in Mbbl
MDWT = ship tonnage in thousands of dead weight tons as indicated by Clarkson
B segregated = the percent of segregated or dedicated ballast for the ship as indicated by Clarkson or some other reliable source which is

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known to be more current; e.g., ship's records, where the percent is equal to or less than 35. If the percent is greater than 35 than the amount of unsegregated ballast will be zero.

Condition 1910

S1007 Hydrocracker Unit 2nd Stage
S1008 Hydrocracker Unit 1st Stage

PERMIT CONDITION 1910
APPLICATION #548
HYDROCRACKER EXPANSION PROJECT PERMIT CONDITIONS
(S-1007) AND (S-1008)

Application 15944 (May 2007): S-1007 Isocracker Unit: IIR Compressor Leak Control Measure to install a shroud/clamp to capture compressor leaks and route gases to the flare gas recovery header. Add inspection requirements for the shroud/clamp.

Application 16850 (February 2008): S-1007 Isocracker Unit: HIR Compressor Leak Control Measure to install a shroud/clamp to capture compressor leaks and route gases to the flare gas recovery header. Add inspection requirements for the shroud/clamp.

Administratively Changed by Application 18861 (June 2009) Removed completed parts and parts redundant with District Regulations

Administratively Changed by Application 21711 (May 2010). Deleted Parts 3 and 4. Leaks permanently repaired.

1. Deleted. (No pressure relief valves associated with this project vent to atmosphere)

2. Deleted. (Completed. All pumps and compressors have double mechanical seals with a barrier fluid, or equivalent, and all new compressors must meet applicable New Source Performance Standards.)

3. Deleted (Completed. IIR Compressor leak permanently repaired and shroud/clamp removed during 2Q09 Hydrocracker shutdown).

4. Deleted (Completed. HIR Compressor leak permanently repaired and shroud/clamp removed during 2Q09 Hydrocracker shutdown).

Attachment B

Port of Los Angeles Baseline Emission Inventory – 2001

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PORT OF LOS ANGELES BASELINE AIR EMISSIONS INVENTORY - 2001

Report
July 2005

Prepared by:
Starcrest Consulting Group, LLC

During the survey interviews, the proportion of time spent within three zones (the Port harbor, up to 25 miles, and from 25 to 50 miles) was discussed with the vessel operators. Based on the interviews, percentages were given for each vessel type and emissions for each of the pollutants were estimated for each zone. Table 3.3 summarizes the average percent of time spent by each category of harbor vessel in the three zones. These percentages can be used with average annual operating hours data by vessel type presented below to derive annual average hours by zone.

Table 3.3: Average Time Spent in Zone, percent

Category	Percent Time in Zone		
	Harbor	25 Miles	50 Miles
Assist Tug	100%	0%	0%
Tugboat (Unit Tow)	81%	15%	4%
Ferry	35%	51%	14%
Excursion	25%	65%	9%
Crew boat	52%	48%	0%
Work boat	66%	34%	0%
Government	74%	14%	12%
Commercial Fishing	10%	50%	40%
Recreational Vessel	40%	38%	22%
Dredge and Dredging Support	100%	0%	0%
Line Haul Towboat	60%	20%	20%
	58.5%	**30.5%**	**11.0%**

Assist Tugboats

As shown in Tables 3.1 and 3.2, in 2001 the three harbor assist tugboat companies operated a total of 18 diesel-powered boats. The majority of the assist tugboats had two main engines with each engine having a horsepower between 1,500 and 2,500 hp. The most common main engine model found was Caterpillar 3516B. The annual operating hours for main propulsion engines ranged from 300 to 1,900 hours, with an average of 1,043 hours. The average assist tugboat had two 110 hp auxiliary engines used to supply on-board power, navigation systems, and air conditioning/heating for the crew. The most common type of auxiliary engine among assist tugboats was the Caterpillar 3304. The auxiliary engines ranged from 67 to 180 hp. The annual hours of usage for auxiliary engines ranged from 130 to 2,900 hours, with an average of 1,200 hours. One harbor assist tugboat company started using shore power after 2001 for its tugboats while they are at the company's docks. The average hourly fuel consumption for assist tugboats was 39 gallons per hour. Approximately 44% of the assist tugboats had Category 2 main engines.

Attachment C

Ships & Tugs – BAAQMD Prescribed Methodology

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Ships & Tugs - BAAQMD Prescribed Methodology

Assumptions:

180,000	DWT
2	Tugs @ 8 hours each
6	hour transit time (in/out)
20	hour hoteling time
4	hour maneuvering time (in/out)
	Boiler Operational During Hoteling Time

Activity	Fuel Usage (BBL/HR)		Time in Activity	Total Diesel Used (Gal)	Total Fuel Oil Used (Gal)
	Diesel	Fuel Oil			
Transit to/from MOT	19.1		6	4813.2	0
Maneuvering	19.1		4	3208.8	0
Hoteling	3	3	20	2520	2520
Boiler Unloading		19.5	20	0	16380
Tug 1 (Tug Diesel)	3		8	1008	0
Tug 2 (Tug Diesel)	3		8	1008	0

Criteria Pollutant Emission Factors (lbs/1000 gal)						
Activity	POC	SO2	NOx	CO	PM10	PM2.5
Ship Transit	32.8	210.3	367	56.9	20	8.2
Ship Hoteling IC	32.8	210.3	367	56.9	20	8.2
Boiler Unloading	3.1	315.3	48.2	2.62	19	18.2
Boiler Hoteling	3.1	315.3	20.9	2.62	19	18.2
Tug Transit	13	70.1	571.2	56.9	25	10.2

PM2.5 Emission Factor Unit Conversion					
Engine	Mode	Fuel	Fuel Use (g/kW-hr)	PM2.5 (g/kW-hr)	PM2.5 (lbs/1000 gal)
Aux	All	MDO	217	0.23	7.5
		Residual	227	1.46	45.7
Boiler	All	Residual	305	0.78	18.2
Main	Transit	MDO	200	0.23	8.2
		Residual	204	1.46	50.8
	Maneuvering	MDO	194	0.23	8.4
		Residual	204	1.46	50.8

Emissions (lbs) per ship call					
POC	SO2	NOx	CO	PM10	PM2.5
157.87	1,012.22	1,766.44	273.87	96.26	39.23
105.25	674.81	1,177.63	182.58	64.18	26.16
90.47	1,324.51	977.51	149.99	98.28	20.54
50.78	5,164.61	789.52	42.92	311.22	133.52
13.10	70.66	575.77	57.36	25.20	8.22
13.10	70.66	575.77	57.36	25.20	8.22
430.58	**8,317.47**	**5,862.64**	**764.07**	**620.34**	**235.89**
In Tons:					
0.22	**4.16**	**2.93**	**0.38**	**0.31**	**0.12**
2008 had 85 vessel calls (tons/yr)					
18.30	**353.49**	**249.16**	**32.47**	**26.36**	**10.03**
2008 Avg Tons/Day					
0.05	**0.97**	**0.68**	**0.09**	**0.07**	**0.03**
for 90 vessels:					
19.38	**374.29**	**263.82**	**34.38**	**27.92**	**10.61**

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Attachment D

Emissions Estimation Methodology for Ocean-Going Vessels

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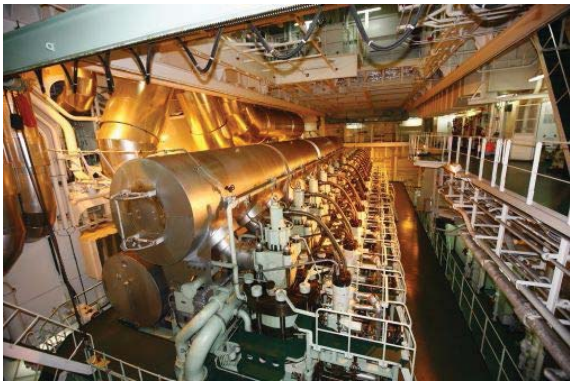
Emissions Estimation Methodology for Ocean-Going Vessels

May 2011



California Air Resources Board
Planning and Technical Support Division

Table II-6: Main Engine Emission Factors – Transit Mode (g/kW-hr)

Engine Speed	Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Slow	Marine Distillate (0.1% S)	0.07	1.10	588	17.0	0.25	0.23	0.78	0.36
Slow	Marine Distillate (0.5% S)	0.07	1.10	588	17.0	0.38	0.35	0.78	1.90
Slow	Heavy Fuel Oil	0.08	1.38	620	18.1	1.50	1.46	0.69	10.50
Medium	Marine Distillate (0.1% S)	0.08	1.10	645	13.2	0.25	0.23	0.65	0.40
Medium	Marine Distillate (0.5% S)	0.08	1.10	645	13.2	0.38	0.35	0.65	2.08
Medium	Heavy Fuel Oil	0.09	1.10	677	14.0	1.50	1.46	0.57	11.50
High	Marine Distillate (0.1% S)	0.08	1.10	645	12.1	0.25	0.23	0.65	0.40
High	Marine Distillate (0.5% S)	0.08	1.10	645	12.1	0.38	0.35	0.65	2.08
High	Heavy Fuel Oil	0.09	1.10	645	12.7	1.50	1.46	0.23	11.50

Table II-7 presents the emission factors for main engines during maneuvering or low load operation near ports.

Table II-7: Main Engine Emission Factors –Maneuvering (g/kW-hr)

Engine Speed	Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Slow	Marine Distillate (0.1% S)	0.07	1.10	588	17.0	0.25	0.23	0.78	0.36
Slow	Marine Distillate (0.5% S)	0.07	1.10	588	17.0	0.38	0.35	0.78	1.90
Slow	Heavy Fuel Oil	0.08	1.38	620	18.1	1.50	1.46	0.69	10.50
Medium	Marine Distillate (0.1% S)	0.08	1.10	645	13.2	0.25	0.23	0.65	0.40
Medium	Marine Distillate (0.5% S)	0.08	1.10	645	13.2	0.38	0.35	0.65	2.08
Medium	Heavy Fuel Oil	0.09	1.10	677	14.0	1.50	1.46	0.57	11.50
High	Marine Distillate (0.1% S)	0.08	1.10	645	12.1	0.25	0.23	0.65	0.40
High	Marine Distillate (0.5% S)	0.08	1.10	645	12.1	0.38	0.35	0.65	2.08
High	Heavy Fuel Oil	0.09	1.10	645	12.7	1.50	1.46	0.23	11.50

Table II-8 presents the emission factors for auxiliary engines, including diesel-electric vessels. As shown in the table, the emission factors for auxiliary engine vary depending on the type of fuel used.

Table II-9 presents the emission factors for auxiliary boilers, which use heavy fuel oil. These emission factors were converted to grams per kilowatt hour from grams per tonne of fuel using methodology developed by Starcrest (Starcrest, 2007a).

Table II-8: Auxiliary Engine Emission Factors – Transit, Maneuvering, and Hotelling (g/kW-hr)

Engine Speed	Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Medium	Marine Distillate (0.1% S)	0.09	1.10	690	13.9	0.25	0.23	0.52	0.40
Medium	Marine Distillate (0.5% S)	0.09	1.10	690	13.9	0.38	0.35	0.52	2.10
Medium	Heavy Fuel Oil	0.09	1.10	722	14.7	1.50	1.46	0.46	11.10

Table II-9: Auxiliary Boiler Emission Factors (g/kW-hr)

Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Heavy Fuel Oil	0.03	0.20	970	2.1	0.80	0.78	0.11	16.50

The emission factors for main engines, auxiliary engines and auxiliary boilers used by ARB staff are generally consistent with the emission factors used by Starcrest in developing the 2005 Port of Los Angeles emissions inventory and the updates done in 2007. The Starcrest emission factors were based on work done by Entec (Entec, 2002). The Entec emission factors were developed using Lloyd's of London and IVL Swedish Environmental Institute data that related emissions to engine speed and the type of fuel used.

ARB staff developed an alternate particulate matter emission factor for engines burning heavy fuel oil based upon an extensive review of emission tests described in scientific literature. This emission factor, set at 1.5 grams/kilowatt-hour, is based upon the use of HFO fuel with 2.5% sulfur content. The basis of this emission factor is fully described in a white paper written by ARB staff in 2007, which is available on the ARB web site (CARB, 2008).

For CO emissions from the main engines during transit, staff elected to use a U.S. EPA emission factor published in the Environ report (Environ, 2007). This emission factor is consistent with the CO emission factors used by Starcrest for the Port of Los Angeles emission inventory (Starcrest, 2005).

6. Fuel Consumption

It was assumed that all main engines and auxiliary boilers burned heavy fuel oil. The main engine assumption was based on the 2005 ARB OGV survey; the auxiliary boiler assumption was based on communications with boiler manufacturers. For auxiliary engines, it was assumed that 92% of cruise ships burned heavy fuel oil and 8% distillate. For all other ships, it was assumed that 71% use heavy fuel oil and 29% use distillate in their auxiliary engines. These data were obtained from the 2005 ARB OGV survey.

Table II-10 Fuel Consumption Rates (g/kW-hr)

Engine	Engine Speed	Mode	Fuel	Fuel Use Rate
Auxiliary	All	All	Marine Distillate	217
	All	All	Residual	227
Boiler	N. A.	All	Residual	305
Main	High	Transit	Residual	213
	Medium	Transit	Marine Distillate	203
	Slow	Transit	Marine Distillate	185
	Medium	Transit	Residual	213
	Slow	Transit	Residual	195
	High	Maneuvering	Residual	213
	Medium	Maneuvering	Marine Distillate	203
	Slow	Maneuvering	Marine Distillate	185
	Medium	Maneuvering	Residual	213
	Slow	Maneuvering	Residual	195

Fuel consumption rates were obtained from Entec (Entec, 2002) and vary by engine, engine speed, and mode of operation. Fuel use rates are expressed in the same units as emission factors; in grams per kilowatt hour. Table II-10 summarizes the fuel consumption rates used.

7. Growth rate

Growth rates were estimated by vessel type and by port. These growth rates were based upon an analysis of US Army Corps of Engineers vessel call data (USACE, 2006) between the years 1994-2005. The total net registered tonnage (NRT), a measure of the volume of cargo a ship can carry, was determined by vessel type and by port. Previous ARB OGV growth rates were based on total installed main engine power determined from vessel call data between the years 1997 and 2003. Growth in NRT is directly proportional to growth in installed power. NRT was used to estimate growth because it was not possible to determine main engine power for many of the records; in contrast, NRT data was available for almost 99% of the records analyzed. The growth rates selected are the midpoint between the best fit compounded annual growth rate in NRT between 1994 through 2005 and the best fit linear (arithmetic) growth rate in NRT for the same time period. The sum of growth of all California ports was set to equal to the statewide growth with the assumption that the ports will grow proportionally to their historical NRT growth between the years 1994-2005.

Growth rates developed using this methodology were checked and verified against other studies, including the Port of Los Angeles and Port of Long Beach emission inventory updates done in 2007 (Starcrest, 2007a and 2007b), the Port of San Diego emission inventory (Starcrest, 2007c), and the Port of Oakland emission inventory (Environ, 2007).

Attachment E

GHG Based on Fuel from BAAQMD Method

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GHG Based on Fuel from BAAQMD Method
EF from CARB May 2011 Appendix D

				GHG EF g/kW-hr				GHG EF $g_{(pollutant)}/g_{(fuel)}$			
Engine	Mode	Fuel	Fuel Use (g/kW-hr)	CH_4	CO_2	N_2O	CO_2e	CH_4	CO_2	N_2O	CO_2e
Aux	All	MDO	217	0.09	690	0.029	700.9234	0.000414747	3.179723502	0.000134286	3.230061751
		Residual	227	0.09	722	0.031	733.5	0.000396476	3.18061674	0.000136564	3.231277533
Boiler	All	Residual	305	0.03	970	0.08	995.43	9.83607E-05	3.180327869	0.000262295	3.263704918
Main	Transit	MDO	200	0.08	645	0.029	655.7134	0.000399334	3.219633943	0.000145458	3.273111814
		Residual	204	0.09	677	0.031	688.5	0.000441176	3.318627451	0.000151961	3.375
	Maneuvering	MDO	194	0.08	644	0.029	654.7134	0.000412371	3.319587629	0.000150206	3.37481134
		Residual	204	0.09	677	0.031	688.5	0.000441176	3.318627451	0.000151961	3.375

Activity	Total Diesel Used (Gal)	Total Fuel Oil Used (Gal)	grams fuel	GHG CO_2e Emissions (metric tons)		
				One Ship	85 Calls	90 Calls
Transit to/from MOT	4813.2	0	15,514,869	50.75	4,313.80	4,567.56
Maneuvering	3208.8	0	10,343,246	34.89	2,965.23	3,139.65
Hoteling Diesel	2520	0	8,122,968	26.22	2,228.83	2,359.94
Hotel Fuel Oil	0	2520	8,122,968	26.23	2,229.67	2,360.83
Boiler Unloading	0	16380	52,799,292	172.22	14,638.29	15,499.37
Tug 1 (Tug Diesel)	1008	0	3,249,187	12.08	1,026.50	1,086.88
Tug 2 (Tug Diesel)	1008	0	3,249,187	12.08	1,026.50	1,086.88
				334.46	28,428.82	30,101.10