Appendix A

Emission Factor Derivations

The following physical constants and standard conditions were utilized to derive the criteria-pollutant emission factors used to calculate criteria pollutant and toxic air contaminant emissions.

standard temperature[a]:	70°F
standard pressure[a]:	14.7 psia
molar volume:	385.3 dscf/lbmol
ambient oxygen concentration:	20.95%
dry flue gas factor[b]:	8535 dscf/MM Btu
natural gas higher heating value:	1030 Btu/dscf

[a]BAAQMD standard conditions per Regulation 1, Section 228.

[b]F-factor is based upon the assumption of complete stoichiometric combustion of natural gas. In effect, it is assumed that all excess air present before combustion is emitted in the exhaust gas stream. Value shown reflects the typical composition and heat content of utility-grade natural gas in San Francisco bay area.

Table A-1 summarizes the regulated air pollutant emission factors that were used to calculate mass emission rates for each source. All units are pounds per million Btu of natural gas fired based upon the high heating value (HHV). All emission factors are after abatement by applicable control equipment.

Table A-1
Controlled Regulated Air Pollutant Emission Factors for
Gas Turbines and HRSGs

Pollutant	Source			
	Gas Turbine		Gas Turbine & HRSG Combined	
	lb/MM Btu	lb/hr	lb/MM Btu	lb/hr
Nitrogen Oxides (as NO_2)	0.00897[a]	16.8	0.00897[a]	20.0
Carbon Monoxide	0.013[b]	24.5	0.013[b]	29.2
Precursor Organic Compounds	0.00255	4.77	0.00250	5.57
Particulate Matter (PM_{10})	0.0059	11	0.00584	13
Sulfur Dioxide	0.00227	5.19	0.00227	6.18

[a]based upon the permit condition emission limit of 2.5 ppmvd NO_x @ 15% O_2 that reflects the use of dry low-NO_x combustors at the CTG, low-NO_x burners at the HRSG, and abatement by the proposed A-11 and A-13 Selective Catalytic Reduction Systems with ammonia injection

[b]based upon the permit condition emission limit of 6 ppmvd CO @ 15% O_2

REGULATED AIR POLLUTANTS

NITROGEN OXIDE EMISSION FACTORS

Combustion Gas Turbine and Heat Recovery Steam Generator Combined

The combined NO_x emissions from the CTG and HRSG will be limited to 2.5 ppmv, dry @ 15% O_2. This emission limit will also apply when the HRSG duct burners are in operation. This concentration is converted to a mass emission factor as follows:

(2.5 ppmvd)(20.95 - 0)/(20.95 - 15) = 8.8 ppmv NO_x, dry @ 0% O_2

$(8.8/10^6)$(1 lbmol/385.3 dscf)(46.01 lb NO_2/lbmol)(8535 dscf/MM Btu)

= **0.00897 lb NO_2/MM Btu**

The NO_x mass emission rate based upon the maximum firing rate of the gas turbine alone is calculated as follows:

(0.00897 lb/MM Btu)(1872 MM Btu/hr) = **16.8 lb NO_x/hr**

The NO_x mass emission rate when duct burner firing occurs is based upon the maximum combined firing rate of the gas turbine and HRSG and is calculated as follows:

(0.00897 lb/MM Btu)(2226.5 MM Btu/hr) = **20.0 lb NO_x/hr**

CARBON MONOXIDE EMISSION FACTORS

Combustion Gas Turbine and Heat Recovery Steam Generator Combined

The combined CO emissions from the CTG and HRSG duct burner will be conditioned to a maximum controlled CO emission limit of 6 ppmv, dry @ 15% O_2 during all operating modes except gas turbine start-up and shutdown. The emission factor corresponding to this emission concentration is calculated as follows:

(6 ppmv)(20.95 - 0)/(20.95 - 15) = 21.13 ppmv, dry @ 0% O_2

$(21.13/10^6)$(lbmol/385.3 dscf)(28 lb CO/lbmol)(8535 dscf/MM Btu)

= **0.013 lb CO/MM Btu**

The CO mass emission rate based upon the maximum firing rate of the gas turbine alone is calculated as follows:

(0.013 lb/MM Btu)(1872 MM Btu/hr) = **24.5 lb CO/hr**

The CO mass emission rate when duct burner firing occurs is based upon the maximum combined firing rate of the CTG and HRSG and is calculated as follows:

(0.013 lb/MM Btu)(2226.5 MM Btu/hr) = **29.2 lb CO/hr**

PRECURSOR ORGANIC COMPOUND (POC) EMISSION FACTORS

Combustion Gas Turbine

General Electric has predicted a maximum POC (non-methane, non-ethane hydrocarbon) emission rate of 4.77 lb/hour for full load operation of the gas turbine alone and 5.57 lb/hr for full load operation of the gas turbine with duct burner firing and steam injection power augmentation. These mass emission rates are derived from the BACT specification for POC of 2 ppmv, dry @ 15% O_2.

This converts to an emission factor as follows:

POC = (4.77 lb/hr)/(1872 MM Btu/hr) = **0.00255 lb/MM Btu**

Converting to a concentration yields:

[(0.00255 lb/MM Btu)(10^6)(385.3 dscf/lbmol)]/[(16 lb CH_4/lb-mol)(8535 dscf/MM Btu)]

= 7.19 ppmvd @ 0% O_2

Converting to 15% O_2:

(7.19 ppmvd)(20.95 – 15)/(20.95) = 2 ppmvd @ 15% O_2

Combustion Gas Turbine and Heat Recovery Steam Generator Combined

General Electric, the turbine vendor, has predicted a maximum POC (non-methane, non-ethane hydrocarbon) emission rate of 5.57 lb/hr for full load operation of the gas turbine with duct burner firing and steam injection power augmentation.

This converts to an emission factor of:

(5.57 lb/hr)/(2226.5 MM Btu/hr) = **0.00250 lb/MM Btu**

Converting to a concentration yields:

[(0.00250 lb/MM Btu)(10^6)(385.3 dscf/lbmol)]/[(16 lb CH_4/lb-mol)(8535 dscf/MM Btu)]

= 7.06 ppmvd @ 0% O_2

Converting to 15% 0_2: (7.06 ppmvd)(20.95 – 15)/(20.95) = 2 ppmvd @ 15% O_2

PARTICULATE MATTER (PM_{10}) EMISSION FACTORS

Combustion Gas Turbine

General Electric has predicted a PM_{10} emission rate of 11 lb/hr at maximum load for the gas turbine. The corresponding PM_{10} emission factor is therefore:

(11 lb PM_{10}/hr)/(1872 MM Btu/hr) = **0.0059 lb PM_{10}/MM Btu**

The following stack data will be used to calculate the grain loading at standard conditions for full load gas turbine operation without duct burner firing to determine compliance with BAAQMD Regulation 6-310.3.

PM_{10} mass emission rate:	11 lb/hr
flow rate:	1,044,947 acfm @ 12.54% O_2 and 195^oF
moisture content:	7.75 % by volume

Converting flow rate to standard conditions (dry, 70°F):

(1,044,947 acfm)(70 + 460 ^oR/195 + 460 ^oR)(1 – 0.0775) = 780,007 dscfm

Converting to grains/dscf:

(11 lb PM_{10}/hr)(1 hr/60 min)(7000 gr/lb)/(780,007 dscfm) = 0.0016 gr/dscf

Converting to 6% O_2 basis:

(0.0016 gr/dscf)[(20.95 - 6)/(20.95 – 12.54)] = 0.0028 gr/dscf @ 6% O_2

Combustion Gas Turbine and HRSG Combined

The PM_{10} emission factor is based upon the General Electric vendor prediction of 13 lb/hr at the maximum combined firing rate of 2226.5 MM Btu/hr during duct burner firing and steam injection power augmentation. The corresponding PM_{10} emission factor is therefore:

(13 lb PM_{10}/hr)/(2226.5 MM Btu/hr) = **0.00584 lb PM_{10}/MM Btu**

It is assumed that this PM_{10} emission factor includes secondary PM_{10} formation of particulate sulfates.

The following stack data will be used to calculate the grain loading for simultaneous CTG and HRSG operation at standard conditions to determine compliance with BAAQMD Regulation 6-310.3.

PM_{10} mass emission rate:	13 lb/hr
typical flow rate:	1,008,429 acfm @ 9.54 % O_2 and 184 ^oF
typical moisture content:	15.96% by volume

Converting flow rate to standard conditions:

(1,008,429 acfm)(70 + 460 ^oR/184 + 460 ^oR)(1 - 0.1596) = 697,463 dscfm

Converting to grains/dscf:

(13 lb PM_{10}/hr)(1 hr/60 min)(7000 gr/lb)/(697,463 dscfm) = 0.002 gr/dscf

Converting to 6% O_2 basis:

(0.002 gr/dscf)[(20.95 - 6)/(20.95 – 15.96)] = 0.007 gr/dscf @ 6% O_2

SULFUR DIOXIDE EMISSION FACTORS

Combustion Gas Turbine & Heat Recovery Steam Generator

The SO_2 emission factor is based upon an expected maximum natural gas sulfur content of 1.0 grains per 100 scf and a higher heating value of 1030 Btu/scf as specified by PG&E.

The sulfur emission factor is calculated as follows:

(1 gr/100scf)(10^6 Btu/MM Btu)(2 lb SO_2/lb S)/[(7000 gr/lb)(1030 Btu/scf)(100 scf)]

= **0.00277 lb SO_2/MM Btu**

The corresponding SO_2 mass emission rate at the maximum gas turbine firing rate of 1872 MM Btu/hr is:

(0.00277 lb SO_2/MM Btu)(1872 MM Btu/hr) = 5.19 lb/hr

The corresponding mass SO_2 emission rate at the maximum combined firing rate of 2226.5 MM Btu/hr is:

(0.00277 lb SO_2/MM Btu)(2226.5 MM Btu/hr) = 6.18 lb/hr

This is converted to an emission concentration as follows:

(0.00277 lb SO_2/MM Btu)(385.3 dscf/lb-mol)(lb-mol/64.06 lb SO_2)(10^6 Btu/8535 dscf)

= 1.95 ppmvd SO_2 @ 0% O_2

which is equivalent to:

(1.95 ppmvd)(20.95 - 15)/20.95 = 0.55 ppmv SO_2, dry @ 15% O_2

Toxic Air Contaminants

The following toxic air contaminant emission factors were used to calculate worst-case emissions rates used for air pollutant dispersion models that estimate the resulting increased health risk to the maximally exposed population. To ensure that the risk is properly assessed, the emission factors are conservative and may overestimate actual emissions.

Table A-2
TAC Emission Factors[a] for Gas Turbines and HRSG Duct Burners

Contaminant	Emission Factor (lb/MM scf)
Acetaldehyde[c]	6.86E-02
Acrolein	2.37E-03
Ammonia[b]	13.7
Benzene[c]	1.36E-02
1,3-Butadiene[c]	1.27E-04
Ethylbenzene	1.8E-02
Formaldehyde[c]	1.10E-01
Hexane	5.28E-01
Naphthalene	1.7E-03
PAHs[c]	1.0E-03
Propylene	1.05
Propylene Oxide[c]	4.78E-02
Toluene	7.26E-02
Xylene	2.89E-02

[a]California Air Toxics Emission Factors (CATEF) Database as compiled by California Air Resources Board under the Air Toxics Hotspot Program or Ventura County APCD (VCAPCD, 1995). The Hexane emission factor has been adjusted to yield an emission rate of 10 tons/year. See discussion below.

[b]based upon maximum allowable ammonia slip of 10 ppmv, dry @ 15% O_2 for A-11 and A-13 SCR Systems

[c]carcinogenic compound

The applicant used an emission factor over three times higher than the one in Table A-2. This was considered to be too high because the source tests this emission factor was derived from are from three gas turbines that were tested in Ventura County in 1994. A review of these tests disclosed that in all cases Hexane was non-detect (below the instrument range). The emission factor was apparently calculated assuming the detection limit as the concentration. This was a very conservative approach and can be expected to overstate the emissions. The applicant is confident hexane emissions are less than

10 tons/year and has agreed to a Permit Condition with that limit. The level of hexane emissions will be verified by source test.

It should be noted that the ammonia emission factor shown here is twice what is expected because it is based on the originally proposed concentration of 10 ppmvd and the applicant has agreed to operate with an ammonia concentration no more than 5 ppmvd.

Table A-3
TAC Emission Factors for 10-Cell Cooling Tower

Toxic Air Contaminant	Maximum Concentration in Cooling Tower Return Water (ug/L)	Emission Factor[a] Per Cell (g/sec)
Arsenic[b]	5.71	2.27E-08
Beryllium	15	5.96E-08
Cadmium[b]	0.03	1.19R-10
Trivalent chromium[b]	6.66	2.65E-08
Copper	8.82	3.51E-08
Lead[b]	1.25	4.97E-09
Manganese	54.33	2.16E-07
Mercury	0.03	1.19E-10
Nickel	8.28	3.29E-08
Selenium	0.9	3.58E-09
Zinc	6.3	2.50E-08

[a]based upon maximum drift rate of 0.0005% and operation of cooling tower at maximum flow rate of 125,000 gallons per minute; for example:

Cu = (8.82 ug/L)(0.000005)(12,500 gal/min)(3.785 L/gal)/[(60 sec/min)(1E06 ug/g)]
= 3.51E-07 g/sec

[b]carcinogenic compound

AMMONIA EMISSION FACTOR

Combustion Gas Turbine & Heat Recovery Steam Generator

Each Gas Turbine/HRSG power train will exhaust through a common stack and be subject to a maximum ammonia exhaust concentration limit of 10 ppmvd @ 15% O_2.

(10 ppmvd)(20.95 - 0)/(20.95 - 15) = 35.2 ppmv NH_3, dry @ 0% O_2

$(35.2/10^6)$(1 lbmol/385.3 dscf)(17 lb NO_2/lbmol)(8535 dscf/MM Btu)

= **0.0133 lb NH_3/MM Btu**

The NH_3 mass emission rate based upon the maximum firing rate of the gas turbine alone is calculated as follows:

(0.0133 lb/MM Btu)(1872 MM Btu/hr) = **34.8 lb NO_x/hr**

The NH_3 mass emission rate when duct burner firing occurs is based upon the maximum combined firing rate of the gas turbine and HRSG and is calculated as follows:

(0.0133 lb/MM Btu)(2226.5 MM Btu/hr) = **29.5 lb NO_x/hr**