

Appendix B

Emission Calculations

Individual and combined heat input rate limits for the Gas turbines, HRSGs, and Fuel Heater are given below in **Table B-1**. These are the basis of permit conditions limiting heat input rates.

Table B-1 Maximum Allowable Heat Input Rates

Source	MM Btu/hour-source	MM Btu/day-source	MM Btu/year-source
S-41 and S-43 Gas Turbines, each	1791	42,984 ^a	15,689,160 ^b
S-41 CTG and S-42 HRSG, each S-43 CTG and S-44 HRSG, each	2226.5 ^c	49,950 ^d	17,440,000 ^e
S-45 Fuel Heater	12	72	

^abased upon specified maximum rated heat input of 1791MM Btu/hr and 24 hour per day operation

^bbased upon 8,760 hours of operation at full load (1791 MM Btu/hr)

^cmaximum combined firing rate for gas turbine and HRSG duct burners

^dbased upon maximum duct burner firing of 16 hours per day; calculated as:

$$(16 \text{ hr/day})(2,226.5 \text{ MM Btu/hr}) + (8 \text{ hr/day})(1791 \text{ MM Btu/hr}) = 49,950 \text{ MM Btu/day}$$

^ebased upon maximum annual duct burner firing of 4,313 hr/year-HRSG, 4,303 hr/yr gas turbine full load and 144 hr/yr of startup at one-half full load fuel rate (896 MM Btu/hr); calculated as:

$$(4,313 \text{ hr/yr})(2,226.5 \text{ MM Btu/hr}) + (4,303 \text{ hr/yr})(1,791 \text{ MM Btu/hr}) + (144 \text{ hr/yr})(896 \text{ MM Btu/day}) = 17,440,000 \text{ MM Btu/year}$$

Table B-2 Maximum Annual Facility Emissions from Permitted Sources (ton/yr)

Source	NO ₂	CO	POC	PM ₁₀	SO ₂
S-41 Gas Turbine and S-42 HRSG ^a	87.1	129.5	23.3	52.5	24.2
S-43 Gas Turbine and S-44 HRSG ^a	87.1	129.5	23.3	52.5	24.2
S-45 Fuel Heater	0.05	0.02	0.02	0.01	0.003
S-46 Cooling Tower				7.5	
Total Permitted Emissions	174.3	259.1	46.6	112.2	48.5

^aincludes gas turbine start-up and shutdown emissions

B-1.0 Gas Turbine Start-Up and Shutdown Emission Rate Calculations

The maximum nitrogen oxide, carbon monoxide, and precursor organic compound emission rates from a gas turbine occur during start-up and shutdown periods. The PM₁₀, sulfur dioxide, ammonia, and toxic compound emissions are a function of fuel use rate only and do not exceed typical full load emission rates during start-up.

**Table B-3 Gas Turbine Start-Up Emission Rates
(lb/start-up)**

Pollutant	Cold Start-Up ^a	Hot Start-Up ^b
NO _x (as NO ₂)	452	189
CO	990	291
POC	109	26
PM ₁₀	47	17
SO _x (as SO ₂)	14	5

^acold start not to exceed 256 min.

^bhot start not to exceed 90 min.

Shutdown emissions for NO_x, CO, and POC are presented in Table B-4. These emissions have been predicted by General Electric for a shutdown of 23 min. duration.

**Table B-4 Gas Turbine Shutdown Emission Rates
(lbs)**

Pollutant	Shutdown Emissions
NO _x	59
CO	73
POC	6

Hot Start-Up Emission Rate Calculations

- Maximum duration: 90 min.

NITROGEN OXIDES (as NO₂)

Maximum NO_x emission rate: 164 lb/hr

Total NO₂ = 189 lb/hot start

CARBON MONOXIDE

Maximum CO emission rate: 268 lb/hr

Total CO = 291 lb/hot start

PRECURSOR ORGANIC COMPOUNDS

Total POC = 26.2 lb/hot start

PARTICULATE MATTER (as PM₁₀)

- PM₁₀ emissions are not increased during start-up
- PM₁₀ emission factor based upon full load operation (emission rate of 11 lb/hr)

Total PM₁₀ = 16.5 lb PM₁₀/ hot start

SULFUR DIOXIDE

- SO₂ emissions are not increased during start-up

Total SO₂ = 4.9 lb SO₂/hot start

Cold Start-Up Emission Rate Calculations

- Maximum duration: 256 min.

NITROGEN OXIDES (as NO₂)

Maximum NO_x emission rate: 170 lb/hr

Total NO₂ = 452 lb/cold start

CARBON MONOXIDE

Maximum CO emission rate: 541 lb/hr

Total CO = 990 lb/cold start

PRECURSOR ORGANIC COMPOUNDS

Total POC = 109 lb/cold start

PARTICULATE MATTER (as PM₁₀)

- PM₁₀ emissions are not increased during start-up
- PM₁₀ emission rate during start-up equals maximum baseload emission rate of 11 lb/hr

Total PM₁₀ = 47 lb PM₁₀/cold start

SULFUR DIOXIDE

- SO₂ emissions are not increased during start-up

Total SO₂ = 14 lb SO₂/cold start

B-2.0 Worst-Case Operating Scenarios and Regulated Air Pollutant Emissions for Gas Turbines, HRSGs, Fuel Heater and Cooling Tower.

The Gas Turbine/HRSG emission rates shown in **Table B-5** are the basis of permit condition limits and emission offset requirements and were also used as inputs for the ambient air quality impact analysis. To provide maximum operational flexibility, no limitations will be imposed on the type or quantity of turbine start-ups. Instead, the facility must comply with rolling consecutive twelve month mass emission limits at all times. The mass emission limits are based upon the emission estimates calculated for the following power plant operating envelope:

- 4,304 hours of baseload (100% load) operation per year for each gas turbine
- 4,313 hours of duct burner firing per HRSG per year with steam injection power augmentation at gas turbine combustors
- 42 hot start-ups per gas turbine per year (90 min. each)
- 14 cold start-ups per gas turbine per year (256 min. each)
- 56 shutdowns per gas turbine (23 Min. each)

Table B-5 Maximum Annual Regulated Air Pollutant Emissions for Gas Turbines, HRSGs, Fuel Heater and Cooling Tower

Source (Operating Mode)	NO ₂ (lb/yr)	CO (lb/yr)	POC (lb/yr)	PM ₁₀ (lb/yr)	SO ₂ (lb/yr)
S-41 & S-43 Gas Turbines (83 total, 90 min. hot start-ups)	15,679	24,135	2,175	1,320	403
S-41 & S-43 Gas Turbines (28 total, 256 min. cold start-ups)	12,658	27,727	3,054	1,314	386
S-41 & S-43 Gas Turbines (8,608 total hours ^a @ 100% load)	141,085 ^b	206,162 ^b	39,252 ^b	94,688	42,782
S-41 & S-43 Gas Turbines and S-42 & S-44 HRSGs (8,626 total hours ^a w/duct burner firing and steam injection power augmentation)	172,520 ^c	252,052 ^c	48,047 ^c	112,138	53,304
S-41 & S-43 Gas Turbines (111 total, 23 min. shutdowns)	6,527	8,087	629	468	138
S-45 Fuel Heater	91	31	38	18	7
S-46 Cooling Tower				14,405	
Total Emissions (lb/yr)	348,560	518,193	93,195	224,333	97,020
(ton/yr)	174.3	259.1	46.6	112.2	48.5

^atotal combined firing hours for both turbines

^bbased upon the heat input rate of 1,791 MM Btu/hr for each gas turbine

^cbased upon the maximum combined heat input rate of 2,226.5 MM Btu/hr for each CTG/HRSG power train

B-3.0 Cooling Tower PM₁₀ Emissions

It is conservatively assumed that all particulate matter will be emitted as PM₁₀.

Cooling tower circulation rate: 125,000 gpm
maximum total dissolved solids: 5666 ppm
Drift Rate: 0.0005 %

Water mass flow rate:

$$(125,000 \text{ gal/min})(60 \text{ min/hr})(8.34 \text{ lb/gal}) = 62,550,000 \text{ lb/hr}$$

Cooling Tower Drift:

$$(62,550,000 \text{ lb/hr})(0.000005) = 312.8 \text{ lb/hr}$$

$$\begin{aligned} \text{PM}_{10} &= (5666 \text{ ppm})(312.8 \text{ lb/hr})/(10^6) \\ &= 1.772 \text{ lb/hr} \\ &= 42.5 \text{ lb/day} \quad (24 \text{ hr/day operation}) \\ &= 14,927 \text{ lb/yr} \quad (8,424 \text{ operating hours per year}) \\ &= \mathbf{7.46 \text{ ton/yr}} \end{aligned}$$

B-4.0 Worst-Case Toxic Air Contaminant (TAC) Emissions

The maximum toxic air contaminant emissions resulting from the combustion of natural gas at the S-41 & S-43 Gas Turbines, S-42 & S-44 HRSGs, S-46 Cooling Tower and S-45 Fuel Heater are summarized in **Table B-6**. These emission rates were used as input data for the health risk assessment modeling and are based upon a maximum annual heat input rate of 19,507,293 MM Btu per year (18,939 MM scf/yr based upon a fuel HHV of 1030 Btu/scf) for each gas turbine/HRSG pair. The derivation of the emission factors is detailed in Appendix A.

Table B-6 Contra Costa Power Plant, Unit #8 – Emissions (Revised 1/19/01)

Pollutant	Gas Turbine (including duct burner)					Cooling Tower		Fuel Preheater					HAPS
	Emission Factors, lbs/MMscf				Emiss. Rate per turbine, g/s (4)	Water Conc. ug/L	Emiss. Rate per cell, g/s (5)	Emission Factors, lb/MMscf			Emission Rate, g/s (6)		Annual Total (T/yr)
	CATEF (1)	Ventura County (2)	AP-42, Sup. F (3)	Used in Analysis (7)				CATEF (1)	AP-42, Sup. D	Used in Analysis	Max. 1-hr.	Annual ave.	
Acetaldehyde	6.86E-02			6.86E-02	1.87E-02			8.87E-03		8.87E-03	1.29E-05	3.60E-07	1.30
Acrolein	2.37E-02			2.37E-02	6.46E-03								0.45
Ammonia					3.73E+00								
Arsenic						5.71	2.27E-08		2.00E-04	2.00E-04	2.92E-07	8.12E-09	
Benzene	1.36E-02			1.36E-02	3.70E-03			4.31E-03	2.10E-03	4.31E-03	6.28E-06	1.75E-07	0.26
Beryllium						15	5.96E-08		1.20E-05	1.20E-05	1.75E-08	4.87E-10	
Butadiene-1,3	1.27E-04			1.27E-04	3.46E-05								0.00
Cadmium						0.03	1.19E-10		1.10E-03	1.10E-03	1.60E-06	4.47E-08	
Chromium VI						6.66	2.65E-08		1.40E-03	1.40E-03	2.04E-06	5.69E-08	
Copper						8.82	3.51E-08		8.50E-04	8.50E-04	1.24E-06	3.45E-08	
Ethylbenzene	1.79E-02			1.79E-02	4.88E-03								0.34
Formaldehyde	1.10E-01			1.10E-01	3.00E-02			2.21E-01	7.50E-02	2.21E-01	3.22E-04	8.98E-06	2.08
Hexane	2.59E-01	1.75E+00		5.28E-01	1.44E-01				1.80E+00	1.80E+00	2.62E-03	7.31E-05	10.00
Lead						1.25	4.97E-09						
Manganese						54.33	2.16E-07		3.80E-04	3.80E-04	5.54E-07	1.54E-08	
Mercury						0.03	1.19E-10		2.60E-04	2.60E-04	3.79E-07	1.06E-08	
Naphthalene	1.66E-03			1.66E-03	4.53E-04				6.10E-04	6.10E-04	8.89E-07	2.48E-08	0.03
Nickel						8.28	3.29E-08		2.10E-03	2.10E-03	3.06E-06	8.53E-08	
PAHs, Total	1.06E-04	1.00E-03		1.00E-03	2.72E-04				9.60E-06	9.60E-06	1.40E-08	3.90E-10	0.02
Propylene	7.71E-01	1.05E+00		1.05E+00	2.87E-01								
Propylene Oxide	4.78E-02			4.78E-02	1.30E-02								0.90
Selenium						0.9	3.58E-09		2.40E-05	2.40E-05	3.50E-08	9.75E-10	
Toluene	7.10E-02	7.26E-02		7.26E-02	1.98E-02				3.40E-03	3.40E-03	4.96E-06	1.38E-07	1.37
Xylene (Total)	2.61E-02	2.89E-02		2.89E-02	7.87E-03								0.55
Zinc						6.3	2.50E-08		2.90E-02	2.90E-02	4.23E-05	1.18E-06	

HAPS Total 17.3

(1) CARB's CATEF Version 1.2 Database emission factors, mean values

(2) Ventura County APCD emission factors for gas turbines (1995) reported by the applicant in Appendix I, Public Health Data

(3) Natural gas heat value used to convert units = 1030 Btu/scf

(4) Both annual average and maximum one-hour emission rates are based on the max. turbine fuel use rate = 2.162 MMscf/hr

The ammonia emission rate is estimated by the applicant based on both gas turbines operating at 100 percent load with supplemental firing and 10 ppm slip (15% O2).

Maximum ammonia emissions are = 259,121 lbs/yr per turbine.

(5) Both annual average and maximum one-hour emission rates are based on the max. cooling tower drift rate = 0.63 gal/min

(6) Fuel preheater max. fuel usage = 11.92 MMBtu/hr; Total number of hours per year = 244

(7) Hexane emission factor adjusted to conform to 10 ton/year conditon limit.

B-5.0 Maximum Facility Emissions

The maximum annual facility regulated air pollutant emissions for the proposed gas turbines and HRSGs have been shown in **Table B-5**. The total permitted emission rates shown are the basis of permit condition limits and emission offset requirements, if applicable.

Table B-7
Maximum Hourly and Daily Regulated
Air Pollutant Emission Rates for Baseload Operation
(Excluding Gas Turbine Start-up Emissions)

	NO ₂	CO	POC	PM ₁₀	SO ₂
S-41 and S-43 Gas Turbines ^a					
lb/hr-source	17.1	25.1	4.8	11.0	5.2
lb/day-source	420	602	115	264	125
S-41 & S-42 and S-43 & S-44 Gas Turbine/HRSG Power Train ^b					
lb/hr-power train	20.0	29.2	5.6	13.0	6.1
lb/day-power train	457	668	128	296	141

^abased upon maximum heat input rate of 1872 MM Btu/hr for each gas turbine

^bBased upon a maximum combined heat input rate for each gas turbine/HRSG power train of 2,226.5 MM Btu/hr and maximum 16 hours per day duct burner firing

The maximum daily regulated air pollutant emissions per source including gas turbine start-up emissions are shown in **Table B-8**.

Table B-8
Maximum Daily Regulated Air Pollutant Emissions per
Power Train (lb/day)

Source (operating mode)	NO ₂	CO	POC	PM ₁₀	SO ₂
Gas Turbine (Cold Start-up)	425	990	109	55	26
Gas Turbine (Full load w/o Duct Burner Firing)	36	53	10	29	14
Gas Turbine & HRSG (Full load w/Duct Burner Firing and steam injection power augmentation)	320	468	89	208	99
Gas Turbine (Hot Start-up)	189	291	26	20	9
Total	997	1802	234	312	148

^abased upon one 90 min. hot start-up, one 256 min. cold start-up, 16 hours of full load operation with duct burner firing @ 2,226.5 MM Btu/hr with steam injection power augmentation, and 2.2 hours of full load operation without duct burner firing at 1791 MM Btu/hr over a 24 hour period. These are the basis of permit condition daily mass emission limits.

B-6.0 Modeling Emission Rates

The NO₂ emission rates shown in **Table B-9** were used to model the air quality impacts of the CCPP-Unit 8 to determine compliance with State and Federal annual ambient air quality standards for NO₂, CO, SO₂ and PM₁₀. A screening impact analysis of gas turbine/HRSG duct burner emission rates and stack gas characteristics revealed that the worst-case impacts occur under the equipment operating scenarios listed.

Table B-9
Emission rates used in modeling analysis (lb/hr)

Pollutant Source	Max (1-hour)	Commissioning ^a (1-hour)	Maximum (3-hour)	Maximum (8-hour)	Maximum (24-hour)	Maximum Annual Average	
NO _x	Turbine 1	169.7 ^b	169.7 ^b	n/a	n/a	n/a	21.6
	Turbine 2	19.7	197 ^c				21.6
	Fuel Gas Preheater	0.45	0.45				0.01
	Cooling Tower	---	---				---
CO	Turbine 1	547 ^b	547 ^b	n/a	145.1	n/a	n/a
	Turbine 2	28.7	287 ^c		15.9		
	Fuel Gas Preheater	0.05	0.15		0.15		
	Cooling Tower	---	---		---		
SO ₂	Turbine 1	6.2	6.2	6.2	n/a	6.2	6.2
	Turbine 2	6.2	6.2	6.2		6.2	6.2
	Fuel Gas Preheater	0.03	0.03	0.03		0.03	0.03
	Cooling Tower	---	---	---		---	---
PM ₁₀	Turbine 1	n/a	n/a	n/a	n/a	11.0	12.0
	Turbine 2					11.0	12.0
	Fuel Gas Preheater					0.09	0.002
	Cooling Tower					1.8	1.7

^aCommissioning is the original startup of the turbines and only occurs during the initial operation of the equipment after installation.

^bTurbine 1 in Cold Startup.

^cCommissioning emissions for SCR and CO Oxidation Systems increased by factor of 10.