Exploration and Production Emission Calculator II (EPEC II) User's Guide

API PUBLICATION 4661
SECOND EDITION, JANUARY 2007

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Exploration and Production Emission Calculator II (EPEC II) User's Guide

Regulatory and Scientific Affairs Department

API PUBLICATION 4661
SECOND EDITION, JANUARY 2007

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Washington, D.C.

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1. INTRODUCTION

The Exploration and Production Emission Calculator Version 2.0 (EPEC II) is a software tool that can be used to estimate emissions for exploration and production (E&P) facilities. EPEC II integrates user inputs, emission calculations, and data summaries for many equipment types common to E&P facilities. The calculation techniques and emission factors utilized by the EPEC II software were, in most cases, established by the U.S. Environmental Protection Agency (EPA), the American Petroleum Institute (API), and the Gas Research Institute (GRI). Published references that provide background information for the calculation methods used in EPEC II are given for each equipment type in both the software and in each section of this User's Guide. EPEC II can be used to estimate emissions of criteria pollutants (carbon monoxide [CO], nitrogen oxides [NO_x], sulfur oxides [SO_x], particulate matter under 10 μm [PM_{10}], and volatile organic compounds [VOCs]), hydrogen sulfide (H_2S), greenhouse gases (GHGs—carbon dioxide [CO_2], methane, and ethane), and hazardous air pollutants (HAPs), such as benzene, toluene, ethylbenzene, xylenes, 1,3-butadiene, n-hexane, 2,2,4-trimethylpentane, formaldehyde, and acetaldehyde. The types of equipment addressed by the EPEC II software include amine units, cooling towers, diesel/gasoline internal combustion (IC) engines, external combustion emission units, fixed-roof storage tanks, flares, fugitive emissions, glycol dehydrators, loading operations, natural gas engines, natural gas turbines, and vents. The user also has the flexibility to include emissions from additional equipment types, or to use alternative means to calculate emissions.

1.1 PRINCIPLES OF USE AND SYSTEM REQUIREMENTS

EPEC II operates as a stand-alone program under the Microsoft® Windows 95/NT™ operating environment. At a minimum, a 486DX2 Windows 95 platform with 16 Mbyte RAM and 30 Mbytes of available hard disk storage space is needed to operate the EPEC II. The EPEC II user should possess a modest familiarity with the Windows operating environment and should understand a few of its common features, such as point-and-click, copy-and-paste, and text editing. EPEC II accepts user inputs, calculates emissions, generates emissions summaries as text files, and saves any user-input data and calculated results to a Microsoft Access™ data file. As an alternative to using EPEC II's text file reports, users can take advantage of Access's automated report generation features to create customized reports.

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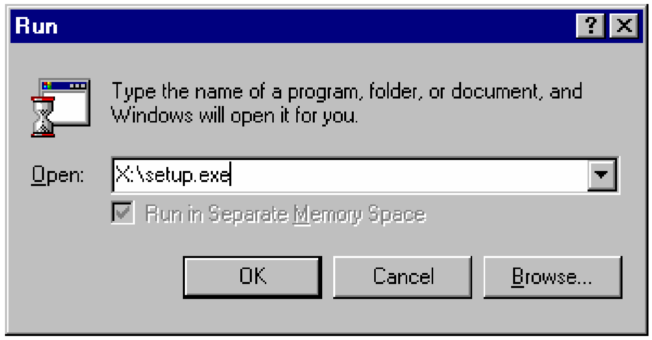
1.2 INSTALLATION

The EPEC II distribution pack includes this User's Guide and an Installation Disk. Complete the following steps to install EPEC II:



1. Insert the Installation Disk into the x:\ compact disk (CD) drive (where "x" is the CD drive).
2. Click Start from the Windows Taskbar, then select Run....
3. Type x:\setup and click OK.
4. Follow the instructions that appear on each successive screen: (1) close down any programs that may running; (2) select the destination directory where the program files will be installed; and (3) provide a name for the program group where a shortcut to EPEC II will be placed on the Windows taskbar.
5. Remove the Installation Disk from the CD drive. Store the Installation Disk in a safe place.

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2. USING EPEC II

2.1 STARTING EPEC II AND CREATING A NEW FACILITY DATA FILE

To start EPEC II, click Start from the Windows taskbar, then select Programs ▸ | EPEC II. Upon starting EPEC II, the Welcome screen will appear (**Figure 2-1**).

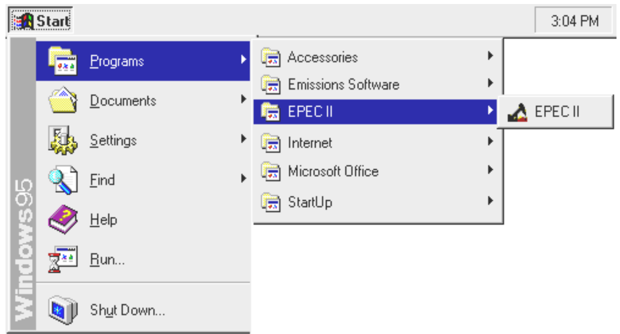

Figure 2-1. EPEC Welcome screen.

On the Welcome screen, click ⦿Create a new facility and OK. Enter the name of a file that will store the new facility's data and click Save. The General Facility Information screen will appear (**Figure 2-2**).

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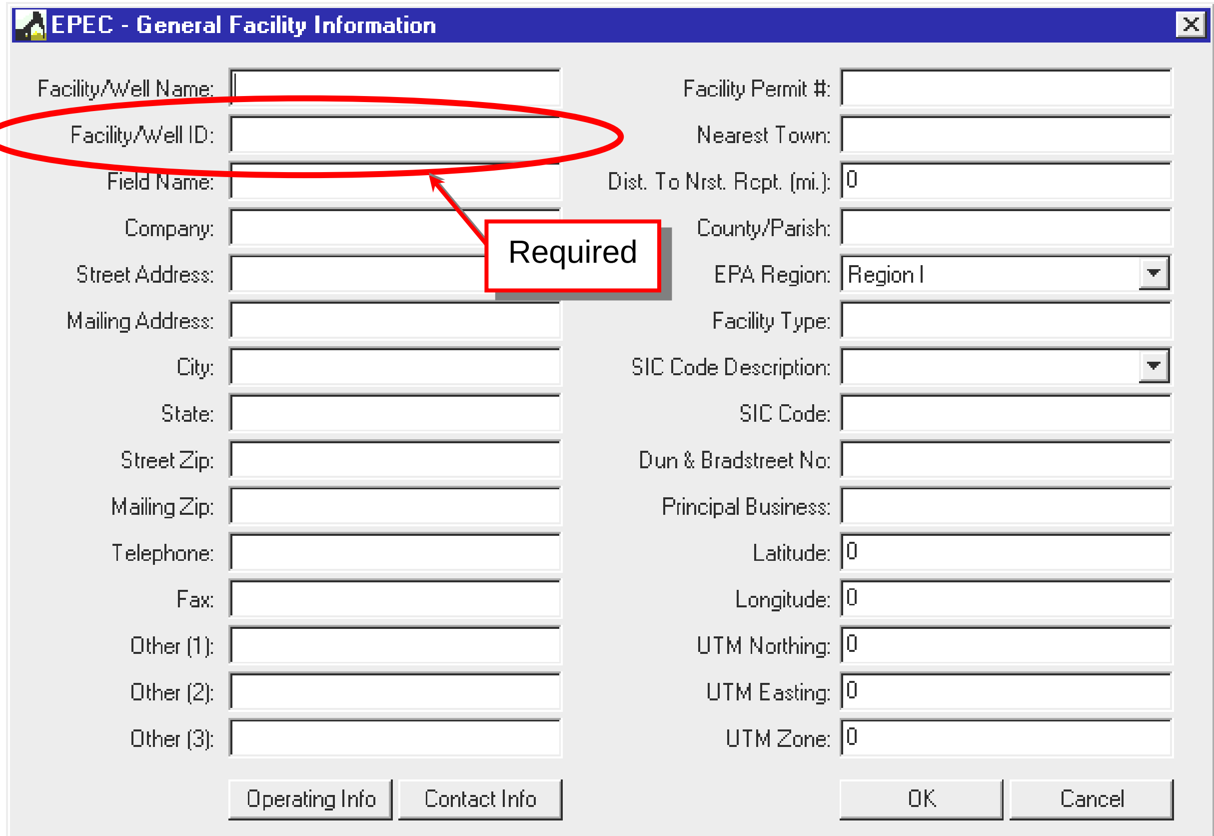

Figure 2-2. General Facility Information screen.

On the General Facility Information screen, enter any desired descriptive information and click OK. (Note that the Facility/Well ID is required.) The EPEC Control Panel will appear (**Figure 2-3**).

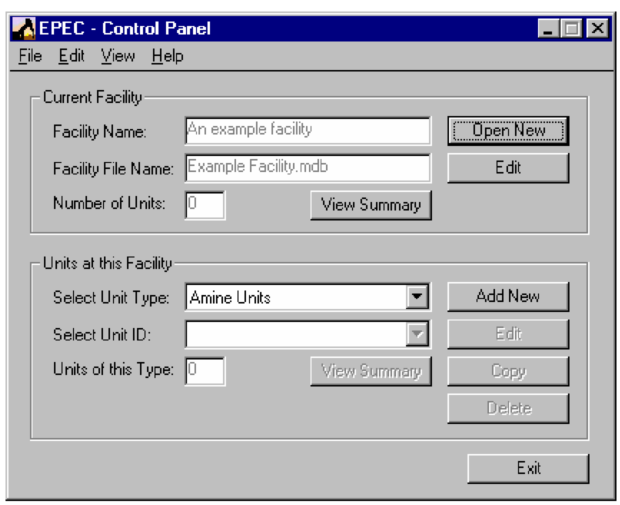

Figure 2-3. EPEC Control Panel.

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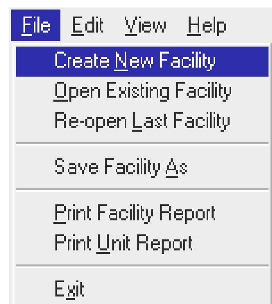
From the EPEC Control Panel, the EPEC user may perform the following tasks.

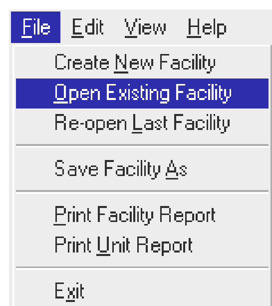
- Create new or open existing facility data files.
- Save the current facility data file under a different file name.
- Edit general information for the current facility.
- Create new, edit existing, copy, or delete equipment units for the current facility.
- View and print emissions summary reports for facilities or equipment units.
- Exit EPEC II.

2.2 WORKING WITH FACILITIES

2.2.1 Create a New Facility

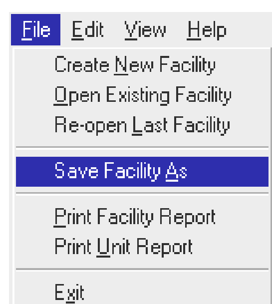


Select File | Create New Facility from the Control Panel menu. Enter a file name where the new facility's data will be stored and click Save. The General Facility Information screen will appear (Figure 2-2). On the General Facility Information screen, enter any desired descriptive information and click OK. (Note that the Facility/Well ID is required.) The EPEC Control Panel will appear with the new facility's file name identified as current.



2.2.2 Open an Existing Facility

Select File | Open Existing Facility from the Control Panel menu. Select the file name where the facility's data was previously stored and click Open. The EPEC Control Panel will reappear with the selected facility's file name identified as current.



2.2.3 Save the Current Facility Under a New File Name

Select File | Save Facility As from the Control Panel menu. Enter a file name where the facility's data will be stored and click Save. The EPEC Control Panel will reappear with the new file name identified as current.

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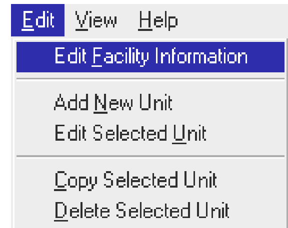
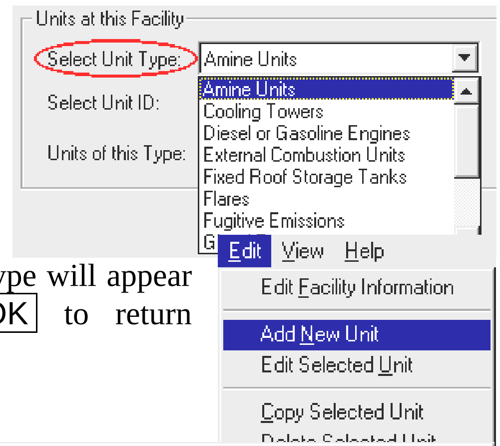
2.2.4 Edit General Information for the Current Facility



Select Edit | Edit Facility Information from the Control Panel menu. The General Facility Information screen will appear (Figure 2-2). On the General Facility Information screen, enter or change any descriptive information and click OK. (Note that the Facility/Well ID is required.)

2.3 WORKING WITH EQUIPMENT UNITS

2.3.1 Adding New Equipment Units to the Current Facility



First, a facility must be created or opened from an existing file (see Section 2.2). Select the type of new equipment to be added from the Select Unit Type drop-list on the Control Panel.

From the Control Panel menu, select Edit | Add New Unit. The data entry screen for the selected equipment type will appear (**Figure 2-4**). Enter the information and click OK to return to the Control Panel. (Note that the Unit ID is required.)

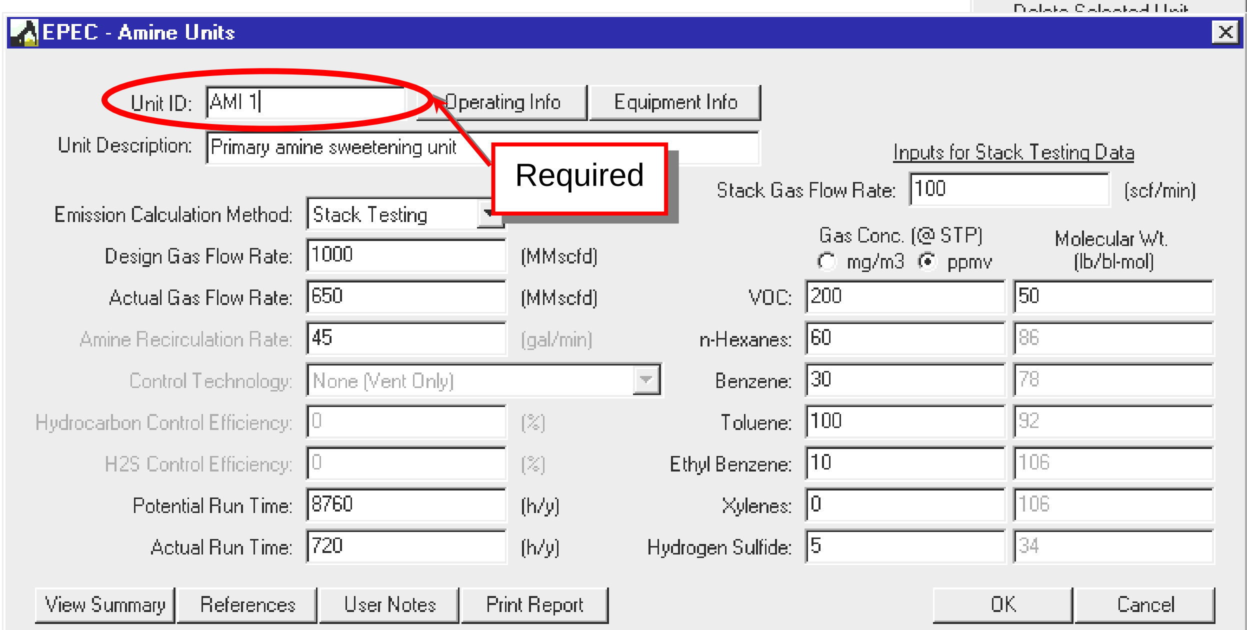


Figure 2-4. Data entry screen for an amine gas sweetening unit.

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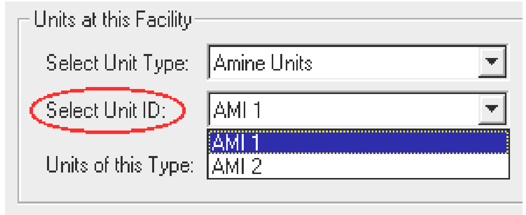
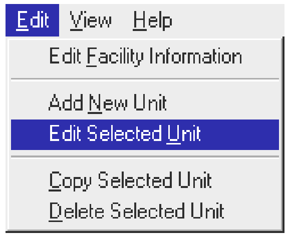
2.3.2 Editing Existing Equipment Units

Select the type of equipment to be edited from the Select Unit Type drop-list on the Control Panel. Then, select the unit to be edited from the Select Unit ID drop-list.



From the Control Panel menu, select Edit | Edit Selected Unit. The data entry screen for the selected equipment unit will appear. Enter or change the existing data and click OK to return to the Control Panel.



2.3.3 Selecting Alternative Emission Factors

Within EPEC II, the user may enter or select alternative emission factors for use in estimating emissions from the following equipment types.

- Cooling towers
- Diesel/gasoline engines
- External combustion units
- Flares
- Natural gas engines
- Natural gas turbines

For each of these equipment types, EPEC II determines which emission factors are applicable from parameters entered on the equipment data entry screen. For example, the determining parameters for diesel/gasoline engines are Fuel Type, Emission Factor Units, Make, and Model. Click the Emission Factors button to display and edit currently selected emission factors (**Figure 2-5**). EPEC II defaults to emission factors that are published in the EPA's document, *Compilation of Air Pollutant Emission Factors (AP-42)*, where available. If none are published in *AP-42*, EPEC II defaults to factors published by the Gas Research Institute or provided by engine manufacturers.

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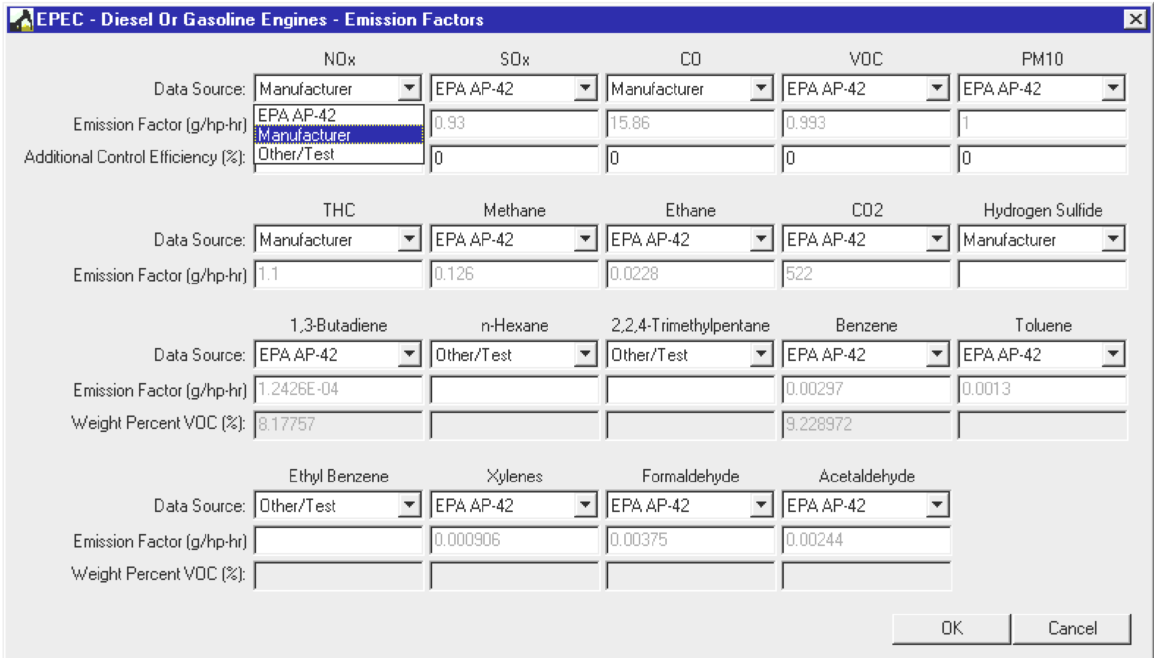
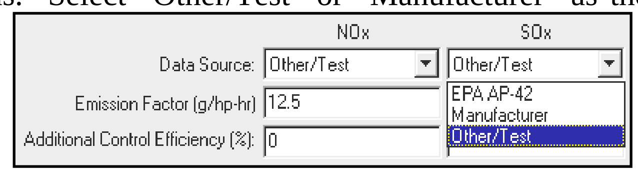


Figure 2-5. Emission factors display screen for diesel/gasoline engines.

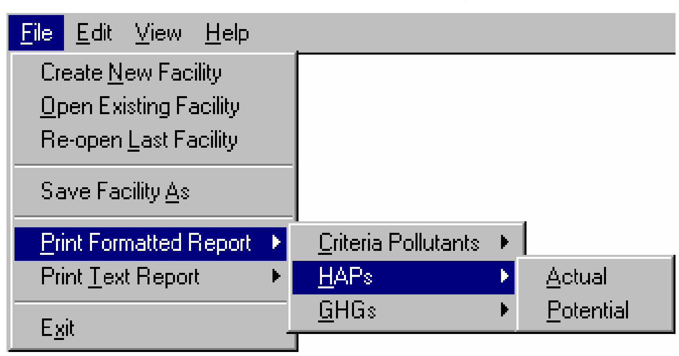
If no published emission factors are available for a particular pollutant, the user must enter an emission factor in order to estimate emissions. Select "Other/Test" or "Manufacturer" as the Data Source and enter an emission factor in the space provided.



2.4 WORKING WITH EMISSIONS REPORTS AND SUMMARIES

2.4.1 View, Print, or Save Formatted Reports

To create tabulated reports of emissions from all equipment units at a facility (or Formatted Reports), select File | Print | Formatted Report | … from the Control Panel menu. Then, select from the menu the pollutant type of interest (Criteria Pollutants, HAPs, or GHGs), and the emissions type of interest (Actual or Potential). A print preview of the Formatted Report will appear (**Figure 2-6**).



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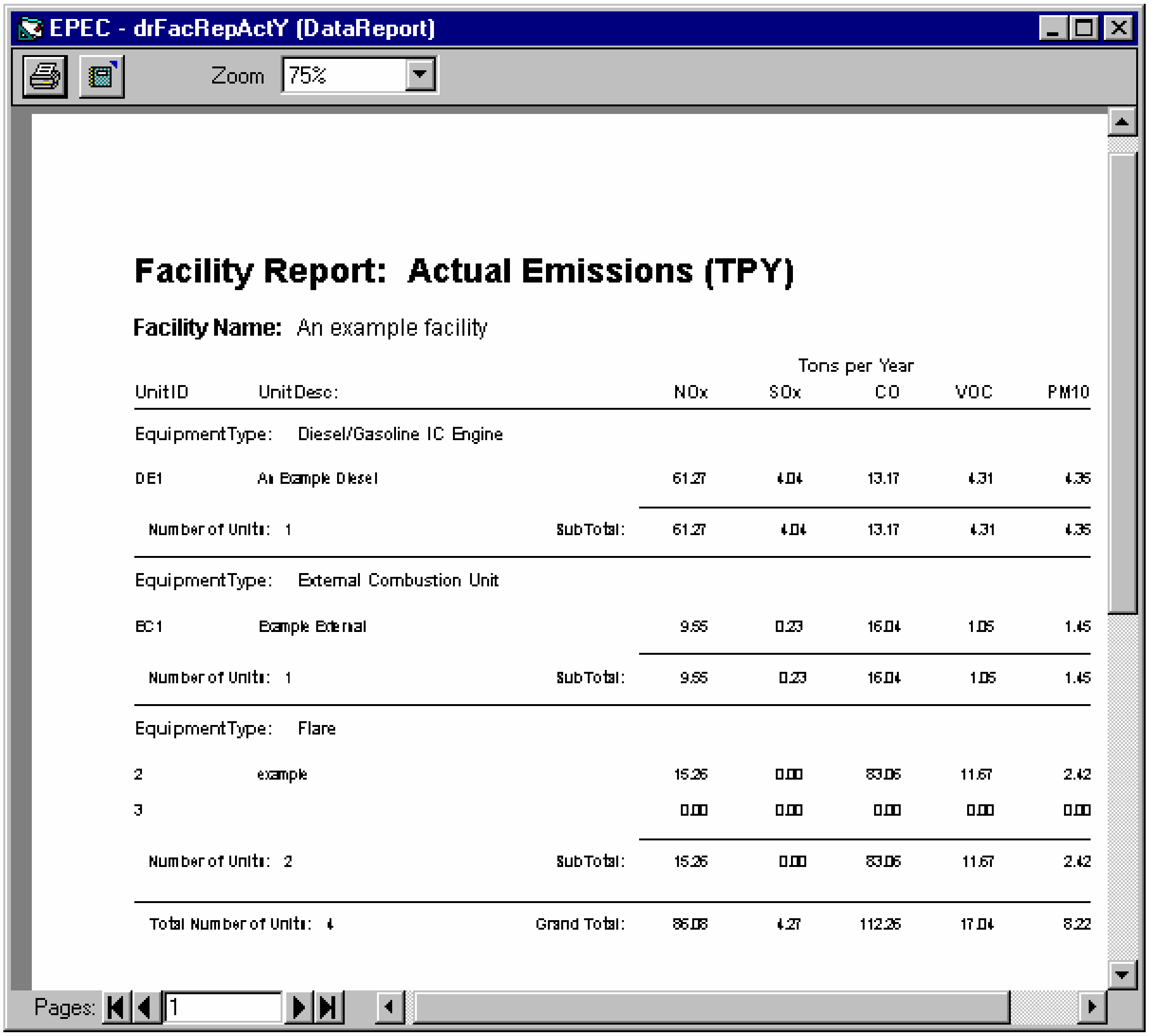


EPEC - drFacRepActY (DataReport)

Zoom 75%

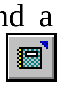
Facility Report: Actual Emissions (TPY)

Facility Name: An example facility

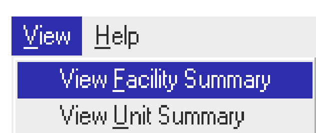
UnitID	UnitDesc:		NOx	SOx	CO	VOC	PM10
			Tons per Year				
EquipmentType:	Diesel/Gasoline IC Engine						
DE1	An Example Diesel		61.27	4.04	13.17	4.31	4.35
Number of Units: 1		SubTotal:	61.27	4.04	13.17	4.31	4.35
EquipmentType:	External Combustion Unit						
EC1	Example External		9.55	0.23	16.04	1.05	1.45
Number of Units: 1		SubTotal:	9.55	0.23	16.04	1.05	1.45
EquipmentType:	Flare						
2	example		15.26	0.00	83.06	11.67	2.42
3			0.00	0.00	0.00	0.00	0.00
Number of Units: 2		SubTotal:	15.26	0.00	83.06	11.67	2.42
Total Number of Units: 4		Grand Total:	86.08	4.27	112.26	17.04	8.22

Pages: 1

Figure 2-6. Formatted Report of actual criteria pollutant emissions – print preview screen.

To send a Formatted Report to the printer or to export it to a file, click the printer  or export  buttons from the print preview screen. Formatted Reports may be exported as HTML or text files.

2.4.2 View and Print Facility Summaries



First, a facility must be created or opened from an existing file (see Section 2.2). To view the Facility Summary, select View | View Facility Summary from the Control Panel menu or click the View Summary button in the Current Facility area, or the top half, of the EPEC II Control Panel. A summary of the total criteria pollutant, HAP, and CO_2 emissions for the current facility will appear in the Facility Summary viewer screen (**Figure 2-7**). To print, click the Print button on the Facility Summary viewer screen.

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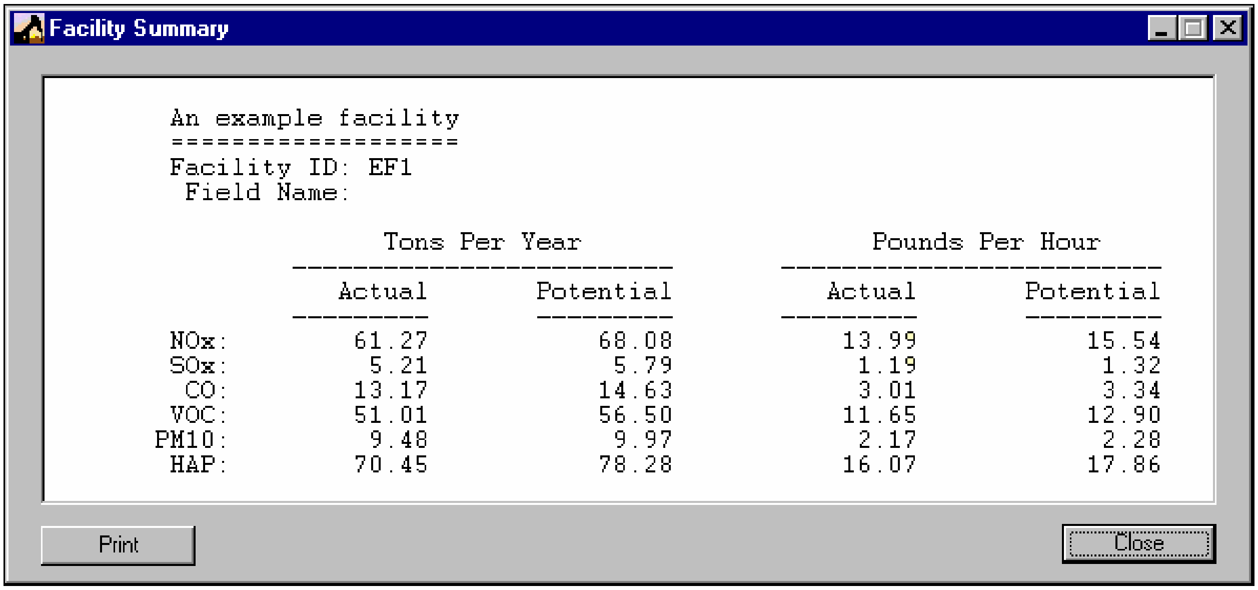
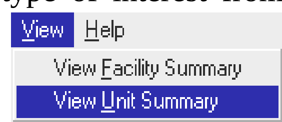


Figure 2-7. Facility Summary viewer screen.

2.4.3 View and Print Equipment Emissions Summaries



To view an Equipment Emissions Summary, select the equipment type of interest from the Select Unit Type drop-list on the Control Panel. Then, select the desired unit from the Select Unit ID drop-list. Select View | View Unit Summary from the Control Panel menu or click the View Summary button in the Units at Facility area, or the bottom half, of the Control Panel. A summary of the total criteria pollutant, HAP, and CO_2 emissions for the selected equipment unit will appear in the Equipment Summary viewer screen (**Figure 2-8**). To print, click the Print button on the Equipment Summary viewer screen.

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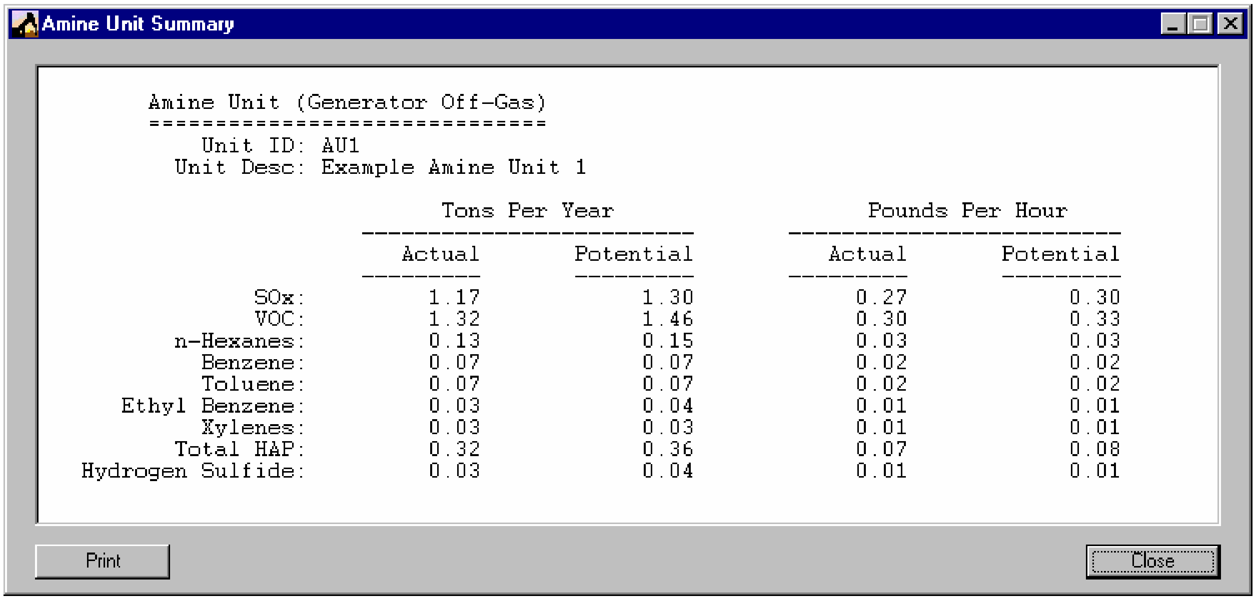

	Tons Per Year		Pounds Per Hour	
	Actual	Potential	Actual	Potential
SOx:	1.17	1.30	0.27	0.30
VOC:	1.32	1.46	0.30	0.33
n-Hexanes:	0.13	0.15	0.03	0.03
Benzene:	0.07	0.07	0.02	0.02
Toluene:	0.07	0.07	0.02	0.02
Ethyl Benzene:	0.03	0.04	0.01	0.01
Xylenes:	0.03	0.03	0.01	0.01
Total HAP:	0.32	0.36	0.07	0.08
Hydrogen Sulfide:	0.03	0.04	0.01	0.01

Figure 2-8. Equipment Summary viewer screen.

2.5 QUITTING EPEC II

Exiting EPEC II is only permitted from the Control Panel. Use one of the following techniques to exit EPEC II from the Control Panel: (1) click File | Exit from the menu, (2) click the ☒ symbol in the upper right corner, or (3) click the Exit button in the lower right corner.

2.6 BACKING UP DATA FILES

It is very important to periodically back up data files created using EPEC II in order to minimize the risk of data loss. Back up data files using Windows Explorer by browsing to the location and file where data are stored and copying the data file to a secure location, such as a floppy disk or zip drive. Or, use the File | Save Facility As option from the Control Panel and save the data file to a secure location (see Section 2.2.3). EPEC II data files are usually stored with an *.mdb file name extension.

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3. METHODS USED BY EPEC II TO CALCULATE EMISSIONS

This section describes the calculation methods available to the EPEC user for amine units, cooling towers, diesel/gasoline IC engines, external combustion emission units, fixed-roof storage tanks, flares, fugitive emissions, glycol dehydrators, loading operations, natural gas engines, natural gas turbines, vents, and other emission units. Methods to customize facility-specific emission estimates are also described. Appendix A contains data for an example facility.

Whenever possible, the most recently available calculation techniques and emission factors from published literature have been integrated into EPEC II. In most cases, these methods have gained past acceptance by the EPA, and are recommended in literature published by the EPA, API, GRI, or the Emission Inventory Improvement Program (EIIP). EPEC also offers the flexibility to input emission factors which are facility-specific or have been updated since the release of EPEC II.

Features that are common to many equipment types include potential and actual emission calculations, HAPs speciation calculations, applications of control efficiencies, facility-specific emission calculations, and the inclusion of default input values.

- Potential emissions are calculated assuming maximum operating time, maximum fuel usage, maximum rated horsepower, etc. Potential emissions are meant to reflect the maximum capacity of the facility to create airborne emissions, while actual emissions are meant to reflect actual operating conditions.

- In EPEC II, HAP emissions are usually calculated as a percent of VOC emissions.

- Emission reductions due to control technologies are included such that:

$$\text{Reduced Emissions} = \text{Emissions} \times (1 - \text{Control efficiency \%} / 100\%) \qquad \textbf{(3-1)}$$

- At many points within EPEC, emission factors or speciation profiles are blank because these data are not currently available. However, the appropriate equations have been integrated into the EPEC spreadsheets for calculating emissions, therefore, users are encouraged to provide their own facility-specific or more recently updated published factors.

- Many of the data entry fields contain default values from published literature. Users are encouraged to enter more applicable or timely data as it becomes available.

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3.1 AMINE UNITS

Process

Amine units are used for removal of H_2S and CO_2 from natural gas, a process called "gas sweetening." These compounds must be removed from natural gas prior to pipeline injection because they are corrosive.

The key components of the process are the amine contact tower and the amine regenerator. The H_2S and CO_2 are absorbed from the natural gas stream via contact with a lean amine solution. The spent amine (or enriched amine) is then recycled in an amine regenerator. The regeneration process involves heating the amine in order to volatilize the absorbed H_2S and CO_2. Hydrocarbons also can be absorbed from the gas stream and can be volatilized as a by-product of this process. Without a control device, such as a flare, the by-product hydrocarbons are emitted to the atmosphere.

Emissions

The amine unit emissions may be associated with three gaseous streams: (1) the regenerator off-gas, (2) the regenerator burner exhaust, and possibly (3) flash tank gas. Several options are available to dispose of the flash tank gas. It may be flared, used to power a combustion emission unit, or vented. Using EPEC II, flash tank emissions should be assigned to an appropriate equipment unit category, according to the disposal method. Emissions from the burner are best included with external combustion emission units. The off-gas from the amine regenerator is typically vented or flared. If flared, emissions may be included with flares or they may be calculated using the Atmospheric Rich-Lean or NG Balance Methods (discussed below) with "Combustion" selected as the Control Technology. If vented, emissions may be calculated using the GRI HAPCalc™ program (Ferry et al., 1996), or any of the estimation techniques included in EPEC II (discussed below). Note that EPEC II also permits direct entry of actual emission rates (lb/hr) estimated using GRI HAPCalc (select "HAPCalc" as the Emission Calculation Method).

Atmospheric Rich-Lean Calculation Option (Amine Balance)

The atmospheric rich-lean calculation method requires laboratory analyses of enriched and lean amine samples for the emission components of interest [H_2S and reduced sulfur compounds, VOCs, and benzene, ethyl benzene, toluene, and xylenes (BTEX)]. It is possible that the lean analyses may be eliminated since concentrations in the lean amine stream tend to be negligible.

Emissions (E) for each analyte in tons per year are calculated according to the following equation:

$$E = \left(C_{Rich} - C_{Lean}\right) \times Q_{Recirc} \times t \times 3.785\,\mathrm{L/gal} \times 60\,\mathrm{min/hr} \times \mathrm{lb}/453{,}600\,\mathrm{mg} \times \mathrm{ton}/2000\,\mathrm{lb} \qquad \textbf{(3-2)}$$

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where:

E = Emissions in tons per year
C_{Rich}, C_{Lean} = Concentration of the analyte of interest in the rich and lean samples (mg/L)
Q_{Recirc} = Amine recirculation rate (gal/min)
t = Annual time of operation (hr/yr)

NG Balance Calculation Option

The NG Balance method requires laboratory analyses of the natural gas stream at the inlet to the amine unit with results corrected to standard temperature and pressure (60ºF, 1 atm). Emissions (E) for each analyte, in tons/year, are calculated according to the following equation:

$$E = C \times \frac{EF_c}{100\%} \times Q \times t \times m_c \times \frac{ton}{2000\ lb} \times \frac{day}{24\ hr} \times \frac{lb - mol}{379.4\ scf} \quad \textbf{(3-3)}$$

where:

E = Emissions in tons per year
C = Concentration of analyte *c* in the natural gas, measured at the inlet to the amine unit (ppm)
EF_c = Percent of analyte *c* emitted (%)
Q = Volumetric natural gas throughput rate (MMscfD)
t = Amine unit run time (hr/year)
m_c = Molecular weight of analyte *c* (lb/lb-mol)

Stack Testing Option

Emissions may be calculated using the stack testing option if the volumetric exhaust rate of the amine unit is known, and laboratory analyses of stack gas samples are available. Ideally, the exhaust rate and natural gas process rate should be measured simultaneously as the stack gas samples are collected. This method assumes that the stack gas samples are collected downstream from any pollutant control devices. (No additional emissions reductions will be applied if this option is selected.)

Emissions (E) for each analyte in tons per year are calculated according to one of the following equations, depending upon the concentration units.

$$E = C_{ppmv} \times 10^{-6} \times \frac{lb \cdot mol}{379\ scf} \times mwt_c \times Q_{stack} \times 60\frac{min}{hr} \times t \times \frac{ton}{2000\ lb} \quad \textbf{(3-4)}$$

$$E = C_{mg/m^3} \times \frac{lb}{454{,}000\ mg} \times \frac{m^3}{35.3\ scf} \times Q_{stack} \times 60\frac{min}{hr} \times t \times \frac{ton}{2000\ lb} \quad \textbf{(3-5)}$$

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where:

E = Emissions in tons per year

C_{ppmv} = Concentration of the analyte of interest in the stack gas (ppmv)

C_{mg/m^3} = Concentration of the analyte of interest (c) in the stack gas (mg/m^3)

mwt_c = Molecular weight of analyte c (lb/lb-mol)

t = Amine unit run time (hr/yr)

Emissions from Claus Sulfur Recovery Units

Claus sulfur recovery units (SRU) reclaim sulfur from the amine regenerator off-gas stream. However, some residual amount of sulfur is lost as air emissions. When a sulfur recovery unit is present, EPEC II calculates residual emissions of H_2S and SO_x according to the EIIP's guidance documents. EPEC II reduces H_2S emissions as follows.

$$E_{H_2S,SRU} = E_{non\text{-}SRU} \times \frac{2}{3} \times \left(1 - \frac{\%RE}{100}\right) \qquad \textbf{(3-6)}$$

where:

$E_{H_2S,SRU}$ = H_2S emissions from an amine unit that is equipped with a SRU (tons per year)

$E_{non\text{-}SRU}$ = The H_2S emission rate that would exist if the amine unit were not equipped with a SRU (tons per year)

%RE = The sulfur recovery efficiency of the Claus SRU (percent)

Note that the factor ⅔ is a stoichiometric ratio associated with the Claus sulfur recovery process.

SO_x emissions can arise from two processes associated with Claus SRUs: (1) the sulfur recovery process itself and, (2) if the SRU is equipped with a tail gas flare, the combustion of $H_2S \rightarrow SO_2$. The following equation accounts for both processes.

$$E_{SO_2,SRU} = \left[\left(E^{vent}_{H_2S,SRU} \times \frac{1}{2}\right) + \left(E^{flare}_{H_2S,SRU} \times \frac{\%Eff_{H_2S}}{100 - \%Eff_{H_2S}}\right)\right] \times \frac{64\ lb/lb \cdot mol}{34.1\ lb/lb \cdot mol} \qquad \textbf{(3-7)}$$

where:

$E_{SO_2,SRU}$ = SO_x emissions from an amine unit that is equipped with a SRU (tons per year)

$E^{vent}_{H_2S,SRU}$ = H_2S emissions that would be emitted from an amine unit that is equipped with a SRU but is not equipped with a tail gas flare (tons per year)

$E^{flare}_{H_2S,SRU}$ = H_2S emissions that would be emitted from an amine unit that is equipped with a SRU and a tail gas flare (tons per year)

$\%Eff_{H_2S}$ = The combustion efficiency of the tail gas flare, or the combustion conversion rate of $H_2S \rightarrow SO_2$.

The first term enclosed in parentheses accounts for sulfur emissions due to the sulfur recovery process. The second term accounts for the combustion of $H_2S \rightarrow SO_2$. Note that the factor ½ is a stoichiometric ratio associated with the Claus sulfur recovery process.

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Control Technology Options for Amine Units

The following control options are available to the EPEC II user. (Note that these choices are not available if the Stack Testing or HAPCalc options are selected as the Emission Calculation Method.)

- None (vent only) – Emissions are uncontrolled.
- Condenser – Hydrocarbon emissions are reduced by 80 percent.
- Combustion – Hydrocarbon emissions are reduced by 98 percent. Also, 95 percent of H_2S is converted to SO_x ($\%Eff_{H_2S}$ = 95 percent).
- Condenser + Combustion – Hydrocarbon emissions are reduced by 99 percent. Also, 95 percent of H_2S is converted to SO_x (or, $\%Eff_{H_2S}$ = 95 percent).
- SRU + vent – Hydrocarbon emissions are uncontrolled. Sulfur emissions are calculated as discussed above.
- SRU + tail gas flare – Hydrocarbon emissions are reduced by 98 percent. Sulfur emissions are calculated as discussed above.
- Other – The user must input a percent reduction of hydrocarbon emissions and percent conversion of $H_2S \rightarrow SO_2$.

Amine Unit Worksheet Inputs

Critical user inputs for the amine unit worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

Always needed

- Unit ID
- Emission Calculation Method (select Amine Balance, GRI HAPCalc™, NG Balance, or Stack Testing)
- Design Gas Flow Rate (MMscf/day)
- Actual Gas Flow Rate (MMscf/day)
- Potential Run Time (hours/yr)
- Actual Run Time (hours/yr)

Only needed for Atmospheric Rich-Lean Method (Amine Balance)

- Amine Recirculation Rate (gal/min)
- Inputs for the Amine Balance Method: rich and lean amine constituent concentrations (mg/L)

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Only needed for NG Balance Method

- Inputs for the NG Balance Method, including natural gas constituent concentrations (ppm), emissions factors (% emitted), and average molecular weight (MW) of emitted VOCs (lb/lb-mol)

Needed for either Atmospheric Rich-Lean or NG Balance Method

- Control Technology (select from those listed in the section above)
- Hydrocarbon Control Efficiency (percent; defaults are based on the selection of Control Technology)
- H_2S Control Efficiency (percent; defaults are based on the selection of Control Technology)

Only needed for Stack Testing Option

- Stack testing results, including stack gas constituent concentrations (ppmv or mg/m^3), stack gas flow rate (scf/min), and average molecular weight of emitted VOCs (lb/lb-mol)

Only needed for GRI HAPCalc Option

- Actual emission rates (lb/hr) estimated using GRI HAPCalc

References

1. Emission Inventory Improvement Program (1998) *EIIP Guidance Document Series*: Volume II, Chapter 10 "Preferred and Alternative Methods for Estimating Air Emissions from Oil and Gas Field Production and Processing Operations." Report prepared for the Point Sources Committee of the Emission Inventory Improvement Program by Eastern Research Group, Inc., Morrisville, North Carolina. EPA-454/R-97-004 a-g. External Review Draft. February 1998. http://www.epa.gov/ttn/chief/eiip/techrep.htm
2. Ferry K.R., Hong T.K., Beitler C.A.M., and Thompson P.A. (1996) *Technical reference manual for GRI-HAPCalc™ Version 2.0 and GRI-HAPData™ Version 1.0: software for estimating emissions of hazardous air pollutants and criteria air pollutants from natural gas industry operations*. Technical report prepared for Gas Research Institute, Chicago, IL by Radian Corp., Austin, TX.
3. Skinner D.F., McIntush K.E., and Murff M.C. (1995) *Amine-based gas sweetening and Claus sulfur recovery process chemistry and waste stream surve*y. Technical report prepared for Gas Research Institute, Chicago, IL by Radian Corp., Austin, TX.
4. Skinner D.F., Reif D.L., and Wilson A.C. (1996) *BTEX and other VOC emissions from a natural gas amine treater*. Technical report prepared for Gas Research Institute, Chicago, IL by Radian Corp., Austin, TX.

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3.2 COOLING TOWERS

Process

Cooling towers are used to dissipate large heat loads. Cooling tower designs vary with several factors: the type of heat transfer medium (wet or dry), the type of the airstream draft (natural or induced), the orientation of the draft relative to the cooling water, the geometry of draft-water contact, and the type of water distribution system. Because wet (or evaporative) cooling towers are the most common type, and because dry towers do not tend to produce particulate emissions, *AP-42* (U.S. Environmental Protection Agency, 1996a) only addresses emissions from wet towers. Most wet cooling towers are designed to recirculate cooling water, exploiting water's latent heat of evaporation in order to transfer heat to the atmosphere.

Emissions

Emissions from wet cooling towers include particulate matter of aerodynamic diameter 10 microns or less (PM_{10}) and fugitive VOCs. PM_{10} emissions originate from cooling water droplets that are entrained in the escaping airstream. (These entrained droplets are termed *liquid drift*.) The dissolved solids in the cooling water contribute to airborne particulate emissions. VOC emissions arise from fugitive compounds that leak into the cooling water from heat exchangers and condensers. These compounds are released to the atmosphere when the cooling water comes into contact with air.

Calculations

EPEC uses the following equations to calculate PM_{10} emissions (tpy).

$$E_{PM10} = EF_{PM10} \times Q \times t \times \frac{ton}{2000 lb} \times \frac{60 \min}{hr} \times \frac{MM}{10^6} \quad \textbf{(3-8)}$$

$$EF_{PM10} = L \times TDS_{circ} \times \frac{10^{-6}}{ppm} \times \frac{1000}{M} \quad \textbf{(3-9)}$$

where:

EF_{PM10} = Calculated factor for PM_{10} emissions (lb/MMgal)
Q = Circulating water flow rate (gal/min)
t = Cooling tower run time (hr/yr)
L = Liquid drift factor, or mass of liquid drift per volume of cooling water recirculation (lb/1000 gal), specified in *AP-42*. This factor varies according to the type of airstream draft: natural or induced.
TDS_{circ} = Denotes the user-input total dissolved solids fraction in the circulation water (ppm)

This emission estimate is conservatively high because it assumes that none of the dissolved solids in the liquid drift contribute to the larger size fraction of particulate matter.

If TDS_{circ} is unknown, it may be approximated using the dissolved solid concentration in the makeup water (TDS_{make}) and the ratio of a selected physical parameter (p) between the

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circulation water and the makeup water. *AP-42* suggests several applicable parameters such as calcium, chloride, or phosphate concentration or conductivity. The equation below illustrates.

$$TDS_{circ} \cong TDS_{make} \times \frac{p_{circ}}{p_{make}} \quad \textbf{(3-10)}$$

If the above approximation is not possible, *AP-42* suggests that for induced draft towers, the product $L \times TDS_{circ}$ is set approximately equal to 0.019 lb/1000 gal, which corresponds to TDS_{circ} which is approximately equal to 11,500 ppm. No equivalent estimate is currently available for natural draft towers.

VOC emissions (tpy) are calculated according to the following equation.

$$E_{VOC} = EF_{VOC} \times Q \times t \times \frac{ton}{2000lb} \times \frac{60\,min}{hr} \times \frac{MM}{10^6} \quad \textbf{(3-11)}$$

where:

EF_{VOC} = Emission factor (lb/MMgal), which varies according to whether inspection-and-maintenance control measures are in place for fugitive emissions from condensers and heat exchangers on the cooling tower

Q = Circulating water flow rate (gal/min)

t = Cooling tower run time (hr/yr)

<u>Cooling Tower Worksheet Inputs</u>

Critical user inputs for the cooling tower worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

- Unit ID
- Tower Type (select Unclassified, Induced Draft, or Natural Draft)
- Control Type (select Minimize Hydrocarbon Leaks and Monitor Hydrocarbons in water, or None)
- Tower Run Time (hours/yr)
- Circulating Water Flow (gal/min)
- Total Dissolved Solids Concentration in Water (ppm)
- Additional Control Efficiency (%) - The estimated effectiveness of any installed control devices. (See emission factors worksheet, criteria pollutants only.)

<u>Reference</u>

U.S. Environmental Protection Agency (1996a) Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units. **Sections 5.1 and 13.4, AP-42, 5th ed. (January 1996); Supplements A and B (November 1996)** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

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3.3 DIESEL OR GASOLINE ENGINES

Process

Exploration and production facilities use diesel- and gasoline-fueled internal combustion engines to power generators, pumps, and cranes. This emission unit class only includes stationary industrial engines. It is not necessary to estimate emissions from mobile emission units such as diesel trucks or gasoline-powered boats.

Emissions

EPEC II calculates combustive emissions from diesel and gasoline engines. Emissions are calculated using emission factors and either the annual engine fuel consumption (MMBtu) or power output (hp-hr). Emission factors were obtained from *AP-42* (U.S. Environmental Protection Agency, 1996b), and from some manufacturers for specific engine makes/models. However, the user may input other manufacturers' factors or the results of independent emission tests.

Calculations

EPEC uses one of the following equations to calculate emissions (tpy), depending on user-selected options.

To calculate emissions based on fuel use:

$$E = EF_{(lb/MMBtu)} \times U \times H \times \frac{ton}{2000lb} \times \frac{MM}{10^6} \quad \textbf{(3-12)}$$

To calculate emissions based on power output:

$$E = EF_{(g/hp\text{-}hr)} \times HP \times t \times \frac{lb}{453.6g} \times \frac{ton}{2000lb} \quad \textbf{(3-13)}$$

where:

E = Emissions in tons per year
EF = Emission factor (units are shown in parentheses)
U = Fuel usage (lb/yr)
H = Fuel heating value (BTU/lb)
HP = Engine horsepower (hp)
t = Engine operating time (hr/yr)

HAPs can be calculated using equations similar to those shown above. Alternately, a speciation profile may be used for HAPs. If the default HAPs speciation is used for gasoline, it should be noted that it was obtained directly from the EPA's *Air Emissions Species Manual* (1990) rather than from the SPECIATE database because the appropriate profile (#1011) was not included in the most recent version of SPECIATE (Version 1.5). It should also be noted that the speciation fraction for n-hexane is conservatively high because it was taken to be equal to that for the total of all isomers of hexane, in lieu of a better estimate.

Diesel or Gasoline Engine Worksheet Inputs

Critical user inputs for the diesel or gasoline engine worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

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Always needed:

- Unit ID
- Engine Potential Horsepower (hp) - The maximum rated engine horsepower
- Engine Operating Horsepower (hp) - The actual operating horsepower
- Potential Run Time (hours/yr)
- Actual Run Time (hours/yr)
- Fuel Type (select Gasoline or Diesel)
- Fuel Sulfur Content (% by mass); only needed for diesel engines larger than 600hp
- Fuel Gas Heating Value (Btu/lb)
- Emission Factor Units (select lb/MMBtu or g/hp-hr) - Determines which set of emission factors and equations will be used. The lb/MMBtu selection indicates that emissions will be based on the engine fuel usage, while the g/hp-hr selection indicates that emissions will be based on engine power output.
- Additional Control Efficiency (%) - The estimated effectiveness of any installed control devices. (See emission factors worksheet, criteria pollutants only.)

Only needed when Emission Factor Units are lb/MMBtu:

- Average Fuel Consumption (Btu/hp-hr) and Fuel Gas Heating Value (Btu/lb)
  OR
- Fuel Usage Rate (lb/hp-hr)
- Estimated Actual Fuel Usage (lb/yr)
- Estimated Potential Fuel Usage (lb/yr)

Only needed when default manufacturer's emission factors will be used to estimate emissions:

- Make – The name of the engine manufacturer
- Model – The model number of the engine

References

1. U.S. Environmental Protection Agency (1990) *Air emission species manual. Vol. 1: volatile organic compound species profiles*. **2nd ed.** Report prepared by U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-450/2-90-001a.
2. U.S. Environmental Protection Agency (1996b) *Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units*. **Section 3.3, AP-42, 5th ed. (January 1996); Supplements A and B (November 1996).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.
3. Brooks, G. W.; Waddell, J. T.; Butler, W. A. 1990. *Air Emissions Species Manual. Volume 1. Volatile Organic Compound Species Profiles*. Second Edition. Radian Corp., Research Triangle Park, NC. Environmental Protection Agency, NTIS Accession Number: PB90-185844/XAB EPA/450/2-90/001A 640p.

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3.4 EXTERNAL COMBUSTION UNITS

Process

External combustion units include burners which may be used as line heaters, reboilers for glycol dehydrator and amine gas sweetening units, steam generators, etc. Typically, natural gas is used as the fuel for these units at oil and gas production facilities; therefore, EPEC II assumes natural gas for the fuel type.

Emissions

EPEC II calculates combustive emissions for external combustion units. These emissions are calculated using emission factors and annual fuel consumption (MMscf). Default emission factors were obtained from *AP-42* (U.S. Environmental Protection Agency, 1996c). These emission factors vary with the size of the unit (as indicated by the hourly fuel consumption rate) and emissions control technologies. The user may also input factors obtained from the manufacturer or independent emission testing. Note that *AP-42* should be consulted to select the proper NO_x and CO emission factors for tangentially fired external combustion units.

Calculations

EPEC II uses the following equation to calculate emissions (tpy).

$$E = EF \times HI \div H \times t \times \frac{ton}{2000lb} \qquad \textbf{(3-14)}$$

where:

E = Emissions in tons per year
EF = Emission factor (lb/MMscf)
HI = Design heat input (MMBtu/hr)
H = Fuel gas heating value (Btu/scf)
t = Run time (hr/yr)

This equation is slightly modified for SO_x emission estimates, as follows

$$E = EF \times HI \div H \times t \times \frac{ton}{2000lb} \times \frac{C_S}{3.18ppm} \qquad \textbf{(3-15)}$$

where:

C_s = Sulfur content of the fuel in ppm. *AP-42* factors assume a sulfur content of 3.18 ppm (or 2000 grains/MMscf); however, SO_x emissions vary proportionally with sulfur content

HAPs can be calculated using Equation 3-14, or a speciation profile can be used. It should be noted that the speciation fraction for n-hexane is conservatively high because it was taken to be equal to that for the total of all isomers of hexane, in lieu of a better estimate. Additionally, it should be noted that total organic compounds (TOC) were approximated as total hydrocarbons (THC).

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External Combustion Unit Worksheet Inputs

Critical user inputs for the external combustion unit worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

- Unit ID
- Potential Run Time (hours/yr)
- Actual Run Time (hours/yr)
- Fuel Hydrogen Sulfide H_2S Content (ppmv)
- Fuel Gas Heating Value (Btu/scf)
- Unit Design Heat Input (MMBtu/hr)
- Emission Controls (select None, Low NO_x Burner, or Flue Gas Recirculation)
- Estimated Actual Fuel Usage (MMscf/yr)
- Additional Control Efficiency (%) - The estimated effectiveness of any installed control devices. (See emission factors worksheet, criteria pollutants only.)

References

1. Radian Corp. (1992) SPECIATE, version 1.50. Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC by Radian Corp., Austin, TX, October.
2. U.S. Environmental Protection Agency (1996c) *Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units*. **Section 1.4, AP-42, 5th ed. (January 1996); Supplements A, B, C, and D (August 1998).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

The SPECIATE database was derived from:

3. U.S. Environmental Protection Agency (1990) *Air emission species manual. Vol. 1: volatile organic compound species profiles*. **2nd ed.** Report prepared by U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-450/2-90-001a.

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3.5 FIXED ROOF STORAGE TANKS

Process

Petroleum products are often stored in fixed roof storage tanks, or are passed through large separators, which are similar in construction. Storage conditions are usually near atmospheric conditions. Tanks may be designed to vent freely or they may have pressure/vacuum vents installed. Other design characteristics which influence emissions include the roof type (dome or cone), tank type (vertical or horizontal), paint color, and dimensions.

Emissions

VOCs may be lost from storage tanks as a result of flashing, working, and standing losses. Working losses occur as the tank fluid level changes, while standing losses arise from changes in atmospheric temperature and pressure.

The API has developed calculations for working and standing losses, which they have described in detail (API publication #2518). Recent work by API has involved the development of a software program (E&P TANK) to rigorously calculate flashing losses on the basis of thermodynamics. EPEC II includes the API calculation methods for working and standing losses, and simpler flashing loss techniques based on the Vasquez-Beggs equation (Vasquez and Beggs, 1980) and the RMC method (Rollins et al., 1990).

Calculations and Worksheet Inputs

It is beyond the scope of this document to fully elaborate on all of the equations utilized by EPEC to calculate storage tank losses. The reader is directed to the references listed at the end of this section for a more complete discussion. This section is limited to a cursory explanation of the underlying equations, and a summary of the critical user inputs.

Standing Losses. For underground storage tanks, standing losses are negligible due to the thermal insulating effects of the ground. For above-ground tanks, standing losses (L_s) in tons/yr are calculated according to the following equation:

$$L_s = 365 \times V_V \times W_V \times K_E \times K_S \times \frac{\text{ton}}{2000\text{lb}} \qquad \textbf{(3-16)}$$

where:

V_V = Tank vapor space volume (ft^3)
W_V = Stock vapor density (lb/ft^3)
K_E = Calculated vapor space expansion factor (unitless)
K_S = Calculated vented vapor saturation factor (unitless).

Note that EPEC II provides default values for Reid Vapor Pressure (RVP) (American Petroleum Institute, 1998). If the user enters actual RVP, the K_E could become infinite or negative in some situations. In these cases, the EPEC II default value should be used.

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The approach adopted for EPEC II was slightly modified to include a horizontal tank calculation, as recommended by *AP-42* (U.S. Environmental Protection Agency, 1996d). Horizontal tank modifications involve the assumption that the vapor space outage (H_{vo}) equals 0.5 x the tank shell diameter (D), and the use of an effective shell diameter (De), calculated as follows:

$$De = \sqrt{\frac{D\ H_s}{0.785}} \tag{3-17}$$

where:
D = Tank shell diameter (ft)
H_s = Horizontal tank shell length (ft)

In order to calculate standing losses, critical input fields include:

Tank type (horizontal or vertical)
D Tank shell diameter (ft)
H_s Tank shell height for vertical tanks, shell length for horizontal tanks (ft)
H_l Average liquid height (ft) - not used for horizontal tank
Roof type (dome or cone) - not used for horizontal tank
$H_{r\text{-}cone}$ Height of a cone roof (measured from the top of the tank shell to the roof crest), for cone roof only (ft) - not used for horizontal tank
H_R Height of a dome roof (measured from the top of the tank shell to the roof crest), for cone roof only (ft) - not used for horizontal tank
M_V Molecular weight of the tank vapor
RVP Reid vapor pressure (psia)
Nearest city (select from list)
P_{BP} Breather vent pressure setting (psig)
P_{BV} Breather vent vacuum setting (psig)
Paint color and condition (select from lists)
P_A Average atmospheric pressure (psia)
E Estimated effectiveness of control strategies or devices (percent)

Working Losses. Working losses (L_w) in tons/yr are calculated according to the following equation:

$$L_w = 0.0010 \times M_V \times P_{VA} \times Q \times K_N \times K_P \times \frac{ton}{2000lb} \tag{3-18}$$

where:
M_V = Stock vapor molecular weight (lb/lb-mol; =50 for crude oil)
P_{VA} = Stock vapor pressure at the average daily liquid surface temperature (psia)
Q = Annual stock net throughput (bbl/yr)
K_N = Working loss turnover factor (unitless)
K_p = Working loss product factor (unitless)

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Note that if the stock level never changes (that is, filling and emptying always occur simultaneously and at equal rates; e.g., by use of a separator tank), Q should be set to zero.

In order to calculate working losses, critical input fields include the following:

Q Annual stock throughput (bbl/yr)
K_p Working loss product factor (dimensionless)
Tank type (horizontal or vertical)
D Tank shell diameter (ft)
H_s Tank shell height for vertical tanks, shell length for horizontal tanks (ft)
M_V Molecular weight of the tank vapor
RVP Reid vapor pressure (psia)
Nearest city (select from list)
Paint color and condition (select from lists)
E Estimated effectiveness of control strategies or devices (percent)

Flashing Losses. Flashing losses (L_f) in tons/yr are calculated according to the following equation:

$$L_f = GOR \times Q \times GD \times \frac{ton}{2000lb} \quad \textbf{(3-19)}$$

where:
GOR = Gas-to-oil ratio (scf/bbl)
Q = Annual throughput (bbl/yr)
GD = Tank vent hydrocarbon gas density (lb/ft^3)

The tank vent hydrocarbon gas density (GD) can be calculated from the following equation:

$$GD = C \times M_c \times \left(\frac{P_a}{RT} \right) \quad \textbf{(3-20)}$$

where:
C = Concentration of total hydrocarbons (THC) in tank vent gas (mole fraction, a number between 0.0 and 1.0).
M_c = Molecular weight of THC in tank vent gas (lb/lb mole)
P_a = Pressure of vented tank gas at atmospheric pressure (psia)
R = Ideal gas constant (10.731 psia ft^3/lb mol °R)
T = Temperature of vented tank gas (°R)

At standard temperature (60ºF) and pressure (14.7 psia) the above equation becomes:

$$GD = \frac{C \times M_c}{379scf\ /\ lbmole} \quad \textbf{(3-21)}$$

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Assuming default values of C = 1.0 and M_c = 50 lb/lb mole, the above equation calculates a conservative value of 0.132 lb/ft^3 for GD. Users are encouraged to enter an estimate of GD based upon field measurement data or other data sources (e.g., E&P TANK database). However, EPEC II provides default values for M_c and GD (American Petroleum Institute, 1998), which may be used if needed.

The Vasquez-Beggs and RMC methods differ from one another only in the technique used to calculate the gas-to-oil ratio. The Vasquez-Beggs equation may be expressed as follows:

$$GOR = C_1 \times CSG \times UP^{C_2} \times \exp\left(\frac{C_3 \times APIG}{T + 460}\right) \quad \textbf{(3-22)}$$

where:

GOR	=	Gas-to-oil ratio (scf/bbl)
C_1, C_2, and C_3	=	Correlation coefficients
CSG	=	Corrected specific gravity of the gas (for pure air, CSG = 1.0)
UP	=	Separator pressure (psia)
APIG	=	API gravity of the oil (°API)
T	=	Separator fluid temperature (°F)

The RMC equation may be expressed as follows:

$$GOR = \log^{-1}\left[0.4896 - 4.916 \times \log_{10}(ST) + 3.469 \times \log_{10}(SG) + 1.501 \times \log_{10}(UP) - 0.9213 \times \log_{10}(T)\right] \quad \textbf{(3-23)}$$

where:

GOR	=	Gas-to-oil ratio (scf/bbl)
ST	=	Tank oil specific gravity (for pure water, ST = 1.0)
SG	=	Separator gas specific gravity (for pure air, SG = 1.0)
UP	=	Separator pressure (psia)
T	=	Separator temperature (°F)

In order to calculate flashing losses, critical input fields include the following:

Q	Annual stock throughput (bbl/yr)
SG	Specific gravity of gas in the separator (dimensionless; for pure air, SG = 1.0)
UVP	Upstream vessel pressure (psig)
APIG	API gravity of the product (°API)
T	Fluid temperature in the upstream vessel (°F)
E	Estimated effectiveness of control strategies or devices (percent)

References

1. American Petroleum Institute (1991) *Manual of Petroleum Measurement Standards*, Chapter 19.1, "Evaporative Loss from Fixed Roof Tanks," Measurement Coordination Dept., American Petroleum Institute, Washington, DC.
2. American Petroleum Institute (1998), Publication 4683 *Correlation Equations to Predict Reid Vapor Pressure and Properties of Gaseous Emissions for Exploration and Production Facilities*. Prepared by Sonoma Technology, Inc., Petaluma, CA, December.
3. Radian Corp. (1992) SPECIATE, version 1.50. Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC by Radian Corp., Austin, TX, October.

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4. Rollins J.B., McCain Jr. W.D., and Creeger J.T. (1990) "Estimation of solution GOR of black oils." *J. Petrol. Tech*., January, 92-94.
5. U.S. Environmental Protection Agency (1996d) *Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units*. **Section 7, AP-42, 5th ed. (January 1996); Supplements A and B (November 1996).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.
6. Vasquez M. and Beggs D.H. (1980) "Correlations for fluid physical property prediction." *J. Petrol. Tech*., June.

The SPECIATE database was derived from:

7. U.S. Environmental Protection Agency (1990) *Air emission species manual. Vol. 1: volatile organic compound species profiles*. **2nd ed.** Report prepared by U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-450/2-90-001a.

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3.6 FLARES

Process

Oil and gas exploration and production facilities use flares to dispose of combustible gases safely, and to control emissions of VOCs and H_2S from equipment and processes such as glycol dehydrators, amine units, and others.

Emissions

Flare emissions result from combustion of the flared gas and from the continuous pilot light (if any). Emissions vary widely depending on the type and quality of the gas flared. Both *AP-42* (U.S. Environmental Protection Agency, 1996e) and the Chemical Manufacturers Association (CMA) (1983) have produced emission factors based on the amount of fuel flared (MMBtu). The *AP-42* factors, which are the EPEC II defaults, were developed from propylene flare tests. Nevertheless, they are accepted for application to all types of industrial flares. The CMA factors, however, may be preferred because they account for a greater range of flare types and gas heating values. Although the CMA factors are not included in this version of EPEC II, the user may refer to the CMA publication listed below and include CMA factors in the spaces provided on the Emission Factor display sheet (select other/test factors as the Data Source). The pilot factors are equivalent to those for natural gas combustion published in *AP-42*. A fuel gas analysis is recommended in order to determine an appropriate HAP speciation profile.

Flare Emission Calculations

In general, emissions are calculated as follows (tons/yr):

$$E = V \times H \times EF \times t \times \frac{\text{ton}}{2000\text{lb}} \div \frac{1000}{M} \qquad \textbf{(3-24)}$$

where:

E = Emissions in tons per year
V = Volumetric rate of flare gas feed (Mscf/day)
H = Flare gas heating value (Btu/scf)
EF = Emission factor (lb/MMBtu)
t = Duration that the flare is in operation (days/yr)

If no SO_x emission factor is defined, emissions of SO_x (tons/yr) are calculated according to the following expression.

$$E_{SO_x} = \left(\frac{Eff_F\%}{100\%}\right) \times V \times \frac{1000}{M} \times t \times C_{H_2S} \times \frac{10^{-6}}{\text{ppm}} \times \frac{m_{SO_2}}{379.4\text{scf} / \text{lb} \cdot \text{mol}} \times \frac{\text{ton}}{2000\text{lb}} \qquad \textbf{(3-25)}$$

where:

$Eff_F\%$ = Efficiency of the flare to oxidize H_2S to SO_x (percent; assumed equal to the hydrocarbon oxidation efficiency)
V = Volumetric rate of flare gas feed (Mscf/day)
t = Duration that the flare is in operation (days/yr)

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C_{H_2S} = Concentration of H_2S in the flare gas

m_{SO2} = Molecular weight of SO_2 (64 lb/lb•mol)

Emissions of H_2S (tons/yr) are calculated according to the following expression.

$$E_{H_2S} = \left(\frac{100\% - Eff_F\%}{100\%}\right) \times V \times \frac{1000}{M} \times t \times C_{H_2S} \times \frac{10^{-6}}{ppm} \times \frac{m_{H_2S}}{379.4scf / lb \cdot mol} \times \frac{ton}{2000lb} \quad \textbf{(3-26)}$$

where:

m_{H_2S} = Molecular weight of hydrogen sulfide (34lb/lb • mol).

CO_2 emissions (tons/yr) are calculated according to the following expression, which is based upon an approach recommended by the Emission Inventory Improvement Program (1998) using an assumption of propylene combustion, consistent with the other *AP-42* emission factors included in EPEC II.

$$E_{CO_2} = \frac{Eff_F\%}{100\%} \times V \times \frac{1000}{M} \times t \times \frac{1\,lb \cdot mol\,C_3H_5}{379.4\,scf} \times \frac{3\,lb \cdot mol\,CO_2}{1\,lb \cdot mol\,C_3H_5} \times \frac{44\,lb\,CO_2}{lb \cdot mol\,CO_2} \times \frac{ton}{2000\,lb} \quad \textbf{(3-27)}$$

where:

$Eff_F\%$ = The hydrocarbon oxidation efficiency of the flare (percent)

<u>Pilot Emissions Calculations</u>

Emissions for the flare pilot are calculated in a similar manner to that for external combustion sources (see Section 3.4). For *AP-42* emission factor selection, a heat input rate between 0.3-100 MMBtu/hr and natural gas combustion were assumed.

<u>Flare Worksheet Inputs</u>

Critical user inputs for the flare worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

- Unit ID
- Maximum Volume of Gas Flared (MscfD)
- Actual Volume of Gas Flared (MscfD)
- Potential Flare Duration (days/yr)
- Actual Flare Duration (days/yr)
- Average Gas Heating Value (Btu/scf)
- Flare Efficiency (%)
- Flare Gas Hydrogen Sulfide H_2S Content (ppmv)
- Type of Flare Smoke (select Smokeless, Light, Average, or Heavy)
- Continuous Flare Pilot (select Yes or No)
- Maximum Pilot Fuel Gas Used (MscfD)

<u>References</u>

1. American Petroleum Institute (2001) *Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry*. American Petroleum Institute, Washington, D.C., February.
2. Chemical Manufacturers Association (1983) *A report on a flare efficiency study*. Prepared by chemical Manufacturers Association, Arlington, Virginia 22209.

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3. Emission Inventory Improvement Program (1998) *EIIP Guidance Document Series: Volume VIII, Chapter 1 - Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels.* Report prepared for the Greenhouse Gas Committee of the Emission Inventory Improvement Program by ICF Incorporated, Washington, D.C. EPA-454/R-97-004 a-g. *Review Draft*. December 1998. http://www.epa.gov/ttn/chief/eiip/techrep.htm
4. U.S. Environmental Protection Agency (1996e) *Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units*. **Sections 1.4 and 13.5, AP-42, 5th ed. (January 1996); Supplements A, B, C, and D (August 1998).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

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3.7 EQUIPMENT FUGITIVE EMISSIONS

Process

Fugitive emissions from petroleum and gas facilities include unintended releases of hydrocarbons via leaking equipment components seals, valves, joints, flanges, and others. This type of leakage does not necessarily indicate a malfunctioning component, but rather, arises from normal wear and age. Leak detection and repair (LDAR) strategies are the recommended control measure for fugitive emissions.

Emissions

Fugitive emission calculations include hydrocarbons, VOCs, and HAPs. The API and EPA have established a methodology to determine fugitive emissions from oil and gas production facilities. The technique involves a simple count of all equipment components from which fugitive emissions may escape, differentiating between whether or not the components are subject to various LDAR programs. Unique emission factors and LDAR control efficiencies are then applied to the components' counts in order to calculate emissions, as follows.

$$E_{(tpy)} = EF \times \left[N_{LDAR} \times \left(1 - \frac{Control\%}{100\%} \right) + N_{non-LDAR} \right] \times t \times \frac{ton}{2000 lb} \quad \textbf{(3-28)}$$

where:

EF	=	Emission factor unique to both the type of equipment component and process stream (lb/hr-component)
N	=	Number of components of a particular type (e.g., flanges) present on the facility that are/are not subject to LDAR programs
Control%	=	EPA-accepted percent control applied for the particular LDAR program in place on the facility. Please refer to the listed references for further information regarding types of LDAR programs.
t	=	Plant operating time (hr/yr), from Operating Information

Equipment Fugitive Emissions Inputs

Critical user inputs for the equipment fugitive emissions worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

- Unit ID
- Stream Type (select gas, NGL, light oil, heavy oil, or water/light oil mixture)
- Non-LDAR Count - The number of components not subject to Leak Detection and Repair (LDAR) control strategies
- LDAR Count - The number of components that are subject to LDAR control strategies
- LDAR Control Efficiency (%) - The control efficiencies specified by local and federal regulators for LDAR programs. These values should be obtained from the state government or Section 5.0 of U.S. EPA document, *Protocol for Equipment Leak Emission Estimates*, EPA-453/R-95-017 (published November 1995).
- For heavy oil streams a THC emission factor for pumps must be entered. (None has been published by the API or EPA.)

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References

1. American Petroleum Institute (1996), Publication 4638 *Calculation workbook for oil and gas production equipment fugitive emissions*. Report prepared by Health and Environmental Sciences Department, American Petroleum Institute, Washington, DC , July.
2. U.S. Environmental Protection Agency (1995) *Protocol for equipment leak emission estimates*. Report prepared by U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-453/R-95-017.

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3.8 GLYCOL REGENERATORS

Process

Glycol dehydrator units are used to remove water from natural gas streams. The major components of the process are the contact tower, glycol reboiler, and flash tank. Water is absorbed from the natural gas stream through contact with cool, dry glycol (or lean glycol). The spent (enriched) glycol is cycled into a flash tank where entrained gas is released, and then into a glycol reboiler where water and other compounds with a high affinity for glycol are driven off through a still column.

Emissions

The glycol regenerator emissions can be associated with two gaseous streams: the reboiler off-gas and the reboiler burner exhaust. Emissions for the burner are best included with external combustion units. The off-gas from the glycol reboiler is typically driven off through a still column. The GRI has developed a software package (GRI GLYCalc) (Thompson et al., 1994) which may be used to estimate glycol dehydrator emissions. Alternately, the reboiler off-gas emissions may be calculated using a gas analysis and included with the vent emissions (see Section 3.11). As a third option, EPEC II includes the atmospheric rich-lean estimation method, discussed below. Note that EPEC II also permits direct entry of actual emission rates (lb/hr) estimated using GRI GLYCalc (select "GLYCalc" as the Emission Calculation Method).

Atmospheric Rich-Lean Calculation Method

The rich-lean calculation method requires laboratory analyses of enriched and lean glycol samples for the emission components of interest (VOCs and BTEX compounds) with results corrected to standard temperature and pressure (60ºF, 1 atm).

Emissions (E) in tons per year for each analyte are calculated according to the following equation:

$$E = \left(C_{Rich} - C_{Lean}\right) \times Q_{Recirc} \times t \times 3.785\,L/gal \times 60\,min/hr \times lb/453{,}600mg \times ton/2000lb \qquad \textbf{(3-29)}$$

where:

C_{Rich}, C_{Lean} = Concentration of the analyte of interest in the rich and lean samples (mg/L)
Q_{Recirc} = Amine recirculation rate (gal/min)
t = Annual time of operation (hr/yr)

Glycol Regenerator Worksheet Inputs

Critical user inputs for the glycol regenerator worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

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Always needed

- Unit ID
- Emission Calculation Method (select Atmospheric Rich/Lean or GLYCalc)
- Design Gas Flow Rate
- Actual Gas Flow Rate
- Potential Run Time (hours/yr)
- Actual Run Time (hours/yr)

Needed only for Rich-Lean Calculation

- Glycol Recirculation Rate (gal/min)
- Control Technology (select None, Condenser, Combustion, Both Condenser plus Combustion, or Condenser plus Re-direct)
- Control Efficiency (%)
- Liquid Concentrations (mg/L) of constituents in the rich and lean glycol samples

Needed for GRI GLYCalc™

- Actual emission rates (lb/hr) estimated using GRI GLYCalc

References

1. Rueter C.O., Reif D.L., Myers D.B., and Menzies W.R. (1995) *Glycol dehydrator emissions: sampling and analytical methods and estimation techniques*. Vol. 1. Technical report prepared for Gas Research Institute, Chicago, IL by Radian Corp., Austin, TX.
2. Thompson P.A., Espensheid A.P., Myers D.B., and Berry C.A. (1994) *Technical reference manual for GRI-GLYCalc(TM): a program for estimating emissions from glycol dehydration of natural gas*. Report prepared by Gas Research Institute, Chicago, IL.

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3.9 LOADING OPERATIONS

Process

Loading operations include transfers of liquid products from storage tanks to transport vehicles, such as tankers, pipelines, railway tank cars, or barges. Two types of loading scenarios are in common use: splash loading and submerged loading. Splash loading occurs when a dispensing pipe is lowered only partway into the receiving cargo hold, resulting in a vertical drop between the end of the dispenser and the liquid product surface. Submerged loading is accomplished by lowering the end of the dispensing pipe below the liquid product surface, or by filling the receiving cargo hold from an inlet near its bottom. Submerged loading procedures reduce turbulence and liquid-air contact, and therefore create fewer emissions.

Emissions

Emissions due to petroleum loading operations are generated by the displacement of the vapor space in the receiving cargo hold by liquid product. Vapor losses may include gases that (1) evolved from the residue of the previous cargo, (2) were entrained to the cargo hold during vapor balance operations, or (3) evaporated during the loading of the fresh cargo. Under turbulent loading conditions, liquid droplets may also be lost to the atmosphere. Losses of hydrocarbons and VOCs are of primary concern. Note that for transfers to pipelines, loading losses are considered negligible.

Calculations

EPEC uses the following equations to calculate evaporative hydrocarbon losses (E) for tanker trucks and railway cars in tons per year.

$$E = L_L \times Q \times \frac{42.0\text{gal}}{\text{bbl}} \times \frac{\text{ton}}{2000\text{lb}} \times \frac{M}{1000} \quad \textbf{(3-30)}$$

$$L_L = 12.46 \times \frac{S \times P \times m}{T_b} \quad \textbf{(3-31)}$$

where:

L_L = Loading loss rate (lb/1000 gal or lb/Mgal)
Q = The annual net throughput of the tank from which liquid product is transferred (bbl/yr)
S = Saturation factor (consult **Table 3-1**)
P = True vapor pressure of the loaded liquid (psia)
m = Average molecular weight of vapors (lb/lb-mol)
T_b = Temperature of the bulk loaded liquid (° Rankine)

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Table 3-1. Saturation factors for loading railway tank cars and tanker trucks.

Mode of Operation	S Factor
Submerged loading of a clean cargo tank	0.50
Submerged loading: dedicated normal service	0.60
Submerged loading: dedicated vapor balance service	1.00
Splash loading of a clean cargo tank	1.45
Splash loading: dedicated normal service	1.45
Splash loading: dedicated vapor balance service	1.00

This table was reproduced from EPA, 1996b.

For marine loading of crude petroleum and gasoline, *AP-42* recommends the use of emission factors (see **Table 3-2** below) and the following equations in order to calculate total hydrocarbon emissions (tons per year). On average, VOC emission factors are 85 percent of total hydrocarbon emissions.

$$E = C_L \times Q \times \frac{42.0\text{gal}}{\text{bbl}} \times \frac{\text{ton}}{2000\text{lb}} \times \frac{M}{1000} \qquad \textbf{(3-32)}$$

$$C_L = C_A + C_G \qquad \textbf{(3-33)}$$

$$C_G = 1.84 \times (0.44 \times P - 0.42) \times \frac{mG}{T_b} \qquad \textbf{(3-34)}$$

where:

C_L = Marine loading loss rate for crude oil (lb/1000 gal or lb/Mgal)

Q = The annual net throughput of the tank from which liquid product is transferred (bbl/yr)

C_A = The arrival emission rate, contributed by residue of previous cargo (lb/1000 gal or lb/Mgal)

C_G = The generated emission rate, contributed by loading of fresh cargo (lb/1000 gal or lb/Mgal)

P = True vapor pressure of the loaded liquid (psia)

m = Average molecular weight of vapors (lb/lb-mol)

G = Vapor growth factor = 1.02

T_b = Temperature of the bulk loaded liquid (° Rankine)

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Table 3-2. Arrival emission rates for marine loading of crude oil.

Ship/Ocean Barge Tank Condition	Previous Cargo	Arrival Emission Factor C_A (lb/1000 gal)
Uncleaned	Volatile[a]	0.86
Ballasted	Volatile	0.46
Cleaned or gas-freed	Volatile	0.33
Any condition	Nonvolatile	0.33

[a] Volatile cargoes are those with a true vapor pressure greater than 10 kPa (1.5 psia).
This table was reproduced from EPA, 1996b.

Loading Operations Worksheet Inputs

Critical user inputs for the loading operations worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

Always needed

- Unit ID
- Receiving Carrier Type (select Tanker Truck, Railway Tank Car, Marine Vessel, or Pipeline)
- Nearest City
- Storage Tank Paint Color/Shade/Type (select Aluminum/Specular, Aluminum/Diffuse, Grey/Light, Grey/Medium, Red/Primer, or White)
- Storage Tank Paint Condition (select Good or Poor)
- Reid Vapor Pressure (psia)
- Annual Net Throughput (bbl/yr)
- Saturation Factor
- Molecular Weight of Tank Vapors (lb/lb-mol)

Needed only for Marine Vessels

- Ship's Previous Cargo (select Volatile Liquid or Non-volatile Liquid)
- Ship's Cargo Hold Condition (select Uncleaned, Ballasted, or Cleaned/Gas-Freed)

Reference

U.S. Environmental Protection Agency (1996b) *Compilation of air pollutant emission factors. Volume 1: stationary point and area emission units.* **Section 5.2, AP-42, 5th ed. (January 1996); Supplements A and B (November 1996).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

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3.10 NATURAL GAS ENGINES

Process

Natural gas is frequently the fuel of choice for internal combustion engines located at oil and gas exploration and production facilities due to its low-cost availability. Natural gas engine designs vary in their engine cycle (two- vs. four-stroke) and fuel burn (lean, rich, and clean burn).

Emissions

EPEC II calculates combustive emissions from natural gas emissions. Emissions are calculated using emission factors and either the annual engine fuel consumption (MMBtu/yr) or power output (hp-hr). Emission factors were obtained from *AP-42* (U.S. Environmental Protection Agency, 1996b) and GRI (Shareef et al., 1996), however, the user may input factors obtained from the manufacturer or independent emission tests if preferred. The default EPEC II emission factors vary with engine cycle and fuel burn.

Calculations

EPEC uses one of the following equations to calculate emissions (tpy), depending on user-selected options.

To calculate emissions based on fuel use:

$$E = EF_{(lb/MMBtu)} \times U \times H \times \frac{ton}{2000 lb} \quad \textbf{(3-35)}$$

To calculate emissions based on power output:

$$E = EF_{(g/hp\text{-}hr)} \times HP \times t \times \frac{lb}{453.6 g} \times \frac{ton}{2000 lb} \quad \textbf{(3-36)}$$

where:

EF = Emission factor (units are shown in parentheses)
U = Fuel usage (MMscf/yr)
H = Fuel heating value (BTU/scf)
HP = Engine horsepower (hp)
t = Engine operating time (hr/yr)

This method is consistent across compounds with the exception of SO_x; the *AP-42* SO_x emission factor is designed to be scaled according to the H_2S content of the natural gas fuel (H_2S, ppmv) such that $EF_{SOx} = EF \times H_2S/3.18$ ppmv.

HAP emission factors are available from *AP-42* and GRI. Alternately, the user may choose to estimate HAPs emissions from a speciation profile. The EPA's SPECIATE database was consulted to obtain a default HAPs profile (as a weight percent of VOC emissions) for natural gas internal combustion engines.

Natural Gas-Fired Reciprocating Engine Worksheet Inputs

Critical user inputs for the natural gas engine worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

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Always needed:

- Engine Stroke (select 4-Cycle or 2-Cycle)
- Engine Design (select Lean Burn, Clean Burn, or Rich Burn)
- Emission Factor Units (select lb/MMBtu or g/hp-hr) - Determines which set of emission factors and equations will be used. The lb/MMBtu selection indicates that emissions will be based on the engine fuel usage, while the g/hp-hr selection indicates that emissions will be based on engine power output.
- Manufacturer's Maximum Rated Horsepower (hp)
- Percent Elevation Deration (%)- Needed if the engine is operated at high altitude
- Feet Above Rated Elevation (ft) - Needed if the engine is operated at high altitude
- Engine Potential Horsepower (hp)
- Engine Operating Horsepower (hp) - The actual operating horsepower
- Engine Operating Horsepower (hp)
- Potential Run Time (hours/yr)
- Actual Run Time (hours/yr)
- Additional Control Efficiency (%) - The estimated effectiveness of any installed control devices. (See emission factors worksheet, criteria pollutants only.)

Only needed when Emission Factor Units are lb/MMBtu

- Average Fuel Consumption (Btu/hp-hr) and Fuel Gas Heating Value (Btu/scf)

  OR

- Fuel Usage Rate (scf/hp-hr), Estimated Actual Fuel Usage (MMscf/yr), and Estimated Potential Fuel Usage (MMscf/yr)

References

1. Radian Corp. (1992) SPECIATE, version 1.50. Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC by Radian Corp., Austin, TX, October.
2. Shareef G.S., Ferry K.R., Gundappa M., Leatherwood C.A., Ogle L.D., and Campbell L.M. (1996) *Measurement of air toxic emissions from natural gas-fired internal combustion engines at natural gas transmission and storage facilities*. Technical report prepared for Gas Research Institute, Chicago, IL by Radian Corp., Research Triangle Park, NC.
3. U.S. Environmental Protection Agency (1996b) *Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units*. **Section 3.2, AP-42, 5th ed. (January 1996); Supplements A through F (July 2000).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

The SPECIATE database was derived from:

4. U.S. Environmental Protection Agency (1990) *Air emission species manual. Vol. 1: volatile organic compound species profiles*. **2nd ed.** Report prepared by U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-450/2-90-001a.

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3.11 NATURAL GAS TURBINES

Process

Natural gas is frequently the fuel of choice for internal combustion engines located at oil and gas exploration and production facilities due to its low-cost availability. Natural gas turbines are often used to power compressors and generate electricity.

Emissions

EPEC II calculates combustive emissions from natural gas turbines. Emissions are calculated using emission factors and either the annual engine fuel consumption (MMBtu/yr) or power output (hp-hr). Default emission factors were obtained from *AP-42* (U.S. Environmental Protection Agency, 1996b) and GRI (Shareef et al., 1996), however, the user may input factors obtained from the manufacturer or independent emission tests if preferred.

Calculations

EPEC uses one of the following equations to calculate emissions (tpy), depending on user-selected options.

To calculate emissions based on fuel use:

$$E = EF_{(lb/MMBtu)} \times U \times H \times \frac{ton}{2000 lb} \quad \textbf{(3-37)}$$

To calculate emissions based on power output:

$$E = EF_{(g/hp\text{-}hr)} \times HP \times t \times \frac{lb}{453.6 g} \times \frac{ton}{2000 lb} \quad \textbf{(3-38)}$$

where:

EF = Emission factor (units are shown in parentheses)
U = Fuel usage (MMscf/yr)
H = Fuel heating value (Btu/scf)
HP = Engine horsepower (hp)
t = Engine operating time (hr/yr).

This method is consistent across compounds with the exception of SO_x; the *AP-42* SO_x emission factor was designed to be multiplied by the sulfur content of the fuel (H_2S%, percent), such that $EF_{SOx} = EF \times H_2S\%$.

Some HAP emission factors were available from *AP-42* and GRI. Alternately, the user may choose to estimate HAP emissions from a speciation profile. The EPA's SPECIATE database was consulted to obtain a default HAP profile (as a weight percent of VOC emissions) for natural gas turbines.

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Natural Gas Turbine Worksheet Inputs

Critical user inputs for the natural gas turbine worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

Always needed:

- Unit ID
- Control Technology (select Uncontrolled, Lean-Premix, or Water-Stream Injection)
- Emission Factor Units (select lb/MMBtu or g/hp-hr) - Determines which set of emission factors and equations will be used. The lb/MMBtu selection indicates that emissions will be based on the engine fuel usage, while the g/hp-hr selection indicates that emissions will be based on engine power output.
- Engine Potential Horsepower (hp) - Manufacturer's maximum rated horsepower
- Engine Operating Horsepower (hp) - The actual operating horsepower.
- Potential Run Time (hours/yr)
- Actual Run Time (hours/yr)
- Fuel Hydrogen Sulfide (H_2S) Content (ppmv)
- Additional Control Efficiency (%) - The estimated effectiveness of any installed control devices. (See emission factors worksheet, criteria pollutants only.)

Only needed when Emission Factor Units are lb/MMBtu

- Average Fuel Consumption (Btu/hp-hr) and Fuel Gas Heating Value (Btu/scf)

  OR
- Fuel Usage Rate (scf/hp-hr), Estimated Actual Fuel Usage (MMscf/yr), and Estimated Potential Fuel Usage (MMscf/yr)

References

1. Radian Corp. (1992) SPECIATE, version 1.50. Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC by Radian Corp., Austin, TX, October.

2. Shareef G.S., Ferry K.R., Gundappa M., Leatherwood C.A., Ogle L.D., and Campbell L.M. (1996) *Measurement of air toxic emissions from natural gas-fired internal combustion engines at natural gas transmission and storage facilities*. Technical report prepared for Gas Research Institute, Chicago, IL by Radian Corp., Research Triangle Park, NC.

3. U.S. Environmental Protection Agency (1996b) *Compilation of air pollutant emission factors. Vol. 1: stationary point and area emission units*. **Sections 3.1, AP-42, 5th ed. (January 1996); Supplements A through F (July 2000).** Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

The SPECIATE database was derived from:

4. U.S. Environmental Protection Agency (1990) *Air emission species manual. Vol. 1: volatile organic compound species profiles*. **2nd ed.** Report prepared by U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-450/2-90-001a.

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3.12 VENTS

Process

Oil and gas exploration and production facilities release gases to the atmosphere through process or emergency vents. Process vents may serve leaking valves, pressure release systems, or routine plant depressurization, among other functions. However, emissions from vents that serve fugitive emissions are best quantified as fugitives.

Emissions

EPEC II calculates vent emissions from laboratory vent gas analyses and estimates of the volume of gas released. This technique involves the use of simple engineering calculations to determine emissions.

Calculations

This method requires laboratory analyses of the vent gas exit stream with results corrected to standard temperature and pressure (60ºF, 1 atm). Emissions (E) for individual analytes, in tons/year, are calculated according to the following equations:

If concentrations are known in mole percent:

$$E = \frac{C}{100} \times Q \times t \times m_c \times \frac{1000}{M} \times \frac{ton}{2000\,lb} \times \frac{lb \cdot mol}{379.4\,scf} \qquad \textbf{(3-39)}$$

If concentrations are known in weight percent:

$$E = \frac{C}{100} \times Q \times t \times sg \times m_{air} \times \frac{1000}{M} \times \frac{ton}{2000\,lb} \times \frac{lb \cdot mol}{379.4\,scf} \qquad \textbf{(3-40)}$$

where:

C = Concentration of analyte c in the vent gas (mole percent or weight percent)
Q = Volumetric vent gas flow rate (MscfD)
t = Vent duration (days/year)
m_c = Molecular weight of analyte c (lb/lb-mol)
sg = Specific gravity of the vent gas, corrected to standard temperature and pressure (for pure air, sg = 1.0).
m_{air} = Average molecular weight of air (28.96 lb/lb-mol)

Vent Worksheet Inputs

Critical user inputs for the vent worksheet are listed below. All other data are for informational or reporting purposes, but are not necessary to calculate emissions.

- Unit ID
- Maximum Volume of Gas Vented (Mscf/day)

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- Actual Volume of Gas Vented (Mscf/day)
- Potential Vent Duration (days/yr)
- Actual Vent Duration (days/yr)
- Concentration Units (select Mole % or Weight %) - Reflects the units of the vent gas sample analysis
- Concentrations of the vent gas constituents
- Average Molecular Weight of VOCs in the Vent Gas (lb/lb-mol)
- Hydrocarbon Control Efficiency (%) - The estimated effectiveness of control devices or strategies.

Reference

Boyer B.E. and Brodnax D.D. (1995) *Oil and gas production emission factors and estimation methods*. Presented at the Air & Waste Management Association and U.S. Environmental Protection Agency 6th Annual Conference on the Emission Inventory, New Orleans, LA, September 4-6, Vol. (proceedings to be published in 1997).

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3.13 OTHER EMISSIONS UNITS

The equipment type "Other Emissions Units" is reserved for equipment units that do not fit into any of the previously mentioned categories. This worksheet may also be useful if the user wishes to employ calculation methods that differ from those included with EPEC II.

The user should simply input the results of independent emission calculations. Both potential and actual emissions (tons/year) should be included. These results will then be included in the facility totals for EPEC II's summary reports.

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APPENDIX A

EXAMPLE EPEC II CALCULATIONS

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A.1 AMINE UNIT EXAMPLE CALCULATIONS

Atmospheric Rich-Lean Equation (Amine Balance)

$$E = \left(C_{Rich} - C_{Lean}\right) \times Q_{Recirc} \times t \times 3.785\,L/gal \times 60\,min/hr \times lb/453{,}600\,mg \times ton/2000\,lb$$

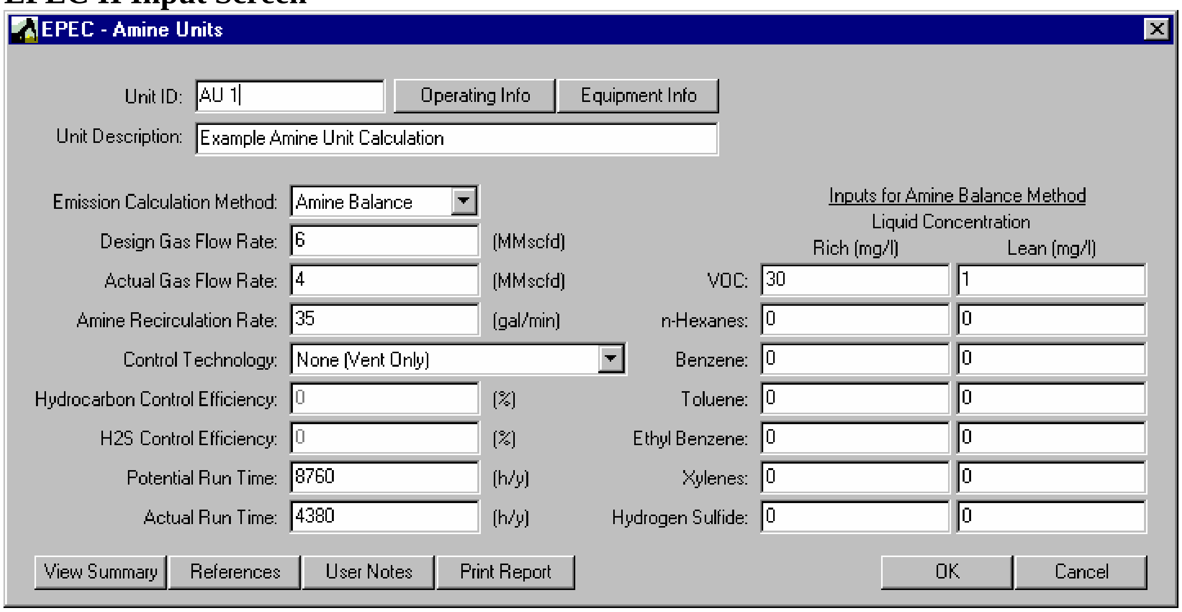
Inputs

C_{Rich}	30 mg/L
C_{Lean}	1 mg/L
Q_{Recirc}	35 gal/min
t	4380 hr/yr

Result

$$E_{VOC} = (30 - 1) \times 35 \times 4380 \times 3.785 \times 60 \div 453600 \div 2000 = 1.1 \text{ tpy}$$

EPEC II Input Screen



EPEC II Output

```
      Amine Unit (Generator Off-Gas)
      ==============================
          Unit ID: AU 1
        Unit Desc: Example Amine Unit Calculation

                            Tons Per Year            Pounds Per Hour
                        ---------------------    ----------------------
                          Actual    Potential      Actual     Potential
                        ---------   ---------    ---------    ---------
                SOx:       0.00        0.00         0.00         0.00
                VOC:       1.11        3.34         0.51         0.76
         n-Hexanes:        0.00        0.00         0.00         0.00
           Benzene:        0.00        0.00         0.00         0.00
           Toluene:        0.00        0.00         0.00         0.00
     Ethyl Benzene:        0.00        0.00         0.00         0.00
           Xylenes:        0.00        0.00         0.00         0.00
         Total HAP:        0.00        0.00         0.00         0.00
   Hydrogen Sulfide:       0.00        0.00         0.00         0.00
```

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NG Balance Equation

$$E = C \times \frac{EF_c}{100\%} \times Q \times t \times m_c \times \frac{ton}{2000\ lb} \times \frac{day}{24\ hr} \times \frac{lb \cdot mol}{379.4\ scf}$$

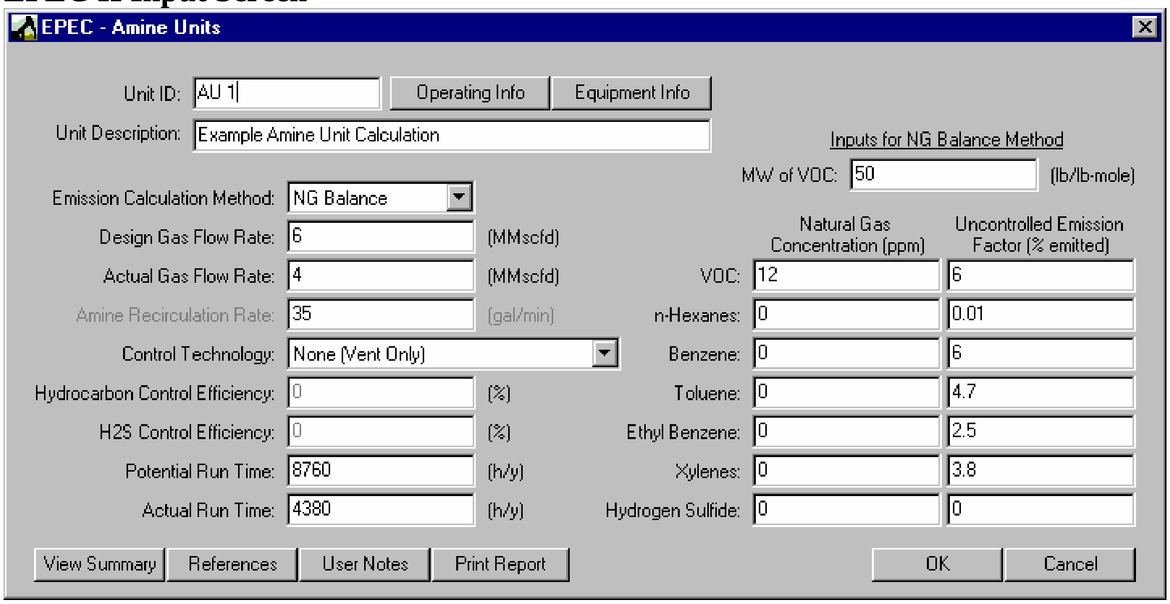
Inputs

C	12 ppmv
EF	6 %
Q	4 MMscfd
t	4380 hr/yr
m_C	50 lb/lb-mol

Result

$E_{VOC} = 12 \times 6 \div 100 \times 4 \times 4380 \times 50 \div 2000 \div 24 \div 379.4 = 0.035$ tpy

EPEC II Input Screen



EPEC II Output

```
        Amine Unit (Generator Off-Gas)
        ==============================
            Unit ID: AU 1
          Unit Desc: Example Amine Unit Calculation

                             Tons Per Year             Pounds Per Hour
                        ----------------------      ----------------------
                           Actual    Potential         Actual    Potential
                         ---------   ---------      ---------   ---------
                SOx:        0.00        0.00           0.00        0.00
                VOC:        0.03        0.10           0.02        0.02
          n-Hexanes:        0.00        0.00           0.00        0.00
            Benzene:        0.00        0.00           0.00        0.00
            Toluene:        0.00        0.00           0.00        0.00
      Ethyl Benzene:        0.00        0.00           0.00        0.00
            Xylenes:        0.00        0.00           0.00        0.00
          Total HAP:        0.00        0.00           0.00        0.00
   Hydrogen Sulfide:        0.00        0.00           0.00        0.00
```

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A.2 COOLING TOWER EXAMPLE CALCULATIONS

PM_{10} Equations

$$EF_{PM10} = L \times TDS_{circ} \times \frac{10^{-6}}{ppm} \times \frac{1000}{M}$$

$$E_{PM10} = EF_{PM10} \times Q \times t \times \frac{ton}{2000\,lb} \times \frac{60 min}{hr} \times \frac{MM}{10^6}$$

VOC Equation

$$E_{VOC} = EF_{VOC} \times Q \times t \times \frac{ton}{2000\,lb} \times \frac{60\,min}{hr} \times \frac{MM}{10^6}$$

Inputs

Tower type and L	Induced Draft, therefore, L = 1.7 lb/Mgal (from *AP-42*)
Control type and EF_{VOC}	No Controls, therefore, EF_{VOC} = 6 lb/MMgal
t	6570 hr/yr
Q	1200 gal/min
TDS	9000 ppm

Results

$$EF_{PM10} = 1.7 \times 9000 \times 10^{-6} \times 1000 = 15.3 \text{ lb/MMgal}$$
$$E_{PM10} = 15.3 \times 1200 \times 6570 \div 2000 \times 60 \div 10^6 = 3.62 \text{ tpy}$$
$$E_{VOC} = 6 \times 1200 \times 6570 \div 2000 \times 60 \div 10^6 = 1.42 \text{ tpy}$$

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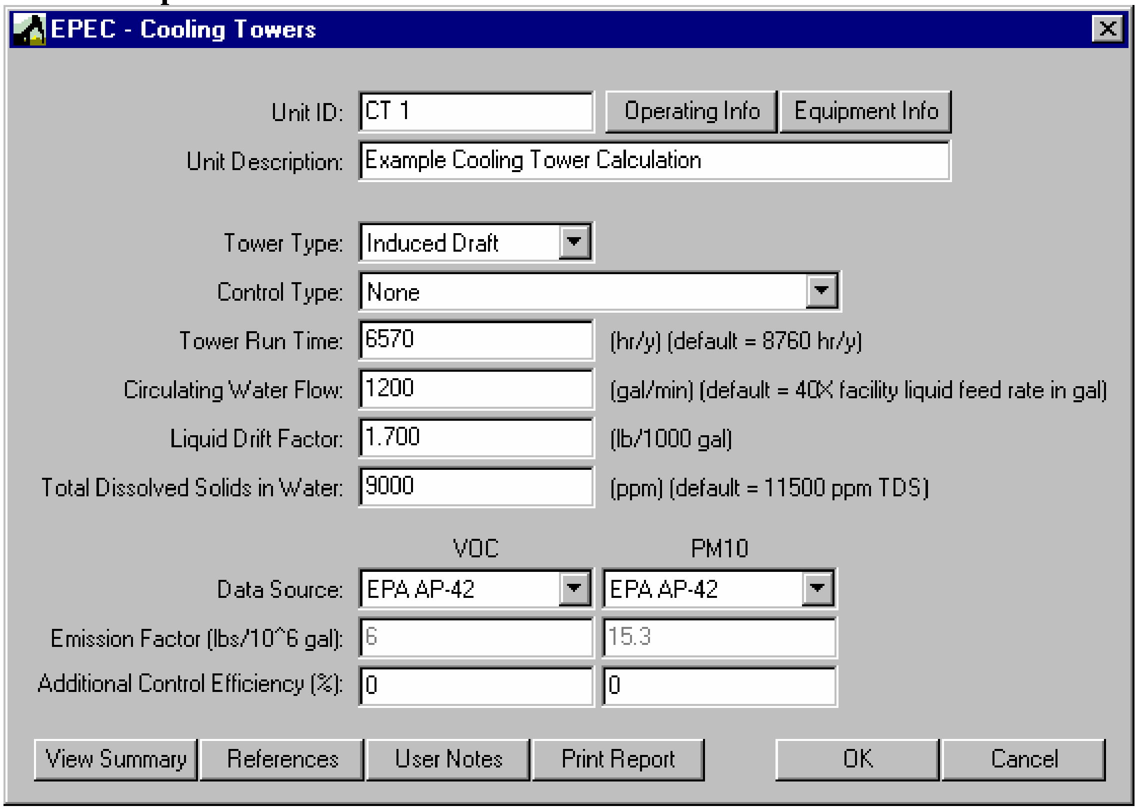
EPEC II Input Screen



EPEC II Output

```
      Cooling Tower
      =============
          Unit ID: CT 1
        Unit Desc: Example Cooling Towers Calculation

                          Tons Per Year            Pounds Per Hour
                       ---------------------    -----------------------
                          Actual    Potential      Actual      Potential
                       ---------   ---------    ---------     ---------
             VOC:           1.42        1.89         0.43          0.43
            PM10:           3.62        4.83         1.10          1.10
```

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A.3 DIESEL OR GASOLINE ENGINES EXAMPLE CALCULATIONS

Power Output Equation

$$E = EF_{(g/hp\text{-}hr)} \times HP \times t \times \frac{lb}{453.6\,g} \times \frac{ton}{2000 lb}$$

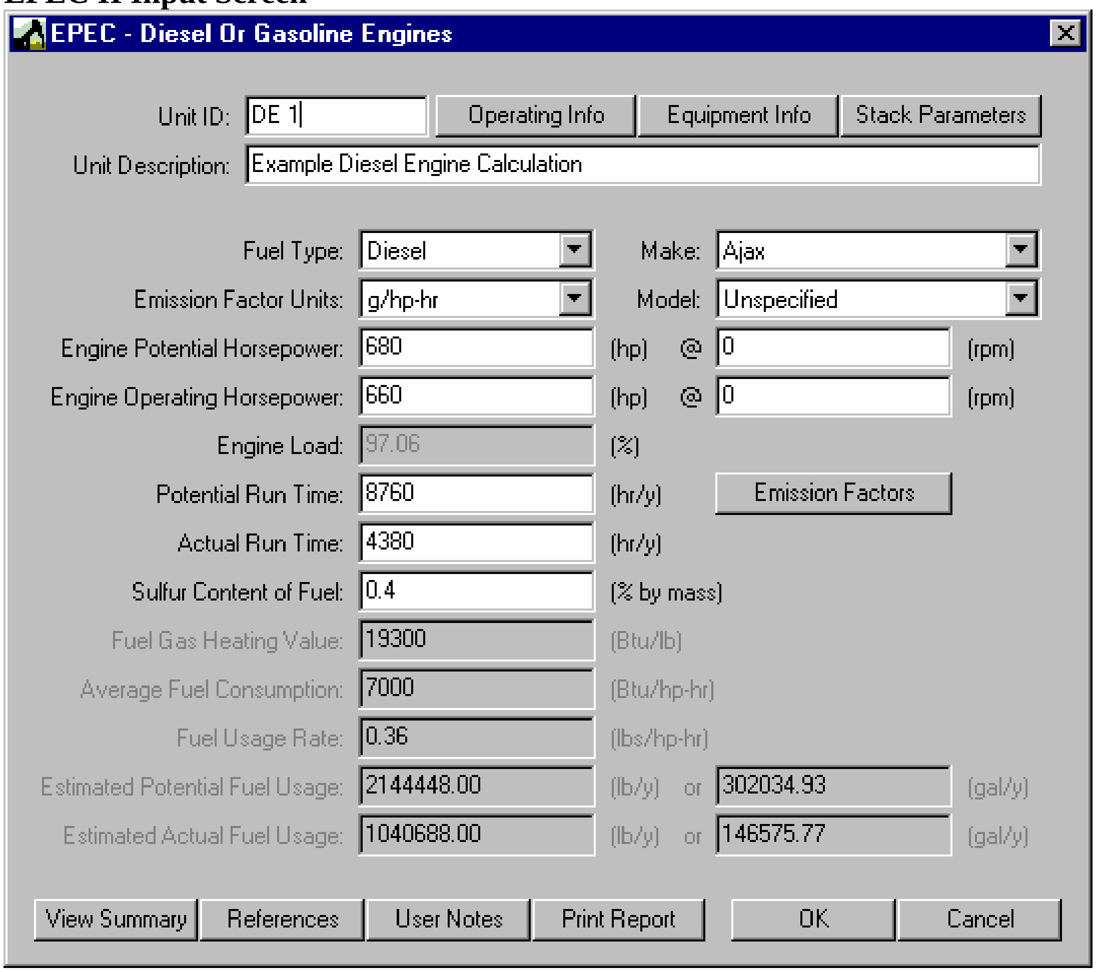
Inputs

HP	660 hp
t	4380 hr/yr
Fuel type	Diesel
EF_{NOx}	10.9 g/hp-hr for diesel engines ≥ 600 hp, from *AP-42*, Section 3.4

Result

$$E_{NOx} = 10.9 \times 660 \times 4380 \div 453.6 \div 2000 = 34.7 \text{ tpy}$$

EPEC II Input Screen



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EPEC II Output

Diesel Or Gasoline Engine

Unit ID: DE 1

Unit Desc: Example Diesel Engine Calculation

	Tons Per Year Actual	Tons Per Year Potential	Pounds Per Hour Actual	Pounds Per Hour Potential
NOx:	34.73	71.57	15.86	16.34
SOx:	4.68	9.64	2.14	2.20
CO:	7.97	16.42	3.64	3.75
VOC:	0.90	1.85	0.41	0.42
PM10:	0.58	1.20	0.26	0.27
THC:	1.02	2.10		
Methane:	0.09	0.19		
Ethane:	0.03	0.06		
CO2:	1679.29	3460.35		
HydrogenSulfide:	NA	NA		
1,3-Butadiene:	NA	NA		
n-Hexane:	NA	NA		
Trimethylpentane:	NA	NA		
Benzene:	0.01	0.02		
Toluene:	0.01	0.02		
EthylBenzene:	NA	NA		
Xylenes:	0.01	0.02		
Formaldehyde:	0.01	0.02		
Acetaldehyde:	0.01	0.02		
HAP:	0.04	0.08		

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Fuel Usage Equation

$$E = EF_{(lb/MMBtu)} \times U \times H \times \frac{ton}{2000\ lb} \times \frac{MM}{10^6}$$

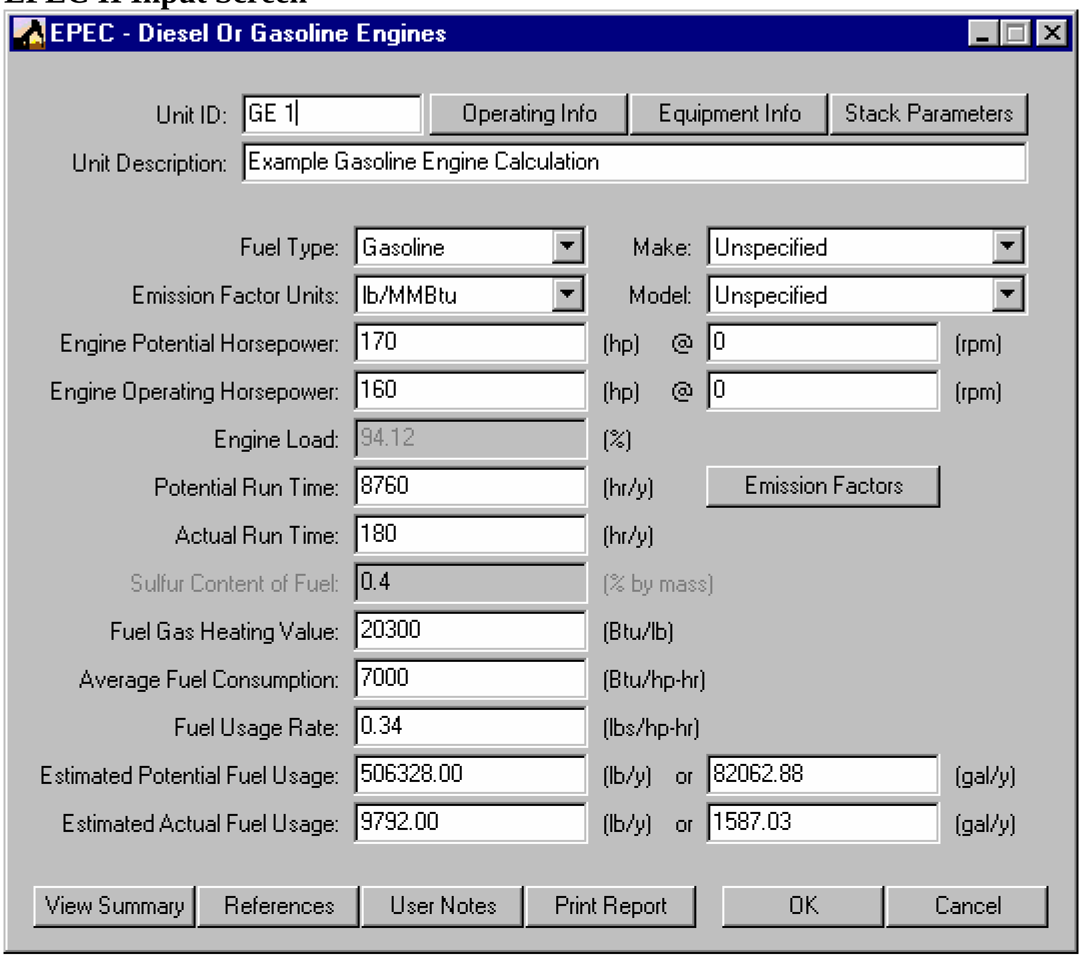
Inputs

HP	160 hp
t	180 hr/yr
Fuel type	Gasoline
H	20300 Btu/lb
Fuel Consumption	7000 Btu/hp-hr
U	7000 ÷ 20300 × 160 × 180 = 9931 lb/yr
EF_{CO}	62.7 lb/MMBtu for gasoline engines (from *AP-42*, Section 3.3)

Result

$$E_{CO} = 62.7 \times 9931 \times 20300 \div 2000 \div 10^6 = 6.32\ tpy$$

EPEC II Input Screen



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EPEC II Output

Diesel Or Gasoline Engine
========================
Unit ID: GE 1
Unit Desc: Example Gasoline Engine Calculation

	Tons Per Year		Pounds Per Hour	
	Actual	Potential	Actual	Potential
NOx:	0.16	8.38	1.80	1.91
SOx:	0.01	0.43	0.09	0.10
CO:	6.23	322.23	69.24	73.57
VOC:	0.26	13.57	2.92	3.10
PM10:	0.01	0.51	0.11	0.12
THC:	0.30	15.57		
Methane:	0.03	1.71		
Ethane:	0.01	0.31		
CO2:	15.31	791.44		
HydrogenSulfide:	NA	NA		
1,3-Butadiene:	0.00	0.00		
n-Hexane:	NA	NA		
Trimethylpentane:	NA	NA		
Benzene:	0.00	0.00		
Toluene:	0.00	0.00		
EthylBenzene:	NA	NA		
Xylenes:	0.00	0.00		
Formaldehyde:	0.00	0.00		
Acetaldehyde:	0.00	0.00		
HAP:	0.00	0.01		

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A.4 EXTERNAL COMBUSTION UNIT EXAMPLE CALCULATIONS

<u>Equation</u>

$$E = EF \times HI \div H \times t \times \frac{\text{ton}}{2000\ \text{lb}}$$

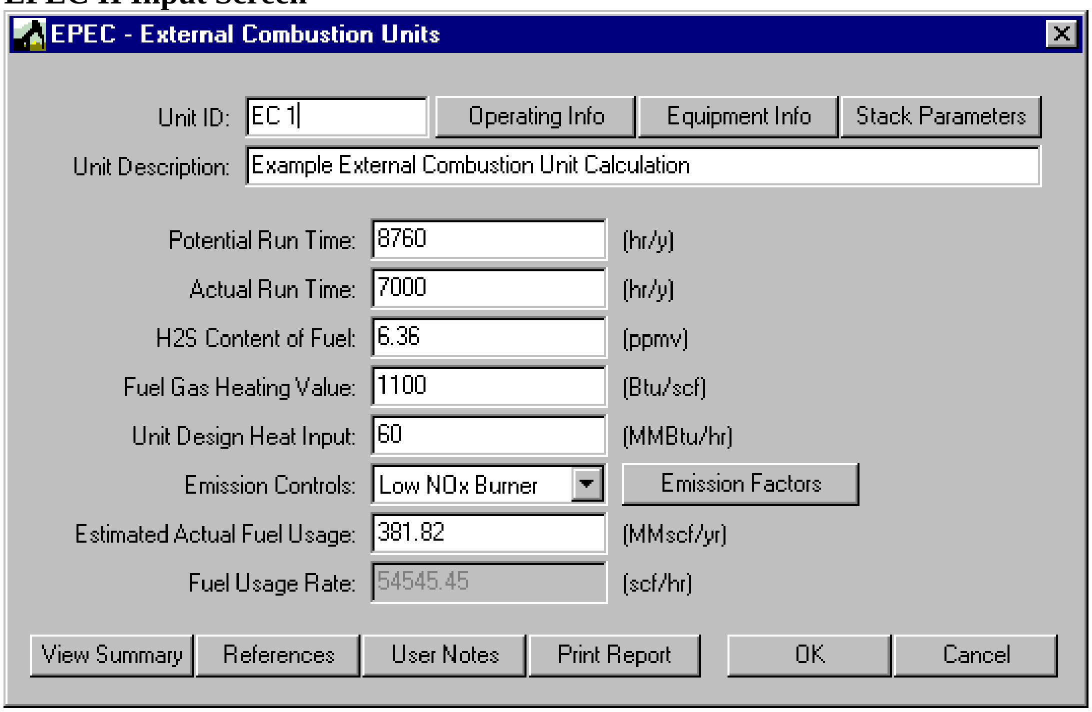
Inputs

t	7000 hr/yr
H_2S Content	6.36 ppmv (Note: default *AP-42* H_2S content = 3.18 ppmv)
H	1100 Btu/scf
Control Type	Low NO_x burner
HI	60 MMBtu/hr
EF_{SOx}	0.6 lb/MMscf × 6.36 ÷ 3.18 = 1.2 lb/MMscf
EF_{NOx}	50 lb/MMscf (for natural gas combustion unit, HI between 10 - 100 MMBtu/hr, from *AP-42* Section 1.4)

Results

$$E_{SOx} = 1.2 \times 60 \div 1100 \times 7000 \div 2000 = 0.23 \text{ tpy}$$
$$E_{NOx} = 50 \times 60 \div 1100 \times 7000 \div 2000 = 9.5 \text{ tpy}$$

EPEC II Input Screen



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EPEC II Output

```
     External Combustion Unit
     ========================
         Unit ID: EC 1
       Unit Desc: Example External Combustion Unit Calculation

                              Tons Per Year            Pounds Per Hour
                           ----------------------   ---------------------
                              Actual    Potential      Actual   Potential
                           ---------    ---------   ---------   ---------
               NOx:             9.55        11.95        2.73        2.73
               SOx:             0.23         0.29        0.07        0.07
                CO:            16.04        20.07        4.58        4.58
               VOC:             1.05         1.31        0.30        0.30
              PM10:             1.45         1.82        0.41        0.41
               THC:             2.10         2.63
           Methane:             0.44         0.55
            Ethane:             0.59         0.74
               CO2:         22909.20     28669.09
    HydrogenSulfide:              NA           NA
      1,3-Butadiene:              NA           NA
          n-Hexane:             0.34         0.43
   Trimethylpentane:              NA           NA
           Benzene:             0.00         0.00
           Toluene:               NA           NA
       EthylBenzene:              NA           NA
           Xylenes:               NA           NA
       Formaldehyde:            0.01         0.02
       Acetaldehyde:              NA           NA
               HAP:             0.36         0.45
```

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A.5 FIXED-ROOF STORAGE TANK EXAMPLE CALCULATIONS

<u>Standing Loss Equation</u>

$$L_s = 365 \times V_V \times W_V \times K_E \times K_S \times \frac{\text{ton}}{2000\,\text{lb}}$$

Standing Loss Inputs

Tank Type	Vertical
D	60 ft
H_s	15 ft
H_l	12 ft
Roof Type	Cone
$H_{r\text{-}cone}$	1.5 ft
Roof Slope, M_r	Hr-cone / (D ÷ 2) = 1.5 ÷ (60 ÷ 2) = 0.05
Vapor molecular weight, M_v	50 lb/lb-mol
Reid Vapor Pressure, RVP	5 psia
Nearest City	Corpus Christi, TX
Paint Color, Condition	Light Gray, Good
P_{bp}, Breather Vent pressure setting	0.03 psig
P_{bv}, Breather Vent Vacuum Setting	–0.03 psig
P_a , Average ambient pressure	14.70 psia

Known Values

Ideal Gas Constant, R = 10.731 psia ft^3 /(lb-mol °R)

Intermediate Calculated Values

Roof Outage

$$H_{ro} = \tfrac{1}{3} \times M_r \times (D \div 2) = \tfrac{1}{3} \times 0.05 \times (60 \div 2) = 0.5 \text{ ft}$$

Vapor Space Outage

$$H_{vo} = Hs - Hl + Hro = 15 - 12 + 0.5 = 3.5 \text{ ft}$$

Vapor Space Volume

$$V_v = \tfrac{\pi}{4} \times D^2 \times H_{vo} = \tfrac{3.14}{4} \times 60^2 \times 3.5 = 9896 \text{ ft}^3$$

Nearest City: Corpus Christi, TX

Therefore,[1]

Daily Maximum Ambient Temperature, T_{ax} = 541.6 °R

Daily Minimum Ambient Temperature, T_{an} = 522.5 °R

Daily Solar Insolation Factor, I = 1521.0 Btu/ft^2-day

---

[1] American Petroleum Institute (1991) *Manual of Petroleum Measurement Standards*, Chapter 19.1, “Evaporative Loss from Fixed Roof Tanks,” Measurement Coordination Dept., American Petroleum Institute, Washington, DC.

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Daily Average Ambient Temperature

$$T_{aa} = (T_{ax} + T_{an}) \div 2 = (541.6 + 522.5) \div 2 = 532.1\ °R$$

Paint Color, Condition = Light Gray, Good

Therefore,[2]

Tank Paint Solar Absorptance, α = 0.540

Liquid Bulk Temperature

$$T_b = T_{aa} + 6\alpha - 1 = 532.1 + 6 \times \alpha - 1 = 534.3\ °R$$

Avg Liquid Surface Temp

$$T_{la} = 0.44 \times T_{aa} + 0.56 \times T_b + 0.0079 \times \alpha \times I$$

$$0.44 \times 532.1 + 0.56 \times 534.3 + 0.0079 \times 0.540 \times 1521.0 = 539.8\ °R$$

True Vapor Pressure

$$P_{va} = \exp\{[12.82 - 0.9672 \ln(RVP)] - [7261 - 1216 \ln(RVP)] \div T_{la}\}$$

$$= \exp\{[12.82 - 0.9672 \ln(5.0)] - [7261 - 1216 \ln(5.0)] \div 539.8\} = 4.21 \text{ psia}$$

Vapor Density

$$Wv = M_v \times P_{va} \div (R \times T_{la}) = 50 \times 4.21 \div (10.731 \times 539.8) = 0.036 \text{ lb/ft}^3$$

Daily Ambient Temperature Range

$$\Delta T_a = T_{ax} - T_{an} = 19.1\ °R$$

Daily Vapor Temperature Range

$$\Delta T_v = 0.72 \times \Delta T_a + 0.028 \times \alpha \times I$$

$$= 0.72 \times 19.1 + 0.028 \times 0.540 \times 1521.0 = 36.7\ °R$$

Daily Pressure Range

$$\Delta P_v = 0.50 \times [7261 - 1216 \ln(RVP)] \times P_{va} \times \Delta T_v \div T_{la}^2$$

$$= 0.50 \times [7261 - 1216 \ln(5.0)] \times 4.21 \times 36.7 \div 539.8^2 = 1.41 \text{ psia}$$

Breather Vent Pressure Setting Range

$$\Delta P_b = 0.03 - (-0.03) = 0.06 \text{ psig}$$

Vapor space expansion factor

$$K_e = \Delta Tv \div Tla + (\Delta P_v - \Delta P_b) \div (P_a - P_{va})$$

$$= 36.7 \div 539.8 + (1.41 - 0.06) \div (14.7 - 4.21) = 0.197$$

Vented vapor saturation factor

$$K_s = 1 \div (1 + 0.053 \times P_{va} \times H_{vo})$$

$$= 1 \div (1 + 0.053 \times 4.21 \times 3.5) = 0.561$$

[2] American Petroleum Institute (1991) *Manual of Petroleum Measurement Standards*, Chapter 19.1, "Evaporative Loss from Fixed Roof Tanks," Measurement Coordination Dept., American Petroleum Institute, Washington, DC.

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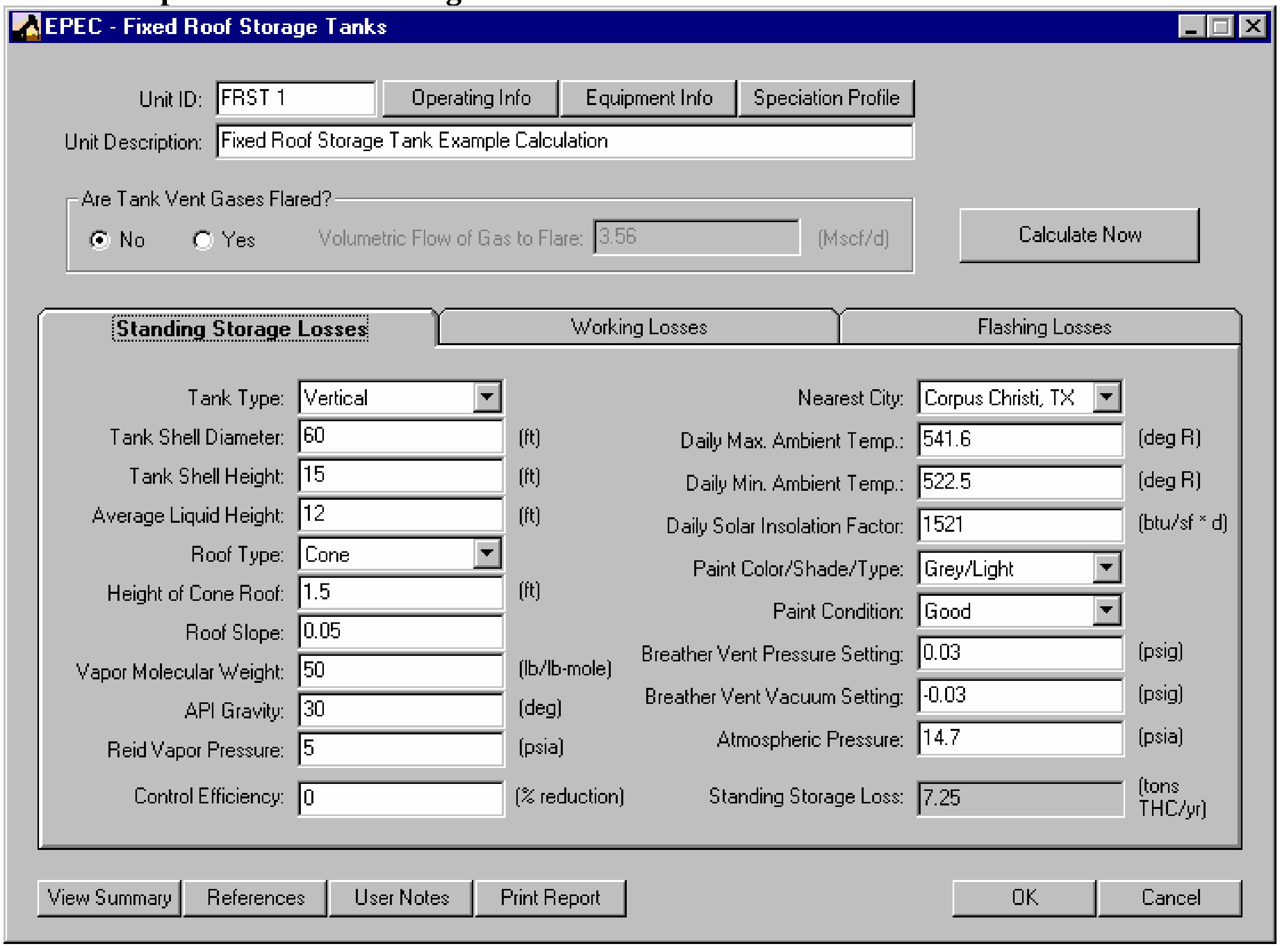
Standing Loss Results

$$L_s = 365 \times V_V \times W_V \times K_E \times K_S \times \frac{\text{ton}}{2000\ \text{lb}}$$

$$= 365 \times 9896 \times 0.036 \times 0.197 \times 0.561 \div 2000 = 7\ \text{tpy}$$

EPEC II Input Screen – Standing Losses



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Working Losses Equation

$$L_w = 0.0010 \times M_V \times P_{VA} \times Q \times K_N \times K_P \times \frac{\text{ton}}{2000\ \text{lb}}$$

Additional Working Loss Inputs (beyond those for standing losses)

Q	365,000 bbl/yr
K_p	Working loss product factor = 0.75 for crude oil

Intermediate Calculations

Maximum Tank Volume

$$V_{lx} = \pi/4 \times D^2 \times H_s = \pi/4 \times 60^2 \times 15 = 42412\ ft^3$$

Number of turnovers per year

$$N = Q \times 5.62\ ft^3/bbl \div V_{lx} = 365000 \times 5.62 \div 42412 = 48\ yr^{-1}$$

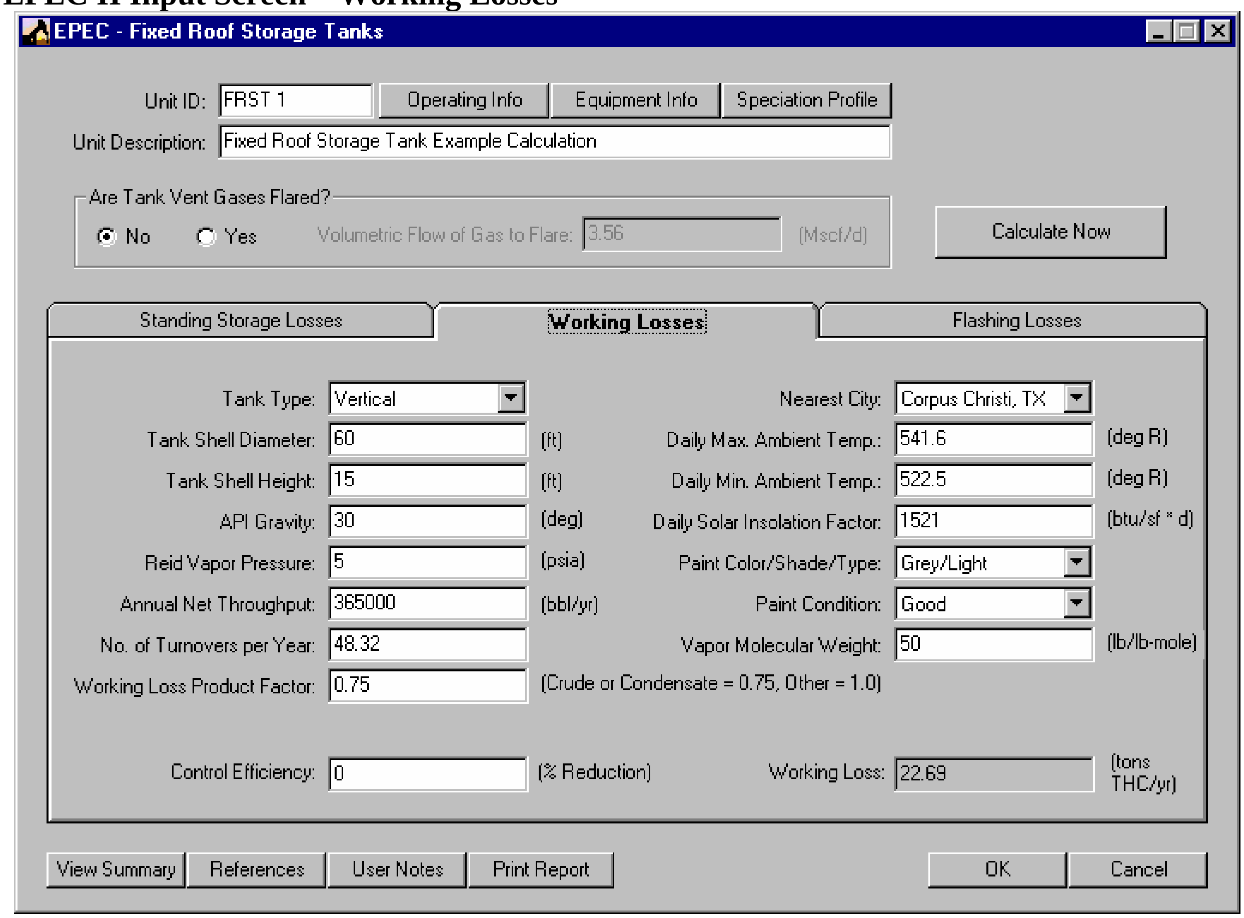
Turnover factor

$$\text{For } N > 36,\ K_N = (180 + N) \div 6N = (180 + 48) \div 6 \div N = 0.79$$

Working Loss Results

$$L_W = 0.0010 \times 50 \times 4.21 \times 365000 \times 0.79 \times 0.75 \div 2000 = 23\ tpy$$

EPEC II Input Screen – Working Losses



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Flashing Losses Equations

$$L_f = GOR \times Q \times GD \times \frac{ton}{2000\,lb}$$

According to the Vasquez-Beggs Equation,

$$GOR_{VB} = C_1 \times CSG \times UP^{C_2} \times \exp\left(\frac{C_3 \times APIG}{T+460}\right)$$

According to the RMC Equation,

$$GOR_{RMC} = \log^{-1}{}_{10}\left[0.4896 - 4.916 \times \log_{10}(ST) + 3.469 \times \log_{10}(SG) + 1.501 \times \log_{10}(UP) - 0.9213 \times \log_{10}(T)\right]$$

Flashing Loss Additional Inputs (beyond those for working and standing losses)

APIG	30 °API
SG, Specific gravity of gas in separator	0.7
UVP, Upstream vessel pressure	4 psig
T, Fluid temperature in upstream vessel	80 °F
C, Mole fraction of THCs	1.0
Mc, Molecular weight of THCs	50 lb/lb-mol

Intermediate Calculations

Vasquez-Beggs Correlation Coefficients

For APIG ≤ 30,
$C_1 = 0.0362$
$C_2 = 1.0937$
$C_3 = 25.724$

Upstream Pressure

UP = UVP + 14.7 psia = 18.7 psia

Corrected Specific Gravity

$CSG = SG \times [1.0 + 0.00005912 \times APIG \times T \times \log_{10}(UP \div 114.7)]$
$= 0.7 \times [1.0 + 0.00005912 \times 30 \times 80 \times \log_{10}(18.7 \div 114.7)] = 0.622$

Tank Vent Hydrocarbon Gas Density

$$GD = \frac{C \times M_c \frac{lb}{lb \cdot mol}}{379\ scf/lb \cdot mol} = \frac{(1.0)(50)}{379} = 0.13 \frac{lb}{ft^3}$$

Specific Gravity of Stock Tank Oil

ST = 141.5 ÷ (APIG + 131.5) = 141.5 ÷ (30 + 131.5) = 0.876

Flashing Loss Results

According to the Vasquez-Beggs Method,

$GOR_{VB} = 0.0362 \times 0.622 \times 18.7^{1.0937} \times \exp[(25.724 \times 30) \div (80 + 460)] = 2.312$

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$$L_f = 2.312 \times 365{,}000 \times 0.132 \div 2000 = 56 \text{ tpy}$$

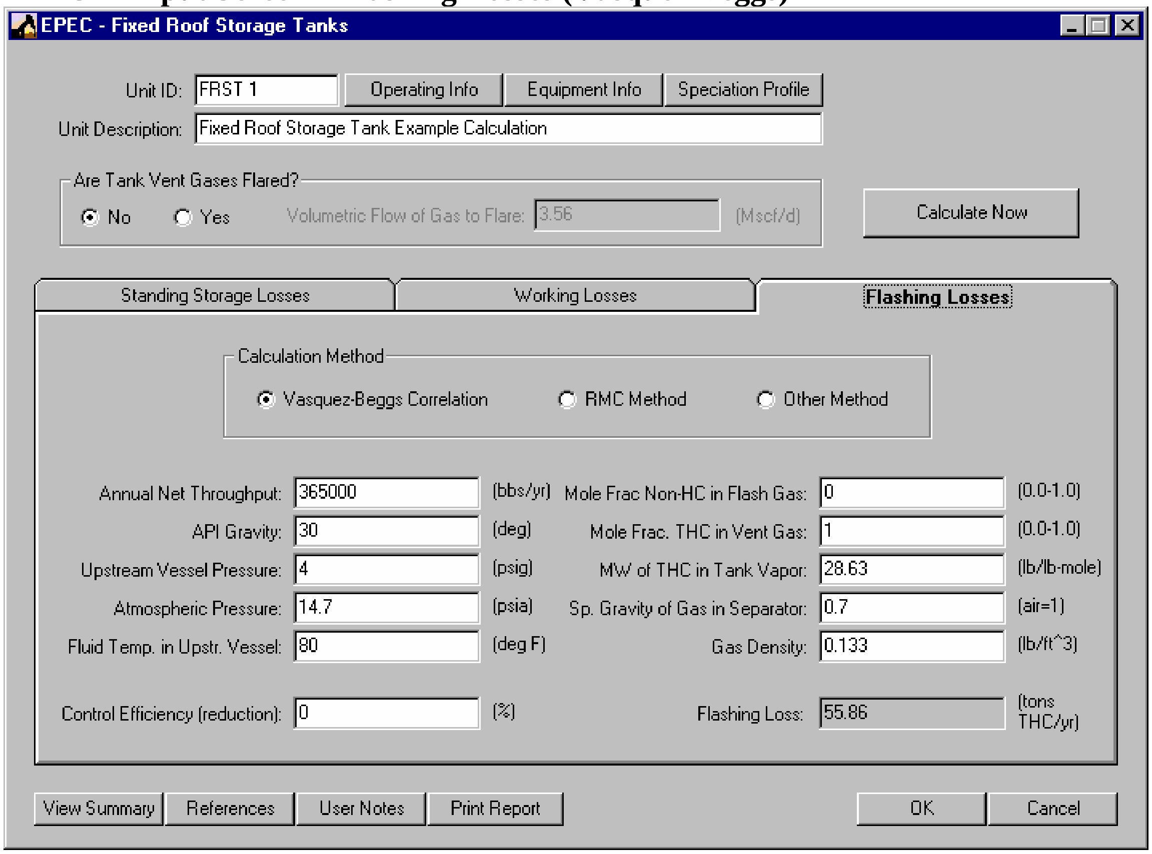
According to the RMC Method,

$$GOR_{RMC} = \log_{10}^{-1}[0.4896 - 4.916\log_{10}(ST) + 3.469\log_{10}(SG) + 1.501\log_{10}(UP) - 0.9213\log_{10}(T)]$$

$$GOR_{RMC} = \log_{10}^{-1}[0.4896 - 4.916\log_{10}(0.876) + 3.469\log_{10}(0.7) + 1.501\log_{10}(18.7) - 0.9213\log_{10}(80)] = 2.45$$

$$L_f = 2.45 \times 365{,}000 \times 0.13 \div 2000 = 59 \text{ tpy}$$

EPEC II Input Screen – Flashing Losses (Vasquez-Beggs)



Total Losses (Standing, Working, and Flashing)

$$L_{TOT} = L_S + L_W + L_F$$

Flashing losses calculated from Vasquez-Beggs equation:

$$L_{TOT} = 7 + 23 + 56 = 86 \text{ tpy}$$

Flashing losses calculated from RMC equation:

$$L_{TOT} = 7 + 23 + 59 = 89 \text{ tpy}$$

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EPEC II Output – Total Losses (using Vasquez-Beggs)

```
      Fixed Roof Storage Tank
      =======================
          Unit ID: FRST 1
        Unit Desc: Fixed-Roof Storage Tank Example Calculation

                                   Tons Per Year
                              -------------------------
                                 Actual       Potential
                              ---------       ---------
                    VOC:          85.79           85.79
                Methane:           0.00            0.00
       C2 Hydrocarbons:           7.96            7.96
       C3 Hydrocarbons:          22.17           22.17
       C4 Hydrocarbons:          23.31           23.31
       C5 Hydrocarbons:          12.10           12.10
       C6 Hydrocarbons:           6.70            6.70
       C7 Hydrocarbons:           3.23            3.23
       C8 Hydrocarbons:           2.54            2.54
       C9 Hydrocarbons:           0.00            0.00
      C10 Hydrocarbons:           0.00            0.00
               n-Hexane:           1.89            1.89
                Benzene:           0.10            0.10
                Toluene:           0.20            0.20
           EthylBenzene:           0.08            0.08
                Xylenes:           0.49            0.49
                    HAP:           2.75            2.75
```

EPEC II Output – Total Losses (using RMC)

```
      Fixed Roof Storage Tank
      =======================
          Unit ID: FRST 1
        Unit Desc: Fixed-Roof Storage Tank Example Calculation

                                   Tons Per Year
                              -------------------------
                                 Actual       Potential
                              ---------       ---------
                    VOC:          89.55           89.55
                Methane:           0.00            0.00
       C2 Hydrocarbons:           8.31            8.31
       C3 Hydrocarbons:          23.14           23.14
       C4 Hydrocarbons:          24.33           24.33
       C5 Hydrocarbons:          12.63           12.63
       C6 Hydrocarbons:           6.99            6.99
       C7 Hydrocarbons:           3.38            3.38
       C8 Hydrocarbons:           2.65            2.65
       C9 Hydrocarbons:           0.00            0.00
      C10 Hydrocarbons:           0.00            0.00
               n-Hexane:           1.97            1.97
                Benzene:           0.11            0.11
                Toluene:           0.21            0.21
           EthylBenzene:           0.08            0.08
                Xylenes:           0.51            0.51
                    HAP:           2.87            2.87
```

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A.6 FLARE EXAMPLE CALCULATIONS

Flare Equation

$$E = V_{Flare} \times H \times EF \times t \times \frac{ton}{2000\ lb} \div \frac{1000}{M}$$

Pilot Equation

$$E = EF \times V_{Pilot} \times t \times \frac{ton}{2000\ lb} \times \frac{M}{1000}$$

Inputs

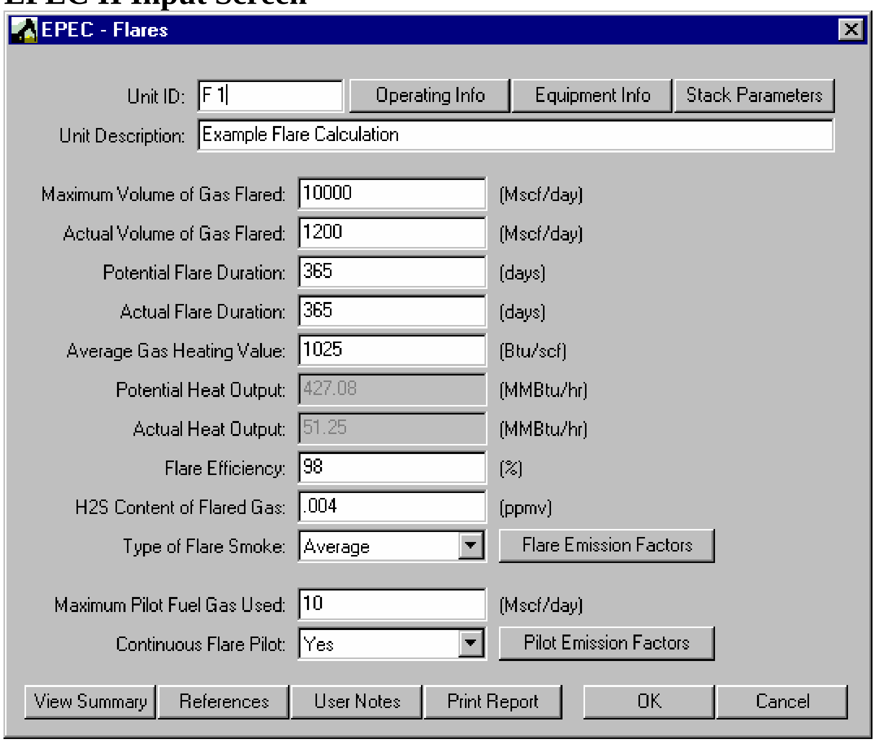
V_{Flare}	1200 Mscf/day
H	1025 Btu/scf
t	365 day/yr
EF_{CO}	0.370 lb/MMBtu (from *AP-42*, Section 13.5)
Smoke Type	Average, therefore EF_{PM10} = 0.011 lb/MMBtu
Flare efficiency	98%
Continuous Pilot	Yes, therefore, t = 365 day/year
V_{Pilot}	10 Mscf/day
EF_{NOx}	100 lb/MMscf (from *AP-42*, Section 1.4)

Results

Flare: E_{CO} = 1200 × 1025 × 0.370 × 365 ÷ 2000 ÷ 1000 = 83.1 tpy

Pilot: E_{NOx} = 100 × 10 × 365 ÷ 2000 ÷ 1000 = 0.18 tpy

EPEC II Input Screen



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EPEC II Output

Flare
=====

Unit ID: F 1

Unit Desc: Example Flare Calculation

	Tons Per Year		Pounds Per Hour	
	Actual	Potential	Actual	Potential
NOx:	14.89	14.89	3.40	3.40
SOx:	0.12	0.12	0.63	0.63
CO:	81.03	81.03	18.50	18.50
VOC:	11.39	11.39	62.40	62.40
PM10:	0.00	0.00	0.00	0.00
CO2:	74687.77	74687.77	17052.00	17052.00
Pilot CO2:	207.47	47.37		
Pilot NOx:	0.18	0.04		
Pilot SOx:	0.00	0.00		
Pilot CO:	0.15	0.04		
Pilot VOC:	0.01	0.00		
Pilot PM10:	0.01	0.00		
THC:	30.66	30.66		
Methane:	16.86	16.86		
Ethane:	2.41	2.41		
HydrogenSulfide:	0.00	0.00		
1,3-Butadiene:	NA	NA		
n-Hexane:	NA	NA		
Trimethylpentane:	NA	NA		
Benzene:	NA	NA		
Toluene:	NA	NA		
EthylBenzene:	NA	NA		
Xylenes:	NA	NA		
Formaldehyde:	NA	NA		
Acetaldehyde:	NA	NA		
HAP:	0.00	0.00		

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A.7 EQUIPMENT FUGITIVE EMISSIONS EXAMPLE CALCULATION

Fugitives Equation

$$E_{THC} = EF \times \left[N_{LDAR} \times \left(1 - \frac{Control\%}{100\%} \right) + N_{non-LDAR} \right] \times t \times \frac{ton}{2000\,lb}$$

$$E_{VOC} = E_{THC} \times \frac{Wt\%}{100\%}$$

Inputs

Calculation for flanges at a gas plant.

EF_{THC}	8.75×10^{-4} lb/hr per flange (from API Publication No. 4638)
N_{LDAR}	67 flanges
$N_{non\text{-}LDAR}$	156 flanges
t	8760 hours/yr
Control%	75% (hypothetical)
Wt%	0.069% for benzene (from API Publication No. 4638)

Results

$$E_{THC} = 8.75 \times 10^{-4} \times [67 \times (1 - 75/100) + 156] \times 8760 \div 2000 = 0.66 \text{ tpy}$$

$$E_{Benzene} = 0.66 \times 0.069/100 = 4.6 \times 10^{-4} \text{ tpy}$$

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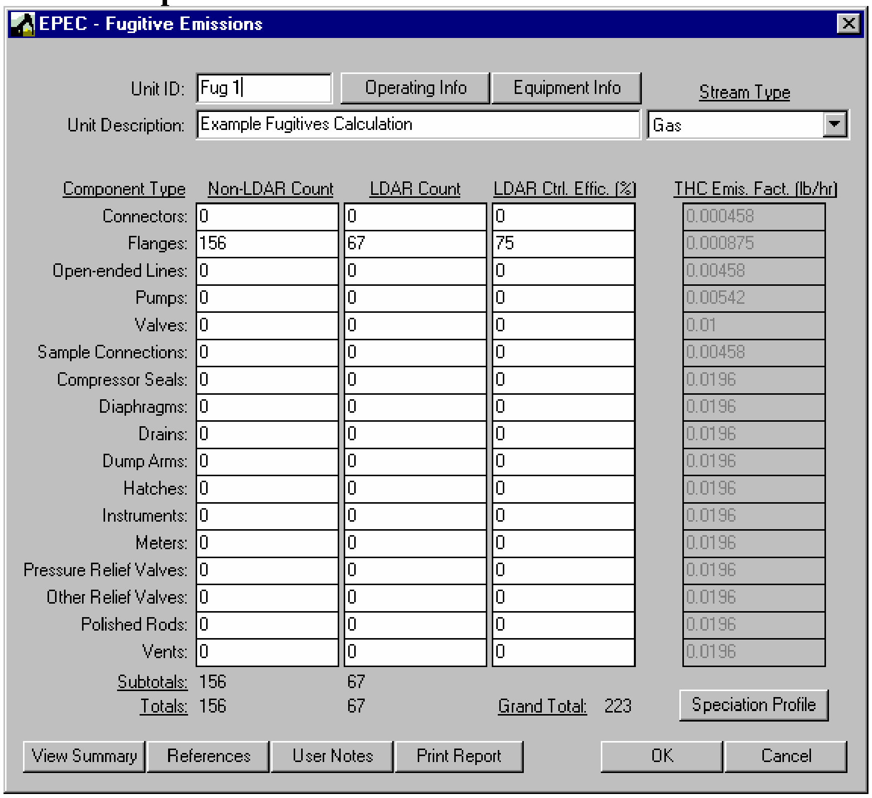
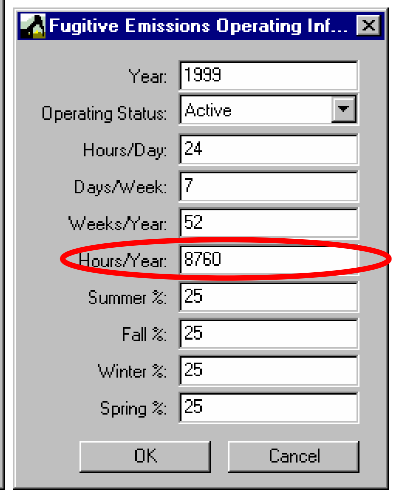
EPEC II Input Screens





EPEC II Output

```
      Fugitive Emissions
      ==================
          Unit ID: Fug 1
        Unit Desc: Example Fugitives Calculation

                              Tons Per Year            Pounds Per Hour
                          ----------------------    --------------------
                            Actual    Potential      Actual    Potential
                          ---------   ---------    ---------   ---------
                VOC:        0.11        0.15         0.03        0.03
          Total HAP:        0.00        0.00         0.00        0.00
                THC:        0.66        0.85
            Methane:        0.45        0.59
             Ethane:        0.09        0.12
               NMHC:        0.21        0.27
                C6+:        0.00        0.01
            Benzene:        0.00        0.00
            Toluene:        0.00        0.00
       EthylBenzene:        0.00        0.00
            Xylenes:        0.00        0.00
```

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A.8 GLYCOL REGENERATOR EXAMPLE CALCULATION

Rich-Lean Equation

$$E = (C_{Rich} - C_{Lean}) \times Q_{Recirc} \times t \times 3.785\ L/gal \times 60\ min/hr \times lb/453{,}600\ mg \times ton/2000\ lb$$

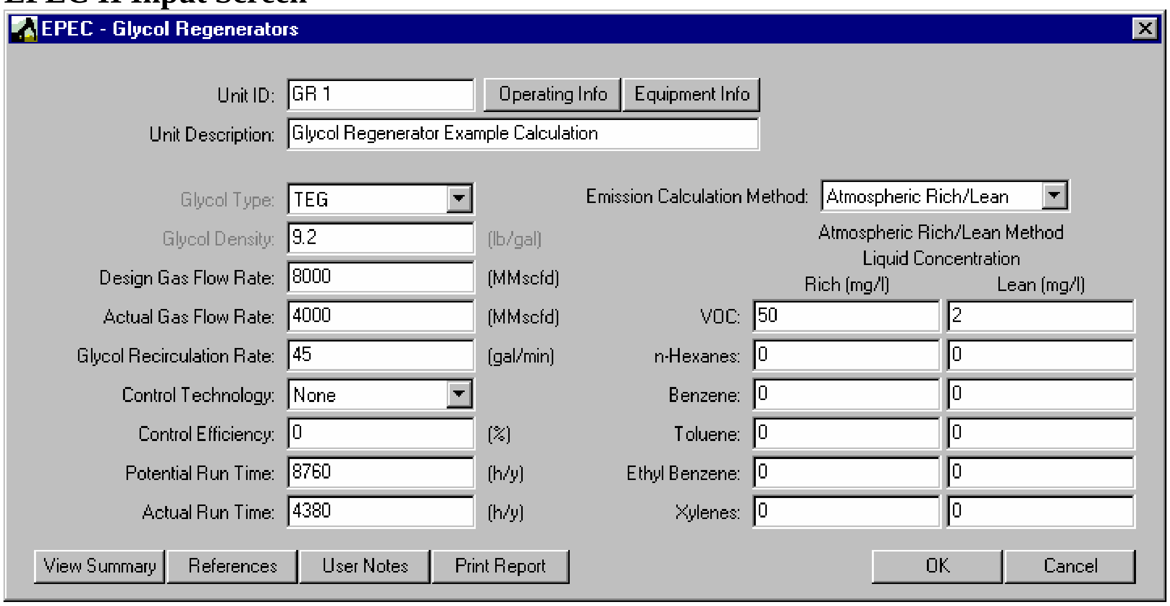
Inputs

Q_{Recirc}	45 gal/min
t	4380 hours/yr
C_{Rich}	50 mg/L
C_{Lean}	2 mg/L
Control Type	None, therefore % Efficiency = 0%

Result

$$E_{VOC} = (50 - 2) \times 45 \times 4380 \times 3.785 \times 60 \div 453600 \div 2000 = 2.37\ tpy$$

EPEC II Input Screen



EPEC II Output

```
      Glycol Regenerator
      ==================
          Unit ID: GR 1
        Unit Desc: Glycol Regenerator Example Calculation

                           Tons Per Year              Pounds Per Hour
                       ---------------------      ------------------------
                         Actual    Potential        Actual       Potential
                       ---------   ---------      ---------      ---------
               VOC:         2.37        9.47           1.08           2.16
         n-Hexanes:         0.00        0.00           0.00           0.00
           Benzene:         0.00        0.00           0.00           0.00
           Toluene:         0.00        0.00           0.00           0.00
     Ethyl Benzene:         0.00        0.00           0.00           0.00
           Xylenes:         0.00        0.00           0.00           0.00
         Total HAP:         0.00        0.00           0.00           0.00
```

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A.9 LOADING OPERATION EXAMPLE CALCULATION

Tanker Truck/Railcar Equations

$$E = L_L \times Q \times \frac{42\text{ gal}}{\text{bbl}} \times \frac{\text{ton}}{2000\text{ lb}} \times \frac{M}{1000}$$

$$L_L = 12.46 \times \frac{S \times P \times m}{T_b}$$

Inputs

RVP	5.0
Q	365,000 bbl/yr
Nearest City	Corpus Christi, TX
Tank Paint Color, Condition	Light Gray, Good
S	0.6 for submerged loading
m	50 lb/lb-mol

Intermediate Calculations

Nearest City: Corpus Christi, TX

Therefore,[3]

Daily Maximum Ambient Temperature, T_{ax} = 541.6 °R

Daily Minimum Ambient Temperature, T_{an} = 522.5 °R

Daily Solar Insolation Factor, I = 1521.0 Btu/ft^2-day

Daily Average Ambient Temperature

$$T_{aa} = (T_{ax} + T_{an}) \div 2 = (541.6 + 522.5) \div 2 = 532.1\ °R$$

Paint Color, Condition = Light Gray, Good

Therefore,[4]

Tank Paint Solar Absorptance, α = 0.540

Liquid Bulk Temperature

$$T_b = T_{aa} + 6\alpha - 1 = 532.1 + 6 \times \alpha - 1 = 534.3\ °R$$

True Vapor Pressure of Loaded Liquid (note: use Liquid Bulk Temperature to calculate True Vapor Pressure due to fluid mixing while loading)

$$P = \exp\{[12.82 - 0.9672 \ln(RVP)] - [7261 - 1216 \ln(RVP)] \div T_b\}$$
$$= \exp\{[12.82 - 0.9672 \ln(5.0)] - [7261 - 1216 \ln(5.0)] \div 534.3\} = 3.80 \text{ psia}$$

[3] American Petroleum Institute (1991) *Manual of Petroleum Measurement Standards*, Chapter 19.1, "Evaporative Loss from Fixed Roof Tanks," Measurement Coordination Dept., American Petroleum Institute, Washington, DC.

[4] ibid.

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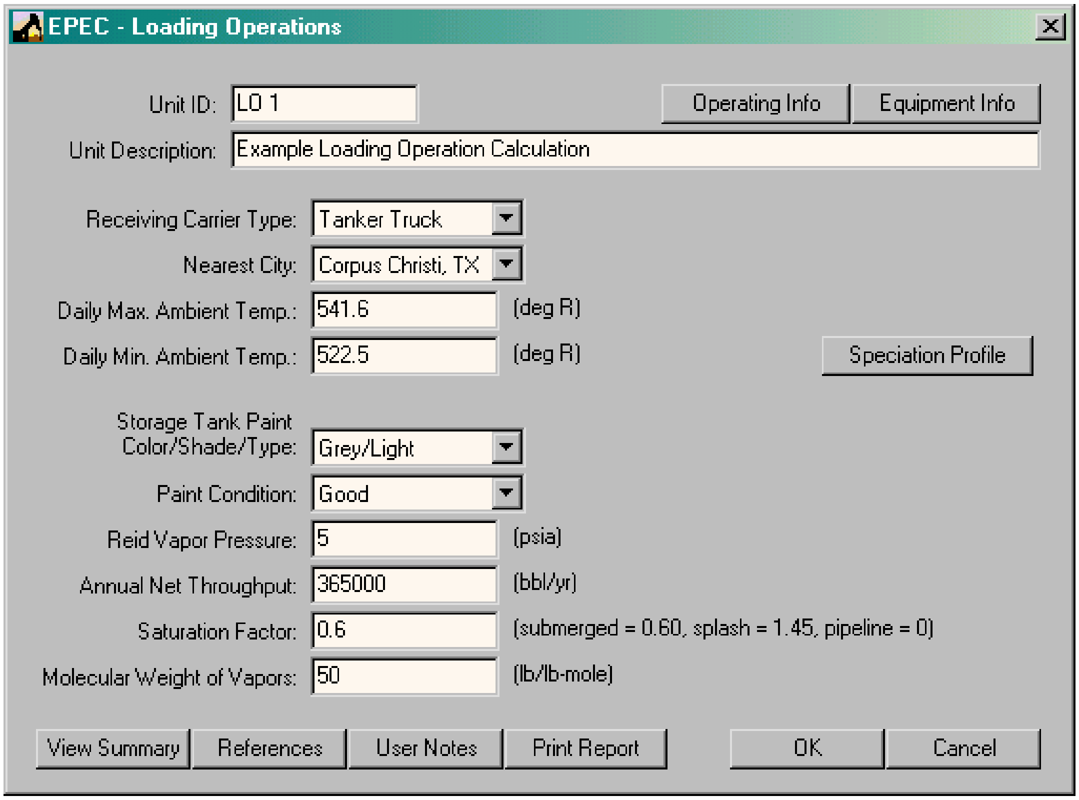
Results

$$L_L = 12.46 \times 0.6 \times 3.80 \times 50 \div 534.3 = 2.66 \text{ lb/Mgal}$$
$$E = 2.66 \times 365000 \times 42 \div 2000 \div 1000 = 20.4 \text{ tpy}$$

EPEC II Input Screen



EPEC II Output

```
       Loading Operations
       ==================
           Unit ID: LO 1
         Unit Desc: Example Loading Operation Calculation

                                      Tons Per Year
                                  ---------------------
                                     Actual   Potential
                                  ---------   ---------
                     VOC:             20.40       20.40
                 Methane:              0.00        0.00
         C2 Hydrocarbons:              1.89        1.89
         C3 Hydrocarbons:              5.27        5.27
         C4 Hydrocarbons:              5.54        5.54
         C5 Hydrocarbons:              2.88        2.88
         C6 Hydrocarbons:              1.59        1.59
         C7 Hydrocarbons:              0.77        0.77
         C8 Hydrocarbons:              0.60        0.60
         C9 Hydrocarbons:              0.00        0.00
        C10 Hydrocarbons:              0.00        0.00
                n-Hexane:              0.45        0.45
                 Benzene:              0.02        0.02
                 Toluene:              0.05        0.05
            EthylBenzene:              0.02        0.02
                 Xylenes:              0.12        0.12
```

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Marine Loading Equations

$$E = C_L \times Q \times \frac{42\ \text{gal}}{\text{bbl}} \times \frac{\text{ton}}{2000\ \text{lb}} \times \frac{M}{1000}$$

$$C_L = C_A + C_G$$

$$C_G = 1.84 \times (0.44 \times P - 0.42) \times \frac{mG}{T_b}$$

Inputs and Known Values

Nearest City	Corpus Christi, TX
Tank Paint Color, Condition	Light Gray, Good
Q	365,000 bbl/yr
C_A	0.86 for uncleaned tanker, volatile previous load
T_b	534.3 °R (from previous calculation)
P	3.80 psia (from previous calculation)
m	50 lb/lb-mol
G	1.02

Results

$$C_G = 1.84 \times (0.44 \times 3.80 - 0.42) \times 50 \times 1.02 \div 534.3 = 0.22$$

$$C_L = 0.86 + 0.22 = 1.08$$

$$E = 1.08 \times 365000 \times 42 \div 2000 \div 1000 = 8.28\ \text{tpy}$$

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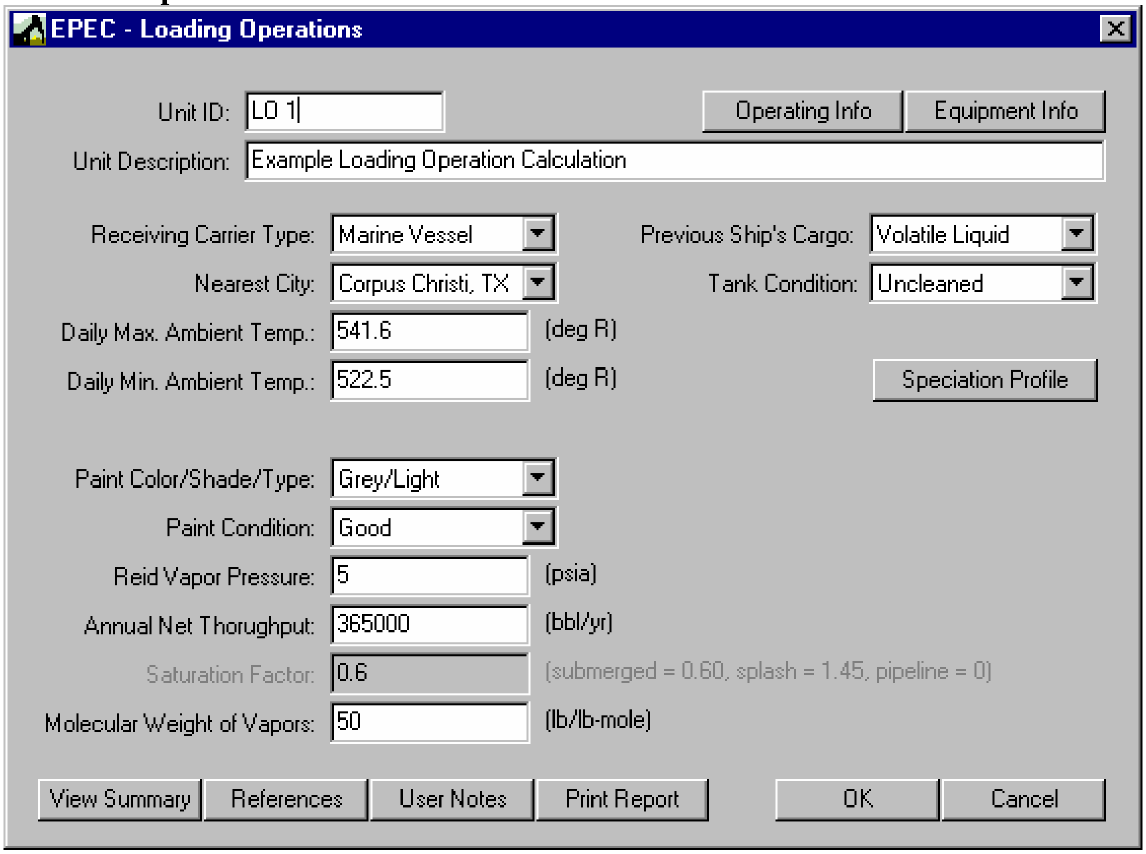

EPEC II Results

```
      LOADING OPERATIONS
      ==================
          UNIT ID: LO 1
        UNIT DESC: EXAMPLE LOADING OPERATION CALCULATION

                                   TONS PER YEAR
                              ---------------------
                                 ACTUAL   POTENTIAL
                              ---------   ---------
                 VOC:              8.28        8.28
             METHANE:              0.00        0.00
     C2 HYDROCARBONS:              0.77        0.77
     C3 HYDROCARBONS:              2.14        2.14
     C4 HYDROCARBONS:              2.25        2.25
     C5 HYDROCARBONS:              1.17        1.17
     C6 HYDROCARBONS:              0.65        0.65
     C7 HYDROCARBONS:              0.31        0.31
     C8 HYDROCARBONS:              0.25        0.25
     C9 HYDROCARBONS:              0.00        0.00
    C10 HYDROCARBONS:              0.00        0.00
            N-HEXANE:              0.18        0.18
             BENZENE:              0.01        0.01
             TOLUENE:              0.02        0.02
        ETHYLBENZENE:              0.01        0.01
             XYLENES:              0.05        0.05
```

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A.10 NATURAL GAS ENGINE EXAMPLE CALCULATIONS

Fuel Usage Equation

$$E = EF_{(lb/MMBtu)} \times U \times H \times \frac{ton}{2000\ lb}$$

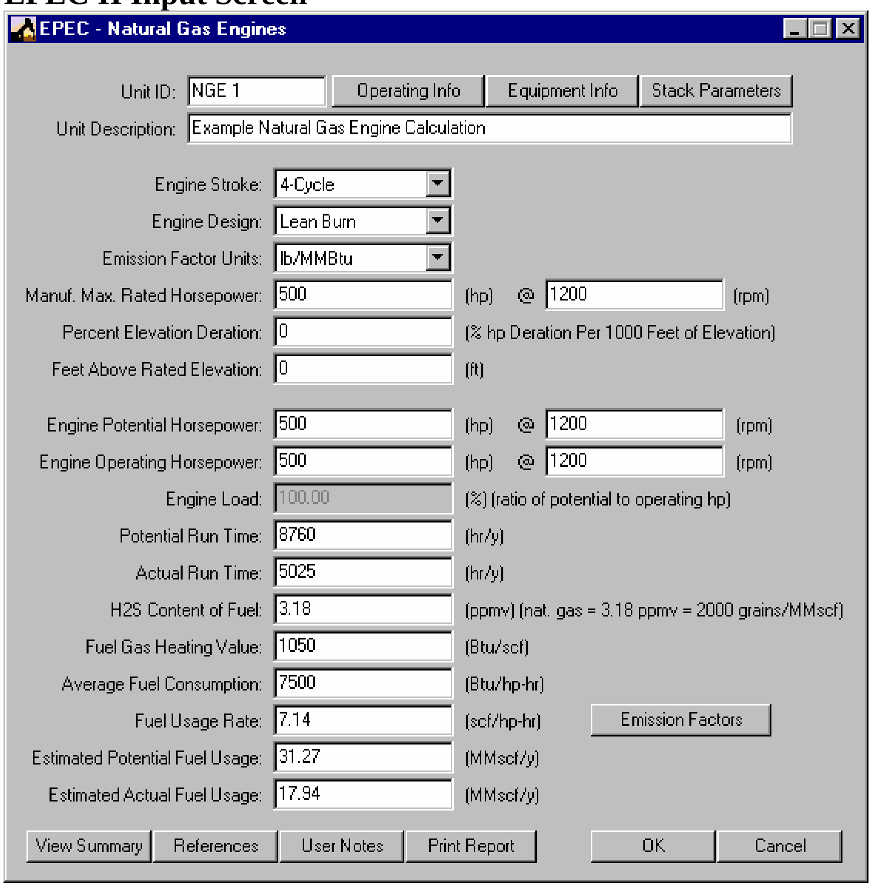
Inputs

HP	500 hp
t	5025 hr/yr
H	1050 Btu/scf
Fuel Consumption, FC	7500 Btu/hp-hr
$U = HP \times t \times FC \div H \div 10^6$	$500 \times 5025 \times 7500 \div 1050 \div 10^6 = 17.95$ MMscf/yr
Engine Stroke, Design	4-Stroke, Lean-Direct
Engine Load	100%
EF_{VOC}	0.118 lb/MMBtu (from *AP-42*, Section 3.2)

Result

$$E_{VOC} = 0.118 \times 17.95 \times 1050 \div 2000 = 1.11 \text{ tpy}$$

EPEC II Input Screen



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EPEC II Output

```
Natural Gas Engine
==================
    Unit ID: NGE 1
  Unit Desc: Example Natural Gas Engine Calculation

                           Tons Per Year               Pounds Per Hour
                      ----------------------      ---------------------
                         Actual    Potential         Actual   Potential
                      ---------    ---------      ---------   ---------
              NOx:        38.43        66.98          15.29       15.29
              SOx:         0.01         0.01           0.00        0.00
               CO:         2.99         5.21           1.19        1.19
              VOC:         1.11         1.94           0.44        0.44
             PM10:         0.09         0.16           0.04        0.04
              THC:        13.85        24.13
          Methane:        11.77        20.52
           Ethane:         0.99         1.72
              CO2:      1036.04      1805.84
  HydrogenSulfide:           NA           NA
    1,3-Butadiene:         0.00         0.00
         n-Hexane:         0.01         0.02
Trimethylpentane:          0.00         0.00
          Benzene:         0.00         0.01
          Toluene:         0.00         0.01
     EthylBenzene:         0.00         0.00
          Xylenes:         0.00         0.00
     Formaldehyde:         0.50         0.87
     Acetaldehyde:         0.08         0.14
              HAP:         0.60         1.05
```

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Power Output Equation

$$E = EF_{(g/hp\text{-}hr)} \times HP \times t \times \frac{lb}{453.6\ g} \times \frac{ton}{2000\ lb}$$

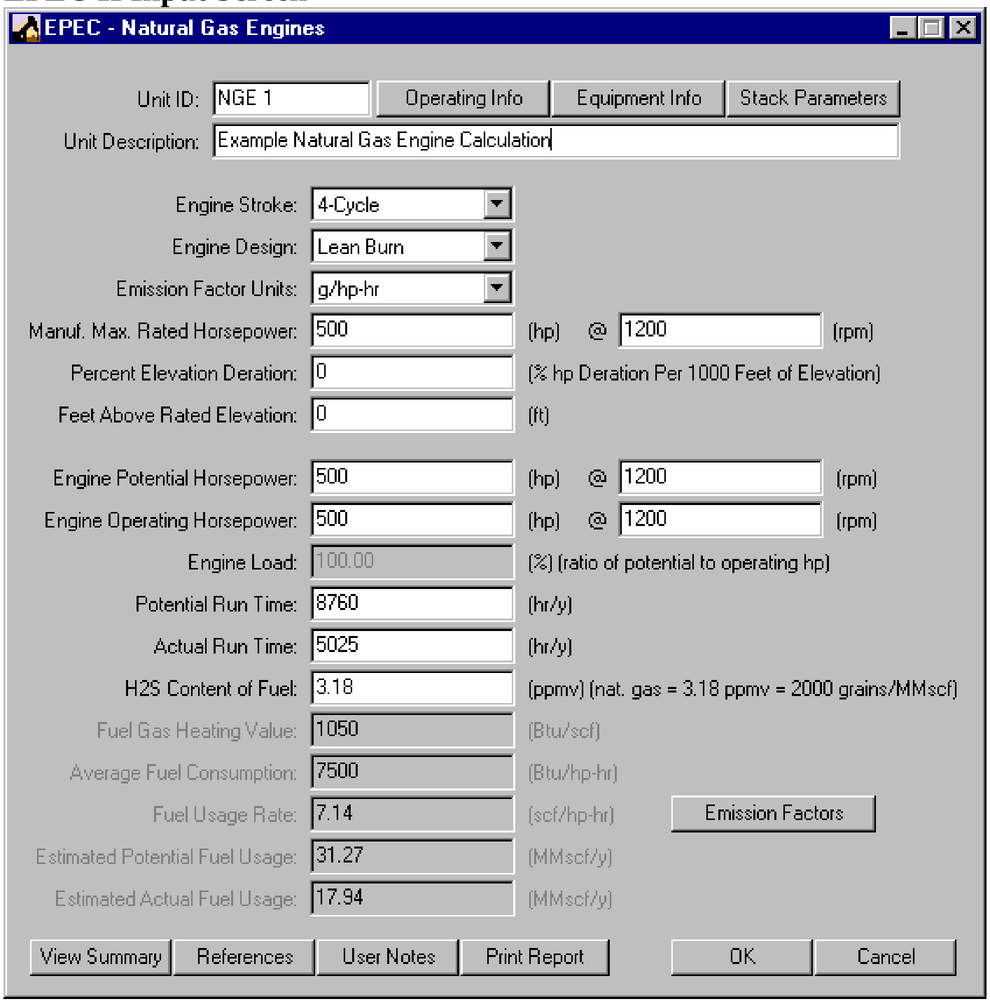
Additional Inputs

EF_{VOC}	0.136 g/hp hr (from *AP-42*, Section 3.2)

Result

$$E_{VOC} = 0.136 \times 500 \times 5025 \div 453.6 \div 2000 = 0.38\ tpy$$

EPEC II Input Screen



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EPEC II Output

```
Natural Gas Engine
==================
    Unit ID: NGE 1
  Unit Desc: Example Natural Gas Engine Calculation

                         Tons Per Year          Pounds Per Hour
                      ----------------------  ----------------------
                        Actual    Potential     Actual    Potential
                      ---------  ---------    ---------  ---------
              NOx:       13.04      22.74         5.19       5.19
              SOx:        0.00       0.00         0.00       0.00
               CO:        1.01       1.77         0.40       0.40
              VOC:        0.38       0.66         0.15       0.15
             PM10:        0.03       0.06         0.01       0.01
              THC:        4.71       8.21
          Methane:        3.99       6.95
           Ethane:        0.34       0.58
              CO2:      351.73     613.16
  HydrogenSulfide:          NA         NA
    1,3-Butadiene:        0.00       0.00
         n-Hexane:        0.00       0.01
 Trimethylpentane:        0.00       0.00
          Benzene:        0.00       0.00
          Toluene:        0.00       0.00
     EthylBenzene:        0.00       0.00
          Xylenes:        0.00       0.00
     Formaldehyde:        0.17       0.29
     Acetaldehyde:        0.03       0.05
              HAP:        0.20       0.36
```

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A.11 NATURAL GAS TURBINE EXAMPLE CALCULATION

<u>Fuel Usage Equation</u>

$$E = EF_{(lb/MMBtu)} \times U \times H \times \frac{ton}{2000\ lb}$$

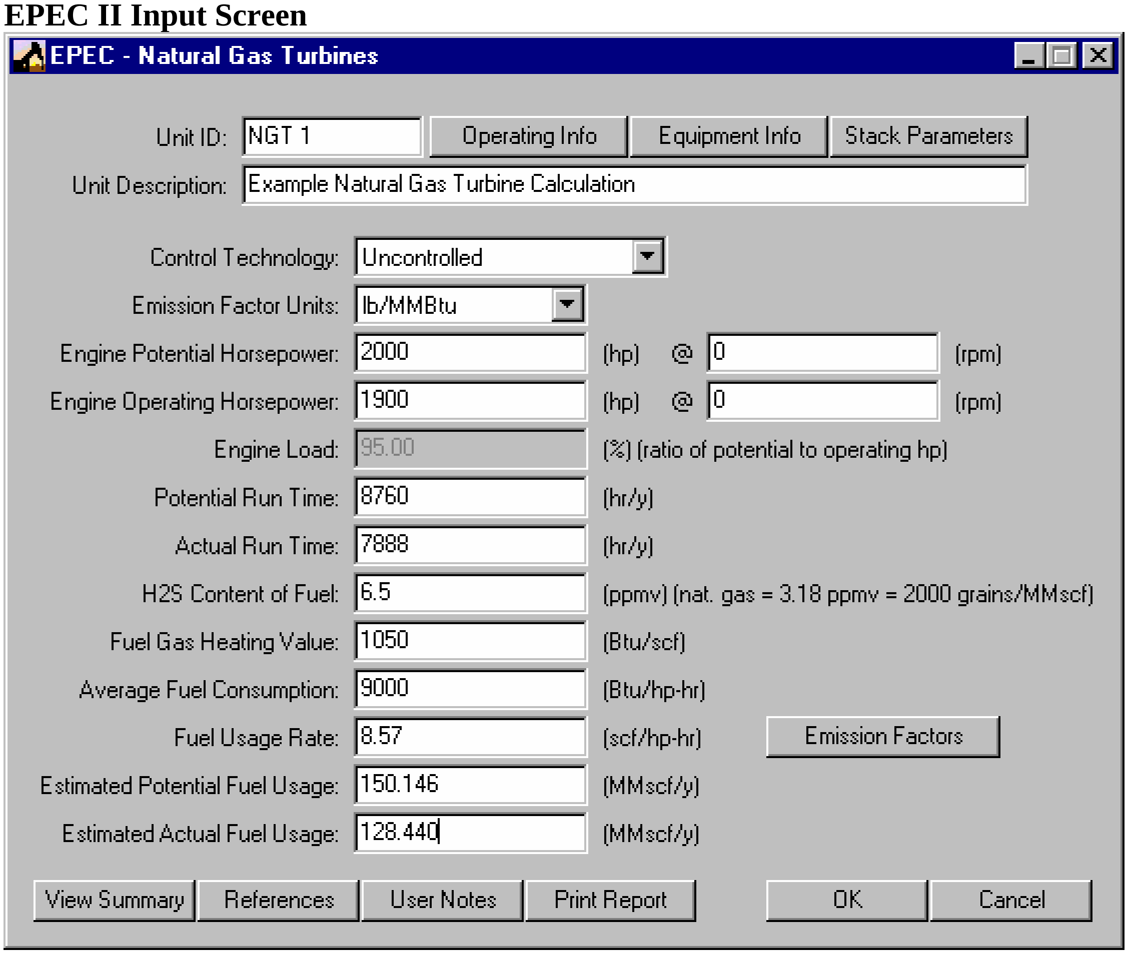
Inputs

Control Technology	Uncontrolled
HP	1900 hp
t	7888 hr/yr
H	1050 Btu/scf
Fuel Consumption, FC	9000 Btu/hp-hr
$U = HP \times t \times FC \div H \div 10^6$	$1900 \times 7888 \times 9000 \div 1050 \div 10^6 = 128.5$ MMscf/yr
EF_{NOx}	0.32 lb/MMBtu (from *AP-42*, Section 3.2)

Result

$$E_{NOx} = 0.32 \times 128.5 \times 1050 \div 2000 = 21.6 \text{ tpy}$$

EPEC II Input Screen



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EPEC II Output

Natural Gas Turbine
=================
Unit ID: NGT 1
Unit Desc: Example Natural Gas Turbine Calculation

	Tons Per Year		Pounds Per Hour	
	Actual	Potential	Actual	Potential
NOx:	21.58	25.22	5.47	5.76
SOx:	0.01	0.01	0.00	0.00
CO:	5.53	6.46	1.40	1.48
VOC:	0.14	0.17	0.04	0.04
PM10:	0.13	0.15	0.03	0.03
THC:	0.74	0.87		
Methane:	0.58	0.68		
Ethane:	0.00	0.00		
CO2:	7417.41	8670.93		
HydrogenSulfide:	NA	NA		
1,3-Butadiene:	0.00	0.00		
n-Hexane:	NA	NA		
Trimethylpentane:	NA	NA		
Benzene:	0.00	0.00		
Toluene:	0.01	0.01		
EthylBenzene:	0.00	0.00		
Xylenes:	0.00	0.01		
Formaldehyde:	0.05	0.06		
Acetaldehyde:	0.00	0.00		
HAP:	0.07	0.08		

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Power Output Equation

$$E = EF_{(g/hp\text{-}hr)} \times HP \times t \times \frac{lb}{453.6\ g} \times \frac{ton}{2000\ lb}$$

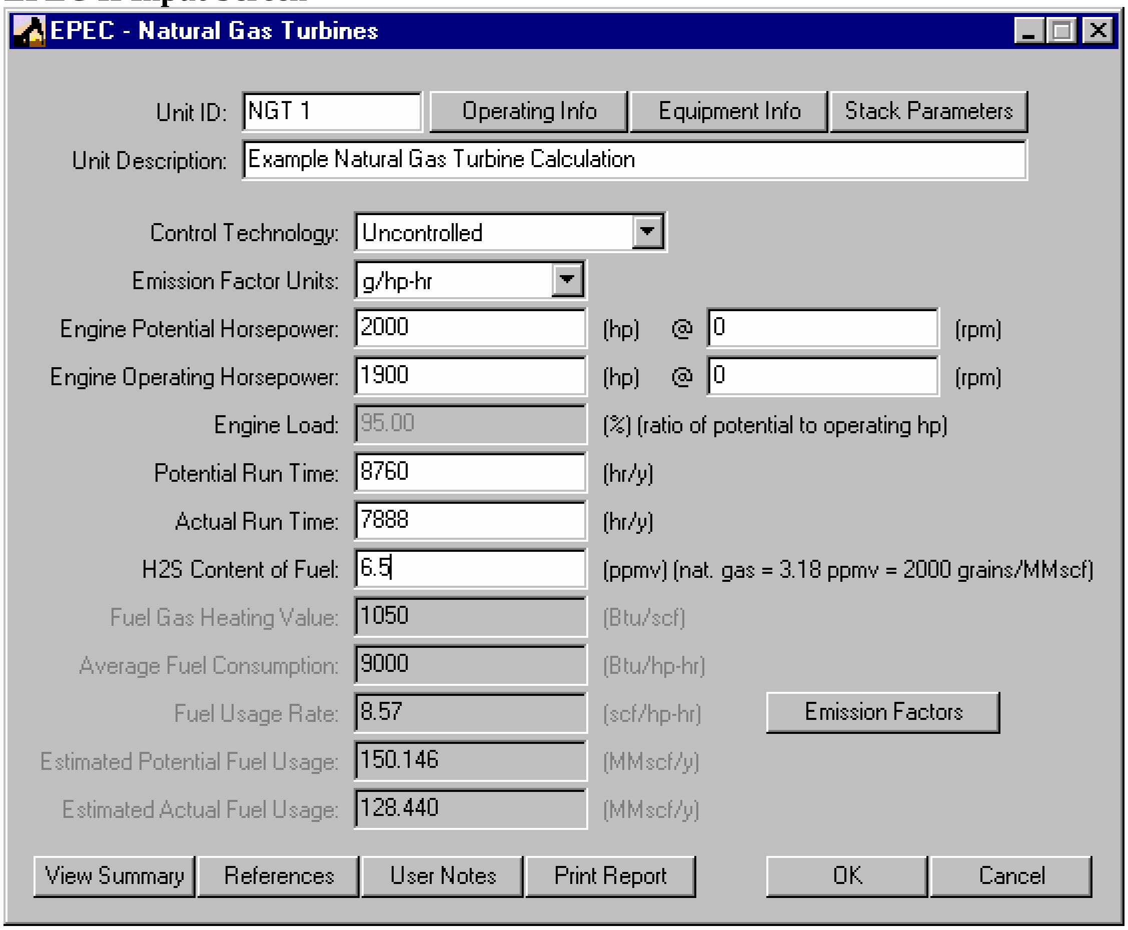
Additional Inputs

EF_{NOx}	0.37 g/hp hr (from *AP-42*, Section 3.2)

Result

$$E_{NOx} = 0.37 \times 1900 \times 7888 \div 453.6 \div 2000 = 6.11 \text{ tpy}$$

EPEC II Input Screen



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EPEC II Output

Natural Gas Turbine
=================
Unit ID: NGT 1
Unit Desc: Example Natural Gas Turbine Calculation

	Tons Per Year		Pounds Per Hour	
	Actual	Potential	Actual	Potential
NOx:	6.11	7.15	1.55	1.63
SOx:	0.00	0.00	0.00	0.00
CO:	1.57	1.83	0.40	0.42
VOC:	0.04	0.05	0.01	0.01
PM10:	0.04	0.04	0.01	0.01
THC:	0.21	0.25		
Methane:	0.16	0.19		
Ethane:	0.00	0.00		
CO2:	2098.08	2452.65		
HydrogenSulfide:	NA	NA		
1,3-Butadiene:	0.00	0.00		
n-Hexane:	NA	NA		
Trimethylpentane:	NA	NA		
Benzene:	0.00	0.00		
Toluene:	0.00	0.00		
EthylBenzene:	0.00	0.00		
Xylenes:	0.00	0.00		
Formaldehyde:	0.01	0.02		
Acetaldehyde:	0.00	0.00		
HAP:	0.02	0.02		

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A.12 VENT EXAMPLE CALCULATION

Vent Equation (for Concentrations in mole percent)

$$E = \frac{C}{100\%} \times Q \times t \times m_c \times \frac{1000}{M} \times \frac{ton}{2000\,lb} \times \frac{lb \cdot mol}{379.4\,scf}$$

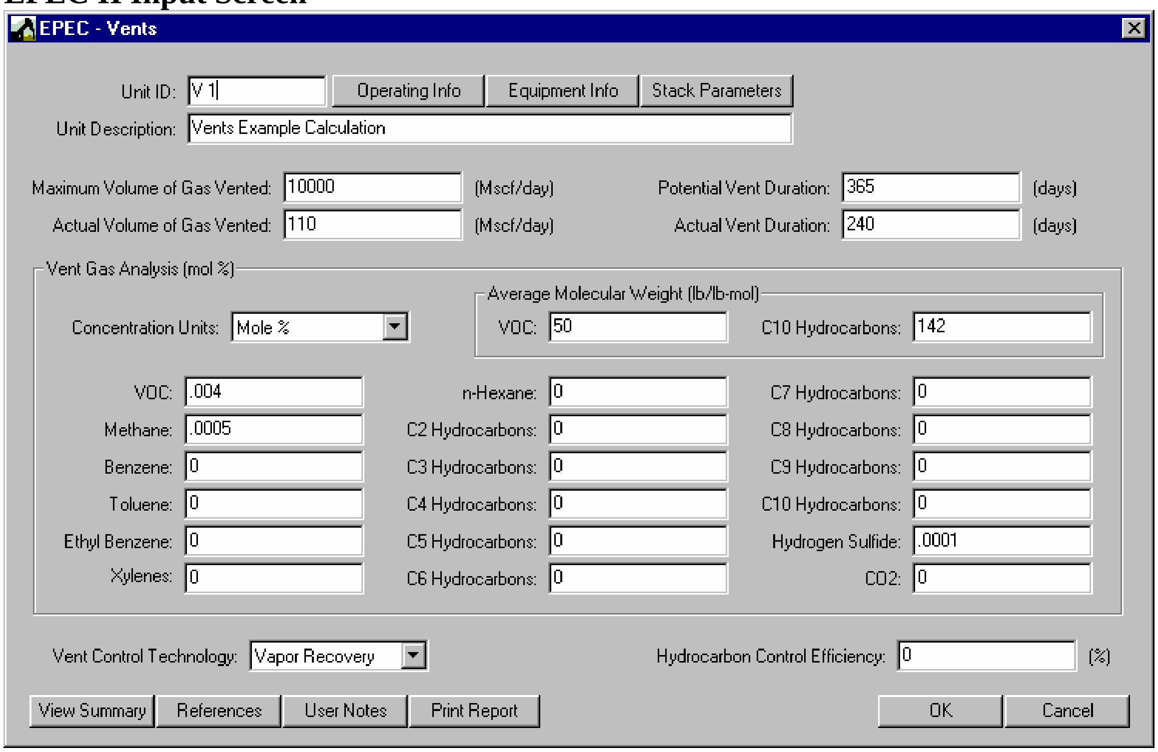
Inputs

C_{VOC}	0.004 percent
Q	110 Mscf/day
t	240 days
m_{VOC}	50 lb/lb-mol

Result

$$E_{VOC} = 0.004 \div 100 \times 110 \times 240 \times 50 \times 1000 \div 2000 \div 379.4 = 0.07\ tpy$$

EPEC II Input Screen



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EPEC II Output

```
    VENT
    ====
        UNIT ID: V 1
      UNIT DESC: EXAMPLE VENT CALCULATION

                             TONS PER YEAR              POUNDS PER HOUR
                         ---------------------      ---------------------
                            ACTUAL   POTENTIAL         ACTUAL    POTENTIAL
                         ---------   ---------      ---------    ---------
                VOC:          0.07        9.63           0.02         2.20
            METHANE:          0.00        0.39
   C2 HYDROCARBONS:          0.00        0.00
   C3 HYDROCARBONS:          0.00        0.00
   C4 HYDROCARBONS:          0.00        0.00
   C5 HYDROCARBONS:          0.00        0.00
   C6 HYDROCARBONS:          0.00        0.00
   C7 HYDROCARBONS:          0.00        0.00
   C8 HYDROCARBONS:          0.00        0.00
   C9 HYDROCARBONS:          0.00        0.00
  C10 HYDROCARBONS:          0.00        0.00
                CO2:          0.00        0.00
   HYDROGENSULFIDE:          0.00        0.16
          N-HEXANE:          0.00        0.00
           BENZENE:          0.00        0.00
           TOLUENE:          0.00        0.00
      ETHYLBENZENE:          0.00        0.00
           XYLENES:          0.00        0.00
```

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Vent Equation (for Concentrations in weight percent)

$$E = \frac{C}{100\%} \times Q \times t \times sg \times m_{air} \times \frac{1000}{M} \times \frac{10^{-6}}{ppm} \times \frac{ton}{2000\,lb} \times \frac{lb \cdot mol}{379.4\,scf}$$

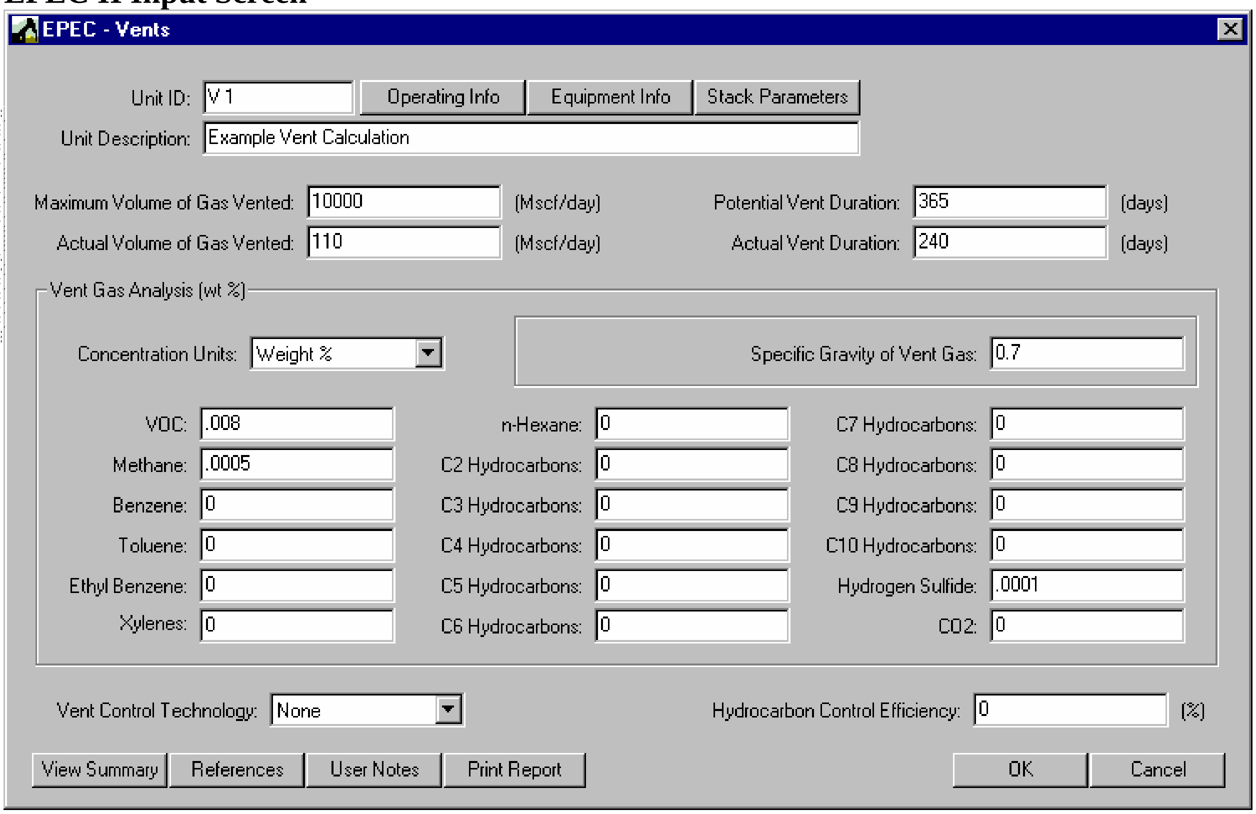
Inputs and Known Values

C_{VOC}	0.008 percent
Q	110 Mscf/day
t	240 days
sg	0.7
m_{air}	28.963 lb/lb-mol (known)

Result

$$E = 80 \div 100 \times 110 \times 240 \times 0.7 \times 28.963 \times 1000 \div 2000 \div 379.4 = 0.06 \text{ tpy}$$

EPEC II Input Screen



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EPEC II Output

```
      Vent
      ====
          Unit ID: V 1
        Unit Desc: Example Vent Calculation

                                  Tons Per Year             Pounds Per Hour
                              ---------------------      ---------------------
                                 Actual   Potential         Actual   Potential
                              ---------   ---------      ---------   ---------
                 VOC:              0.06        7.81           0.02        1.78
             Methane:              0.00        0.49
     C2 Hydrocarbons:              0.00        0.00
     C3 Hydrocarbons:              0.00        0.00
     C4 Hydrocarbons:              0.00        0.00
     C5 Hydrocarbons:              0.00        0.00
     C6 Hydrocarbons:              0.00        0.00
     C7 Hydrocarbons:              0.00        0.00
     C8 Hydrocarbons:              0.00        0.00
     C9 Hydrocarbons:              0.00        0.00
    C10 Hydrocarbons:              0.00        0.00
                 CO2:              0.00        0.00
    HydrogenSulfide:               0.00        0.10
            n-Hexane:              0.00        0.00
             Benzene:              0.00        0.00
             Toluene:              0.00        0.00
        EthylBenzene:              0.00        0.00
             Xylenes:              0.00        0.00
```

The following Example Calculations are merely examples for illustration purposes only. [Each company should develop its own approach.] They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

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APPENDIX B

LIST OF SOURCE CLASSIFICATION CODES

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This text was downloaded December 1996 and August 1999 from the U.S. EPA's website, http://www.epa.gov/ttn/chief/scccodes.html. The purpose of this website is to provide a list of source classification codes (SCC) that is as up-to-date as possible for emission inventory preparers and modelers.

Files downloaded:
General information: Filename = READSCC.txt; Filedate = 6/9/99
SCC Codes (three-, six-, and eight-digit): Filename = SCC-cd.dbf; Filedate = 6/7/99

PURPOSE

The file "SCC-WEB.ZIP" [a compressed file that contains SCC-cd.dbf] posted here is a zipped DBF file containing EPA's current listing of both point and area source classification codes (SCCs) and their descriptions, as of May 14, 1999. These codes are used as a primary identifying data element in EPA's AIRS Facility Subsystem (AFS), National Emission Trends (NET) database, Factor Information and Retrieval database (FIRE), and many State agency emissions data systems. The current file contains 7192 point source SCCs (8-digits) and 2759 area source codes (10-digits plus a preceding letter A). In addition to the code number, the file contains all 4 levels of the description for each code, the thruput units as they appear in AIRS, the thruput units separated into three fields (the unit of measure, the material being measured, and the action performed on that material), and the NET code values for these last three fields. Any comments or suggestions are welcomed, and may be addressed to Ron Ryan at ryan.ron@epa.gov, phone 919-541-4330, or FAX 919-541-0684.

WHAT ARE SCCs?

SCCs are 8-digit codes used to categorize individual processes or unit operations which generate air emissions. The 8-digit codes are divided into four parts (X-XX-XXX-XX) which correspond to four hierarchical levels of source description. This categorization is used to store and retrieve emissions data in an organized way to allow for the planning and analysis of air quality strategies. SCCs are a required key field for submittal of data to EPA's AIRS Facility Subsystem, and this is the primary usage supported by EPA's Emission Factor & Inventory Group (EFIG).

SCCs are also used for a number of other purposes by a wide variety of users. EFIG uses SCCs as a way to disseminate the average emission factors which have been developed for many of the processes and operations represented by SCCs. These emission factors are not regulatory limits. They are provided as a default method of estimating emissions from the various processes if more site-specific or representative data are not available. Although these emission factors are associated with an SCC, they are not inseparable from the SCC. Users are encouraged to make any better estimates of a specific site's emission factor or total emissions that they can, and to report these emissions under the SCC that best describes the process, regardless of the comparability of the emission factor associated with that SCC. Emission factors are not currently included in the SCC files provided here.

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ORGANIZATION OF SCCs

The four levels of source descriptions for SCCs are associated with the first 1, 3, 6, and 8 digits of the codes, (for the point source codes used by AFS - the AMS codes require 3, 5, 8, and 11 digits, including a leading "A"). The first level uses only the first digit and provides only the most general information on the category of the emissions.

The second level of description is associated with the first three digits, and subdivides the five major categories above into major industry groups. For example, 1-01 indicates External Combustion in Utility Boilers, and 1-02 indicates External Combustion in Industrial Boilers. The Manufacturing Processes category (3-) is currently divided into 21 industry classes, such as Chemical Manufacturing (3-01), Food and Agriculture (3-02), and Primary Metal Production (3-03).

The third level of description requires the first six digits to be specified, and it identifies a specific industry or emission source category, e.g., Cotton Ginning (3-02-004), or Primary Copper Smelting (3- 03-005). The three digits which have been added to the industry class description (the first three digits) usually indicate the major product, raw material, or fuel used.

The fourth level of description is associated with the full eight digit code. The addition of two more digits beyond the third level specifies the particular emitting process within the third-level source category. For example, SCC 3-03-005-06 specifies the Ore Concentrate Dryer emission source at a Primary Copper Smelting facility (3-03-005).

An eight-digit code may correspond to a particular boiler type, process heater, process vent, or fuel. A single emission point may have two or more SCCs if it uses more than one material or burns more than one type of fuel, but most emission points will be described by one SCC.

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One-, Three-, Six-, and Eight-Digit SCCs for the Exploration and Production Industry

1 External Combustion Boilers
102 ....Industrial
102004 ....Residual Oil
10200401 ....Grade 6 Oil
10200402 ....10-100 Million Btu/hr **
10200403 ....< 10 Million Btu/hr **
10200404 ....Grade 5 Oil
102005 ....Distillate Oil
10200501 ....Grades 1 and 2 Oil
10200502 ....10-100 Million Btu/hr **
10200503 ....< 10 Million Btu/hr **
10200504 ....Grade 4 Oil
102006 ....Natural Gas
10200601 ....> 100 Million Btu/hr
10200602 ....10-100 Million Btu/hr
10200603 ....< 10 Million Btu/hr
102007 ....Process Gas
10200799 ....Other: Specify in Comments
102010 ....Liquified Petroleum Gas (LPG)
10201001 ....Butane
102017 ....Gasoline
10201701 ....Industrial Boiler
105 ....Space Heaters
105001 ....Industrial
10500105 ....Distillate Oil
10500106 ....Natural Gas
10500110 ....Liquified Petroleum Gas (LPG)
10500113 ....Waste Oil: Air Atomized Burner
10500114 ....Waste Oil: Vaporizing Burner
105002 ....Commercial/Institutional
10500205 ....Distillate Oil
10500206 ....Natural Gas
10500210 ....Liquified Petroleum Gas (LPG)
10500213 ....Waste Oil: Air Atomized Burner
10500214 ....Waste Oil: Vaporizing Burner

2 Internal Combustion Engines
201 ....Electric Generation
201001 ....Distillate Oil (Diesel)
20100101 ....Turbine
20100102 ....Reciprocating
20100105 ....Reciprocating: Crankcase Blowby
20100106 ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20100107 ....Reciprocating: Exhaust
20100108 ....Turbine: Evaporative Losses (Fuel Storage and Delivery System)
20100109 ....Turbine: Exhaust
201002 ....Natural Gas
20100201 ....Turbine
20100202 ....Reciprocating
20100205 ....Reciprocating: Crankcase Blowby
20100206 ....Reciprocating: Evaporative Losses (Fuel Delivery System)
20100207 ....Reciprocating: Exhaust
20100208 ....Turbine: Evaporative Losses (Fuel Delivery System)
20100209 ....Turbine: Exhaust
201007 ....Process Gas
20100702 ....Reciprocating
20100705 ....Reciprocating: Crankcase Blowby
20100706 ....Reciprocating: Evaporative Losses (Fuel Delivery System)
20100707 ....Reciprocating: Exhaust
201013 ....Liquid Waste
20101302 ....Waste Oil - Turbine
202 ....Industrial..
202001 ....Distillate Oil (Diesel)
20200101 ....Turbine
20200102 ....Reciprocating

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20200103...... ....Turbine: Cogeneration
20200104...... ....Reciprocating: Cogeneration
20200105...... ....Reciprocating: Crankcase Blowby
20200106...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20200107...... ....Reciprocating: Exhaust
20200108...... ....Turbine: Evaporative Losses (Fuel Storage and Delivery System)
20200109...... ....Turbine: Exhaust
202002.......... ....Natural Gas
20200201...... ....Turbine
20200202...... ....Reciprocating
20200203...... ....Turbine: Cogeneration
20200204...... ....Reciprocating: Cogeneration
20200205...... ....Reciprocating: Crankcase Blowby
20200206...... ....Reciprocating: Evaporative Losses (Fuel Delivery System)
20200207...... ....Reciprocating: Exhaust
20200208...... ....Turbine: Evaporative Losses (Fuel Delivery System)
20200209...... ....Turbine: Exhaust
20200252...... ....2-cycle Lean Burn
20200253...... ....4-cycle Rich Burn
20200254...... ....4-cycle Lean Burn
20200255...... ....2-cycle Clean Burn
20200256...... ....4-cycle Clean Burn
202003.......... ....Gasoline
20200301...... ....Reciprocating
20200305...... ....Reciprocating: Crankcase Blowby
20200306...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20200307...... ....Reciprocating: Exhaust
202005.......... ....Residual/Crude Oil
20200501...... ....Reciprocating
20200505...... ....Reciprocating: Crankcase Blowby
20200506...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20200507...... ....Reciprocating: Exhaust
202007.......... ....Process Gas
20200701...... ....Turbine
20200702...... ....Reciprocating Engine
20200705...... ....Refinery Gas: Turbine
20200706...... ....Refinery Gas: Reciprocating Engine
20200710...... ....Reciprocating: Crankcase Blowby
20200711...... ....Reciprocating: Evaporative Losses (Fuel Delivery System)
20200712...... ....Reciprocating: Exhaust
20200713...... ....Turbine: Evaporative Losses (Fuel Delivery System)
20200714...... ....Turbine: Exhaust
202010.......... ....Liquified Petroleum Gas (LPG)
20201001...... ....Propane: Reciprocating
20201002...... ....Butane: Reciprocating
20201005...... ....Reciprocating: Crankcase Blowby
20201006...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20201007...... ....Reciprocating: Exhaust
20201008...... ....Turbine: Evaporative Losses (Fuel Storage and Delivery System)
20201009...... ....Turbine: Exhaust
20201011...... ....Turbine
20201012...... ....Reciprocating Engine
20201013...... ....Turbine: Cogeneration
20201014...... ....Reciprocating Engine: Cogeneration
202017.......... ....Gasoline
20201701...... ....Turbine
20201702...... ....Reciprocating Engine
20201705...... ....Reciprocating: Crankcase Blowby
20201706...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20201707...... ....Reciprocating: Exhaust
20201708...... ....Turbine: Evaporative Losses (Fuel Storage and Delivery System)
20201709...... ....Turbine: Exhaust
203................ ....Commercial/Institutional
203001.......... ....Distillate Oil (Diesel)
20300101...... ....Reciprocating
20300102...... ....Turbine
20300105...... ....Reciprocating: Crankcase Blowby

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20300106...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20300107...... ....Reciprocating: Exhaust
20300108...... ....Turbine: Evaporative Losses (Fuel Storage and Delivery System)
20300109...... ....Turbine: Exhaust
203002.......... ....Natural Gas
20300201...... ....Reciprocating
20300202...... ....Turbine
20300205...... ....Reciprocating: Crankcase Blowby
20300206...... ....Reciprocating: Evaporative Losses (Fuel Delivery System)
20300207...... ....Reciprocating: Exhaust
20300208...... ....Turbine: Evaporative Losses (Fuel Delivery System)
20300209...... ....Turbine: Exhaust
203003.......... ....Gasoline
20300301...... ....Reciprocating
20300305...... ....Reciprocating: Crankcase Blowby
20300306...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20300307...... ....Reciprocating: Exhaust
203010.......... ....Liquified Petroleum Gas (LPG)
20301001...... ....Propane: Reciprocating
20301002...... ....Butane: Reciprocating
20301005...... ....Reciprocating: Crankcase Blowby
20301006...... ....Reciprocating: Evaporative Losses (Fuel Storage and Delivery System)
20301007...... ....Reciprocating: Exhaust

3 Industrial Processes
306................ ....Petroleum Industry
306001.......... ....Process Heaters
30600101...... ....Oil-fired **
30600102...... ....Gas-fired **
30600103...... ....Oil-fired
30600104...... ....Gas-fired
30600105...... ....Natural Gas-fired
30600106...... ....Process Gas-fired
30600107...... ....LPG-fired
30600111...... ....Oil-fired (No. 6 Oil) > 100 Million Btu Capacity
30600199...... ....Other Not Classified
306004.......... ....Blowdown Systems
30600401...... ....Blowdown System with Vapor Recovery System with Flaring
30600402...... ....Blowdown System w/o Controls
306006.......... ....Vacuum Distillate Column Condensors
30600602...... ....Vacuum Distillation Column Condenser
30600603...... ....Vacuum Distillation Column Condenser
306007.......... ....Cooling Towers
30600701...... ....Cooling Towers
30600702...... ....Cooling Towers
306008.......... ....Fugitive Emissions
30600801...... ....Pipeline Valves and Flanges
30600802...... ....Vessel Relief Valves
30600803...... ....Pump Seals w/o Controls
30600804...... ....Compressor Seals
30600805...... ....Miscellaneous: Sampling/Non-Asphalt Blowing/Purging/etc.
30600806...... ....Pump Seals with Controls
30600807...... ....Blind Changing
30600811...... ....Pipeline Valves: Gas Streams
30600812...... ....Pipeline Valves: Light Liquid/Gas Streams
30600813...... ....Pipeline Valves: Heavy Liquid Streams
30600814...... ....Pipeline Valves: Hydrogen Streams
30600815...... ....Open-ended Valves: All Streams
30600816...... ....Flanges: All Streams
30600817...... ....Pump Seals: Light Liquid/Gas Streams
30600818...... ....Pump Seals: Heavy Liquid Streams
30600819...... ....Compressor Seals: Gas Streams
30600820...... ....Compressor Seals: Heavy Liquid Streams
30600821...... ....Drains: All Streams
30600822...... ....Vessel Relief Valves: All Streams
306009.......... ....Flares
30600901...... ....Distillate Oil

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30600902...... ....Residual Oil
30600903...... ....Natural Gas
30600904...... ....Process Gas
30600905...... ....Liquified Petroleum Gas
30600906...... ....Hydrogen Sulfide
30600999...... ....Not Classified **
306010.......... ....Sludge Converter
30601001...... ....General
30601011...... ....Oil/Sludge Dewatering Unit: General
306020.......... ....Crude Unit Atmospheric Distillation
30602001...... ....General
306033.......... ....Desulfurization
30603301...... ....Sulfur Recovery Unit
306888.......... ....Fugitive Emissions
30688801...... ....Specify in Comments Field
30688802...... ....Specify in Comments Field
30688803...... ....Specify in Comments Field
30688804...... ....Specify in Comments Field
30688805...... ....Specify in Comments Field
306999.......... ....Petroleum Products - Not Classified
30699998...... ....Not Classified **
30699999...... ....Not Classified **
310 ....Oil and Gas Production
310001.......... ....Crude Oil Production
31000101...... ....Complete Well: Fugitive Emissions
31000102...... ....Miscellaneous Well: General
31000103...... ....Wells: Rod Pumps
31000104...... ....Crude Oil Sumps
31000105...... ....Crude Oil Pits
31000106...... ....Enhanced Wells, Water Reinjection
31000107...... ....Oil/Gas/Water/Separation
31000108...... ....Evaporation from Liquid Leaks into Oil Well Cellars
31000121...... ....Site Preparation
31000122...... ....Drilling and Well Completion
31000123...... ....Well Casing Vents
31000124...... ....Valves: General
31000125...... ....Relief Valves
31000126...... ....Pump Seals
31000127...... ....Ranges and Connections
31000128...... ....Oil Heating
31000129...... ....Gas/Liquid Separation
31000130...... ....Fugitives: Compressor Seals
31000131...... ....Fugitives: Drains
31000132...... ....Atmospheric Wash Tank (2nd Stage of Gas-Oil Separation): Flashing Loss
31000140...... ....Waste Sumps: Primary Light Crude
31000141...... ....Waste Sumps: Primary Heavy Crude
31000142...... ....Waste Sumps: Secondary Light Crude
31000143...... ....Waste Sumps: Secondary Heavy Crude
31000144...... ....Waste Sumps: Tertiary Light Crude
31000145...... ....Waste Sumps: Tertiary Heavy Crude
31000146...... ....Gathering Lines
31000160...... ....Flares
31000199...... ....Processing Operations: Not Classified
310002.......... ....Natural Gas Production
31000201...... ....Gas Sweetening: Amine Process
31000202...... ....Gas Stripping Operations
31000203...... ....Compressors
31000204...... ....Wells
31000205...... ....Flares
31000206...... ....Gas Lift
31000207...... ....Valves: Fugitive Emissions
31000208...... ....Sulfur Recovery Unit
31000209...... ....Incinerators Burning Waste Gas or Augmented Waste Gas
31000211...... ....Pipeline Pigging (releases during pig removal)
31000215...... ....Flares Combusting Gases >1000 BTU/scf
31000216...... ....Flares Combusting Gases <1000 BTU/scf
31000220...... ....All Equipt Leak Fugitives (Valves, Flanges, Connections, Seals, Drains)

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31000221...... ....Site Preparation
31000222...... ....Drilling and Well Completion
31000223...... ....Relief Valves
31000224...... ....Pump Seals
31000225...... ....Compressor Seals
31000226...... ....Flanges and Connections
31000227...... ....Glycol Dehydrator Reboiler Still Stack
31000228...... ....Glycol Dehydrator Reboiler Burner
31000229...... ....Gathering Lines
31000230...... ....Hydrocarbon Skimmer
31000231...... ....Fugitives: Drains
31000299...... ....Other Not Classified
310003.......... ....Natural Gas Processing Facilities
31000301...... ....Glycol Dehydrators: Reboiler Still Vent: Triethylene Glycol
31000302...... ....Glycol Dehydrators: Reboiler Burner Stack: Triethylene Glycol
31000303...... ....Glycol Dehydrators: Phase Separator Vent: Triethylene Glycol
31000304...... ....Glycol Dehydrators: Ethylene Glycol: General
31000305...... ....Gas Sweeting: Amine Process
31000306...... ....Process Valves
31000307...... ....Relief Valves
31000308...... ....Open-ended Lines
31000309...... ....Compressor Seals
31000310...... ....Pump Seals
31000311...... ....Flanges and Connections
31000321...... ....Glycol Dehydrators: Niagaran Formation (Mich.)
31000322...... ....Glycol Dehydrators: Prairie du Chien Formation (Mich.)
31000323...... ....Glycol Dehydrators: Antrim Formation (Mich.)
310004.......... ....Process Heaters
31000401...... ....Distillate Oil (No. 2)
31000402...... ....Residual Oil
31000403...... ....Crude Oil
31000404...... ....Natural Gas
31000405...... ....Process Gas
31000406...... ....Propane/Butane
31000411...... ....Distillate Oil (No. 2): Steam Generators
31000412...... ....Residual Oil: Steam Generators
31000413...... ....Crude Oil: Steam Generators
31000414...... ....Natural Gas: Steam Generators
31000415...... ....Process Gas: Steam Generators
310005.......... ....Liquid Waste Treatment
31000501...... ....Floatation Units
31000502...... ....Liquid - Liquid Separator
31000503...... ....Oil-Water Separator
31000504...... ....Oil-Sludge-Waste Water Pit
31000505...... ....Sand Filter Operation
31000506...... ....Oil-Water Separation Wastewater Holding Tanks
310888.......... ....Fugitive Emissions
31088801...... ....Specify in Comments Field
31088802...... ....Specify in Comments Field
31088803...... ....Specify in Comments Field
31088804...... ....Specify in Comments Field
31088805...... ....Specify in Comments Field
31088811...... ....Fugitive Emissions
385................ ....Cooling Tower
385001.......... ....Process Cooling
38500101...... ....Mechanical Draft
38500102...... ....Natural Draft
38500110...... ....Other Not Specified

4 Petroleum and Solvent Evaporation

404................ ....Petroleum Liquids Storage (non-Refinery)
404003.......... ....Oil and Gas Field Storage and Working Tanks
40400301...... ....Fixed Roof Tank: Breathing Loss
40400302...... ....Fixed Roof Tank: Working Loss
40400303...... ....External Floating Roof Tank with Primary Seals: Standing Loss
40400304...... ....External Floating Roof Tank with Secondary Seals: Standing Loss
40400305...... ....Internal Floating Roof Tank: Standing Loss

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40400306...... ....External Floating Roof Tank: Withdrawal Loss
40400307...... ....Internal Floating Roof Tank: Withdrawal Loss
40400311...... ....Fixed Roof Tank, Condensate, working+breathing+flashing losses
40400312...... ....Fixed Roof Tank, Crude Oil, working+breathing+flashing losses
40400315...... ....Fixed Roof Tank, Produced Water, working+breathing+flashing
40400321...... ....External Floating Roof Tank, Condensate, working+breathing+flashing
40400322...... ....External Floating Roof Tank, Crude Oil, working+breathing+flashing
40400325...... ....External Floating Roof Tank, Produced Water-working+breathing+flashing
40400326...... ....External Floating Roof Tank, Diesel, working+breathing+flashing
40400331...... ....Internal Floating Roof Tank, Condensate, working+breathing+flashing
40400332...... ....Internal Floating Roof Tank, Crude Oil, working+breathing+flashing
40400335...... ....Internal Floating Roof Tank, Produced Water-working+breathing+flashing
40400340...... ....Pressure Tanks (pressure relief from pop-off valves)
404004.......... ....Petroleum Products - Underground Tanks
40400407...... ....Crude Oil RVP 5: Breathing Loss
40400408...... ....Crude Oil RVP 5: Working Loss
40400497...... ....Specify Liquid: Breathing Loss
40400498...... ....Specify Liquid: Working Loss
42500101...... ....Fixed Roof Tanks (210 Bbl Size) Breathing Loss
42500102...... ....Fixed Roof Tanks (210 Bbl Size) Working Loss
42500201...... ....Fixed Roof Tanks (500 Bbl Size) Breathing Loss
42500202...... ....Fixed Roof Tanks (500 Bbl Size) Working Loss
42500301...... ....Fixed Roof Tanks (1,000 Bbl Size) Breathing Loss
42500302...... ....Fixed Roof Tanks (1,000 Bbl Size) Working Loss
42505001...... ....Floating Roof Tanks (1,000 Bbl Size) Standing Loss
42505002...... ....Floating Roof Tanks (1,000 Bbl Size) Working Loss
42505101...... ....Floating Roof Tanks (5,000 Bbl Size) Standing Loss
42505102...... ....Floating Roof Tanks (5,000 Bbl Size) Crude Oil: Working Loss
42505202...... ....Floating Roof Tanks (1,000 Bbl Size) Working Loss

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