# Texas Commission on Environmental Quality
# Air Permits Division

## New Source Review (NSR) Emission Calculations

This information is maintained by the Chemical NSR Section and is subject to change. Last update was made **October 2006**. These emission calculations represent current NSR guidelines and are provided for informational purposes only. The emission calculations are subject to change based on TCEQ case by case evaluation. Please contact the appropriate Chemical NSR Section management if there are questions related to the emission calculations.

## Sample Calculations for Flares

The flare destruction efficiencies and emission factors are used in the sample calculations that follow. Assuming an ideal gas mixture, use the ideal gas law to convert the volumetric flow rates from Attachment B and Table 6 into mass flow rates. The values are shown in Table 7.

$$m = \frac{60(MW)PV}{RT}$$

Where: $m$ = mass flow rate in lb. per hour,
$MW$ = molecular weight in lb. per lbmole,
$P$ = standard pressure = 14.7 psia,
$V$ = flow rate in scfm,
$R$ = gas constant = $10.73 \frac{psia \cdot ft^3}{lbmol \cdot {}^oR}$
$T$ = standard temperature = $528\ {}^oR$

**Table 6. Waste Stream Constituents in Mole Percent**

| Constituent | Average Case | | Maximum Case | |
|---|---|---|---|---|
| | scfm | mole % | scfm | mole % |
| Butane | 10.16 | 5.08 | 12.70 | 5.08 |
| Propylene | 5.94 | 2.97 | 7.43 | 2.97 |
| Propane | 5.08 | 2.54 | 6.35 | 2.54 |
| Ethylene | 84.74 | 42.37 | 105.93 | 42.37 |
| Ethane | 37.28 | 18.64 | 46.60 | 18.64 |
| Hydrogen | 22.04 | 11.02 | 27.55 | 11.02 |
| Ammonia | 4.24 | 2.12 | 5.30 | 2.12 |
| Inerts | 30.50 | 15.26 | 38.13 | 15.26 |
| Totals | 200.00 | 100.00 | 250.00 | 100.00 |

**Table 7. Estimation of Average Mass Flow Rates**

| Constituent | scfm | MW | lb/hr |
|---|---|---|---|
| Butane | 10.16 | 58.12 | 91.91 |
| Propylene | 5.94 | 42.08 | 38.91 |
| Propane | 5.08 | 44.09 | 34.86 |
| Ethylene | 84.74 | 28.05 | 369.95 |
| Ethane | 37.28 | 30.07 | 174.47 |
| Hydrogen | 22.04 | 2.02 | 6.92 |
| Ammonia | 4.24 | 17.03 | 11.24 |

***Waste Stream DRE.*** Applying 98 percent destruction efficiency for butane+ and hydrogen, and 99 percent destruction efficiency for propylene, propane, ethylene, and ammonia, the hourly maximum and annual emission rates may then be estimated (Table 8). The hourly emissions are calculated using the maximum case flow rate, which is 25 percent greater than the average case. Note that the ethane and hydrogen emission rates need not be shown on the NSR Table 1(a) submitted with the permit application, since these emissions are not regulated as pollutants.

**Table 8. Emission Rates**

| Constituent | lb/hr | TPY |
|---|---|---|
| Butane | 2.30 | 8.0 |
| Propylene | 0.49 | 1.7 |
| Propane | 0.44 | 1.5 |
| Ethylene | 4.63 | 16.3 |
| Ethane | 2.11 | 7.6 |
| Hydrogen | 0.18 | 0.6 |
| Ammonia | 0.14 | 0.5 |

***$NO_x$ and CO Emissions***. The mole percent of each constituent in the waste stream may be calculated for both the average and maximum scenarios by dividing the individual flow rates by the total flow rates and multiplying by 100 percent (Table 6). In this case, the calculations are simplified since the average and maximum case waste streams have the same compositions. If they were of different composition, the heating value calculations would be required for both cases. Note that the maximum case shows the maximum vent stream to the flare under normal operating conditions for calculating emissions from the flare (upset and maintenance conditions are not considered). Emergency and maintenance emissions are not directed to the example flare.

Next, estimate the net, or lower, heating value of the waste stream by assuming a basis of 1 scf. Heats of combustion for most compounds may be found in any common engineering reference book. The net heat release will be used in determining which $NO_x$ and CO factors to use as well as verifying that the flare will meet the minimum heating value requirements of 40 CFR § 60.18. Based on the overall net heat release (see Table 9), it is now evident that the $NO_x$ and CO factors for high-Btu, air-assisted flares should be used. Using these factors:

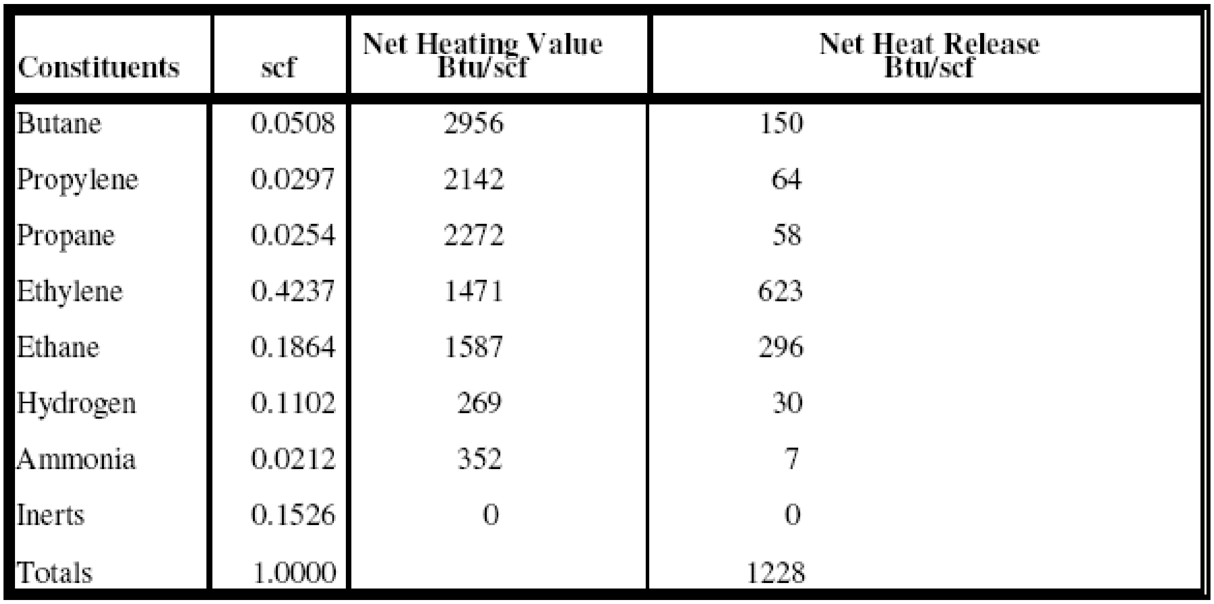
$$\left(\frac{0.138\ lb\ NO_x}{MMBtu}\right)\left(\frac{1228\ Btu}{scf}\right)\left(\frac{1\ MMBtu}{10^6\ Btu}\right)\left(\frac{250\ scf}{\min}\right)\left(\frac{60\ \min}{hr}\right)=2.54\ lb\ NO_x/hr$$

$$\left(\frac{0.138\ lb\ NO_x}{MMBtu}\right)\left(\frac{1228\ Btu}{scf}\right)\left(\frac{1\ MMBtu}{10^6\ Btu}\right)\left(\frac{200\ scf}{\min}\right)\left(\frac{ton}{2000\ lb}\right)\left(\frac{60\ \min}{hr}\right)\left(\frac{8760\ hr}{yr}\right)=8.91\ tons\ NO_x/yr$$

$$\left(\frac{0.2755\ lb\ CO}{MMBtu}\right)\left(\frac{1228\ Btu}{scf}\right)\left(\frac{1\ MMBtu}{10^6\ Btu}\right)\left(\frac{250\ scf}{\min}\right)\left(\frac{60\ \min}{hr}\right)=5.07\ lb\ CO/hr$$

$$\left(\frac{0.2755\ lb\ CO}{MMBtu}\right)\left(\frac{1228\ Btu}{scf}\right)\left(\frac{1\ MMBtu}{10^6\ Btu}\right)\left(\frac{200\ scf}{\min}\right)\left(\frac{ton}{2000\ lb}\right)\left(\frac{60\ \min}{hr}\right)\left(\frac{8760\ hr}{yr}\right)=17.78\ tons\ CO/yr$$

**Table 9. Estimation of Net Heat Releases**



| Constituents | scf | Net Heating Value Btu/scf | Net Heat Release Btu/scf |
|---|---|---|---|
| Butane | 0.0508 | 2956 | 150 |
| Propylene | 0.0297 | 2142 | 64 |
| Propane | 0.0254 | 2272 | 58 |
| Ethylene | 0.4237 | 1471 | 623 |
| Ethane | 0.1864 | 1587 | 296 |
| Hydrogen | 0.1102 | 269 | 30 |
| Ammonia | 0.0212 | 352 | 7 |
| Inerts | 0.1526 | 0 | 0 |
| Totals | 1.0000 |  | 1228 |

The $NO_x$ emissions also need to be corrected for the fuel $NO_x$ from ammonia. In this case, 11.2 lb. ammonia/hr(0.005)(250/200) = **0.08 lb/hr** $NO_x$. This results in total $NO_x$ emissions of 2.62 lb/hr and 9.15 tons per year.

***Particulate Emissions.*** Particulate emissions should be negligible and should therefore not be estimated, since smoking flares are excluded from permitting as defined in 30 TAC Section 111.111. There may be cases where there are noncombustible elements (such as metals) associated with the VOC being combusted. If this is the case, these emissions should be estimated based on sampling results from the waste stream. The AP-42 landfill flare particulate matter factor may be used if the flare controls landfill gas.

The following sample calculation demonstrates how to handle waste streams with hydrogen sulfide.

***$H_2S$ Emissions.*** For instances where a waste stream to a flare contains $H_2S$, assume that 100 percent by weight of $H_2S$ is converted to $SO_2$ (the $H_2S$ allowable DRE is 98 percent but actual flare operation could combust almost 100 percent of the waste stream). Referring to Attachment C, convert the design maximum $H_2S$ volumetric waste flow rate into a molar flow rate using the ideal gas law:

$$\frac{\left(4.5\ ft^3/\min\right)\left(14.7\ psia\right)\left(60\ \min/hr\right)}{\left(10.73\ psia\cdot ft^3/lbmol\cdot{}^oR\right)\left(528\ {}^oR\right)} = 0.701\, lbmol\ H_2S/hr$$

One mole of $H_2S$ will form one mole of $SO_2$:

$$\frac{\left(0.701\, lbmol\ H_2S/hr\right)\left(1\, lbmol\ SO_2/lbmol\ H_2S\right)}{\left(1\, lbmol\ SO_2/64\ lb\ SO_2\right)} = 44.9\ lb\ SO_2/hr$$

and as much as 2 percent of the $H_2S$ will remain:

$$(0.02)\left(\frac{0.701\ lbmol\,H_2S}{hr}\right)\left(\frac{34 lb\,H_2S}{lbmol\,H_2S}\right) = 0.48\ lb\,H_2S/hr$$

Calculations for annual emissions should be performed in a similar manner using the average $H_2S$ flow rate of 3.5 scfm, resulting in 0.55 lbmol $H_2S$/hr, and 34.9 lb $SO_2$/hr. The annual $SO_2$ emissions should then be estimated on a TPY basis:

$$\left(\frac{34.9 lb}{hr}\right)\left(\frac{1\,ton}{2000 lb}\right)\left(\frac{24 hr}{day}\right)\left(\frac{365 day}{yr}\right)=152.7\ TPY\ \ SO_2$$

and, likewise, 2 percent of the $H_2S$ will remain:

(0.02)(0.545)(34)(24)(365)/2,000 = **1.62 TPY $H_2S$**

**40 CFR § 60.18 BACT Check**

Calculations should also be performed to ensure the proposed flare meets BACT requirements of 40 CFR § 60.18 . It was noted that $H_T$ = 1,228 Btu/scf (Table 9) is greater than the minimum heating value of 300 Btu/scf required for air-assisted flares according to 40 CFR § 60.18(c)(3); therefore, this flare would be in compliance. In accordance with 60.18(5), air-assisted flares designed for and operated with an exit velocity less than the value $V_{max}$ as calculated below, and less than 122 m/s (400 ft/s) are allowed. For this flare:

$V_{max}$ = 8.706 + 0.7084$H_T$ = 8.706 + 0.7084(43.3) = **39.4 m/s**

The actual flare tip velocity may then be calculated for comparison using the design maximum flow rate and the flare tip area based on the flare tip diameter:

$V_{actual}$ = Q/A

where Q = volumetric flow rate, $ft^3$/min, and
A = flare tip area, $ft^2$

$$V_{actual} = \left(\frac{250\,ft^3}{\min}\right)\left(\frac{4}{\pi\cdot(1\,ft)^2}\right)\left(\frac{1\min}{60\sec}\right)\left(\frac{0.3048 m}{ft}\right)=1.62 m/s$$

So, the sample flare meets the flare tip velocity restrictions of 40 CFR § 60.18.

**40 CFR § 60.18 BACT Check for Hydrogen Flares**

Similar to the previous example, calculations should also be performed to ensure a proposed hydrogen flare meets the BACT requirements of 40 CFR § 60.18. The heating value is calculated in the same manner as the above example. The flare diameter must be greater than 3 inches, the hydrogen content must be greater than 8.0 percent by volume and the exit velocity, $V_{max}$, less than 37.2 m/s (122 ft/s) as calculated below. For example, a stream with a 11.0 percent hydrogen volume on a wet basis the maximum velocity would be:

$$V_{\max} = (X_{H_2} - K_1) \cdot K_2 = (11.0 - 6.0) \cdot 3.9 = 19.5\, m/s\ (64.0\, ft/s)$$

So, the sample hydrogen flare would meet the flare tip velocity requirements of 40 CFR § 60.18.

**Modeling Calculations**

The net heating value of the waste gas stream to the flare and the flare height is sufficient information for the reviewing engineer to perform initial screen modeling using the EPA Screen 3 model with the built-in flare source algorithm; however, additional calculations must be provided to the reviewing engineer if refined modeling using the EPA ISC series of models and the point source algorithm is required. It should be noted that refined modeling is the applicant's responsibility and may be requested as determined to be appropriate by the reviewing engineer.

Flares are considered a special type of elevated source that may be modeled as a point source. In a flare, the velocity of the waste stream and the flare temperature are not used to determine the plume rise; rather, the TCEQ suggests use of the parameters and formula explained below to calculate the effective stack diameter based upon the net heat release and the average molecular weight of the compounds being burned.

If a flare is to be treated as a point source, accurate determination of all stack parameters is not possible. Since combustion occurs at or beyond the flare tip in the atmosphere, appropriate values for stack exit temperature and exit velocity cannot be accurately determined. The diameter of the pipe leading to the flare tip is not a factor in determining plume rise. The point source algorithm can be used with arbitrary values assigned for stack exit velocity (20 m/s or 66 fps) and temperature (1,273K or 1,831_F) to predict dispersion for flare type sources.

A stack height equal to the height of the flare tip is recommended for flares. The effective flare tip diameter is determined using the following equation:

$$D = \sqrt{(10^{-6})q(1 - 0.048\sqrt{(MW)})}$$

where D = effective flare tip diameter, meters,
q = net or lower heat release, cal/sec, and
MW = volume average molecular weight, g/g-mole.

First, estimate the net heat release based upon the overall net heating value from Table 9 and maximum waste gas stream flow rate from Table 6:

$$q = \left(\frac{1228\, Btu}{scf}\right)\left(\frac{250\, scf}{\min}\right)\left(\frac{1 \min}{60 \sec}\right)\left(\frac{252\, cal}{Btu}\right) = 1.289{,}400\, cal/\sec$$

Next, estimate the volume average molecular weight based upon the maximum volumetric flow rate (Table 6) and the molecular weights of the individual constituents (Table 10). Finally, estimate the effective flare tip diameter based on the net heat release and average molecular weight:

$$D = \sqrt{(10^{-6})\left(1{,}289{,}400\frac{cal}{\sec}\right)(1 - 0.048\sqrt{(27.61)}\,)} = 3.22\ ft$$

Enclosed vapor combustion units should not be modeled with the above parameters, but instead with stack parameters that reflect the physical characteristics of the process unit.

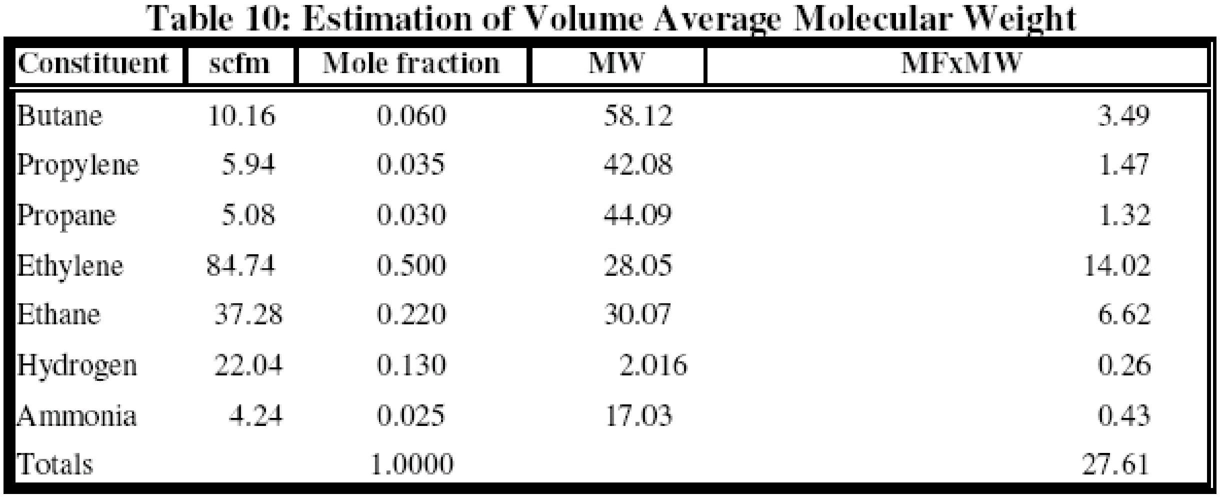


**Table 10: Estimation of Volume Average Molecular Weight**

| Constituent | scfm | Mole fraction | MW | MFxMW |
|---|---|---|---|---|
| Butane | 10.16 | 0.060 | 58.12 | 3.49 |
| Propylene | 5.94 | 0.035 | 42.08 | 1.47 |
| Propane | 5.08 | 0.030 | 44.09 | 1.32 |
| Ethylene | 84.74 | 0.500 | 28.05 | 14.02 |
| Ethane | 37.28 | 0.220 | 30.07 | 6.62 |
| Hydrogen | 22.04 | 0.130 | 2.016 | 0.26 |
| Ammonia | 4.24 | 0.025 | 17.03 | 0.43 |
| Totals | | 1.0000 | | 27.61 |

## Attachment B—Typical Refinery Flare Data
(from NSR Table 8, Flare Systems)

### TABLE 8. FLARE SYSTEMS

| **Number from Flow Diagram** | **Manufacturer & Model No. (if available)** |
|---|---|
| **1 (Refinery Flare)** | **N/A** |

CHARACTERISTICS OF INPUT

| Waste Gas Stream | Material | Min. Value Expected | Ave. Value Expected | Design Max. |
|---|---|---|---|---|
| | | (scfm [68°F, 14.7 psia]) | (scfm [68°F, 14.7 psia]) | (scfm [68°F, 14.7 psia]) |
| | 1. Butane+ | | 10.16 | 12.70 |
| | 2. Propylene | | 5.94 | 7.43 |
| | 3. Propane | | 5.08 | 6.35 |
| | 4. Ethylene | | 84.74 | 105.93 |
| | 5. Ethane | | 37.28 | 46.60 |
| | 6. $H_2$ | | 22.04 | 27.55 |
| | 7. $NH_3$ | | 4.24 | 5.30 |
| | 8. Inerts | | 30.50 | 38.13 |
| % of time this condition occurs | | 5 | 80 | 15 |

| | Flow Rate (scfm [68°F, 14.7 psia]) | | Temp. °F | Pressure (psig) |
|---|---|---|---|---|
| | Minimum Expected | Design Maximum | | |
| Waste Gas Stream | 200 | 250 | 130 | 0 |
| Fuel Added to Gas Steam | | 0.5 | 110 | 0 |

| | Number of Pilots | Type Fuel | Fuel Flow Rate (scfm [68°F & 14.7 psia]) per pilot |
|---|---|---|---|
| | 1 | Natural Gas | 0.5 |

| For Stream Injection | Stream Pressure (psig) | | Total Stream Flow | Temp. °F | Velocity (ft/sec) |
|---|---|---|---|---|---|
| | Min. Expected | Design Max. | Rate (lb/hr) | | |
| | | | | | |
| | Number of Jet Streams | Diameter of Steam Jets (inches) | Design basis for steam injected (lb steam/lb hydrocarbon) | | |
| | | | | | |

| For Water Injection | Water Pressure (psig) Min. Expected Design Max. | Total Water Flow Rate (gpm) Min. Expected Design Max. | No. of Water Jets | Diameter of Water Jets (inches) |
|---|---|---|---|---|
| | | | | |

| | |
|---|---|
| Flare Height (ft) 60 | Flare tip inside diameter (ft) 1 |
| Capital Installed Cost $20,000 | Annual Operating Cost $15,000 |

Supply an assembly drawing, dimensioned and to scale, to show clearly the operation of the flare system. Show interior dimensions and features of the equipment necessary to calculate its performance. Also describe the type of ignition system and its method of operation. Provide an explanation of the control system for steam flow rate and other operating variables.

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