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 March 2021. 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. The TCEQ accepted destruction efficiencies and emission factors used in the sample calculations are included in Attachment A. Assuming an ideal gas mixture, use the ideal gas law to convert the volumetric flow rates from Attachment B (table template uses TCEQ NSR Table 8, Flare systems) and Table 1 into mass flow rates. The values are shown in Table 2.

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

Where:
m = mass flow rate in lb/hr,
MW = molecular weight in lb/lbmole,
P = standard pressure = 14.7 psia,
V = flow rate in scfm,

R = gas constant = $10.73 \dfrac{psia \cdot ft^3}{lbmol \cdot {}^oR}$

T = standard temperature = $528\ {}^oR$

Table 1. 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	38.15	15.26
Totals	200.00	100.00	250.00	100.00

Table 2. Estimation of Average Mass Flow Rate

Constituent	scfm	MW	lb/hr
Butane	10.16	58.12	91.93
Propylene	5.94	42.08	38.91
Propane	5.08	44.09	34.87
Ethylene	84.74	28.05	370.05
Ethane	37.28	30.07	174.52
Hydrogen	22.04	2.02	6.93
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[1], the hourly maximum and annual emission rates may then be estimated (Table 3). 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 3. Emission Rates

Constituent	lb/hr	tpy
Butane	2.30	8.05
Propylene	0.49	1.70
Propane	0.44	1.53
Ethylene	4.63	16.21
Ethane	2.18	7.64
Hydrogen	0.17	0.61
Ammonia	0.14	0.49

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 1). 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.

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[1] The destruction efficiency of ammonia is subject to case-by-case review.

Based on the overall net heat release (see Table 4), it is now evident that the NO_x and CO factors for high-Btu[2], 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 4. Estimation of Net Heat Releases

Constituent	scf	Net Heating Value Btu/scf	Net Heat Release[3] Btu/scf
Butane	0.0508	2,956	150
Propylene	0.0297	2,142	64
Propane	0.0254	2,272	58
Ethylene	0.4237	1,471	623
Ethane	0.1864	1,587	296
Hydrogen	0.1102	269	30
Ammonia	0.0212	352	7
Inerts	0.1526	0	0
Totals	1.000		1,228

The NO_x emissions also need to be corrected for the fuel NO_x from ammonia. Fuel NO_x is assumed 0.5 wt percent of inlet NH_3[4].

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[2] The high-Btu waste streams referred to streams have a heating value greater than 1,000 Btu/scf.
[3] Net heat release assumes a basis of 1 scf.
[4] NH_3 to fuel NO_x conversion is subject to case-by-case review.

In this case,

$$\left(11.24 \frac{lb}{hr} \, ammonia\right)\left(\frac{0.5 \, NO_x}{100 \, ammonia}\right)\left(\frac{250 \, scfm}{200 \, scfm}\right) = 0.07 \frac{lb}{hr} NO_x$$

$$\left(11.24 \frac{lb}{hr} \, ammonia\right)\left(\frac{0.5 \, NO_x}{100 \, ammnonia}\right)\left(\frac{24 \, hr}{day}\right)\left(\frac{365 \, day}{yr}\right)\left(\frac{1 \, ton}{2000 \, lb}\right) = 0.25 \, tpy \, NO_x$$

This results in total NO_x emissions of 2.61 lb/hr (=2.54 lb/hr +0.07 lb/hr) and 9.16 tpy (=8.91 tpy+0.25 tpy).

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.

H₂S 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 (table template uses TCEQ NSR Table 8, Flare systems), 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 tons-per-year (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:

$$\frac{(3.5 \frac{ft^3}{min})(14.7 \, psia)(\frac{60 \, min}{hr})}{(10.73 \, psia \cdot \frac{ft^3}{lbmol} \cdot {}^oR)(528 {}^oR)} = 0.545 \frac{lbmol \, H_2S}{hr}$$

$$(0.02)\left(0.545\ \frac{lbmol\ H_2S}{hr}\right)\left(\frac{34\ lb\ H_2S}{lbmol\ H_2S}\right)=\frac{0.37lb\ H_2S}{hr}$$

$$\left(\frac{0.37lb\ H_2S}{hr}\right)\left(\frac{1\ ton}{2000\ lb}\right)\left(\frac{24\ hr}{day}\right)\left(\frac{365\ day}{yr}\right)=1.62\ ton\ SO_2/yr$$

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 4) 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:

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

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, ft³/min, and
      A = flare tip area, ft²

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

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, Vmax, less than 37.2 m/s (122 ft/s) as calculated below. For example, a stream with an 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 1,831F) 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 4 and maximum waste gas stream flow rate from Table 1:

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

Next, estimate the volume average molecular weight based upon the maximum volumetric flow rate (Table 1) and the molecular weights of the individual constituents (Table 5). 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 5. Estimation of Volume Average Molecular Weight

Constituent	scfm	Mole Fraction (MF)	Molecular Weight (MW)	MF x MW
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	2.02	0.26
Ammonia	4.24	0.025	17.03	0.43
Totals		1.0000		27.61

Waste Stream[5]	Destruction/Removal Efficiency (DRE)
VOC	98 percent (generic)
	99 percent for compounds containing no more than 3 carbons that contain no elements other than carbon and hydrogen in addition to the following compounds: methanol, ethanol, propanol, ethylene oxide and propylene oxide.
H_2S	98 percent
NH_3	case-by-case
CO	case-by-case

Air Contaminants	Emission Factors	Btu	lb/MMBtu
Thermal NO_x	Steam-assist	High Btu	0.0485 lb/MMBtu
		Low Btu	0.068 lb/MMBtu
	Other	High Btu	0.138 lb/MMBtu
		Low Btu	0.0641 lb/MMBtu

Air Contaminants	Emission Factors
Fuel NO_x	NO_x is 0.5 wt percent of inlet NH_3 in the sample calculations. The actual conversion of ammonia and other fuels to Fuel NO_x are subject to case-by-case review.

Air Contaminants	Emission Factors	Btu	lb/MMBtu
CO	Steam-assist	High Btu	0.3503 lb/MMBtu
		Low Btu	0.3465 lb/MMBtu
	Other	High Btu	0.2755 lb/MMBtu
		Low Btu	0.5496 lb/MMBtu

Air Contaminants	Emission Factors
PM	None, required to be smokeless
SO_2	100 percent S in fuel to SO_2

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[5]The only exception of this is if inorganics might be emitted from the flare. In the case of landfills, the AP-42 PM factor may be used. In other cases, the emissions should be based on the composition of the waste stream routed to the flare.

Texas Commission on Environmental Quality
Table 8
Flare Systems

Emission Point No. (EPN): Refinery Flare
Manufacturer: NA
Model No. (if available): NA

Type (elevated, ground level, pit)	Assisted (air, steam, non-assisted)	Operation (routine, MSS, emergency, dual)	Flare Height (ft.)	Flare tip inside diameter (ft.)
Elevated	Steam-assisted	Routine	60	1

Characteristics of Input

Waste Gas Stream Material (identify stream)	Minimum Value Expected (scfm [68°F, 14.7 psia])	Average Value Expected (scfm [68°F, 14.7 psia])	Design Maximum (scfm [68°F, 14.7 psia])	BTU/scf Rating
1. Butane	0	10.16	12.70	2956
2. Propylene	0	5.94	7.43	2142
3. Propane	0	5.08	6.35	2272
4. Ethylene	0	84.74	105.93	1471
5. Ethane	0	37.28	46.60	1587
6. H_2	0	22.04	27.55	269
7. NH_3	0	4.24	5.30	352
8. Inerts	0	30.50	38.15	0
Percent of time this condition occurs:	5	80	15	

Commercial products appearing in our Effects Screening Levels (ESLs) list, such as gasoline, may appear on this table as such or as individual constituents.

Attachment B — Example Refinery Flare Data

Number of Pilots	Type Fuel	Fuel Flow Rate (scfm [70°F and 14.7 psia]) per pilot	Total Heat Release Rate (Btu/hr)	Fuel Usage (scfm) Minimum	Fuel Usage (scfm) Maximum
1	Natural Gas	0.5			

Stream	Flow Rate (scfm [68°F, 14.7 psia]) Minimum Expected	Flow Rate (scfm [68°F, 14.7 psia]) Design Maximum	Total Heat Release Rate Average Btu/hr	Total Heat Release Rate Maximum Btu/hr	Btu/scf	Temp. °F	Pressure (psig)
Assist Gas		0.5				110	0
Waste Gas	200	250				130	0

For Steam Injection

Steam Pressure (psig) Minimum Expected	Steam Pressure (psig) Design Maximum	Total Steam Flow Rate (lb/hr)	Temp. °F	Velocity (ft/sec)	Number of Jet Streams	Diameter of Steam Jets (inches)	Design basis for steam injected (lb steam/lb hydrocarbon)

For Water Injection

Water Pressure (psig) Minimum Expected	Water Pressure (psig) Design Maximum	Total Water Flow Rate (gpm) Minimum Expected	Total Water Flow Rate (gpm) Design Maximum	Number of Water Jets	Diameter of Water Jets (inches)

Attachment B — Example Refinery Flare Data

Operating Schedule

Normal (hours/day)	Normal (days/week)	Normal (weeks/yr)	Maximum (hours/day)	Maximum (days/week)	Maximum (weeks/yr)
24	7				

Supply an assembly drawing, dimensioned and to scale, to clearly show 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.

Texas Commission on Environmental Quality
Table 8
Flare Systems

Emission Point No. (EPN): Acid Gas Flare
Manufacturer: NA
Model No. (if available): NA

Type (elevated, ground level, pit)	Assisted (air, steam, non-assisted)	Operation (routine, MSS, emergency, dual)	Flare Height (ft.)	Flare Tip Inside Diameter (ft.)
Elevated	Non-assisted	Routine	60	0.20

Characteristics of Input

Waste Gas Stream Material (identify stream)	Minimum Value Expected (scfm [68°F, 14.7 psia])	Average Value Expected (scfm [68°F, 14.7 psia])	Design Maximum (scfm [68°F, 14.7 psia])	BTU/scf Rating
1. H_2S	0	3.5	4.5	
2.				
3.				
4.				
5.				
6.				
7.				
8.				
Percent of time this condition occurs:				

Commercial products appearing in our Effects Screening Levels (ESLs) list, such as gasoline, may appear on this table as such or as individual constituents.

Attachment C — Example Acid Gas Glare Data

Number of Pilots	Type Fuel	Fuel Flow Rate (scfm [70°F and 14.7 psia]) per pilot	Total Heat Release Rate (Btu/hr)	Fuel Usage (scfm) Minimum	Fuel Usage (scfm) Maximum
1	Natural Gas	0.6			

Stream	Flow Rate (scfm [68°F, 14.7 psia]) Minimum Expected	Flow Rate (scfm [68°F, 14.7 psia]) Design Maximum	Total Heat Release Rate Average Btu/hr	Total Heat Release Rate Maximum Btu/hr	Btu/scf	Temp. °F	Pressure (psig)
Assist Gas	0	7.5				90	10
Waste Gas	0	4.5				200	10

For Steam Injection

Steam Pressure (psig) Minimum Expected	Steam Pressure (psig) Design Maximum	Total Steam Flow Rate (lb/hr)	Temp. °F	Velocity (ft/sec)	Number of Jet Streams	Diameter of Steam Jets (inches)	Design Basis for Steam Injected (lb steam/lb hydrocarbon)

For Water Injection

Water Pressure (psig) Minimum Expected	Water Pressure (psig) Design Maximum	Total Water Flow Rate (gpm) Minimum Expected	Total Water Flow Rate (gpm) Design Maximum	Number of Water Jets	Diameter of Water Jets (inches)

Attachment C — Example Acid Gas Glare Data

Operating Schedule

Normal (hours/day)	Normal (days/week)	Normal (weeks/yr)	Maximum (hours/day)	Maximum (days/week)	Maximum (weeks/yr)
			24	7	52

Supply an assembly drawing, dimensioned and to scale, to clearly show 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.