Modeling Flares

NOTE: There is an accompanying spreadsheet for flare calculations.

Flares can be modeled in AERMOD different ways: a) as a standard point source (no modified stack parameters); b) a point source (modified stack parameters); and c) as a flare (or pseudo-point source). This document discusses the first two methods.

Flare as Standard Point Source
Enter the following stack parameters into AERMOD for source type "point":

- Stack height (actual)
- Stack diameter (actual)
- Stack (flame) temperature (default temperature is 1832°F)[1]
- Flow rate or exit velocity

Flare as Modified Point Source
In this case, the flare spreadsheet, available on the website, may be used to calculate the modified parameters. Enter the following stack parameters into AERMOD for source type "point":

- Stack height (effective height from spreadsheet)
- Stack diameter (effective diameter from spreadsheet)
- Stack (flame) temperature (default temperature is 1832°F)[2]
- Exit velocity (set by flow rate from spreadsheet)

For this second option, flare sources are treated in a similar way to point sources, except the thermal effects of the flame with its lift and expansion of the plume require an effective stack height and effective stack diameter to be calculated. The pertinent calculations are summarized in the Addendum below.

[1]Default values are from EPA's SCREEN3 dispersion model.
[2]Ibid.

Addendum[3]

Flare sources can be treated in a similar way as point sources, except that there are buoyancy flux adjustments associated with radiative heat and heat losses. The thermal effects of the flame with its lift and expansion of the plume require an effective stack height and effective stack diameter to be calculated.

Effective stack height:
Due to the high temperature associated with flares, the effective release height of the plume can be calculated as follows:

$$h_{sl} = h_s + (4.56 \times 10^{-3}) \left(\frac{H_r}{4.1868}\right)^{0.478} \qquad (meters)$$

(Q may be used in some references instead of H)

where:
h_{sl} = effective flare release height (m)
h_s = stack height above ground (m)
H_r = net heat release rate (J/s) = (1 - f)H (for a single gas)
H = total heat (sensible + radiated) release rate (J/s)
f = radiative loss factor (%)

The value of the radiative heat loss factor depends on the burning conditions of the flare. If there is information specific to the flare, DNR recommends that the specific information be used. (SCREEN3 recommends a default radiative heat loss factor of 55%. This is very conservative as most gases have values about half of that.)

Gathering the constants together and converting from meters to feet:

$$h_{sl} = h_s + (7.54 \times 10^{-3}) {H_r}^{0.478} \qquad (feet)$$

Effective stack diameter:
The idea here is to adjust the stack diameter (holding other stack parameters constant, including the exit velocity) so that the point source (a virtual flare) will yield the same predicted ambient pollutant concentrations as a flare (modeled as a flare). The effective stack diameter can be determined by equating the buoyancy flux from the flare (hot source—Brigg's equation 4.20[4]) to the general buoyancy flux equation. Equivalently, this is making the flare plume height equal to that associated with a conventional stack.

The buoyancy flux from the flare is:

$$F = \frac{g * H_r}{\pi * \rho * T * C_p} = 2.59 \times 10^{-3} * H_r/T$$

where:
g = acceleration due to gravity = 9.81 (m/s^2)
ρ = density of air = 1.2 (kg/m^3)
T = air temperature (°K)
C_p = specific heat of dry air constant = 1004 (J/(Kg °K)

[3]Lakes Environmental Consultants' report: PROPOSED GUIDANCE FOR AIR DISPERSION MODELING at https://www.weblakes.com/products/aermod/resources/Ontario_MOE_Proposed_Air_Dispersion_Modelling_Guidance.pdf.
[4]*Plume Rise*, G. A. Briggs, 1969.

The buoyancy flux for stack releases is:

$$F = g * V_s * {r_s}^2 * (T_s - T)/T_s$$

where:
V_s = exit velocity (m/s)
r_s = stack inner radius (m)
T_s = stack exit temperature (°K)

Setting these two equations equal, solving for the stack diameter (2*r_s), substituting the above values for the constants, and converting from meters to feet:

$$d_s = 0.1066 * \left[\frac{T_s}{T(T_s - T)} * \left(\frac{H_r}{V_s}\right)\right]^{0.5} \qquad (feet)$$

NOTE 1: All parameters in the above equations are in metric units. The calculation spreadsheet automatically converts input to these working units.
NOTE: 2: The equations presented herein are equivalent to those presented by Trinity Consultants.[5]

[5]*Fundamentals of Dispersion Modeling*, Trinity Consultants.