Ontario Air and Noise Best Practices		
Topic	**ASHRAE Self-Contamination Calculations**	**Date: October 1, 2012** **Version 1.2**
Purpose	**Self-Contamination Screening Using ASHRAE Chapter 44 Equations in Support of Certificate of Approval (Air) Applications**	**Page 1 of 4**

The ASHRAE method of calculation refers to the method described in the American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook, Chapter 44 – Building Air Intake and Exhaust Design (ASHRAE). As described in ASHRAE, two methods can be used to calculate dilution: a screening method and a more comprehensive method.

This best practice has been developed for practitioners to demonstrate the use of the **screening method** described in ASHRAE in determining the effects of self-contamination at a facility.

Practice

The ASHRAE screening method that uses a Gaussian plume equation to calculates a dilution ratio which can be used to assess contaminant concentration at an onsite receptor. The dilution equations predict the dilution ratio (D_r), which is the ratio of the contaminant concentration (C_e) at the exit of the exhaust to the concentration at the plume centerline (C_r) at a specific horizontal distance (in the x-direction) between the two points. D_r is represented by the following equation:

$$D_r = \frac{C_e}{C_r}$$ (ASHRAE, equation 11)

To calculate the contaminant concentration at the exhaust exit, the contaminant emission rate, the exhaust flow rate and the exhaust exit diameter are used as per the following equation:

$$C_e = \frac{ER}{Q}$$

$$C_e = \frac{ER}{\frac{\pi}{4} d_e^2 V_e}$$ (ASHRAE, equation 13)

Where:
ER = Emission rate
Q = Exhaust flow rate
d_e = Effective exhaust exit diameter (if the exhaust exit is not circular, the effective exhaust diameter can be calculated using the following equation)

$$d_e = \left(\frac{4A}{\pi}\right)^{0.5}$$ (ASHRAE, equation 8)

Where A = exhaust area
V_e = Exhaust velocity

The plume dilution is affected by numerous factors, including the wind speed (U_H), the stack height and the effect of rooftop obstacles. To simplify the calculation, the effects of stack height and rooftop obstacles will be removed from the calculation by the assumption that the source exhaust is located flush with the roof (i.e. there is no stack height relative to the roof) and that the stack is uncapped. Additionally, it is assumed that the minimum wind speed is 2 m/s; at lower wind speeds, the atmosphere will tend to develop high levels of turbulence that increase stack dilution.

To calculate the dilution ratio for a flush, uncapped vent, the following equation is used:

$$D_r = 4\frac{U_H}{V_e}\left[0.071\left(\frac{t_{avg}}{2.0}\right)^{0.2}\frac{S}{d_e}+\frac{\sigma_o}{d_e}\right]\left(0.071\frac{S}{d_e}+\frac{\sigma_o}{d_e}\right) \qquad \text{(ASHRAE, equation 23)}$$

Where:
t_{avg} = Concentration averaging time in minutes. This equation works over an averaging time of 2 minutes to 180 minutes. For an averaging time outside of this range, the final concentration must be adjusted using the factors described in the regulation
S = Stretched string distance between the nearest edge of the exhaust and the nearest edge of the intake
σ_o = The initial spread component. This can be calculated using the following equation:

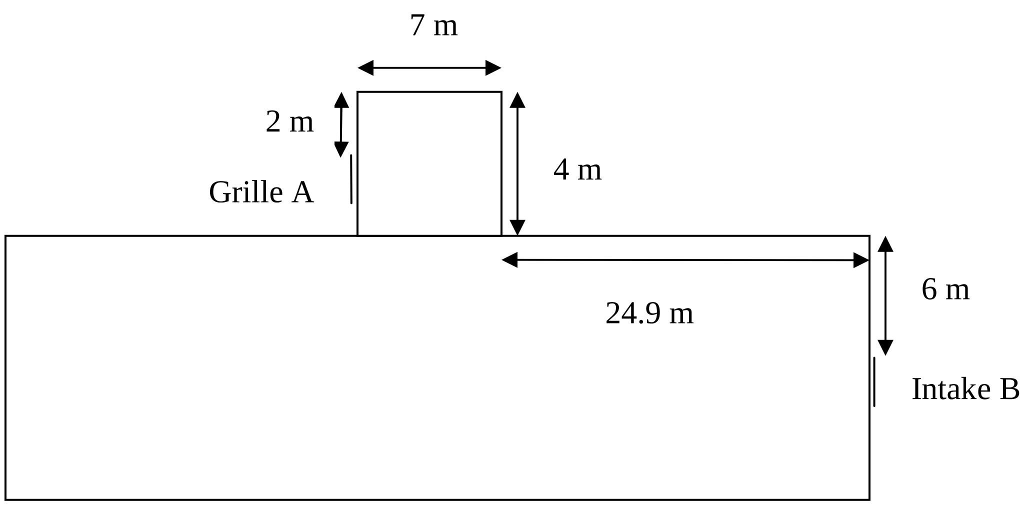
$$\frac{\sigma_o}{d_e} = \left[0.125\beta\frac{V_e}{U_H}+0.911\beta\left(\frac{V_e}{U_H}\right)^2+0.250\right]^{0.5} \qquad \text{(ASHRAE, equation 22)}$$

Where:
β = Capping factor (assumed equal to 1 for flush, uncapped vent)

When these values are entered into the equation, it results in the dilution ratio. Then, using equation 11, the concentration at the POI can be determined. This value is then compared to the MOE POI limit for the contaminant; it is less than the MOE POI, the contaminant will pass for self-contamination. If the contaminant fails, more stringent values will need to be used.

Example (from ASHRAE Handbook, Chapter 44, Example 3):

A contaminant exhausts from a louvered Grille A, which is located on a penthouse on the building below. The flow rate out of the grille is 1.76 m^3/s, and the length and width of the grille is 0.7 m each. If the contaminant emits at 1 g/s, what is the dilution ratio at Intake B for an averaging time of 1 hour?



From this information, the stack effective diameter and the stack velocity can be calculated:

$$V_e = \frac{1.76m^3/s}{0.7m \times 0.7m}$$

$$V_e = 3.59m/s$$

$$d_e = \left(\frac{4 \times 0.7m \times 0.7m}{\pi}\right)^{0.5}$$

$$d_e = 0.79m$$

The stretched string distance between Grille A and Intake B is the sum of the 2 m from the top of the grille to the top of the penthouse roof, the 7 m to the downwind edge of the penthouse and the direct distance from the edge of the penthouse to the top of the intake (which includes the horizontal distance of 24.9 m and the vertical distance of 4 m to the top of the roof and the 6 m to the top of the intake). This is calculated below:

$$S = 2m + 7m + \sqrt{(24.9m)^2 + (4m + 6m)^2}$$

$$S = 35.8m$$

Then, the initial plume spread is calculated:

$$\frac{\sigma_o}{d_e} = \left[0.125(1.0)\frac{3.59m/s}{2m/s} + 0.911(1.0)\left(\frac{3.59m/s}{2m/s}\right)^2 + 0.250\right]^{0.5}$$

$$\frac{\sigma_o}{d_e} = 1.85$$

Finally, the dilution ratio at the intake can be calculated.

$$D_r = 4\frac{2m/s}{3.59m/s}\left[0.071\left(\frac{60\min}{2.0}\right)^{0.2}\left(\frac{35.8m}{0.79m}\right)+1.85\right]\left(0.071\left(\frac{35.8m}{0.79m}\right)+1.85\right)$$

$$D_r = 93$$

The dilution ratio must be evaluated at a range of wind speeds to determine the minimum dilution ratio, which results in the highest concentration of contaminant. This may be done through an iterative process to determine the appropriate wind speed. In this case, the lowest dilution ratio is found at the tested wind speed of 2 m/s.

To determine the concentration at the intake, the concentration of the contaminant at Grille A is calculated:

$$C_e = \frac{1\frac{g}{s}\times 10^6\frac{\mu g}{g}}{1.76m^3/s}$$

$$C_e = 5.68\times 10^5 \mu g/m^3$$

Therefore, from the calculated dilution ratio, the concentration of the contaminant at Intake B is:

$$C_r = \frac{C_e}{D_r}$$

$$C_r = \frac{5.68\times 10^5 \mu g/m^3}{93}$$

$$C_r = 6.11\times 10^3 \mu g/m^3$$

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