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ASHRAE Methodology of Determining Minimum Dilution for Self Contamination Assessments

Taken from 2011 ASHRAE Handbook – HVAC Applications (Chapter 45)

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Before O. Reg. 419/05 (Scorer-Barrett)

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Now we have ASHRAE

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Goal of this presentation

- Provide some of the concepts that will help you develop your own working copy of the equations in the ASHRAE Methodology
- Provide some of the examples of when you would need to use the ASHRAE Methodology

Not a Goal of this lecture

- Make it so that when you leave here you are an expert in the details of the ASHRAE Methodology

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Disclaimer

- Page 12 of the ADMGO says "The US EPA models referred to in Section 6 of the Regulation are available on the US EPA website. The ASHRAE method of calculation is copyrighted and a license to use these methods must be purchased from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (www.ashrae.org)."
- MOE references the ASHRAE methodology found in the 2003 Handbook in O. Reg. 419/05.
- MOE references the ASHRAE methodology found in the 2007 Handbook in the ADMGO.
- This presentation used the ASHRAE methodology found in the 2011 Handbook in the ADMGO.

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When to use ASHRAE

- The Air Dispersion Modeling Guideline for Ontario ("ADMGO"[1]) says that the ASHRAE method of calculation must be used to assess "same structure contamination" when assessing against Schedule 3.
- For this application "same structure" means that the source and the receptor are on the same building.

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POI Definition

Points of impingement

"2. (1) A reference in this Regulation to a point of impingement with respect to the discharge of a contaminant does not include any point that is located on the same property as the source of contaminant.

(2) Despite subsection (1), a reference in this Regulation to a point of impingement with respect to the discharge of a contaminant includes a point that is located on the same property as the source of contaminant, if that point is located on,

(a) a child care facility; or

(b) a structure, if the primary purpose of the property on which the structure is located, and of the structure, is to serve as,

(i) a health care facility,

(ii) a senior citizens' residence or long-term care facility, or

(iii) an educational facility."

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Building which crosses property boundary

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Child Care Facility

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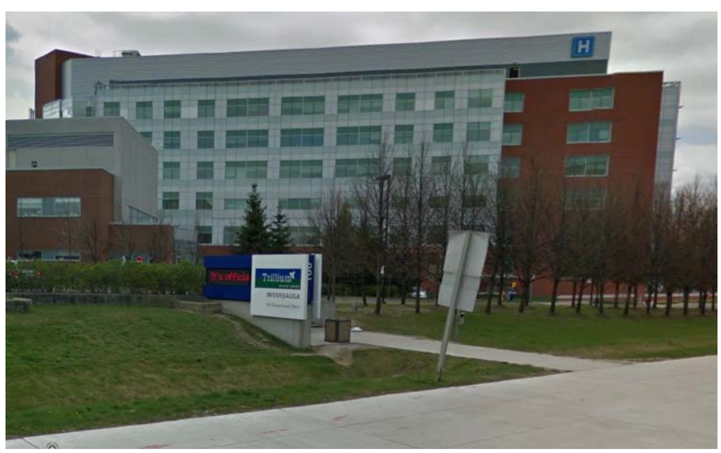
Health Care Facility



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Senior citizens' residence or long-term care facility

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Educational facility

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When to use ASHRAE

- ADMGO: "Same structure contamination becomes especially important within industrial parks, or multi-unit commercial complexes where emissions from one unit can impact neighbouring units (where the neighbouring unit is within the same structure as the emission source) through air intakes, open doors, or windows. The ASHRAE model is for use with respect to a point of impingement that is located on the same structure as the source of contaminant."

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What sort of buildings will require ASHRAE

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ASHRAE Methodology Layout

- Stack and Intake Design Strategies
- Geometric Method For Estimating Stack Height
- Exhaust-to-Intake Dilution Calculations
- Other methods of predicting concentrations
  - EPA Models (AERMOD)
  - Wind Tunnel Modelling
  - Computer Simulations
- Annual Hours of Occurrence of Highest Intake Concentration
- Combined Exhausts
- Ganged Exhausts
- Architectural Screens

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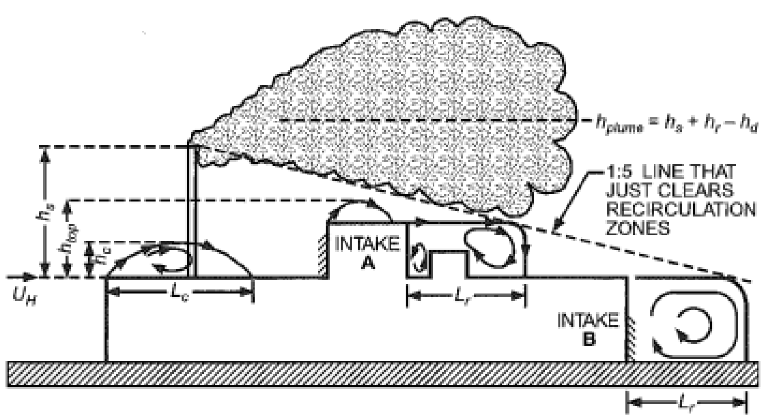
Fig.1 Flow Recirculation Regions and Exhaust Parameters



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What you get when you are done

- Remember that the larger the dilution, the better so the worst case dilution is the minimum (smallest) number.
- The equations provide a dilution factor
- Assuming the exhaust is 1 g/m^3, at the intake, the concentration will be 1 g/m^3 / 400 * 1,000,000 µg/g = 2,500 $\mu g/m^3$.

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Determine $\zeta = H_{plume} - H_{top}$

- First step is to calculate h_{plume} and h_{top}
- If $H_{plume} - H_{top} < 0$, $\zeta = 0$ and we use equation 23 otherwise we use equation 19

$$D_r(x) = \frac{4U_H \sigma_y \sigma_z}{V_e d_e^2} \exp\left(\frac{\zeta^2}{2\sigma_z^2}\right) \qquad (19)$$

$$D_s(x) = \frac{4U_H \sigma_y \sigma_z}{V_e d_e^2} \qquad (23)$$

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Computing Critical Dilutions

- First step is to calculate h_{plume}
- $h_{plume} = h_s + h_r - h_d$
- $h_{plume} = h_{stack} + h_{rise\ (momentum)} - h_{downwash}$

- Buoyancy is ignored to be conservative unless the exhaust is very hot.
- h_r is the momentum from the velocity of the air in the exhaust. Obviously, a capped stack has no h_r.

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Computing Critical Dilutions

- h_{top} is the top of the highest active obstacle.
- To identify active obstacles, start by drawing a line in plan view from the exhaust point to the intake of interest. All obstacles along this line or one obstacle width laterally (y-direction) from the line are considered active.
- Active Object = Any thing that may disturb the flow between the exhaust and the intake

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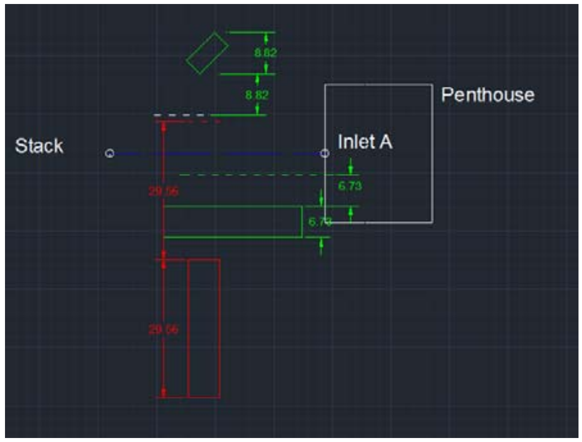
Identify Active Objects – Roof Objects



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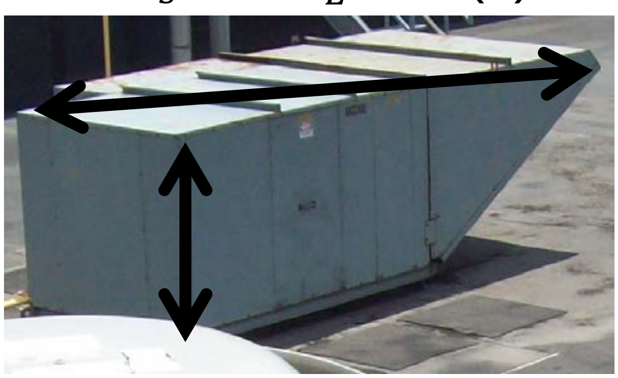
Determine H_{top} - Recirculation Zone

- $R = B_S^{0.67} * B_L^{0.33}$ (5)



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Determine H_{top} - Recirculation Zone

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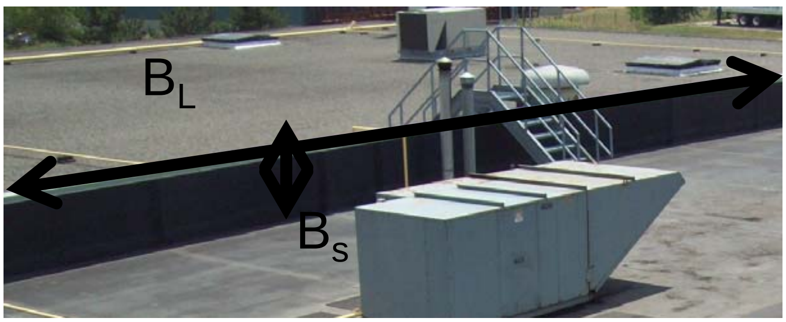

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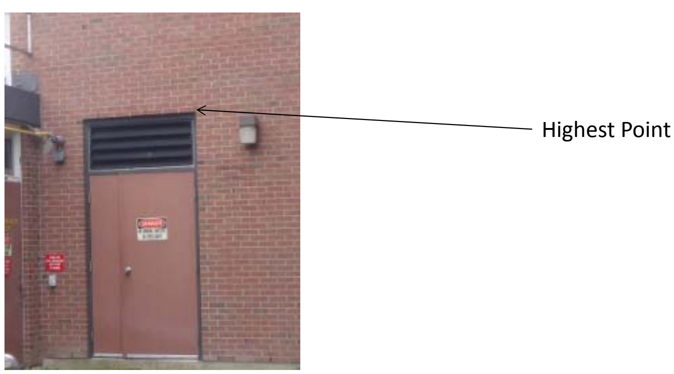
Determine H_{top}

- For the intakes, H_{top} is the highest point on the intake



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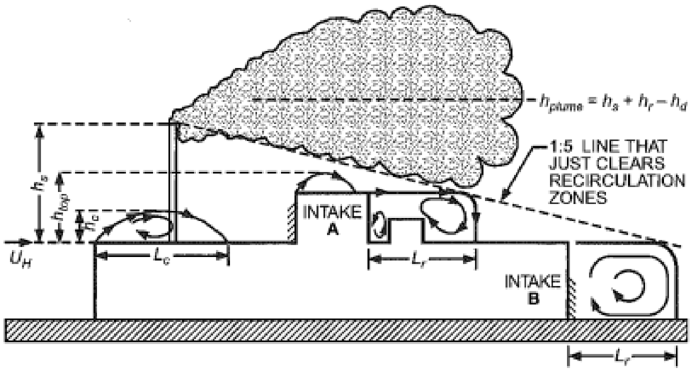
Determine H_{top}

- $H_c = 0.22R$



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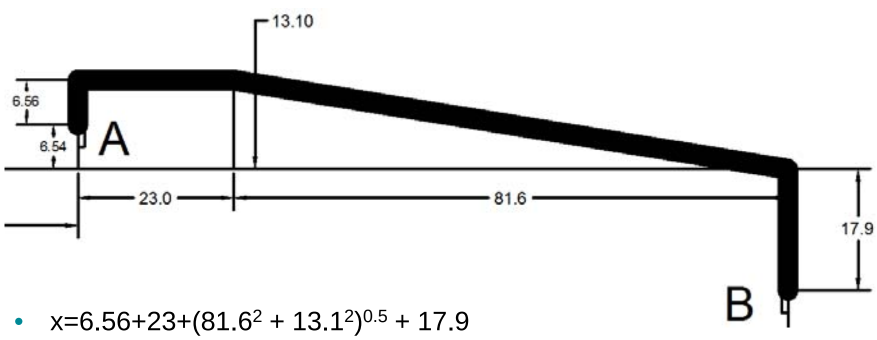
Determine x

- X = stretched string distance from exhaust point to intake.



- $x=6.56+23+(81.6^2 + 13.1^2)^{0.5} + 17.9$

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Determine U_{met}

- U_{met} is the design wind speed that is exceeded less than 1% of the time.
- U_H equal to 2.5 times the annual average hourly wind.
- http://climate.weather.gc.ca has historical data for the country
- This data is found under the “Data” heading “Canadian Climate Normals”
- Toronto’s average hourly wind speed from 1971 to 2000 is 14.7 km/h (4.08 m/s) so U_H is 2.5*4.08 = 10.2 m/s

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Determine U_{met}

- Toronto’s average hourly wind speed from 1981 to 2010 is 14.99 km/h (4.16 m/s) so U_H is 2.5*4.08 = 10.4 m/s
- Windsor’s average hourly wind speed from 1971 to 2000 is 16.0 km/h (4.44 m/s) so U_H is 2.5*4.44 = 11.11 m/s

- Since the equations are trial and error to find the minimum dilution, the MOE recommends testing every 0.5 m/s from 2 to 11.5 m/s.

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Table 1 Atmospheric Boundary Layer Parameters

Terrain Category	z_g, ft	a	δ, ft
Flat, water, desert	0.03	0.10	700
Flat, airport, grassland	0.16	0.14	900
Suburban	2.1	0.22	1200
Urban	6.0	0.33	1500

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Things that will help when developing your spreadsheet

- Make all the source values in SI units and convert them to US units. The original examples were all done in SI units and then published in US units to 2 decimal places so it is much easier to get your values to match the example values if you use SI units except where the US values are nice numbers (like 20 ft).

- ß has nothing to do with $ß_j$.

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Cases where ζ=0 (h_{top} >= h_{plume})

- ASHRAE Example 3 shows using a reduced set of equations when ζ=0.
- Because exp(0)=1, you can use the same set of equations by putting an "IF" statement in the cell that calculates ζ.
- Something like "=IF(h_{plume}- h_{top} >=0,100,000, h_{plume} - h_{top})"

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What to do with the result

- The equations provide a result of 400
- Since the result is a dilution factor, assuming the exhaust is 1 g/m^3
- At the intake, the concentration will be 1 g/m^3 / 400 * 1,000,000 µg/g
- = 2,500 µg/m^3 on a 1 hour basis. This value may need to be converted to the 24 hour basis for comparison to the MOE limit.
- ASHRAE has a method for changing the time basis but the ADMGO tells us to use the MOE method $(x_1/x_2)^{0.28}$

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What to do with the result

- Converting to 24 hour basis give 2,500 * $(1/24)^{0.28}$ = 1027
- Converting to 10 minute basis give 2,500 * $(60/10)^{0.28}$ = 4129

- So if the emission was toluene, this example would show compliance with the MOE guideline of 2000 µg/m^3.
- If the emission was isopropyl acetate, this example would not show compliance with the 10 minute POI limit of 2000 µg/m^3.

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Thank you

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- John Liu, MOE

Questions?

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