Alberta Energy Regulator

AERflare

A Dispersion Modelling Tool with AI (Assumptions Included)

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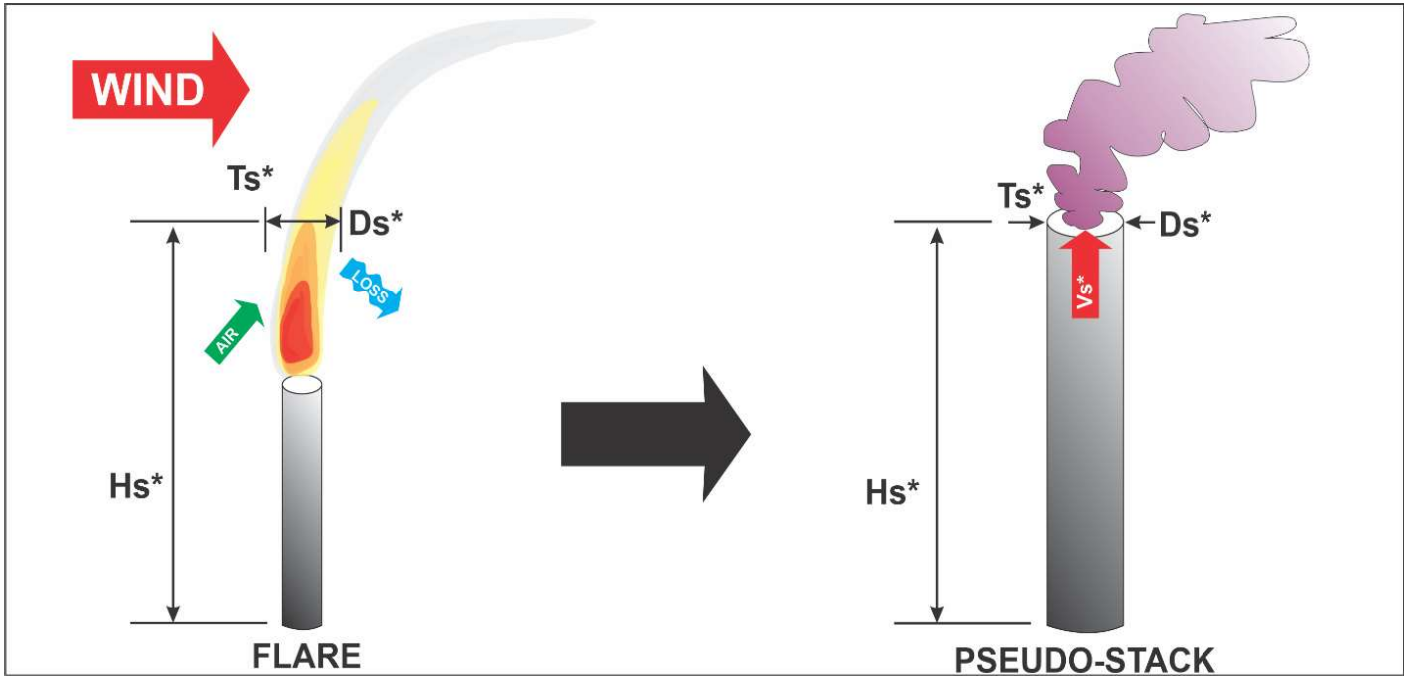
Modelling a Flare as a Stack



- Require pseudo- velocity, diameter and temperature of flare combustion products
- Effective stack height to allow for flame
- Flare-tip, not pseudo-stack downwash

Definition of Pseudo Prefix

- **Pseudo-parameters:** In mathematics, the 'pseudo' prefix is applied to items that are similar to (or mathematically behave like) something else, but not exactly that.
- **Pseudo-science:** Consists of approaches that are incompatible with the scientific method

Pseudo-science based Pseudo-parameters

- Buoyancy only – 1 equation,
  3 unknowns, specify 2 (T_s, V_s), solve for 1 (D_s)

Stack Buoyancy at Source

$$F_{bs} \equiv Q_s \frac{g}{\pi}\left(\frac{\rho_a - \rho_s}{\rho_a}\right) \approx V_s D_s^2 \frac{g}{4}\left(1 - \frac{T_a}{T_s}\right)$$

Flare Buoyancy in Plume

$$F_{bs} \approx H_C (1-f) \frac{g}{\pi \rho_a T_a C_{pa}} = \dot{m}_f NHV_f^0 (1-f) \frac{g R_U}{\pi P_a M_a C_{pa}}$$

Science Based Pseudo-parameters

- Volume, Buoyancy and Momentum
  - 3 known values that can be calculated with assumptions included
- Dispersion model inputs calculated from rigorously derived Volume, Buoyancy and Momentum equated to simplified equations dispersion models use
- 3 equations with 3 unknowns, specify none, solve for 3 (T_s, D_s, V_s)

Science Based Buoyancy

- Buoyancy

$$F_{bp} = \frac{\dot{m}_f}{P_a}\frac{g\,R_U}{\pi\,M_a}\left[\begin{array}{l}\dfrac{NHV_f^0\eta_{plume}}{C_{pa}} \\ +\dfrac{C_{pf}\left(T_f - T_r\right)}{C_{pa}} \\ +R_{s/f}\left(\dfrac{M_a}{M_{stoich}} - 1\right)T_a \\ -R_{s/f}\left(\dfrac{C_{pstoich}}{C_{pa}} - 1\right)\left(T_a - T_r\right) \\ -\left(T_a - T_r\right)\end{array}\right] = \frac{g}{4}V_s D_s^{\,2}\frac{T_s - T_a}{T_s}$$

$$V_s D_s^{\,2} = \frac{4}{g}F_{bp}\frac{T_s}{T_s - T_a}$$

Science Based Momentum and Mass

- Momentum

$$F_{mf} = \frac{1}{4}\frac{M_f T_a}{M_a T_f} V_f{}^2 D_f{}^2 = F_{ms} = \frac{1}{4} V_s{}^2 D_s{}^2 \frac{T_a}{T_s}$$

$$V_s{}^2 D_s{}^2 = 4 F_{ms} \frac{T_a}{T_s}$$

- Mass/Volume

$$Q_{sr} = Q_{fr}\left(\frac{molexhaust_s}{molflaregas_f}\right)$$

$$Q_{sa} = \frac{\pi}{4} D_s{}^2 V_s = Q_{sr}\left(\frac{P_r}{P_a}\frac{T_s}{T_r}\right)$$

$$V_s D_s{}^2 = \frac{4}{\pi} Q_{sr}\left(\frac{P_r}{P_a}\frac{T_s}{T_r}\right)$$

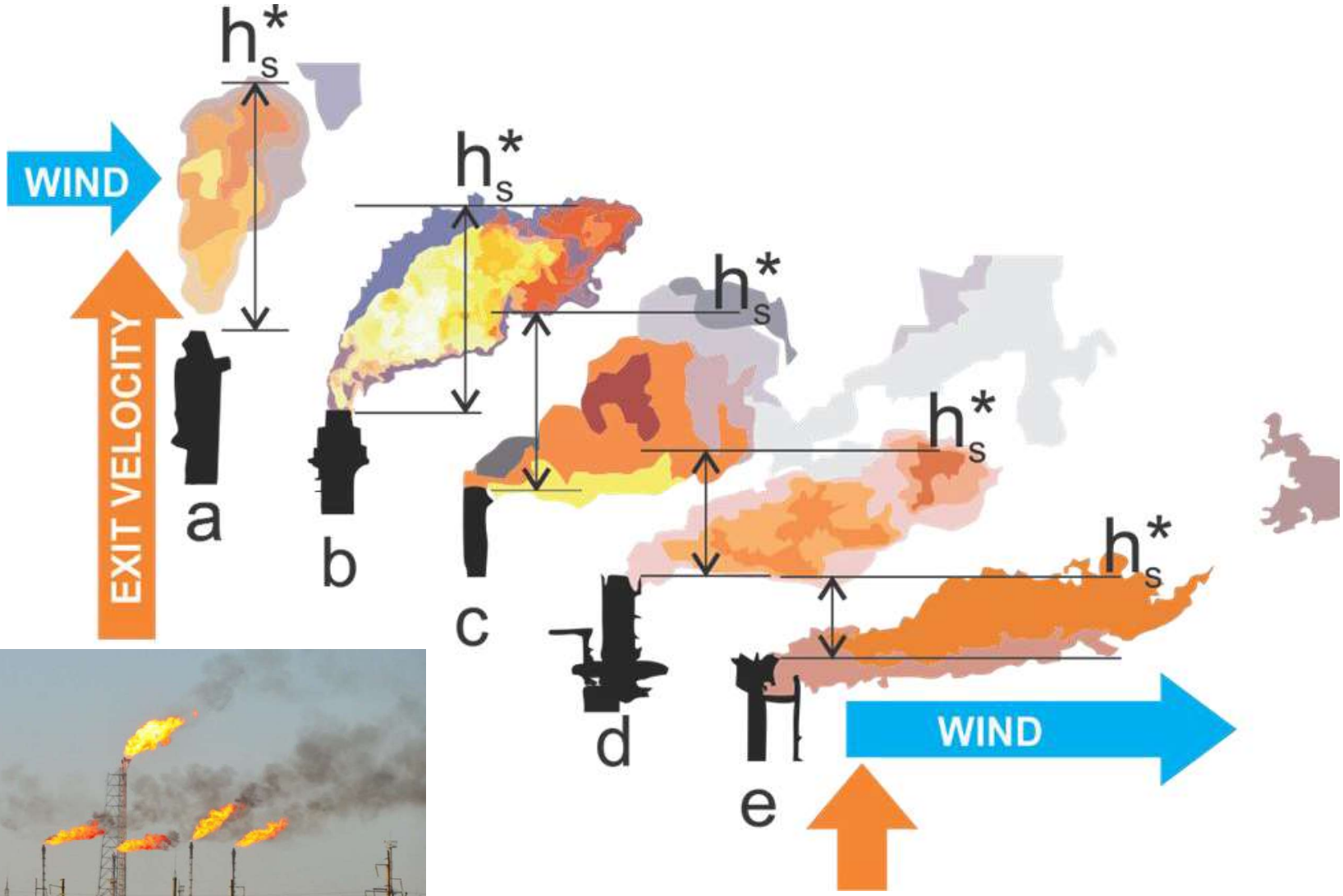
Science Based Flaring Pseudo-parameters

$$T_s = \frac{\pi}{g}\frac{F_{bp}}{Q_{sr}}\frac{P_a}{P_r}T_r + T_a$$

$$V_s = \pi\frac{F_{ms}}{Q_{sr}}\frac{T_r}{T_a}\frac{P_a}{P_r}$$

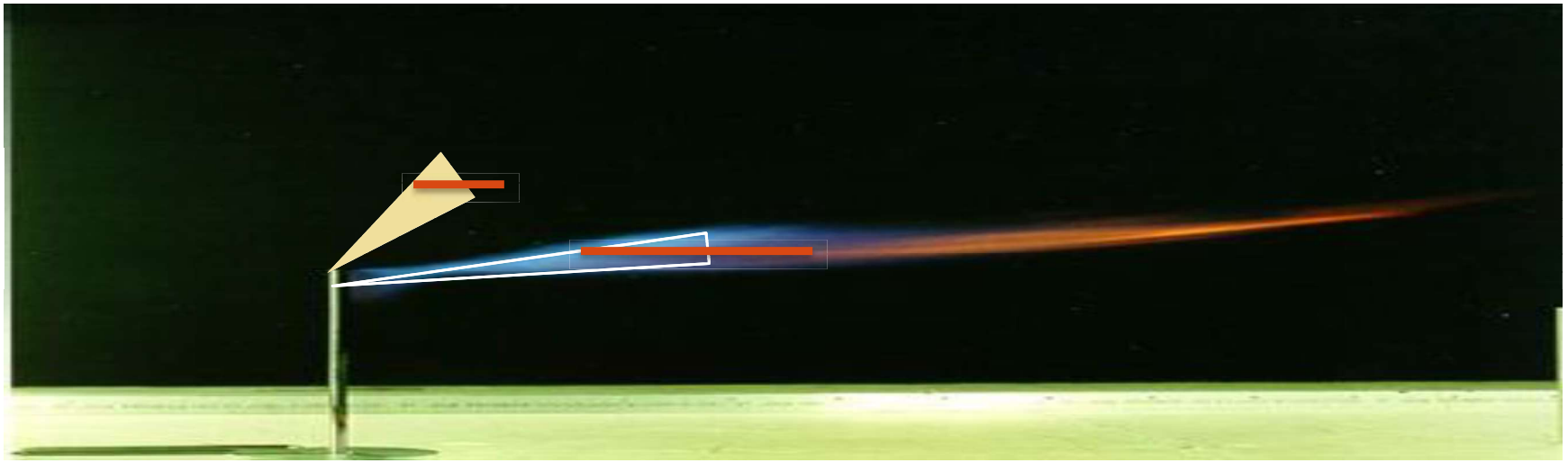
$$D_s = \frac{2}{\pi}\sqrt{\frac{P_r}{P_a}\frac{T_a}{T_r}\frac{Q_{sr}}{F_{ms}}\left(\frac{\pi}{g}F_{bp} + \frac{P_r}{P_a}\frac{T_a}{T_r}Q_{sr}\right)}$$

Flare Effective Stack Height and Downwash Variation with Wind Speed



https://guardian.ng/news/senate-penalises-gas-flaring-in-new-bill-offenders-to-pay-n10-million-fine/

Constant vs. Hour-by-Hour Modelling



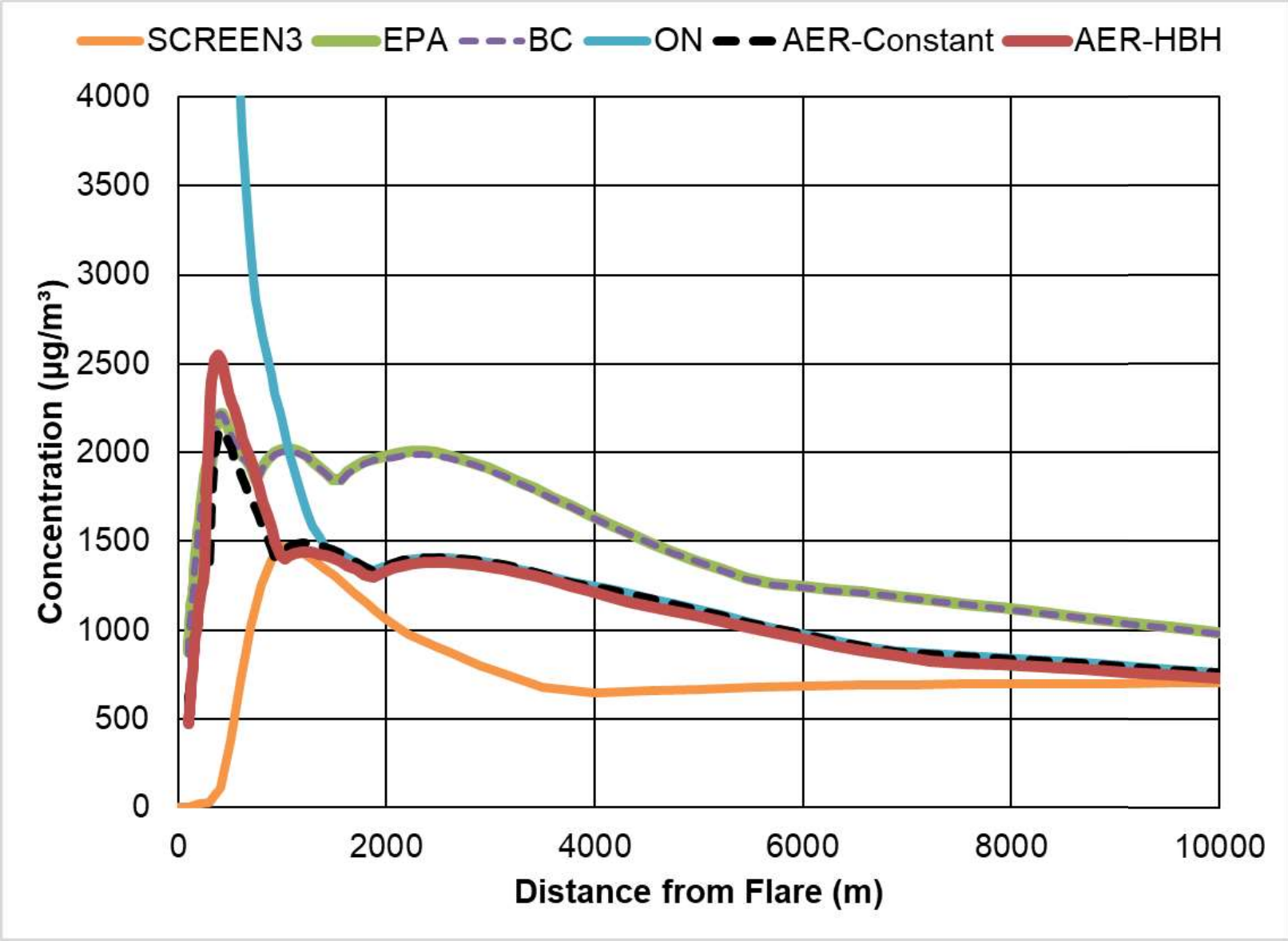
http://uintah.utah.edu/

- EPA approach is to use single set of pseudo-source parameters with downwash
- AER approach is to invoke NOSTD option, and input multiple emission sources with effective stack heights based on V_f / U_a

Example Flare Dispersion Model Input Parameters by Regulator

	Sea level elevation 0 m	Calgary elevation 1000 m	
Dispersion Model Input Parameter	**EPA / BC**	**Ontario**	**AER -constant**
Pseudo-Temperature (K)	1273	1273	1164
Pseudo-Velocity (m/s)	20.0	1.5	0.6
Pseudo-Diameter (m)	1.92/1.93	9.04	15.11
Effective Stack Height (m)	39.8	38.3	35.1
Flare Heat Loss (fraction)	0.55	0.30	0.25
Reference Flow Rate (Rm^3/s)	11.6/11.7	19.4	24.1
Buoyancy Flux (m^4/s^3)	139.0/140.4	231.6	260.8
Momentum Flux (m^4/s^2)	84.8/85.7	10.6	5.1

AERSCREEN Predicted SO_2 for Example Flare by Regulator



AERflare Source Model Summary

- Pseudo-source parameters are based on conservation of mass, momentum and energy.
- The flare effective stack height changes with wind speed based on a flare flame model and accounts for flare-tip downwash.
- Implemented in AERMOD with hourly pseudo-source and emission parameters.

Suggestions for revised Flare Approach

- Develop FLARE source for AERMOD
  - Remove ambient temperature sensitivity
  - Invoke NOSTD and set effective height based on hour-by-hour wind speed and actual flare tip velocity and diameter
  - Account for flare tip downwash properly
- Reduce flare radiation loss from 55% to a more realistic value
  - Account for flare combustion in-efficiency

Access AERflare

- Current regulatory version:
  AER.ca > Regulating Development > Rules and Directives > Directives > Directive 60

- Most recent version contact:
  brian.zelt@aer.ca

Questions

Thank you

Protecting what matters

www.aer.ca

www.youtube.com/user/ABEnergyRegulator

resource.aer.ca

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