Model Plume Rise

12th Modeling Conference on Air Quality Modeling

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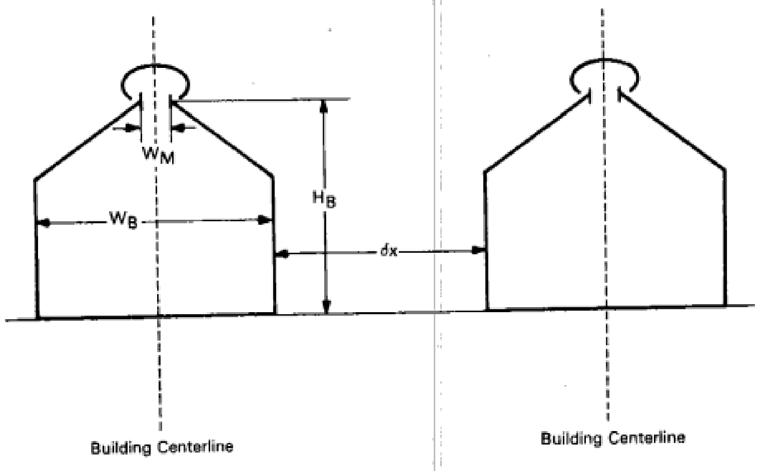
Current White Paper on Saturated Plumes

- NOx and SOx controls can add heat and moisture to stack effluent
- Condensation of moisture in these plumes can increase plume rise
- Plume rise is considered for POINT sources in AERMOD
  - Calculation accounts for both momentum and buoyancy
  - Buoyancy is based on exit temperature and does not consider any additional heat inputs, i.e., the heat of condensation
- PLURIS is generic plume rise model that "can be applied to situations with arbitrary three-dimensional wind fields, arbitrary directions of the source exit, and to both dry and wet plumes"
  - Janicke, U., Janicke, L.: A three-dimensional plume rise model for dry and wet plumes. Atm. Env. 35, 2001
- Paine et al., 2016, recommend a pre-processor to adjust POINT source temperature to account for additional buoyancy from condensation
  - Need update to AERMOD formulation that allows for calculation in the model
- Currently no model performance evaluation of the suggested pre-processor

Summary of Buoyant Line Plume

- EPA incorporated the Buoyant Line Plume (BLP) model into AERMOD as part of the 2017 Appendix W update
  - BLP was integrated "as is", with no scientific changes
  - AERMOD met is converted to PG stability class for BUOYLINE calculations in AERMOD
- BLP was formulated for "roof vents", mainly for smelter facilities
  - Plume rise from these sources includes buoyancy only, i.e., no momentum
  - BLP considers wind-angle specific entrainment, such that plume rise can be enhanced when winds are parallel to vents
  - BLP has been applied in various ways for other "long and hot" sources

BLP/ BUOYLINE Formulation



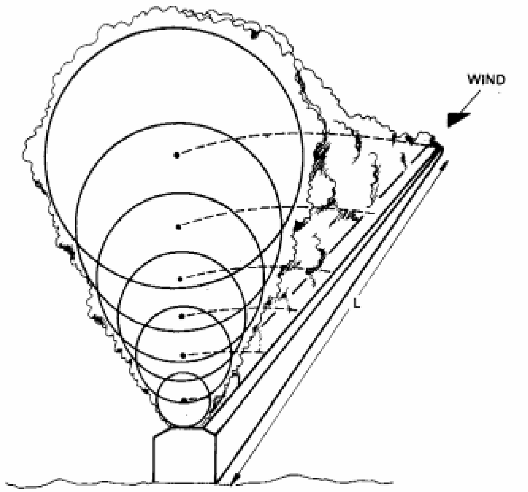


Figure 2-9 Cross Section of Line Source at $X = X_{FB}$ with Parallel Winds

- The buoyance flux for BLP:

$$F' = \frac{g * L * W_m * w * (T_s - T_a)}{T_s}$$

  - *g* is gravity, *L* is the length of the source, W_m is the width of the source, *w* is the vertical exit velocity of the vent, T_s is the exit temperature, and T_a is the ambient temperature.

- AERMOD point source buoyance flux

$$F_b = \frac{g * w_s * r_s^2 * (T_s - T_a)}{T_s}$$

- Buoyancy flux formula is essentially the same among the various models

Recent Model Clearinghouse Actions

- Three recent MCH actions, all titled "BLP/AERMOD Hybrid Approach for Buoyant Fugitives in Complex Terrain"
  - 2 coke oven facilities, one in Allegheny, PA and one in Follansbee, WV
  - Both also the subject of MCH records from early 1990's
  - Hybrid approach seeks to maximize scientific features from both formulations, i.e., enhanced plume rise from BLP, better dispersion estimates from AERMOD POINT/AREA sources

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The challenge of coke ovens

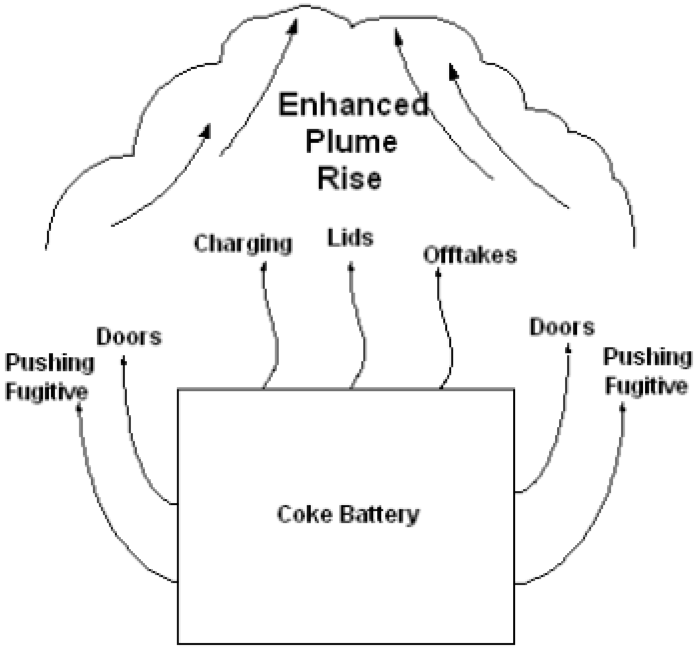
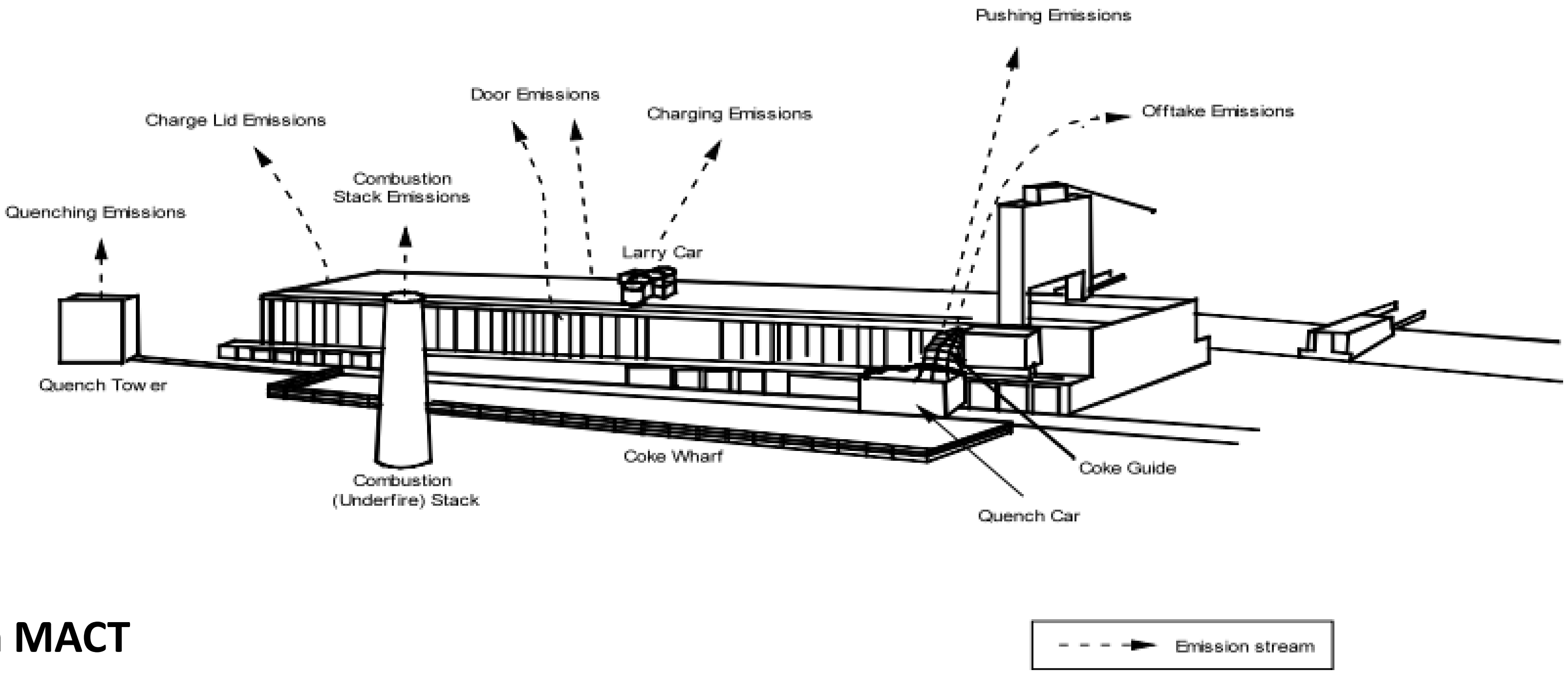


Figure D-1. Enhanced Plume Rise Sources



Risk Assessment Document for Coke Oven MACT Residual Risk, December 22, 2003

Other features of coke ovens

- Highly variable temperatures
  - Oven surface temperatures 450 F
  - Internal oven temperatures 1800 F
- Highly variable emissions
  - Individual ovens opened and closed constantly along the length of the oven for short periods of time
  - Quench car runs from ovens to quench tower with hot coke
  - Many fugitive emission sources
- Overall buoyancy is not just from emissions
  - RRA computed heat flux from surface heat transfer in addition to flux from emissions

Potential future topics on plume rise

- Buoyancy from fugitives could be important for some sources
- Buoyancy from generally "hot" facilities, even if not the specific emissions themselves, could be important for some sources
- Plume merging from nearby stacks not explicitly accounted for in AERMOD, but another feature of plume rise that could be important
- Plume rise is calculated independently, but plume height important in many other model formulation aspects
  - Interaction with downwash
  - Interaction with top of the mixing layer, i.e., the penetrated plume white paper submitted recently
  - Despite efforts to approach individual model updates, issues are interrelated