Bounding the Safe Separation Distance (SSD)

A Modeling Study in Support of Structure Separation Experiments

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NIST WUI Fire Day

NIST Technical Note, in WERB Review, June 2022

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July 13, 2022

Modeling to Estimate Safe Separation Distance

- Structure-to-structure fire spread occurs in WUI communities.
- Estimating the spacing between the source and target structure is critical for protecting communities.

- Primary objective of Structure Separation Experiment project : assess structure-to-structure fire spread for structures located in WUI
    - Full-scale fire experiments
    - Source structures generated radiative / convective heat exposures on target structures.

- Goal : Develop a **simple** modeling approach for estimating the minimum safe separation distance (upper bound for SSD)
    - Assist with design of Structure Separation Experiments
    - Enable development of test methods for Codes and Standards
    - Scenarios where it is difficult to conduct experiments (sloping terrains etc.)

Burning of wood / steel shed with wood cribs

- After ignition, fire initially spread slowly through the cribs.
  - Wood slabs stacked horizontally and vertically inside a small enclosure (oxygen limited)
  - Modeling flame spread and estimating heat flux is computationally challenging.

- Wood cribs can ignite a wooden shed
  - Two different peaks in the total heat release rate curve.
  - Loss of structural integrity. Glass windows can get compromised.
  - New pathways for smoke to pour out (doors, windows, roof).
  - New pathways for oxygen to enter the shed
- Modeling the changing geometry of a burning shed / cribs is critical to estimate the heat flux.

- Shed obstructs the flow-field. Diverts air around the source structure.

- **Summary : Real source introduce new physical processes. Modeling Challenges**

Effect of a target on the Flow Field

- Target structures aligned with the computational mesh – bluff body – dead zone.
- Re-circulating zone : conducive for firebrands to settle down and ignition.

- Target walls oriented at an angle – introduces computational complexity.
- Roof of the target structure is usually not aligned with the underlying mesh.
    - Stair step pattern produces dead zones - artificially increase ignition propensity.

- **Both source / target structure can only slow the ambient flow.**
- Neither add energy to the ambient flow. Incorporating them reduces SSD

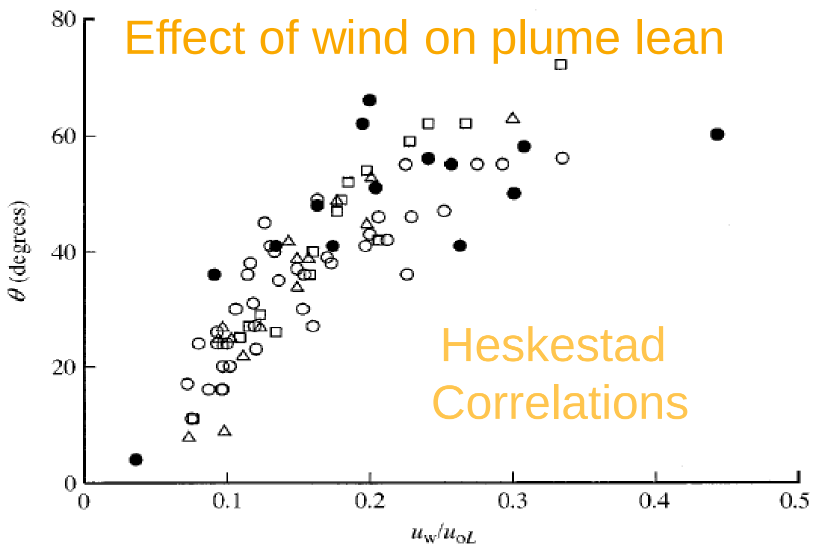
- Due to the computational complexity associated with modeling real sources / target
- A simple, efficient method to estimate SSD is proposed

Estimating SSD – Simple Alternate Approach

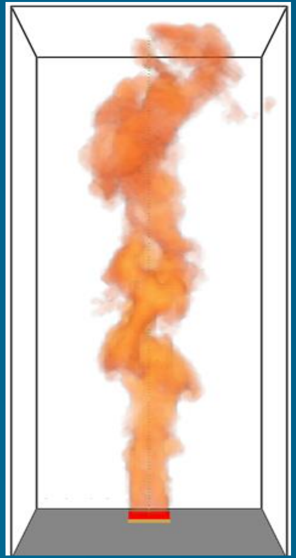
- Approximate the shed (source) as a simple square burner in ambient wind
- Removes the un-certainty associated with modeling a complex source
- Heat released in the source is prescribed at the burner surface. Parametric Studies
- Conservative worst-case scenario for bounding Safe Separation Distance (SSD)

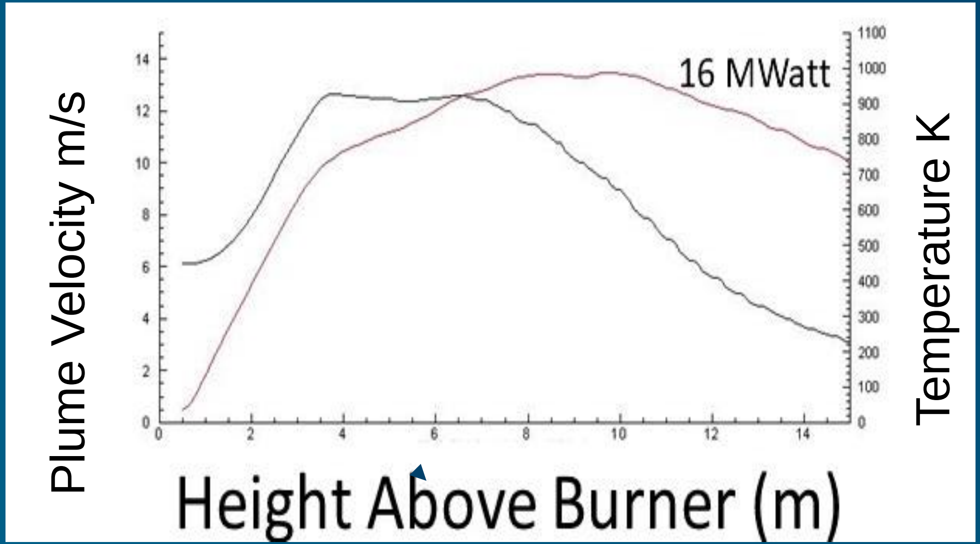
Simulating Plume Lean : Burner in Ambient Wind

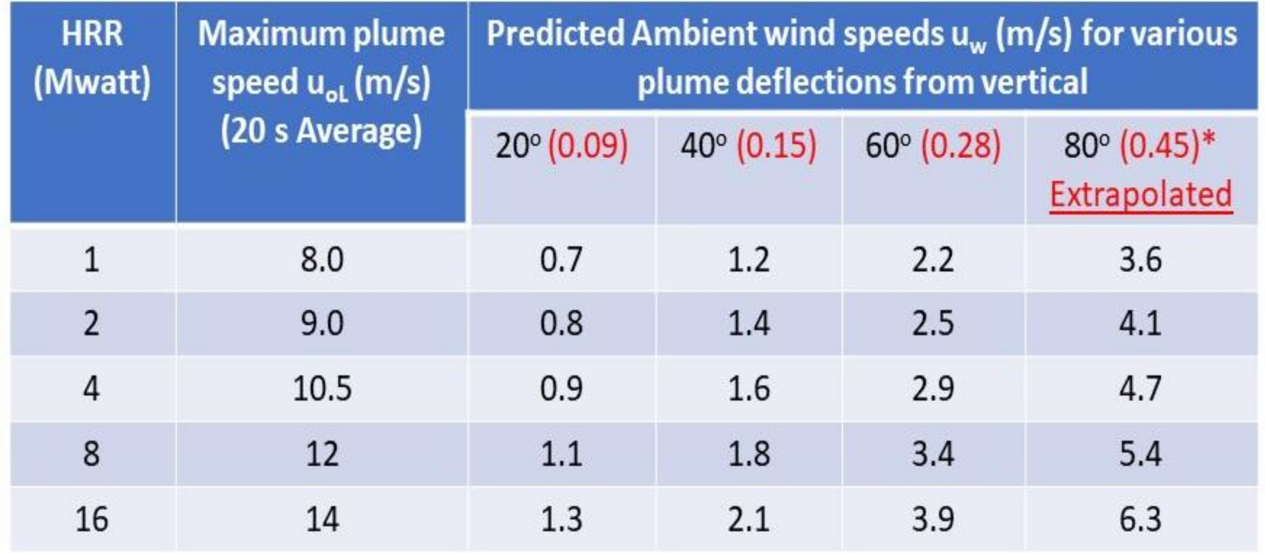
- Buoyant plume bends in the direction of the ambient wind. Flame stretch. Plume dilution.
- Is flame tilt predicted correctly. Heskestad correlations


Effect of wind on plume lean

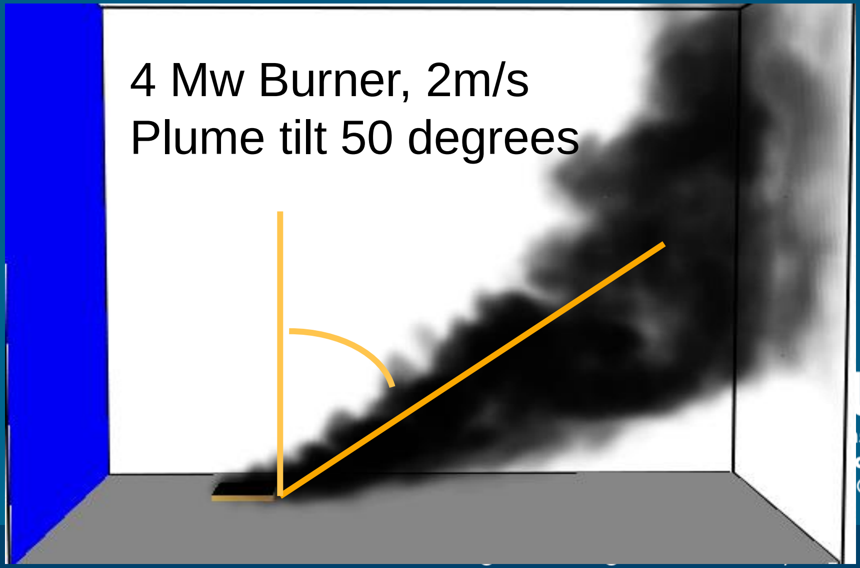
Heskestad Correlations



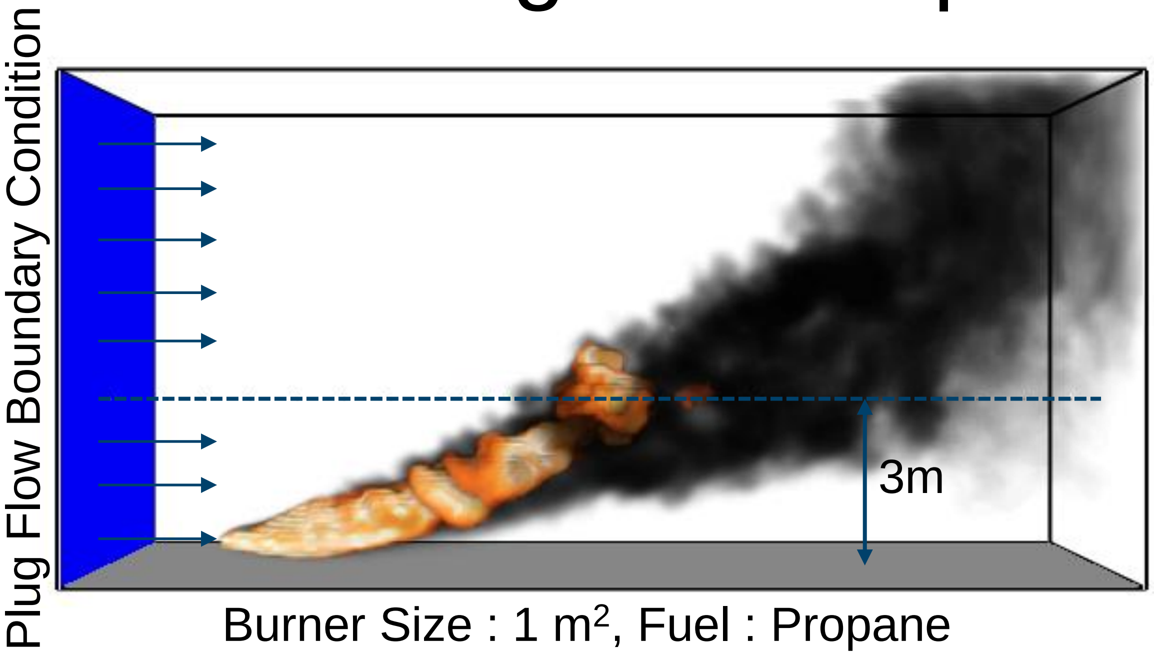




HRR (Mwatt)	Maximum plume speed u_{oL} (m/s) (20 s Average)	Predicted Ambient wind speeds u_w (m/s) for various plume deflections from vertical			
		20° (0.09)	40° (0.15)	60° (0.28)	80° (0.45)* Extrapolated
1	8.0	0.7	1.2	2.2	3.6
2	9.0	0.8	1.4	2.5	4.1
4	10.5	0.9	1.6	2.9	4.7
8	12	1.1	1.8	3.4	5.4
16	14	1.3	2.1	3.9	6.3


4 Mw Burner, 2m/s
Plume tilt 50 degrees

Bounding Safe Separation Distance - Methodology

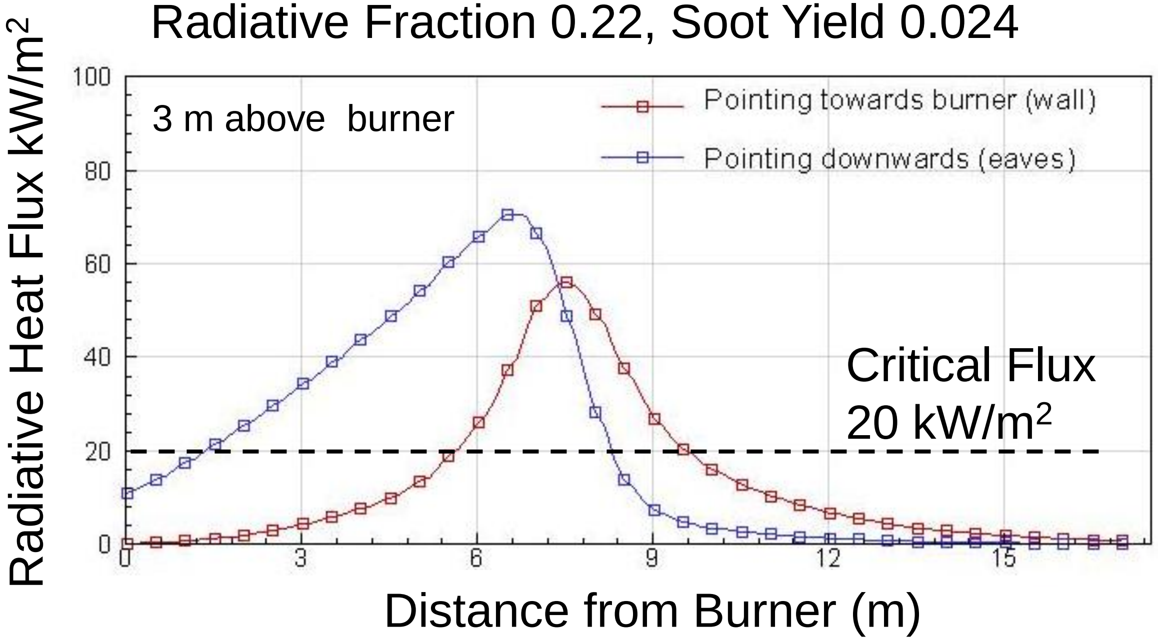


Burner Size : 1 m², Fuel : Propane
Radiative Fraction 0.22, Soot Yield 0.024

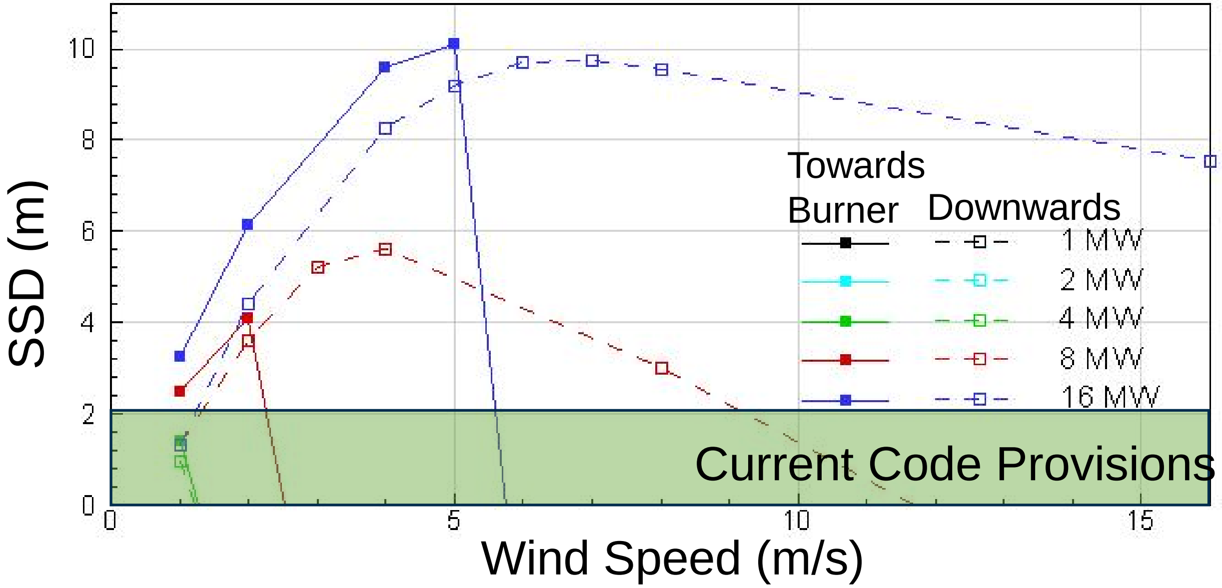
- 16 MW Burner (Medium Size Shed): Wind 4 m/s

- Heskestad correlations : flame tilt 60 degrees
- FDS simulations consistent with Heskestad correlations

- Wind Speed (1- 20 m/s). Heat Release Rate (1- 16 MW)



Bounding Minimum Structure Separation Distance
(Critical Radiative Heat Flux of 20 kW/m²)



Summary and Future Work

- Modeling fire spread on a full-scale shed / target is challenging.
- Proposed a simple approach to bound the Safe Separation Distance (SSD).
- Validation of plume lean : Comparison with Heskestad Correlations.

- **Predicted Safe Separation Distance**
  - **Heat Release Rate (1-16 Mwatt)**
  - **Wind Speeds (1-20 m/s)**

- Simple approach : extended to consider both convective and radiative flux.
- Simulations : performed for sloping terrains.

- **Future work : Compare results from the simple methodology with experimental data.**

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