LA-UR-07-3169

Presented to EFCOG 2007

Ensuring Conservatism in Leak Path Factor Calculations with MELCOR

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Introduction

- The use of codes for LPF has been challenged as having "uncertainties and non-conservatisms"
- Presentation examines the conservatisms for the LANL TA-55 DSA LPF calculations.
- Models can be very useful for determining system and facility performance and system interactions.
  - Results from statistical analysis will be presented to examine the relationship of systems and boundary conditions on results

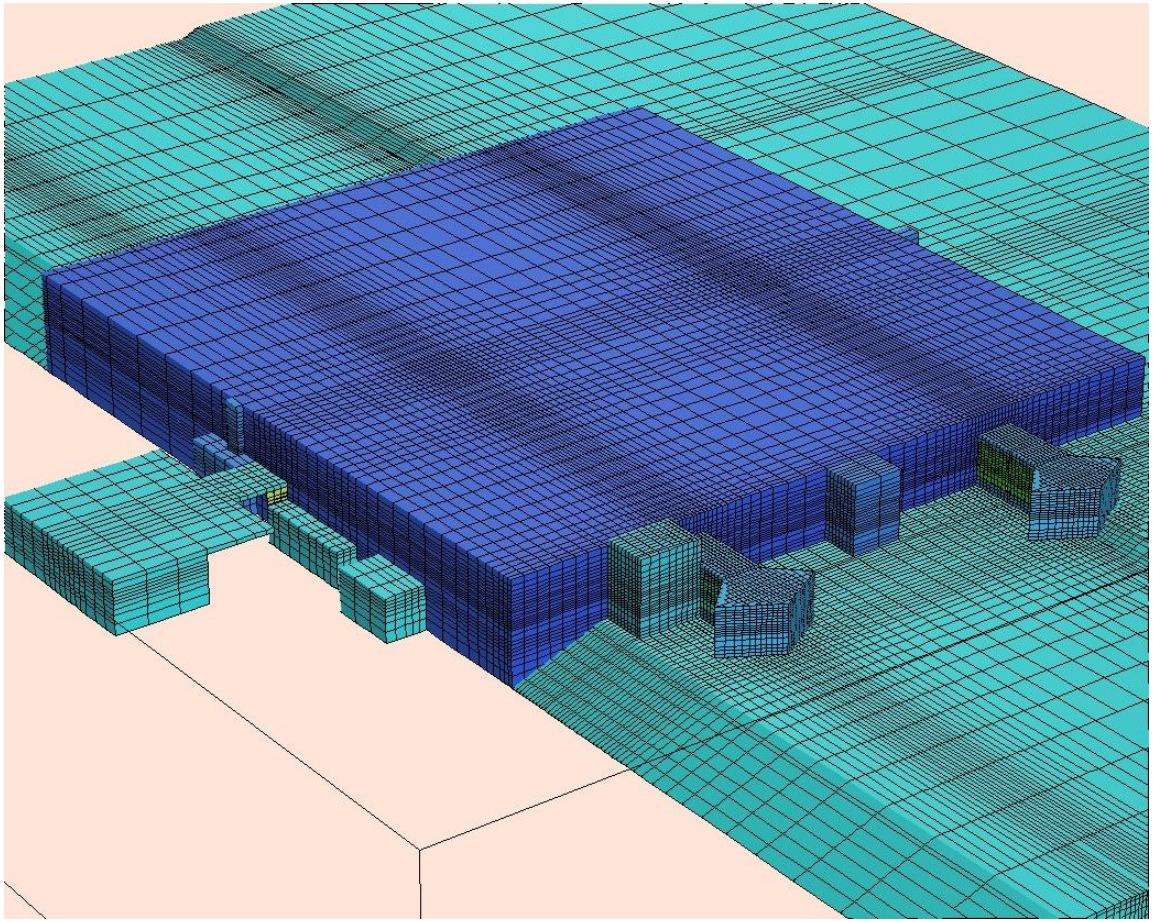
Where Can You Find Conservatism

- Code physics
  - Physics that is not accounted for (impaction of aerosols)
  - Adjustable parameters in closure relationships.
- Facility model
  - the input describing the facility, for a MELCOR model the control volumes, flow paths, and control functions used to describe the facility.
- Boundary conditions,
  - including the aerosol release parameters,
  - fire energy
  - wind driven pressure fields around the facility.
  - Door closing times

Example Problem

- Trash fire ignites gloves and PMMA shielding covering gloveboxes.
- Radionuclide aerosols are entrained into air currents induced in gloveboxes and flow into room by way of glove-ports.
- Fire energy carries aerosolized materials into hot-layer.
- From hot-layer, aerosolized materials are transported out of room into corridor.
- From corridor, aerosolized materials are transported to outside by way of wind induced corridor air flows or by natural circulation flows.

Rendering of Facility



Some Conservatism to be Covered

- Release mechanisms
- Aerosol distribution
- Fire dynamics
- Release timing
- Flow modeling

Release in Fire

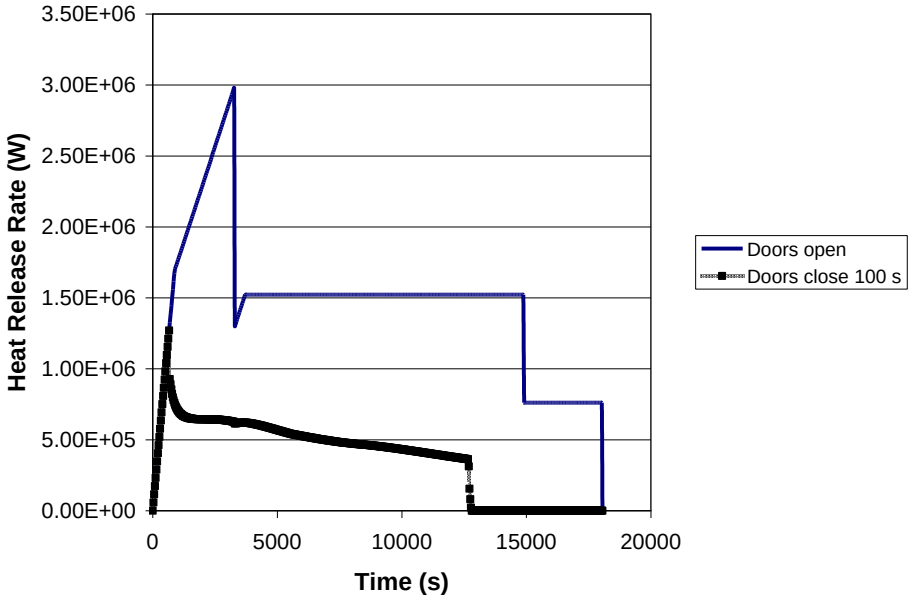
- ARF (from HDBK-3010) based on idealized conditions, air velocities in glovebox induced by external fire are most likely less than in experiment.
- In glovebox, even with open containers, less intimate contact of moving air with material
- Material size was more conducive to entrainment in experiment
  - ~ 1 µm in facility
  - 4.4 – 13 µm in experiment

Aerosol Distribution

- Real material is grams of ball-milled powder with a non-uniform aerosol distribution that has sizes greater than 1 micron.
- Quantity and size of aerosol conservative in MELCOR calculations
  - 1 gram quantity, makes agglomeration conservative
  - 1 micron size, monodisperse, minimizes settling

Fire Conditions

- Done using CFAST toolbox methodology for 150% base curve.
- Done for doors open
- The lower fire curve is for doors closing at 100 s. This shows the conservatism in the fire energy.
- Higher fire energy tends to push more material out the room door and from the corridor to the outside.

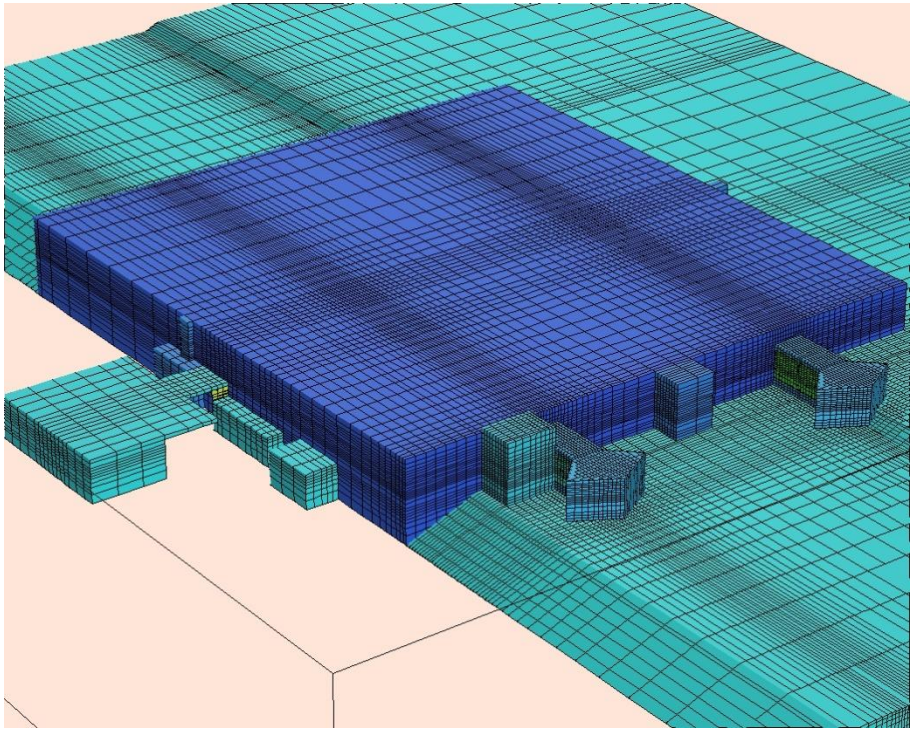


Release Timing

- Because door closing times are considered early (during evacuation of building,) the earlier the release the more gets out of the fire room, thus, a puff release at fire ignition time is conservative.
- Entrainment (aerosolization) of material is likely to be approximately proportional to air velocities in glovebox which are likely to be a strong function of fire energy.
  - CFD calculation used to determine release from glovebox assuming puff release at time zero, fully involved fire.
  - CFD calculation showed about 97% of material released from glovebox in 10 min, this was normalized for MELCOR input so that 100% of material is released in 10 min.

Wind Conditions

- Assume simple cube and use ASHRAE correlations for BCs
- CFD calculations to account for building geometry and surrounding terrain.
- Other structures that are not PC3 are not accounted for although they cover east entrances



Flow Modeling

- Doors are either 2 or 3 in series, only the inner door is modeled (conservative, less flow resistance gives higher flow rates).
- With doors open, full area used, pressure boundary applied at door location.
- When doors closed, K for sudden contraction + sudden expansion used, flow area set to give about 500 cfm at nominal DP, compared to 90 – 130 cfm actual. (Conservative in that form losses reasonably estimated and flow areas are larger than best estimate).
- Two choices for scale for roughness, the scale of door jams and lights or the scale of roughness, the smaller scale is used.
- MELCOR works fine for bulk (1-D) flows in corridor, i.e. has right physics.

Conservatism – Wrap up

- Many conservatisms in model and calculations:
  - Attempt to be "reasonably conservative" without being extremely conservative

[3009, pg A-3, section A.3].....General discussion is provided for source term calculation and dose estimation, as well as prescriptive guidance for the latter. *The intent is that calculations be based on reasonably conservative estimates of the various input parameters*.....

Detailed Parametric Study

- Large model of plutonium processing facility
  - Hundreds of volumes and flow-paths representing building and ventilation.
- Concern over wind effects because of two main East-West corridors in facility.
- Numerous boundary conditions needed to be evaluated

Range of Calculations

- 6 Wind Speeds
- 8 Directions
- 127 different combinations of accident conditions
  - Door configurations
  - HVAC configurations
  - Accident type and location
- Over 6000 calculations

Range Example

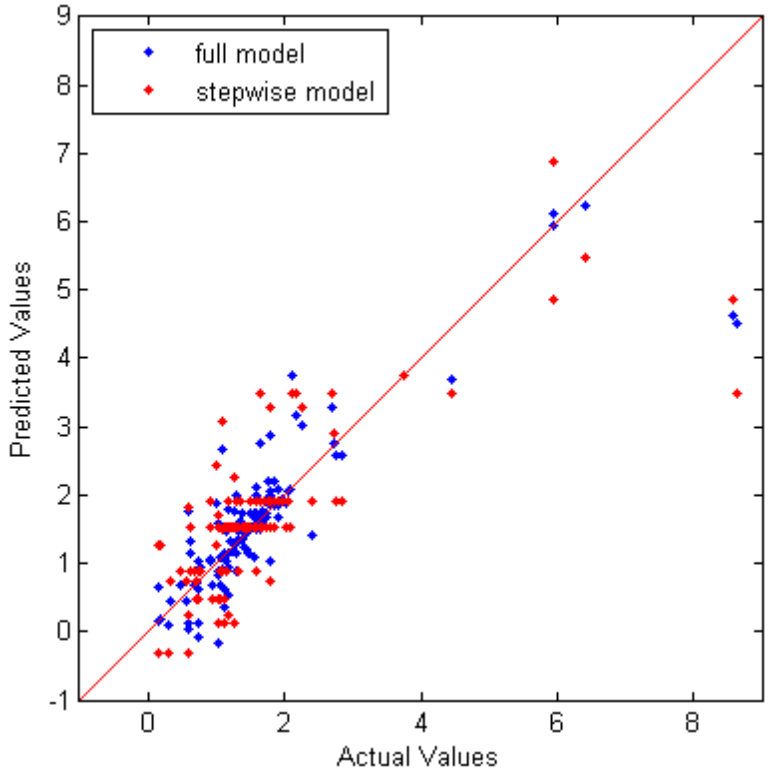
A	B	C	D	W	R	S	F	LPF95		
A1	B1	C1	D2	W1	R1	S1	F1	7.20E-01	1.39E+00	0.14
A1	B1	C1	D3	W1	R1	S1	F1	7.10E-01	1.41E+00	0.15
A1	B1	C1	D1	W1	R1	S1	F1	6.70E-01	1.49E+00	0.17
A2	B1	C1	D3	W1	R1	S1	F1	5.00E-01	2.00E+00	0.30
A2	B1	C2	D3	W1	R1	S1	F1	4.70E-01	2.13E+00	0.33
A2	B1	C1	D3	W2	R1	S1	F1	3.35E-01	2.99E+00	0.47
A2	B1	C2	D3	W1	R1	S1	F1	2.70E-01	3.70E+00	0.57
A3	B1	C1	D3	W1	R1	S1	F1	2.60E-01	3.85E+00	0.59
A3	B1	NA	D3	W2	R1	S3	NA	2.60E-01	3.85E+00	0.59
A3	B1	NA	D4	W2	R1	S3	NA	2.60E-01	3.85E+00	0.59
A3	B1	C1	D3	W2	R2	S1	F2	2.41E-01	4.15E+00	0.62
A3	B10	C5	D3	W2	R2	S1	F2	2.34E-01	4.27E+00	0.63
A3	B1	C1	D3	W2*	R1	S1	F1	2.13E-01	4.69E+00	0.67
A3	B1	C1	D3	W2	R1	S1	F1	2.10E-01	4.76E+00	0.68
A3	B1	C3	D3	W1	R1	S1	F1	2.00E-01	5.00E+00	0.70
A3	B2	C1	D3	W2	R1	S1	F1	2.00E-01	5.00E+00	0.70

Example of Parameter Space

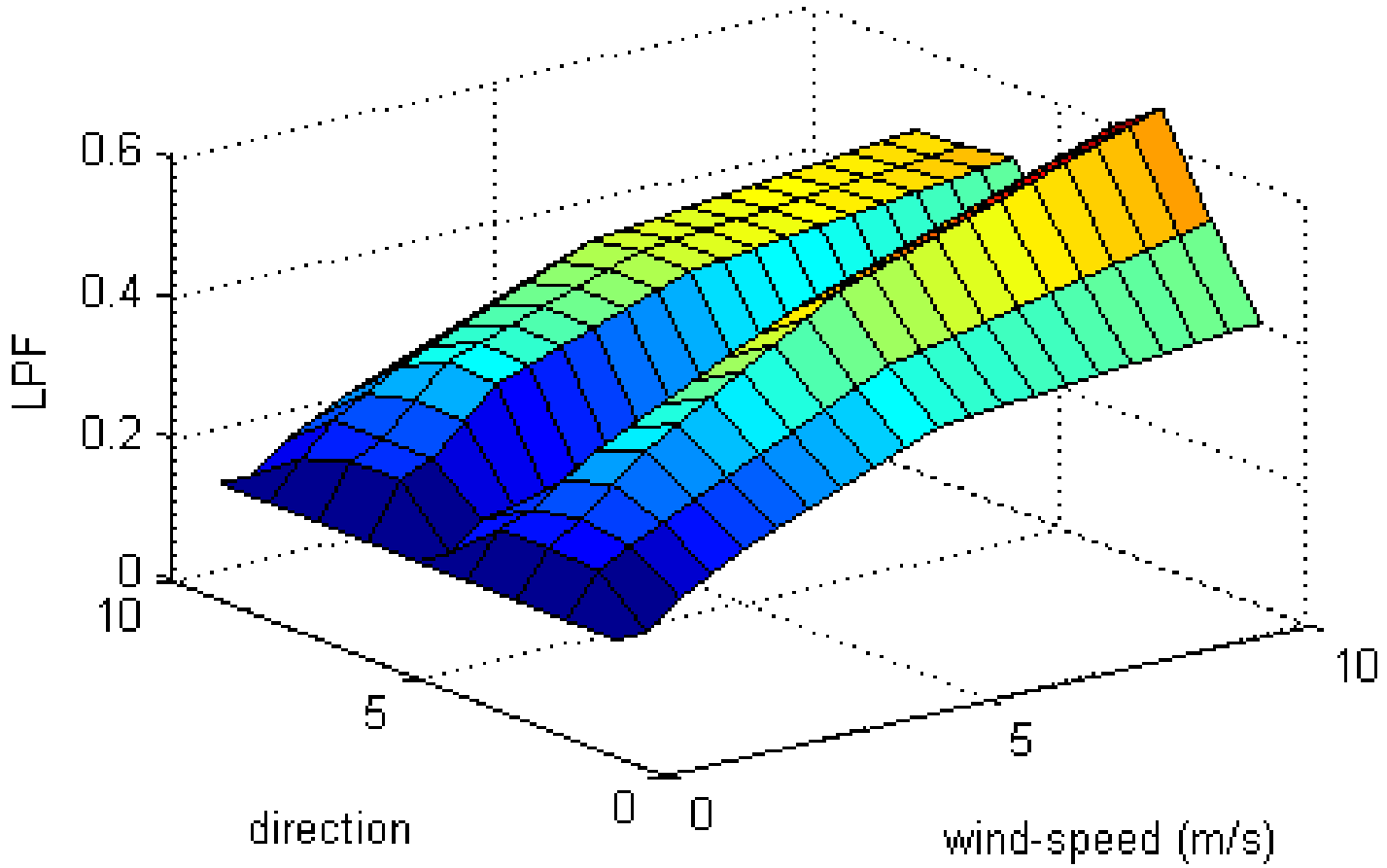
Category		Parameter Tag	Definition
Door Condition	1	A1	Both E and W doors always open
	2	A2	Both E and W doors closed at 10 min
	3	A3	Both E and W doors closed at 5 min
	4	A4	Both E and W doors always closed
	5	A5	E door closed, W door closed at 5 min
	6	A6	Both E and W doors closed at 2 min
	7	A7	E door closed at 5 min, W door closed at 30 s
	8	A8	E door closed at 5 min, W door closed at 1 min
	9	A9	E door closed at 5 min, W door closed

Regression Analysis

- Regression Analysis used to examine importance of parameters.
- Inclusion into model of parameter , value of coefficient, degree of correlation used as a measure of importance



Example Results



Conclusions of Parametric Study

- The external doors on the east and west end of the building and their state of closure is very important to having a very high or very low LPF. In addition, the orientation of the wind was also very important in that the wind tunnel effect was greatly enhanced if the wind was parallel to the main east – west corridor.
- The fire door that leads from the fire room to the corridor was important. Large LPFs were due to this door being open, small LPFs were enhanced (although not completed mitigated) by the closure of this door.

Conclusions of Parametric Study (cont.)

- The HVAC would only be helpful if the natural building boundaries, such as the external doors and the fire doors were in place. Either the presence of a wind tunnel effect in the corridor cause by the external doors being open or the presence of the fire room pressure overcoming the negative pressure of the HVAC were enough that the intended safety function of the HVAC was defeated.
- The other important insight was that many parameters such as extra corridor doors, various fire room nodalizations, changes in release timing seemed to have less of an impact on the results.