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In-Facility Transport Modeling
(Leak Path Factor Determination)

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Unclassified – Non Sensitive

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- New material provided by Chip Lagdon at EH-31/GTN (MELCOR LPF Guidance, May 2004)

In-Facility Transport Modeling

- In-Facility Transport Modeling is the analytical technique used to characterize the effectiveness of passive & active confinement systems.
- This course reviews the major elements of in-facility transport modeling, such as:
  - Transport pathway determination and intra-facility flow modeling
  - Aerosol transport & deposition
  - Hand calculations to estimate LPF
  - Computer code calculations to estimate LPF
  - Basic rules to use in selecting an appropriate method

Course Outline

- What is an LPF?
- Describe a typical situation requiring in-facility transport (LPF) analysis.
- Highlight the physical processes that influence the value of LPF.
- Summarize methods for calculating LPF.
  - First-order (hand calculations)
  - Refined analysis (code calculations)
- Present a few examples.

MELCOR and Computer Codes

- What is MELCOR?
  - Primer, Packages and How to Run
- How do you build a model?
  - Advice on model construction
- What about aerosols?
  - How to model and where to get information
- Fires and Wind the Basics
  - Energy input and Boundary Conditions for MELCOR

What is "LPF"?

- DOE-HDBK-3010 defines the source term to the environment by the Five Factor Formula:

$$ST = MAR \times DR \times RF \times ARF \times LPF$$

where:

Leak Path Factor (LPF) is the fraction of the airborne material that is transported *from the source* through some confinement mechanism *to the environment*.

When is LPF important?

- STD-3009 requires an unmitigated consequence calculation (i.e. LPF = 1)
  - If offsite dose is in the very low (say in the milli-rem range), calculating a LPF less than 1.0 may not be very useful.
  - If dose is high (> 1 Rem), estimating LPF may be very important.
    - » Engineering calculations or computer code modeling are necessary to support any quantitative estimate of LPF.
    - » Conservatism can be retained in LPF estimate by neglecting certain deposition mechanisms.

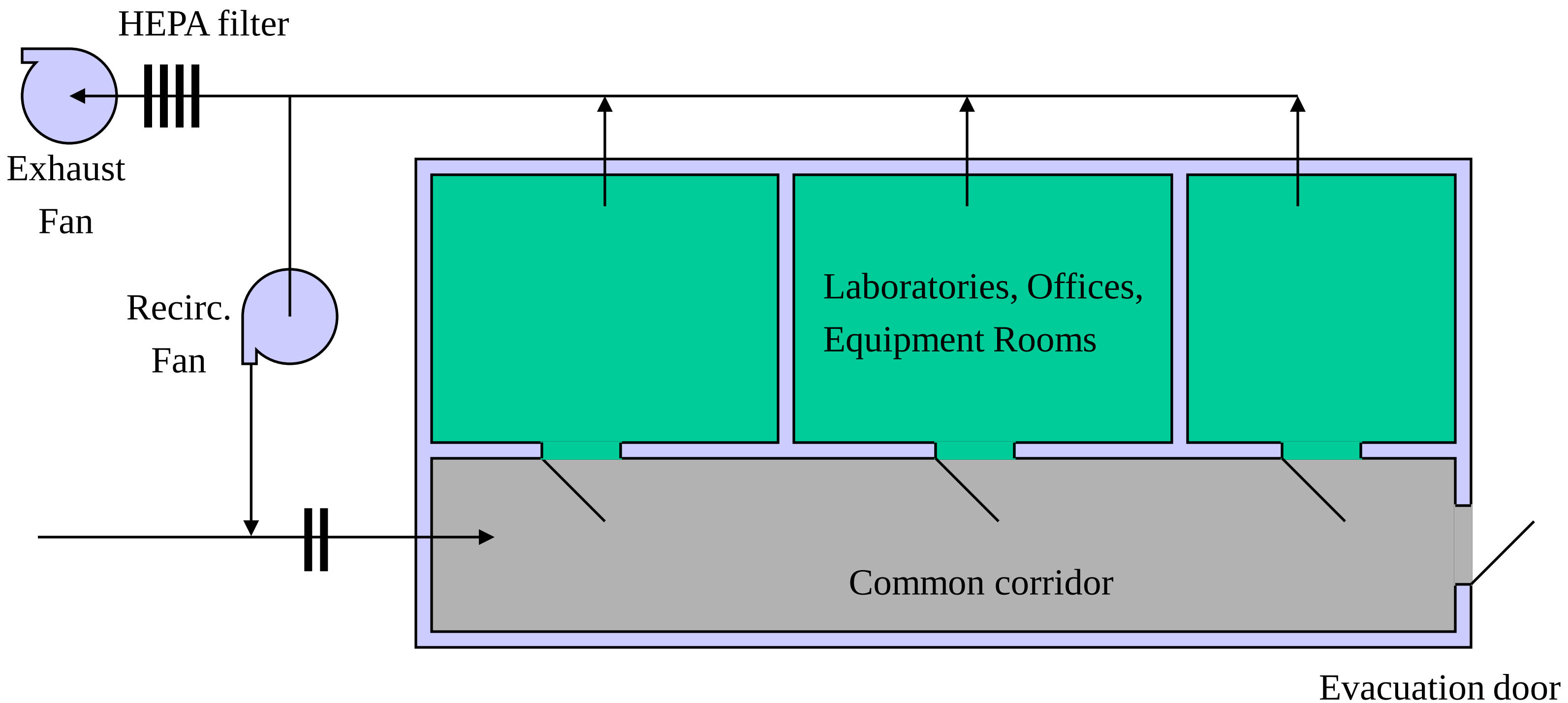
Does the number matter?

- LPF can have a large impact on dose to public
  - If source is large, and distance to MEOI is small, the effectiveness of barriers to release is critical to dose.
- Therefore, the value of LPF can influence the selection of safety SSCs
  - May drive Safety-SSC requirements
  - May guide selection of alternative improvements or upgrades to facility.
- Rigorous LPF analysis identifies the specific facility design/performance features important to mitigating the magnitude of accidental releases.

Other Uses of LPF

- The calculation of LPF can be used to help define functional requirements for safety SSCs
  - Example: Door leakage (cracks in perimeter) < 1/4-inch
  - Example: Leakage past fire/smoke dampers < 200 cfm.
- In-facility transport analysis can provide useful insights for emergency planning:
  - Example: Identify personnel egress pathways and timing with minimum exposure to moving cloud.
  - Example: Characterize critical times for accident intervention to protect barriers and prevent offsite release.

Example Confinement Building for a DOE Facility



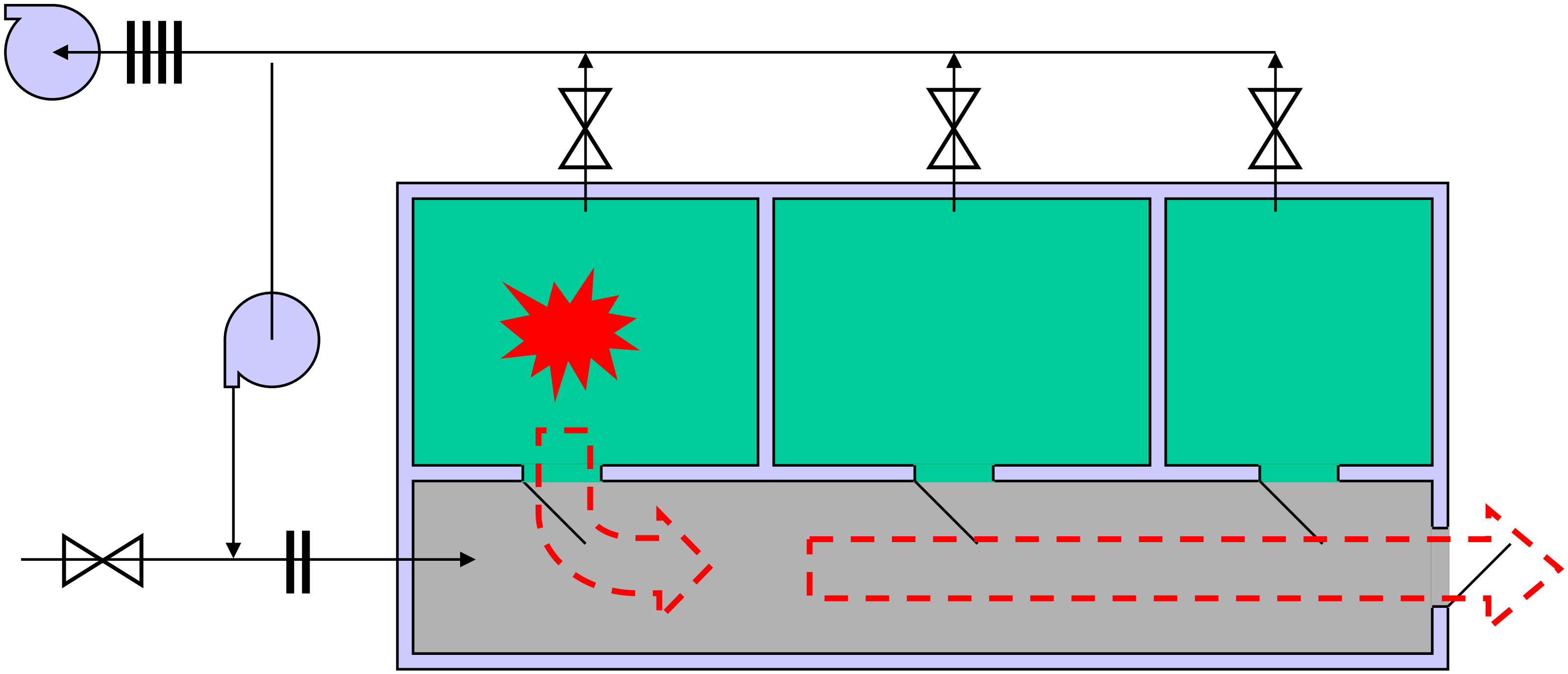
Contaminant Transport Analysis: A Blend Two Technical Disciplines

- Fluid mechanics/heat transfer
  - Defines the flow field and thermal environment for airborne contaminant transport
- Suspended material transport phenomena
  - Aerosol mechanics
  - Chemistry and phase change

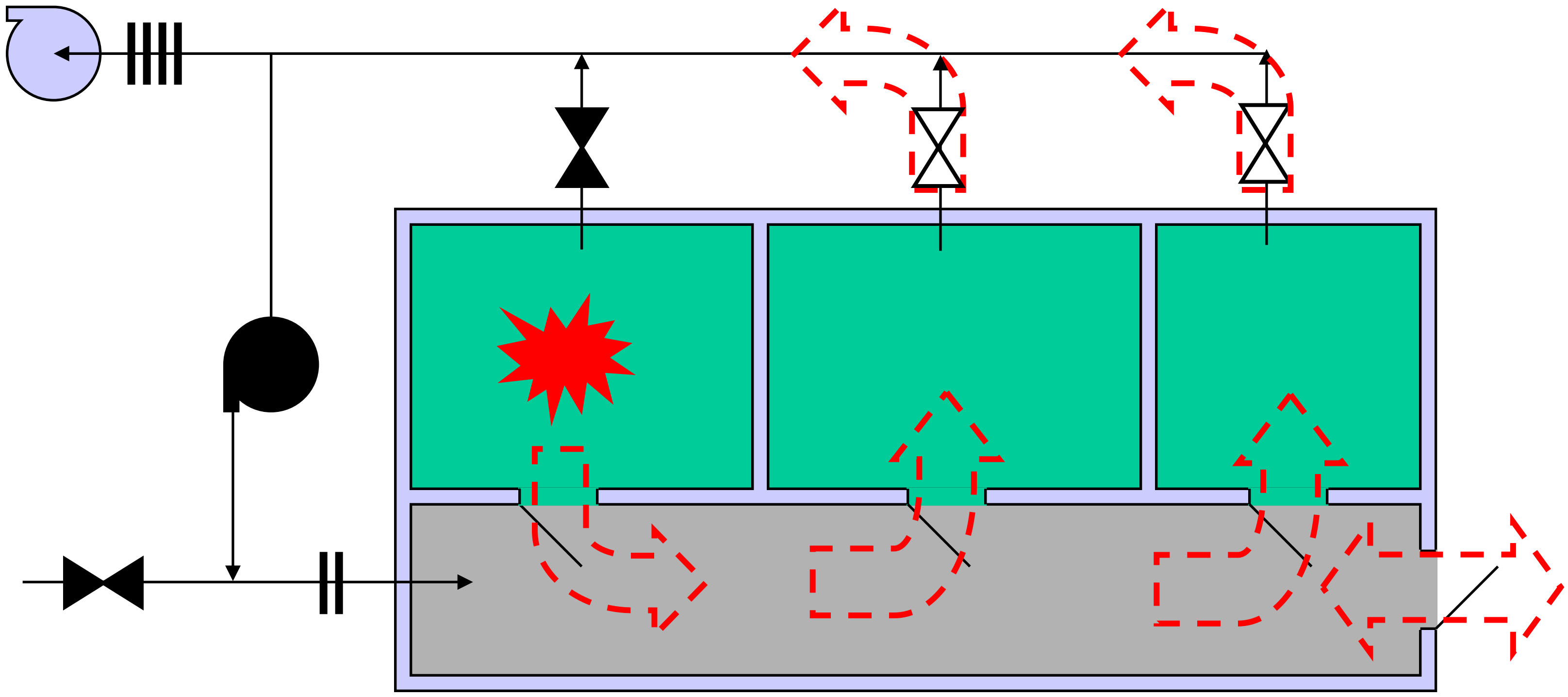
Flow Field During the Accident

- Air flow out of building is typically the primary carrier for released material
  - flow path defines barriers to release
  - flow rate determines residence time
    - time for retention mechanisms to take hold
- Mixing with clean air dilutes source reduces concentration of airborne contaminants

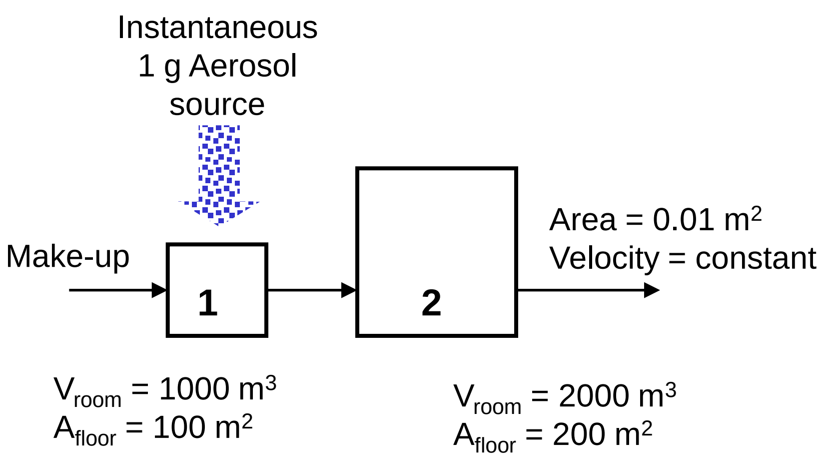
Defining Leak Paths: Worst-case Assumption Usually Obvious



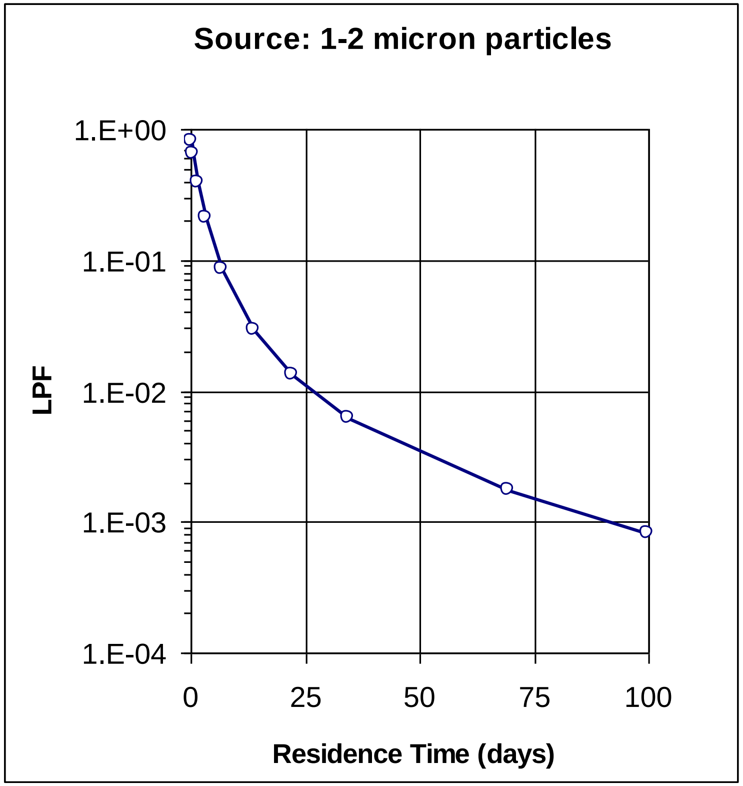
Actual Leak Path Not Always Obvious



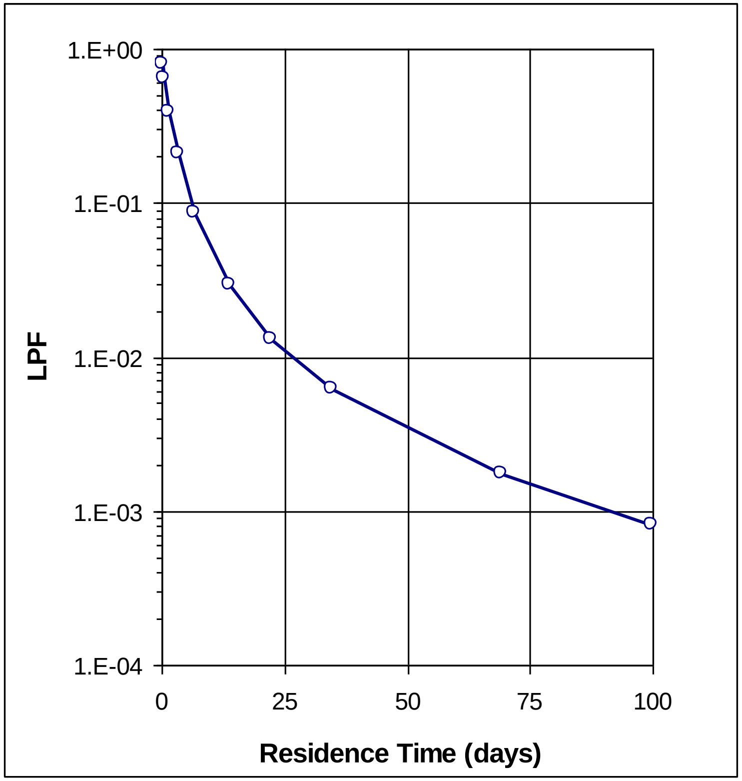
Flow Rate (Residence Time) and LPF

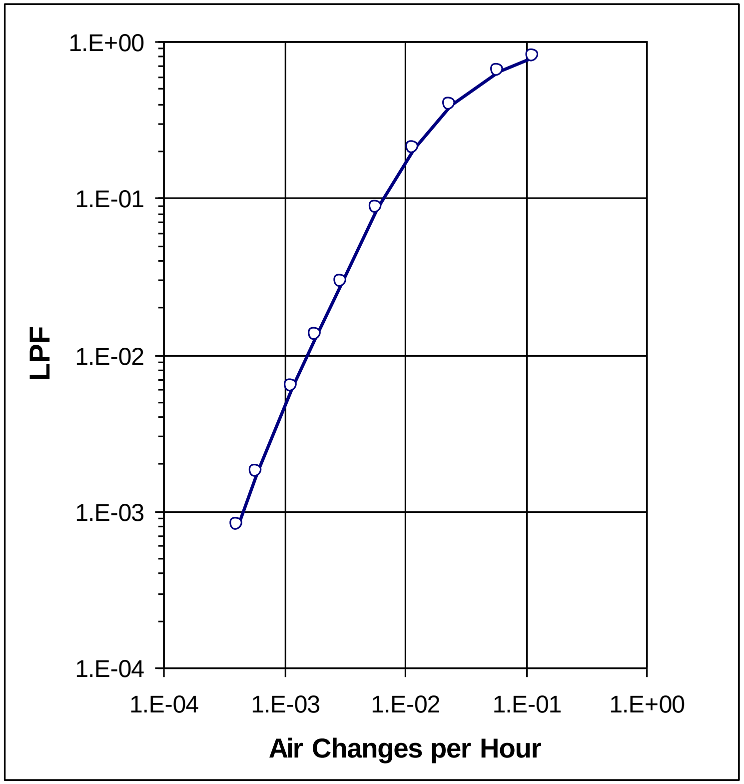


Residence time = Volume/(Velocity*Area)



Residence Time ⇔ Air Changes/Hr

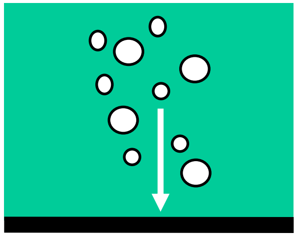




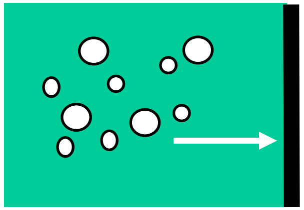
Specific values relate to 2-volume problem from previous slide, and 1-2 micron particles.

Contaminant Retention Mechanisms -- Aerosols --

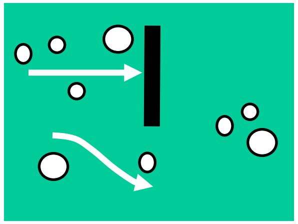
- Gravitational settling on horizontal surfaces
  - dominant mechanism for most applications
  - highly sensitive to particle size, and concentration



- Diffusion to surfaces
  - only important for very small particles in confined spaces

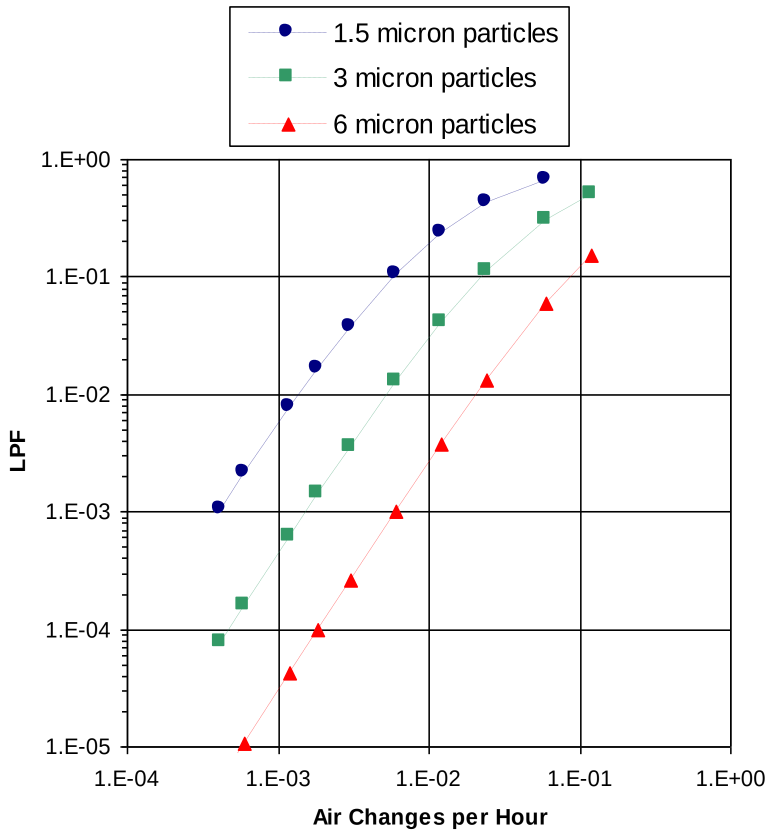


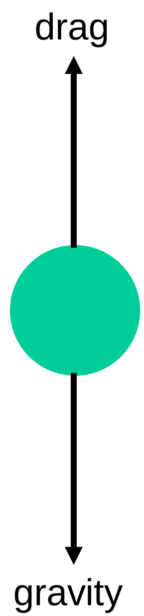
- Impaction on flow obstructions
  - a contributor to deposition in directed flows within confined spaces (e.g, ventilation system ductwork)
  - very difficult to account for analytically



- Engineered devices (filters, sprays)

Particle Size and Gravitational Settling

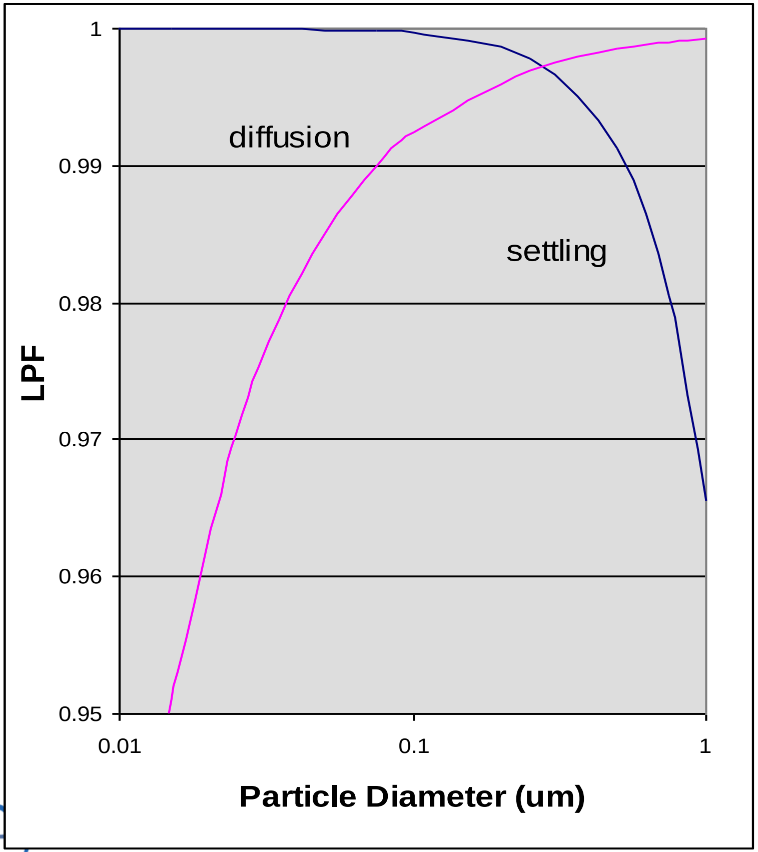


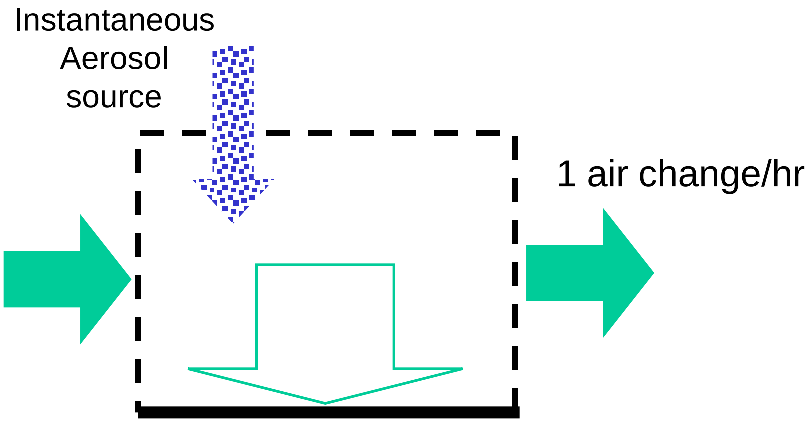


Settling (terminal) velocity is proportional the square of particle diameter: ($v_d \propto d^2$)

Diameter (μm)	Terminal Velocity (cm/s)
1.0	3.0E-3
2.0	1.2E-2
4.0	4.7E-2
8.0	1.9E-1

Other Aerosol Deposition Mechanisms Typically Not Significant Contributors





Example: Diffusion important only for sub-micron particle sizes.

But: Mass of airborne material in the sub-micron range normally negligibly small.

Contaminant Retention Mechanisms -- Gases & Vapors --

- Adsorption on surfaces
- Reaction with surfaces
- Interaction with aerosol particles
  - reaction, adsorption, condensation/evaporation
- Phase change during transport (conversion to aerosols -- mixed field of contaminants)

Methods for Calculating LPF

- If the problem is simple enough, hand calculations will suffice.
  - Always useful for ‘sanity checks’ and bounding LPF analysis.
  - Difficult if flow field and/or release characteristics vary significantly with time.
- Complex accident scenarios, or multiple-parallel leak paths may demand computer code simulations.

Hand Calculation of LPF
(well-mixed volumes)

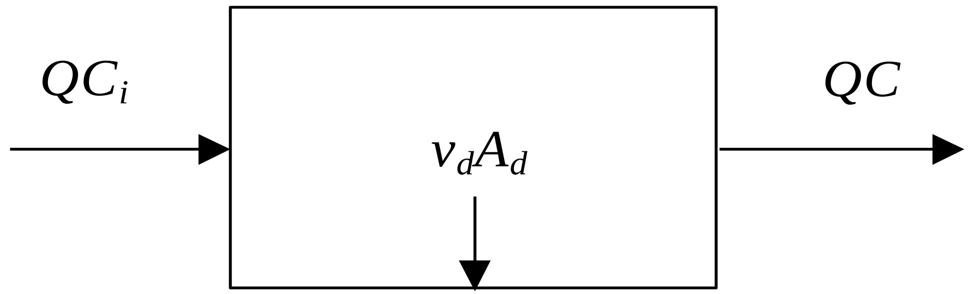
Steady state flow balance:

Q = flow rate

C = particle concentration

v_d = particle settling velocity

A_d = horizontal (settling) area

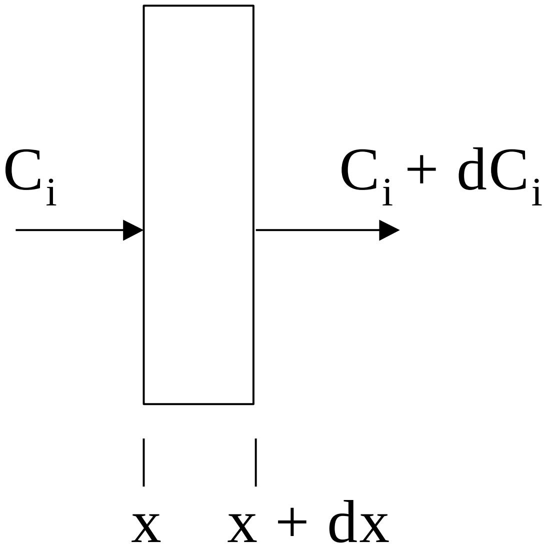


$$v_d A_d = Q(C_i - C)$$

$$LPF = \left(\frac{QC}{QC_i}\right) = \frac{C}{C_i} = \frac{1}{1 + \frac{v_d A_d}{Q}} = \frac{1}{1+\alpha}$$

Transport and Retention in LP, cont.
(Plug Flow LPF)

- Steady state flow balance - plug flow

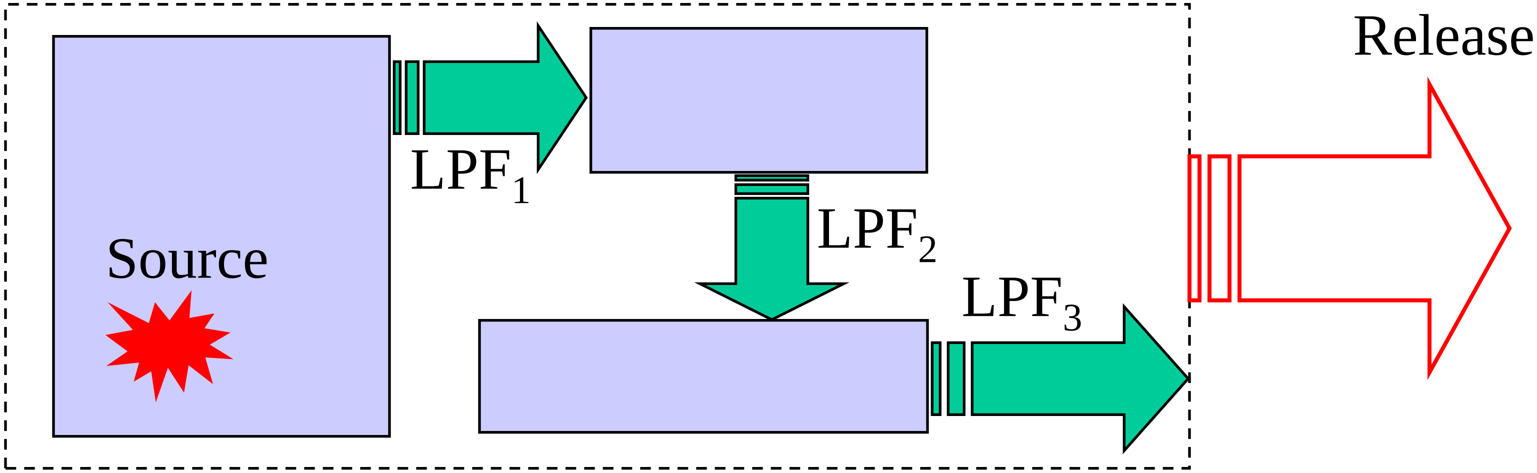


$$\frac{dC}{dx} = -\frac{v_d W}{Q} C$$

$$C = C_i e^{-\frac{v_d A_d}{Q}} = C_i e^{-\alpha}$$

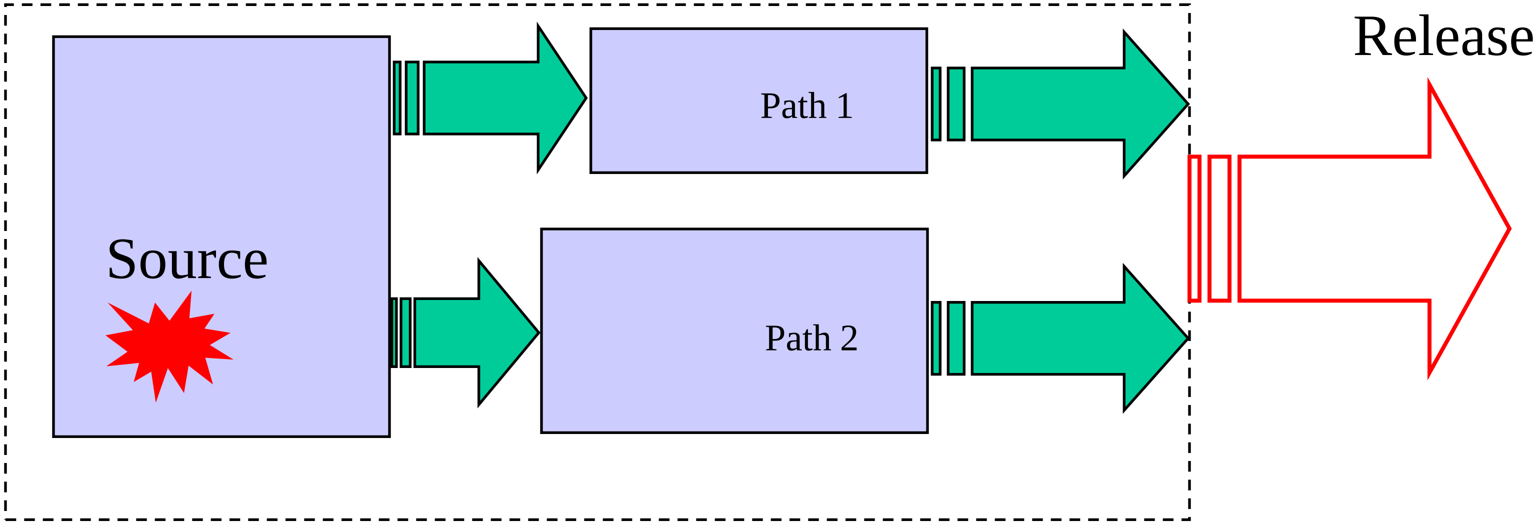
$$LPF = \frac{C}{C_i} = e^{-\alpha}$$

LPFs Involving Multiple Volumes in **Series**



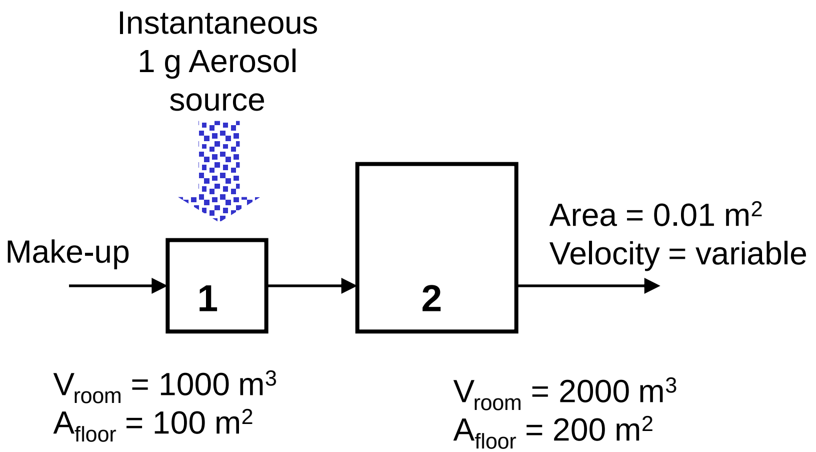
$$LPF = \prod_{i} LPF_i$$

LPFs Involving Multiple Volumes in **Parallel**



$$LPF = \sum_j f_j \, LPF_j$$

Example Hand Calculation of LPF



Account only for gravitational settling

$$v_d = \frac{d_p^2 \, \rho_p \, g \, C_m}{18 \, \mu \, \chi}$$

where

v_d = particle settling velocity

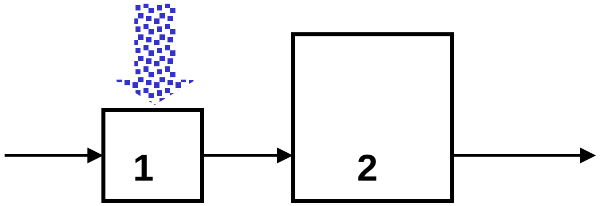
d_p, ρ_p = particle diameter, density

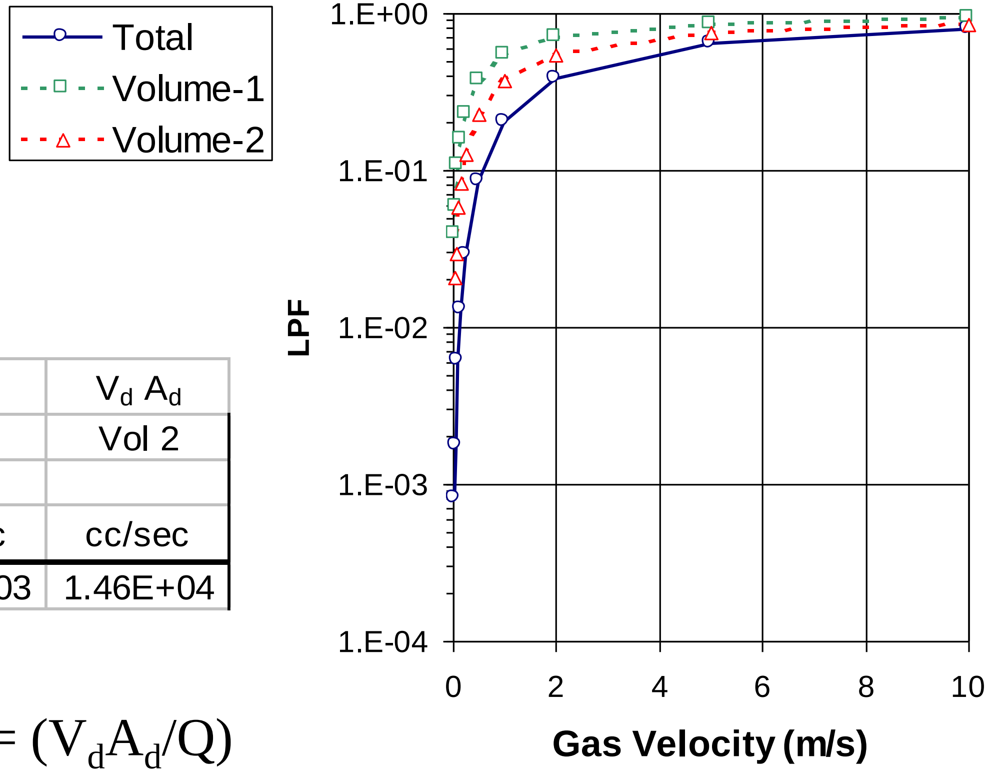
C_m = slip correction factor

μ = viscosity of air

χ = dynamic shape factor

Hand Calculation of LPF (cont)





Particle Diam (cm)	Slip Correction Factor (C_m)	Settling Velocity (cm/sec)	$V_d A_d$ Vol 1 cc/sec	$V_d A_d$ Vol 2 cc/sec
1.50E-04	1.12E+00	7.32E-03	7.32E+03	1.46E+04

$LPF_i = 1/(1+\alpha_i)$, where $\alpha_i = (V_d A_d / Q)$

and, $LPF = LPF_1 * LPF_2$

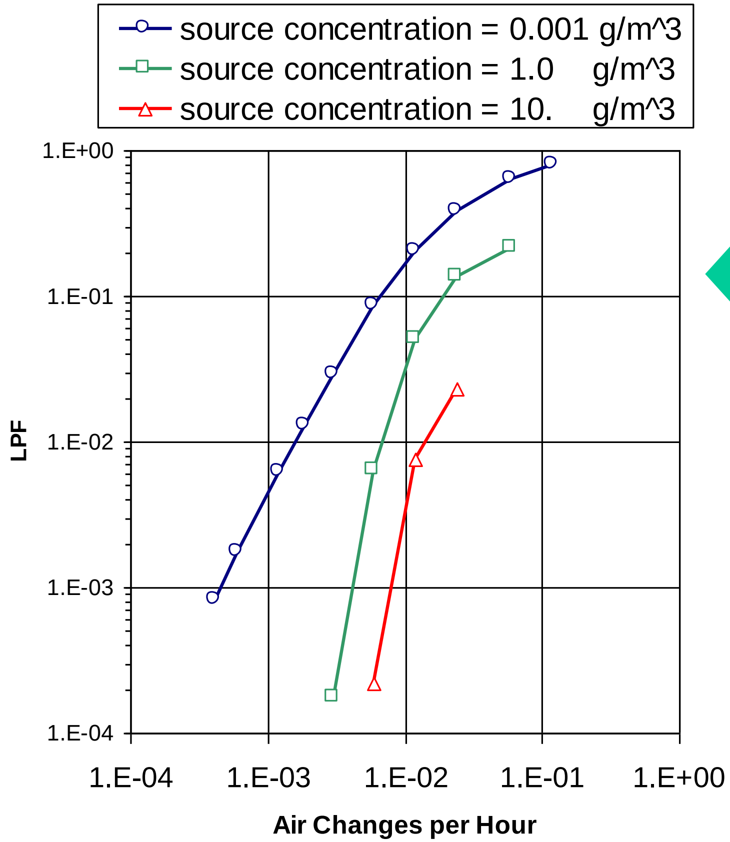
Complex Problems: Code Calculations

- Several generalized codes available for LPF analysis (CONTAIN, MELCOR, FIRAC, KBERT, GASFLOW)
- Codes vary considerably in the level of modeling detail, flexibility, and ease-of-use.
- APAC Working Group evaluated the alternatives and recommended:
  - MELCOR for problems in which multi-dimensional flow effects are not important.
  - GASFLOW as a benchmark tool and for problems where multi-dimensional effects are important.
- Analysts primarily using CONTAIN or MELCOR
- Safety Analysis Software designated by DOE/EH in March 2003 (The Toolbox)
  - MELCOR designated by DOE charted Safety Analysis Software Group

When should a code be considered?

- Highly complex facility configurations.
  - When flow field, and relative importance of multiple leak paths is not obvious.
- Time-dependent accident phenomena
  - Fires that propagate
  - Post-accident recovery operations
- When contaminant transport processes are complex.
  - Particle size(s) cover a wide range
  - Multiple, coupled transport/deposition processes.

Complexity not limited to **leak path**



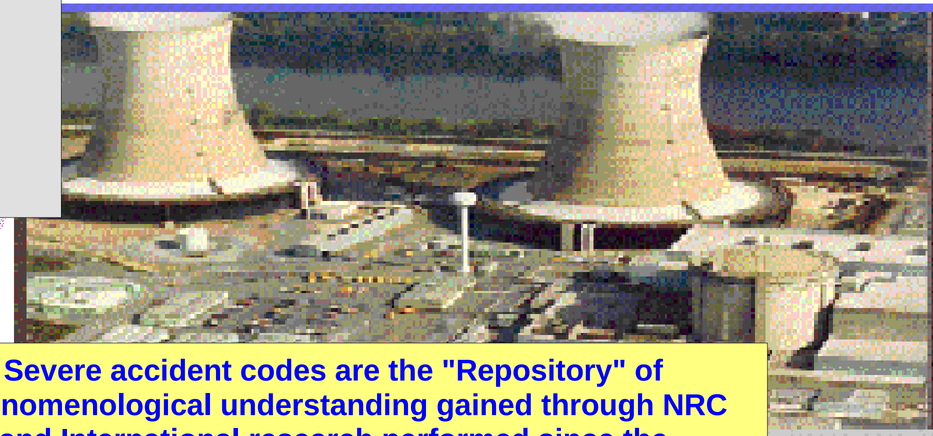
- Agglomeration in high particulate concentrations:
  - Time-dependent changes in particle size distribution (particle growth) impractical to calculated by hand.

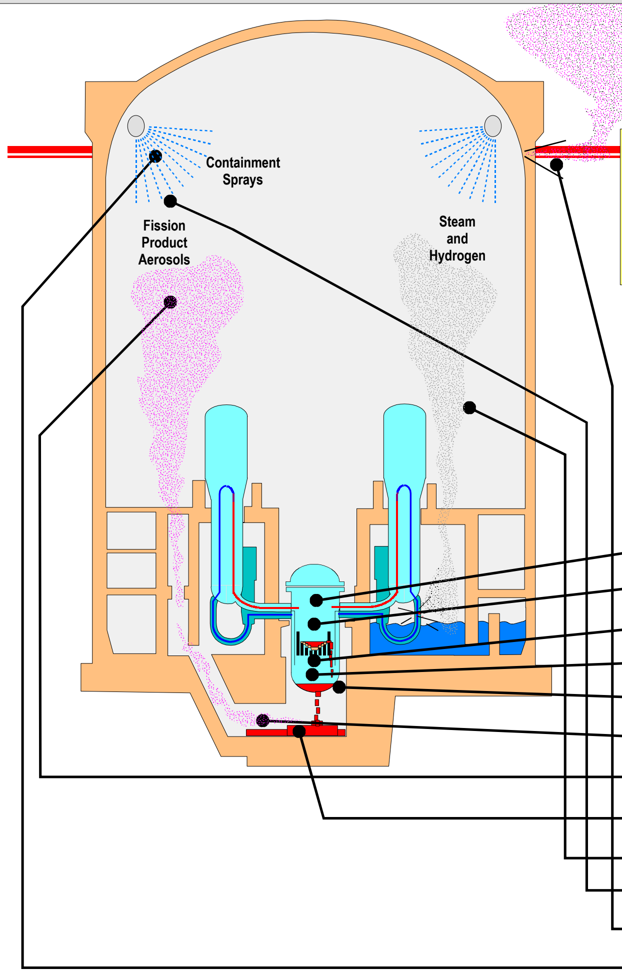
- Other examples: Deposition due to thermophoresis during accident scenarios with large temperature gradients (e.g., fires)

What is MELCOR

- MELCOR is the NRC's integrated mechanistic computer code used to model the progression of severe nuclear-power-plant accidents.
- For our purposes it is a generalized code for doing aerosol transport using a simple lump-parameter (control volume) method.

Modeling and Analysis of Severe Accidents in Nuclear Power Plants





Severe accident codes are the "Repository" of phenomenological understanding gained through NRC and International research performed since the TMI-2 accident in 1979

<u>Integrated</u> models required for self consistent analysis

Important Severe Accident Phenomena

Phenomenon	MELCOR	CONTAIN	VICTORIA	IFCI
Accident initiation	■	□	□	□
Reactor coolant thermal hydraulics	■	□	□	□
Loss of core coolant	■	□	□	□
Core meltdown and fission product release	■	□	◪	□
Molten fuel/coolant interactions	■	□	□	■
Reactor vessel failure	■	□	□	□
Transport of fission products in RCS and Containment	■	■	■	□
Fission product aerosol dynamics	■	■	■	□
Molten core/basemat interactions	■	■	□	□
Containment thermal hydraulics	■	■	□	□
Fission product removal processes	■	■	◪	□
Release of fission products to environment	■	■	■	□
Engineered safety systems - sprays, fan coolers, etc	■	■	□	□
Iodine chemistry, and more	■	□	□	□

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NNSA

MELCOR Packages
(Of Interest)

- CVH – Control Volume Hydrodynamics
- FL – Flow Paths
- HS – Heat Structures
- RN – Radionuclides
- MP/NCG – Material Properties and Non-Condensable Gases
- CF/TF – Control functions and Tabular Functions

MELCOR Execution

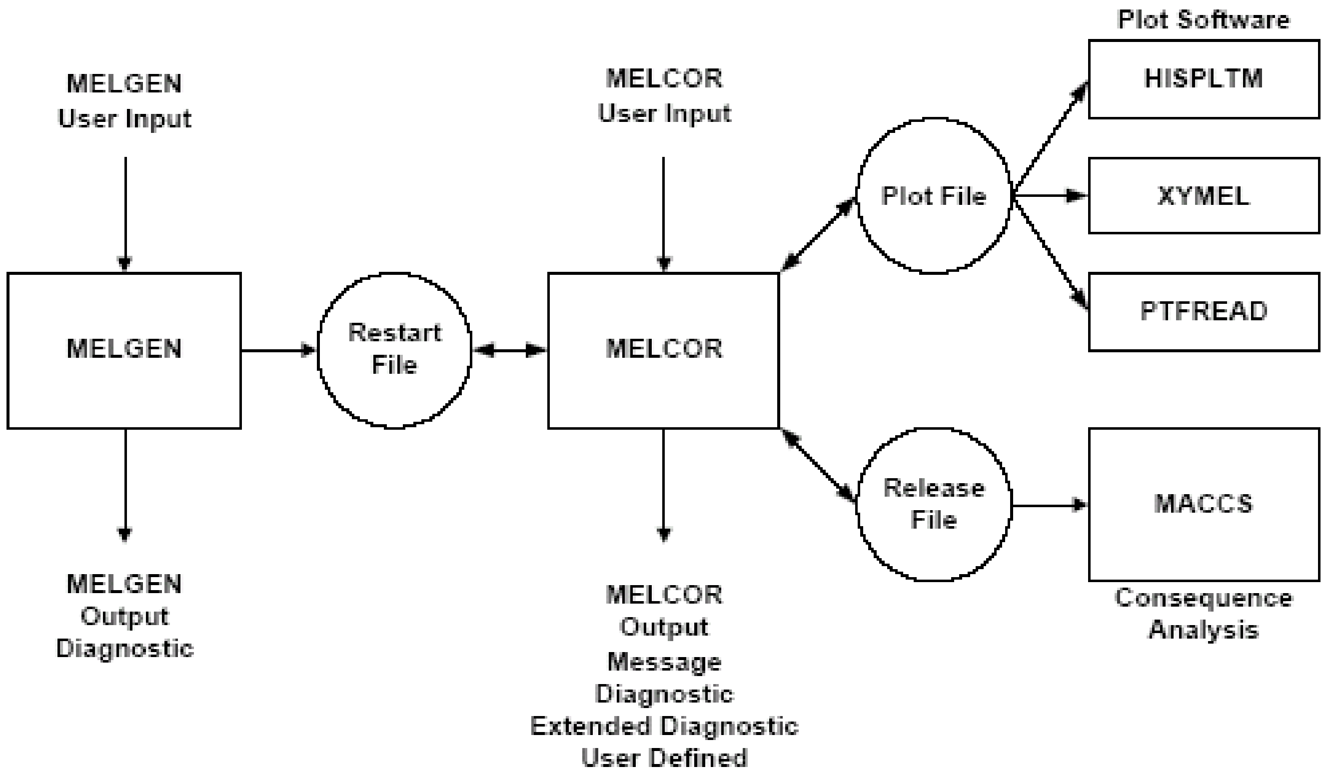


Figure 2-1. MELCOR Execution Flowchart

Input

- Input file is a text file
- Usually have main input file with main portions of the model read in from separate decks
  – Rooms, ventilation, fire, etc.
- Second text file to perform model execution
  – Time step control, plot intervals

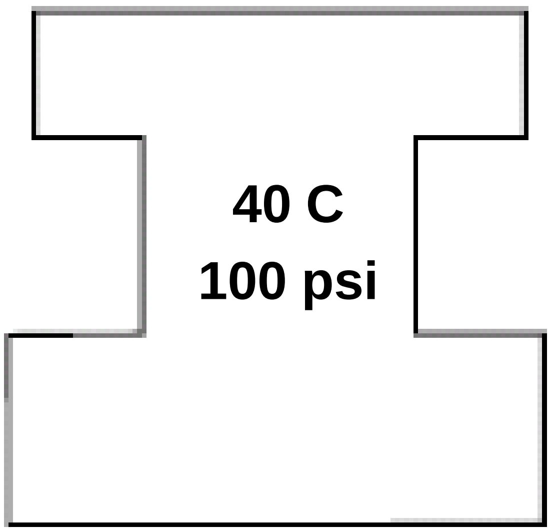
Output

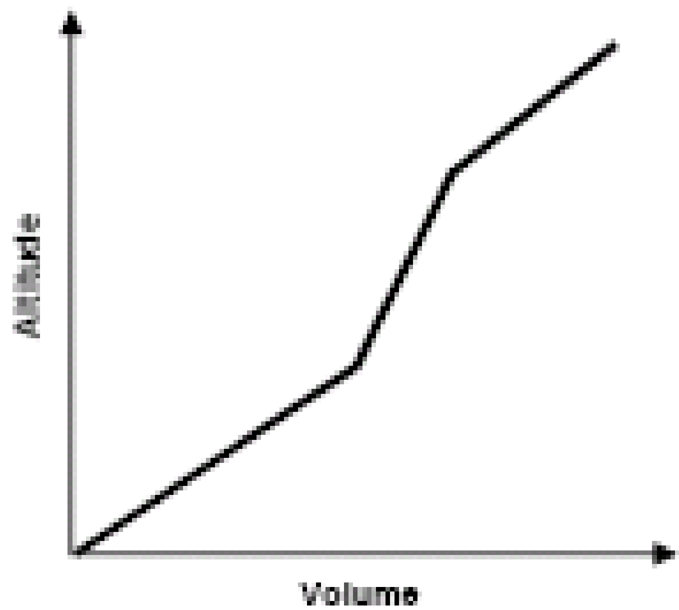
- PTFREAD
  - An Excel spreadsheet utility to make plots from MELCOR generated plot file
- Text Files
  - Output file that contains detailed information for specific time intervals
  - Message file for user specified events

MELCOR Basics

- Control Volumes
- Flow Paths
- Heat Structures
- Aerosols (RN)
- Energy (Fires)
- Boundary Conditions (Wind and Pressure)

Example Control Volume

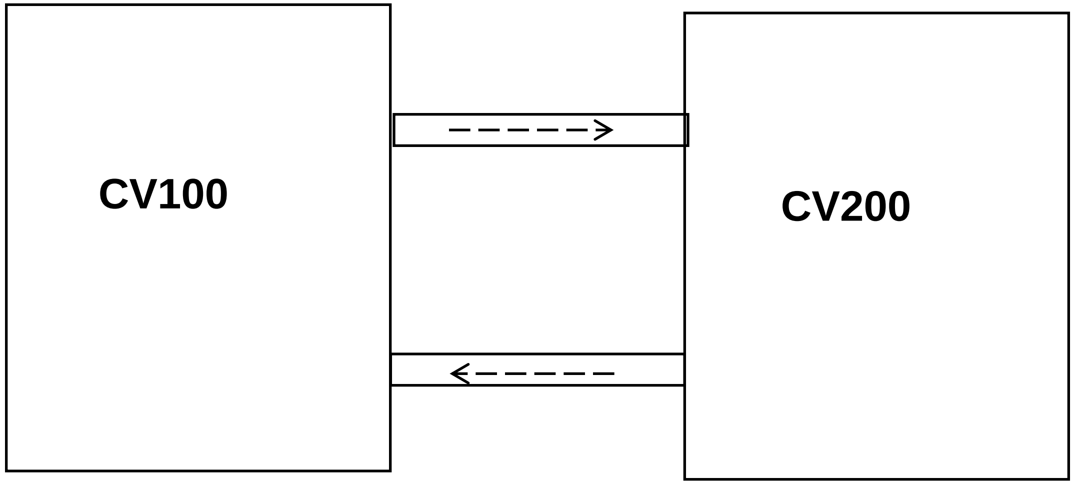




Example of CV Input

```
cv00200  RCP_Seals     2   2   2
cv00201  0      -1                 * time indep
cv002a0  3
cv002a1  pvol          15513203.9  * normal op press
cv002a2  tatm          564.        * normal op temp
cv002a3  zpol          9.9999
cv002a4  mlfr.5        0.79
cv002a5  mlfr.4        0.21
cv002a6  rhum          1.0
cv002b2    0.0        0.0000
cv002b3   10.0        1.0e6
```

Example Flow Path



Example of FL Input

```
*
FL24400  'CL A TO VESSEL'  240  101  8.0892  8.0892
FL24401  0.3832  4.3056  1.0
FL24402  3
FL24403  0.7   0.7
FL24405  0.75
FL244S3  0.3832  2.4646  0.6985
FL244S4  0.4532  1.8410  0.7597
```

Example Heat Structure

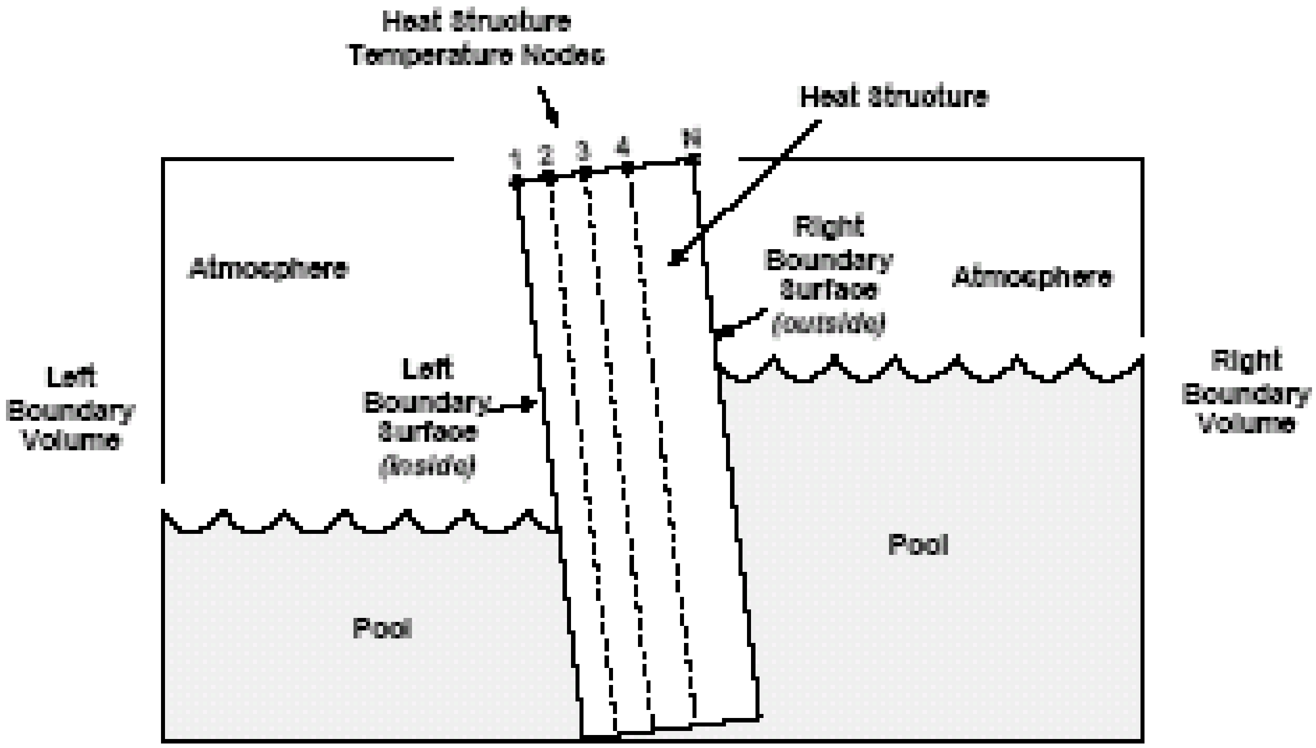


Figure 1.1 Heat Structure in a Control Volume

Example of HS Input

```
*
HS09003001  'MISC C.STEEL 20'
HS09003002  10.875  0.0
HS09003003  0.030
HS09003100  -1  1  0.0
HS09003101  0.00695  3
HS09003201  CARBON-STEEL  2
HS09003300  -1
HS09003400  1  020  EXT  0.0  1.0
HS09003500  20410.0  10.000  10.000
HS09003600  0
*rnds903     09003   lhs  inactive
*
```

A Simple Nodalization Scheme

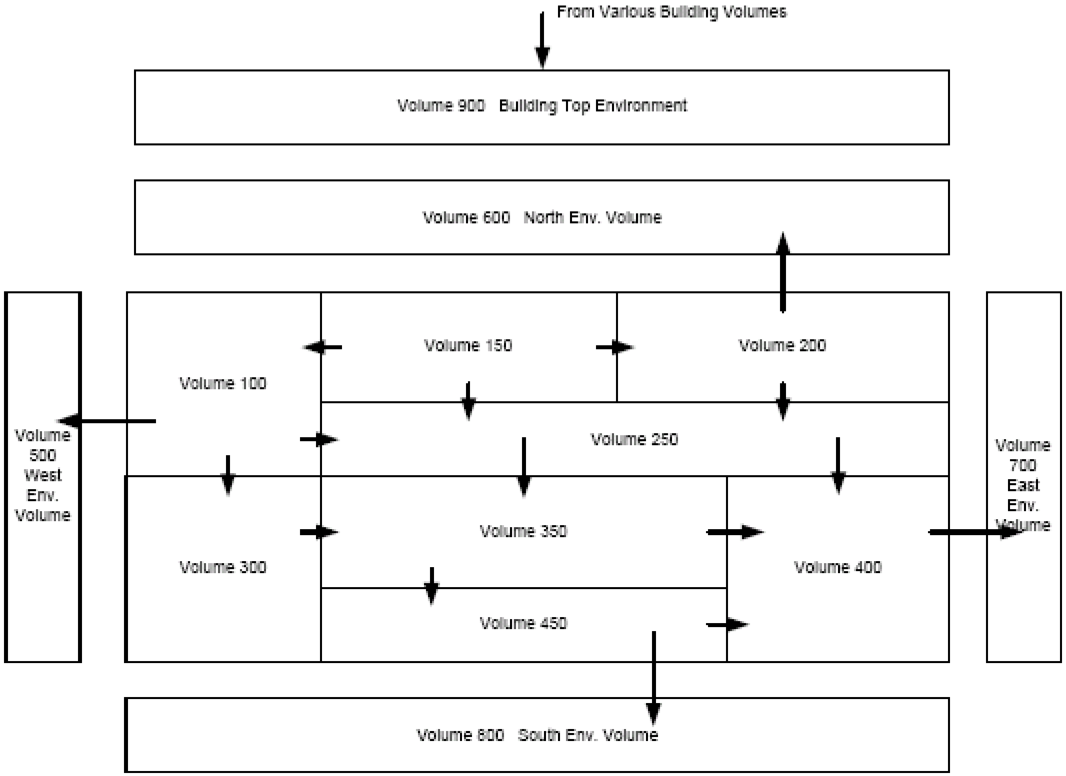
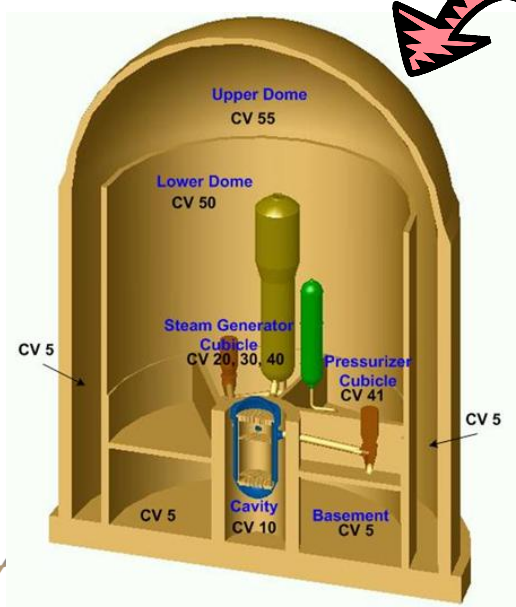
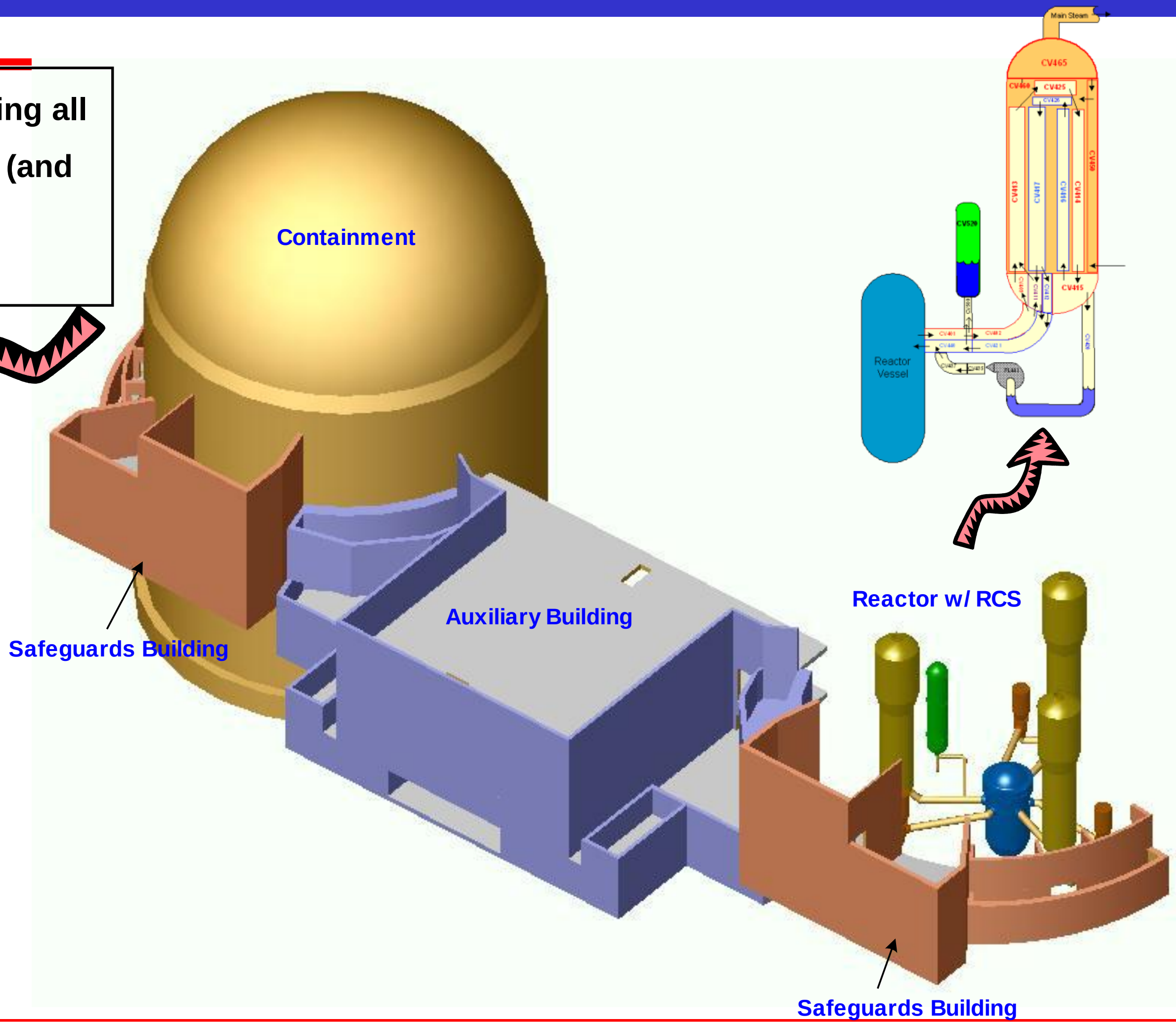


Figure 4-1. Typical Building Nodalization

Nodalization Can Be Complex

Typically model entire plant, including all potential radiological release paths (and therefore potential fission product retention mechanisms)





Model Building Advice

- If possible make each room a control volume
  - An exception may be a room that contains a fire
- Lump together dead end volumes
- Avoid long single volumes that can transport material long distances horizontally or vertically
  - Example is elevator shaft (break up into more volumes)

Flow Path Advice

- Most ventilation systems can be modeled using interconnected flow paths and control volumes (known flow-rates and pressure drops can be used to approximate losses)
- Doors and windows can be a single flowpath
  - An exception might be a room with a fire that can have bi-directional flow

Flow Path Advice

- Time dependent doors can be useful, but watch assumptions and how they can be defended.
  - For example the length of time the door is open may be dependent on assumptions about evacuation

Heat Structure Advice

- Each control volume must have one horizontal HS
  - Used to hold gravitationally settled aerosols
- Most volumes with no energy change (like no fire in the room) need only one HS
- If large temperature changes occur, all walls and floors are needed for appropriate heat transfer.

Modeling Fires

- Simple – Energy source into a volume to represent fire
- More Complex – Energy and mass sources into a volume to represent fire energy, addition of combustion products, and removal of oxygen.

Energy Addition

Table 4-6. Typical Fire Input

Typical Fire Input			
Time	Mass	Enthalpy	Energy
s	kg/s	J/kg	W
0.0	0.0	0.0	0.0
300.0	0.0	0.0	0.0
600.0	0.001	1.0E+9	1.0E+6
2400.0	0.001	1.0E+9	1.0E+6
2700.0	0.0	0.0	0.0
5000.0	0.0	0.0	0.0

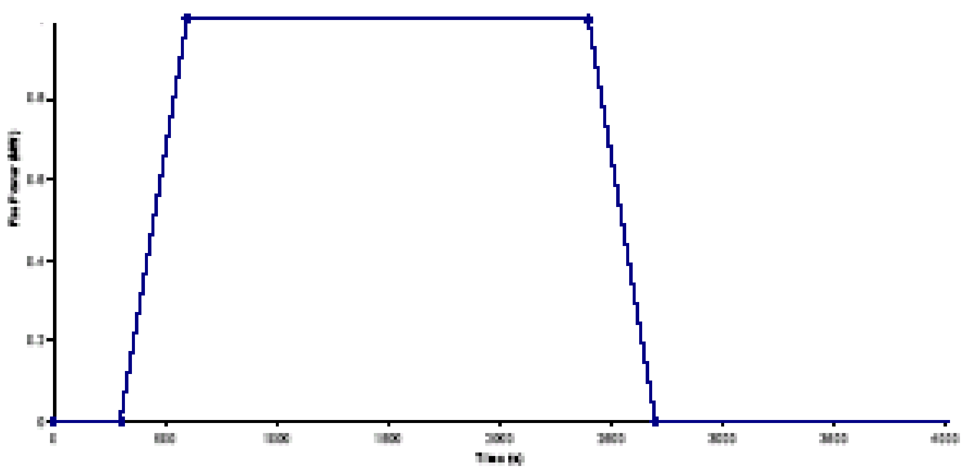
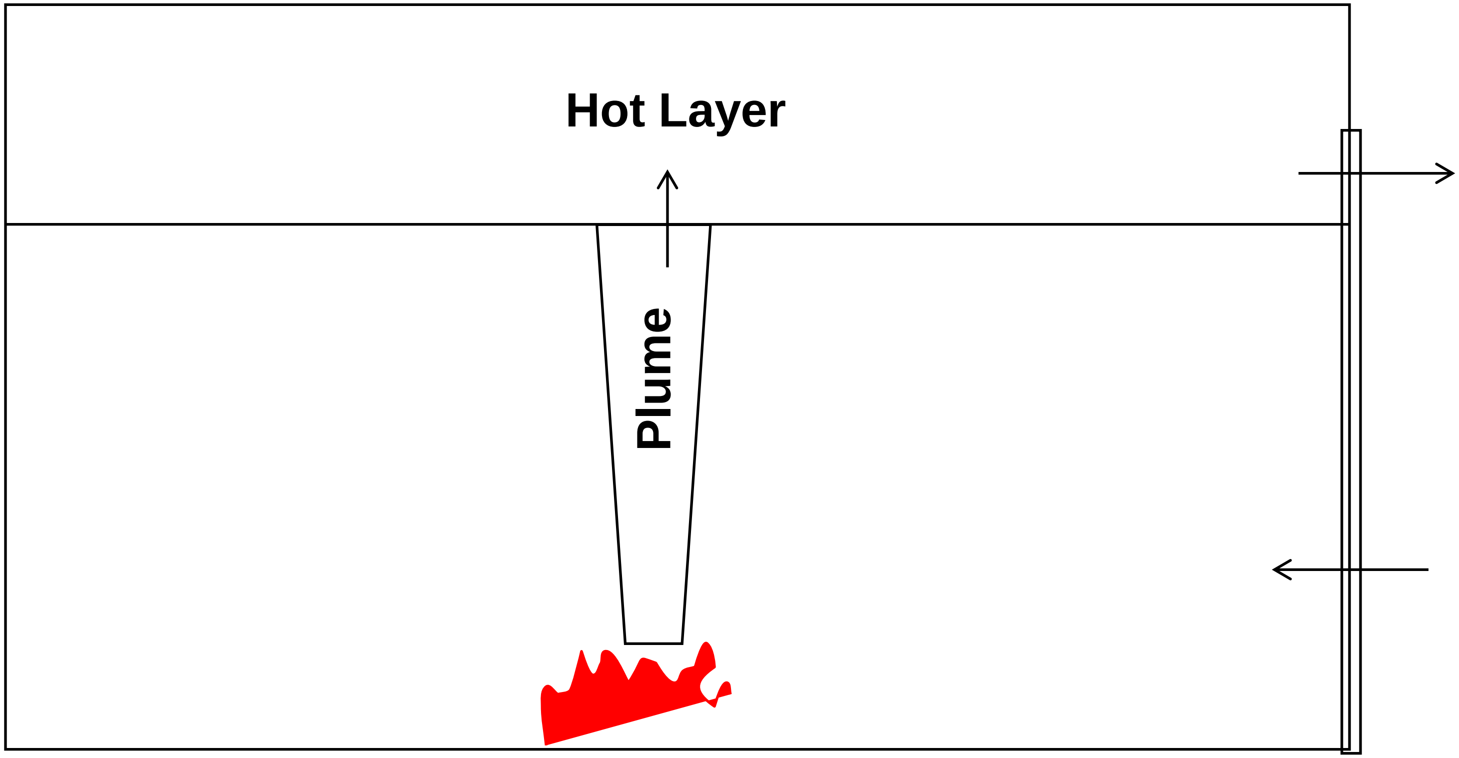


Figure 4-9. Typical Fire Input — Fire Power Versus Time

Fire Room Modeling

- Fire room can be a single volume
- Fire room can be multiple volumes based on another code calculation like CFAST
  - Volume to represent Hot Layer, Cold Layer and Plume
  - Flow paths to represent natural circulation in room
  - Flow paths to represent bi-directional flow

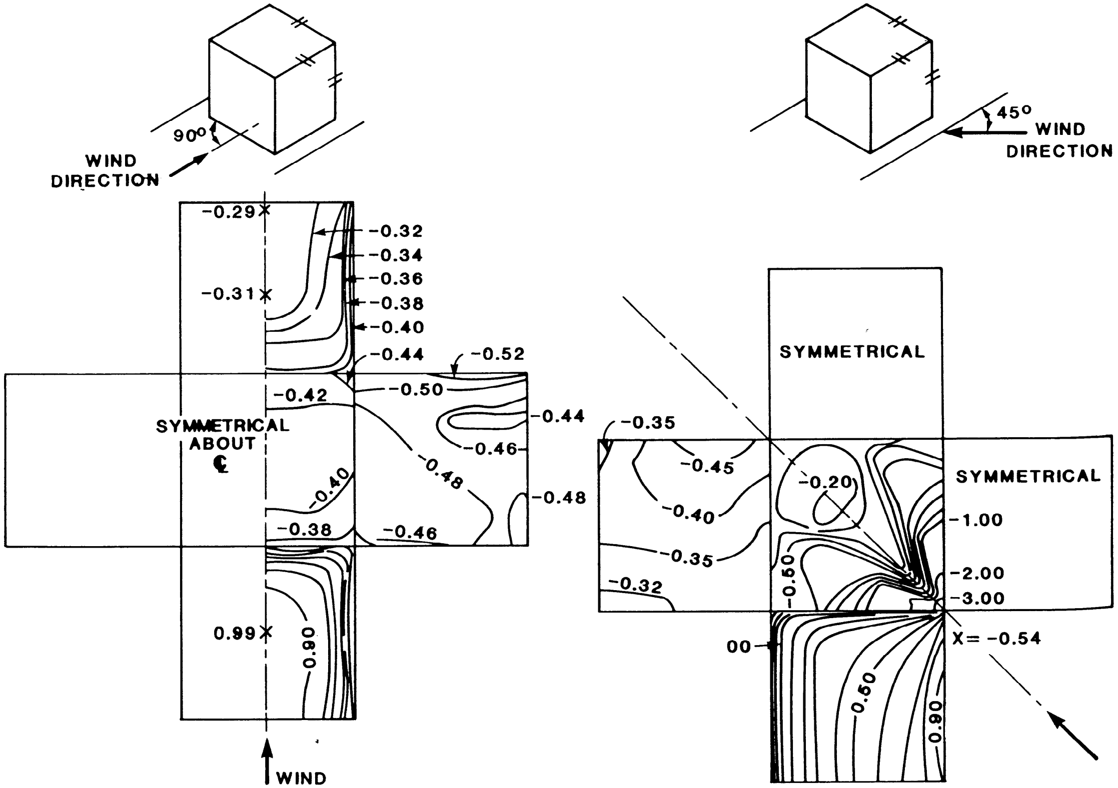
Fire Room Example



Wind Modeling

- Typically wind is modeled as a constant pressure boundary condition.
  - Usually a time independent control volume is linked to a flow path representing a door, window or building crack
- Simple ASHRE correlations
- CFD code boundary condition

ASHRAE Handbook of Fundamentals



Handbook Correlations

The local air pressure due to wind condition is given by, (ASHRAE, 1977):

$$\Delta P = c_p \rho \frac{v^2}{2}$$

where:

c_p	=	Pressure coefficient
ρ	=	Local air density
v	=	Wind speed

Assuming a value for the wind speed of 2.24 m/s (5 mph), and using a pressure coefficient for a normal building from, (ASHRAE, 1977):

Table 4-2. Typical Building Wind Pressure Coefficients

Wind Pressure Coefficients	
Upwind Pressure Coefficient	0.7
Downwind Pressure Coefficient	-0.4
Side and Top of Building	-0.35

Aerosols

- A single aerosol distribution typically is used in codes such as MELCOR (can use more than one, but computationally expensive)
- Options for aerosol distribution
  - log-normal distribution (Mean and Std Dev.)
  - User defined

Sample Aerosol Distribution

Table 4-4. Oxide Powders Particle Size Distribution

Oxide Powders Particle Size Distribution

Spill in Static Air
Weight percent airborne 0.03% median (equivalent to ARF)
Geometric Standard deviation = 2 (lognormal distribution)
Particle size median = 8 µm (Aerodynamic Equivalent Diameter (AED))

Particle Diameter Range µm AED		Particle Diameter Range µm		Fraction in Range	Cumulative Fraction
0.0	0.1	0.00	0.03	0.001	0.001
0.1	1.0	0.03	0.30	0.064	0.065
1.0	3.0	0.30	0.89	0.165	0.230
3.0	10.0	0.89	2.95	0.330	0.560
10.0	70.0	2.95	20.68	0.360	0.920
70.0	200.0	20.68	59.08	0.040	0.960
200.0	1000.0	59.08	295.40	0.030	0.990
> 1000.0		> 295.40		0.01	1.00

Translated to Log Normal Distribution

- The aerodynamic shape factor is assumed to be 1.
- The maximum Aerodynamic Equivalent Diameter of 10 µm for Plutonium Oxide with a density of 11.46 g/cm3 corresponds to a maximum geometric diameter of approximately 3 µm.
  - Maximum aerosol particle diameter = 3 µm
  - Minimum aerosol particle diameter = 0.01 µm (arbitrary minimum)
  - Volume-equivalent mass median particle diameter = 2.3 µm (8 µm AED)
  - Geometric standard deviation of the particle size distribution = 2 (95%)
- REMEMBER - we do not count aerosols greater than 10 µm AED

Input of Aerosols into MELCOR

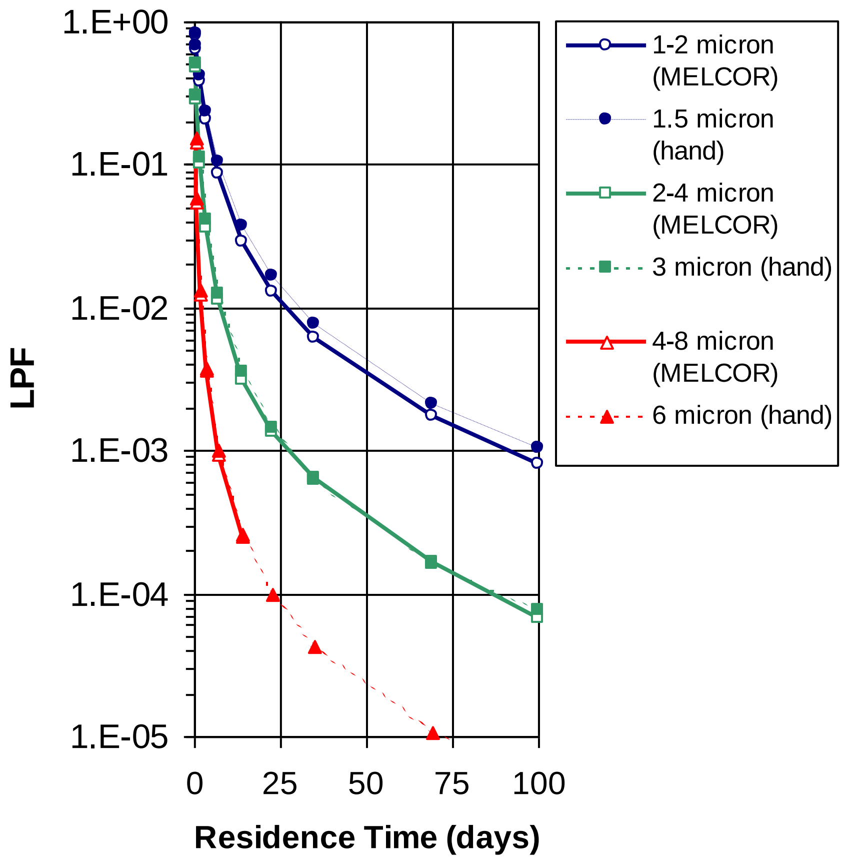
- Add aerosols as a source to room where accident occurs
  - Can be put into problem at initiation
  - Can be sourced in instantaneously at a point in time
  - Can be sourced in over specific time interval
- Example Input

```
RN1001 20 2 17 0 0 3 0
RN1100 1.0e-8 3.0e-6 11.46E+3
RNACOEF 1
RNAS000 350 2 1 1. 1.0 601 2
```

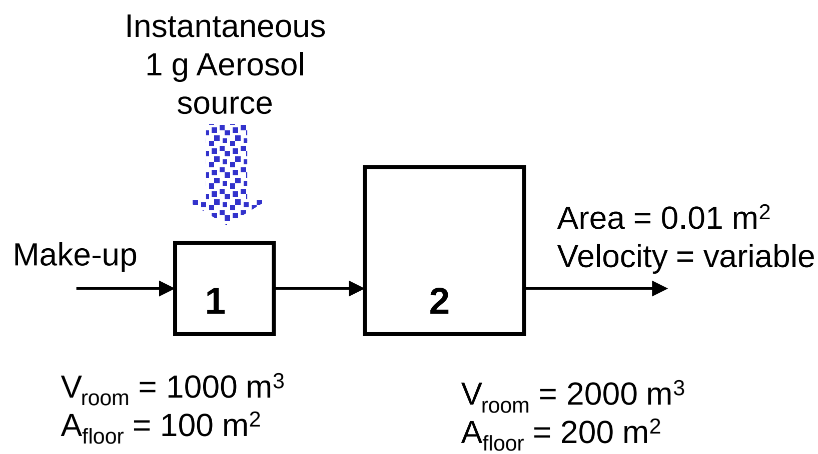
Example Problems Run with MELCOR

- ‘Baby-problems’ for comparison to hand calcs
- Compartmentalized building LPF analysis
  - Research Building
- Dynamic transient (explosion) transport analysis
  - Weapons Assembly/Disassembly Facility
- Secondary benefits of code modeling
  - Detailed analysis of accident behavior
- New – <u>More detailed example of a parametric study</u>

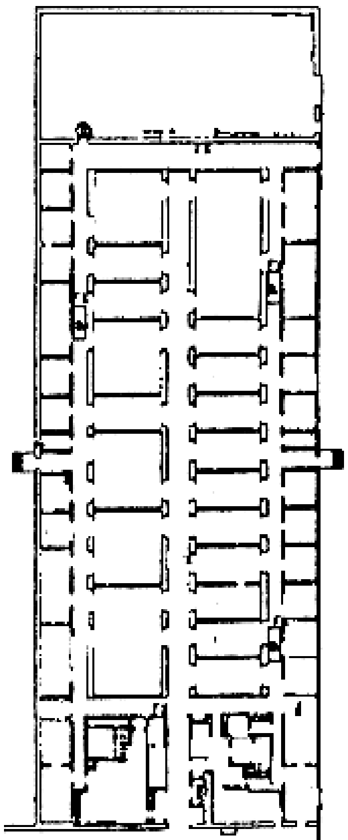
Comparison of Hand and Code Calcs



- MELCOR match 2-volume hand calculation results described earlier.

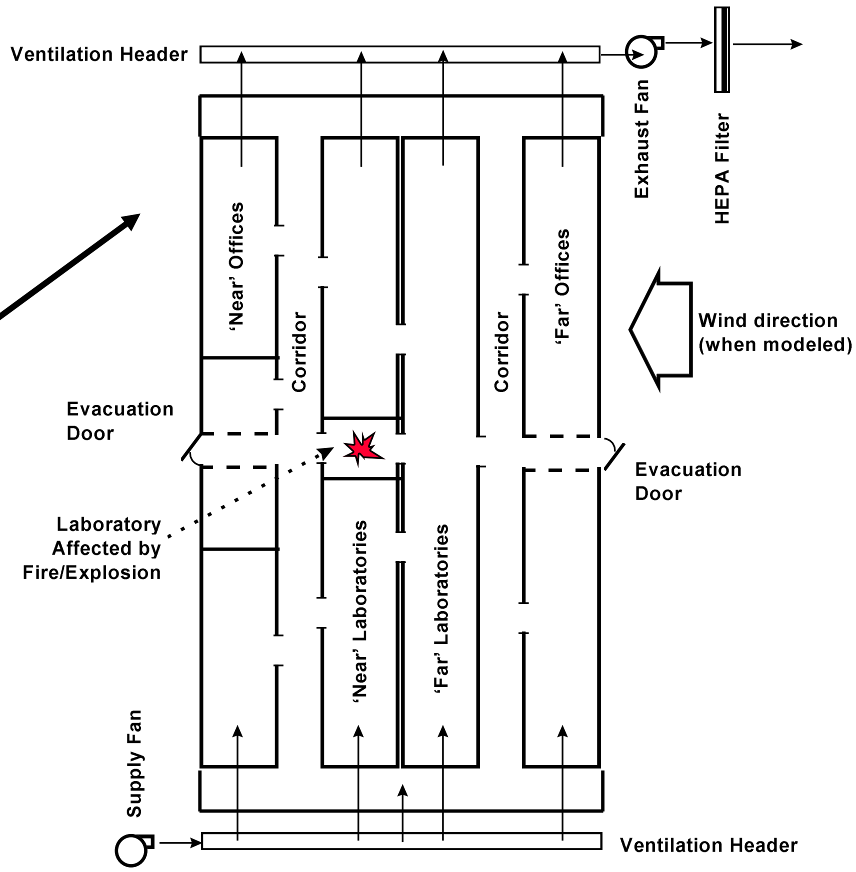


A More Complex MELCOR Example: Large Bldg with Multiple Leak Paths

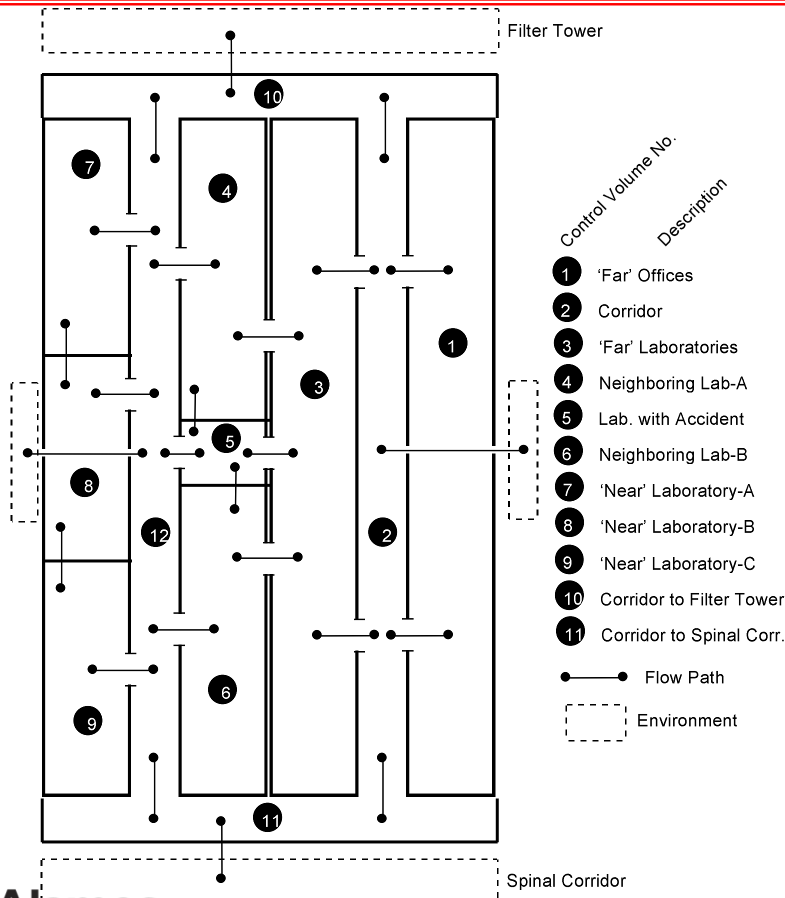


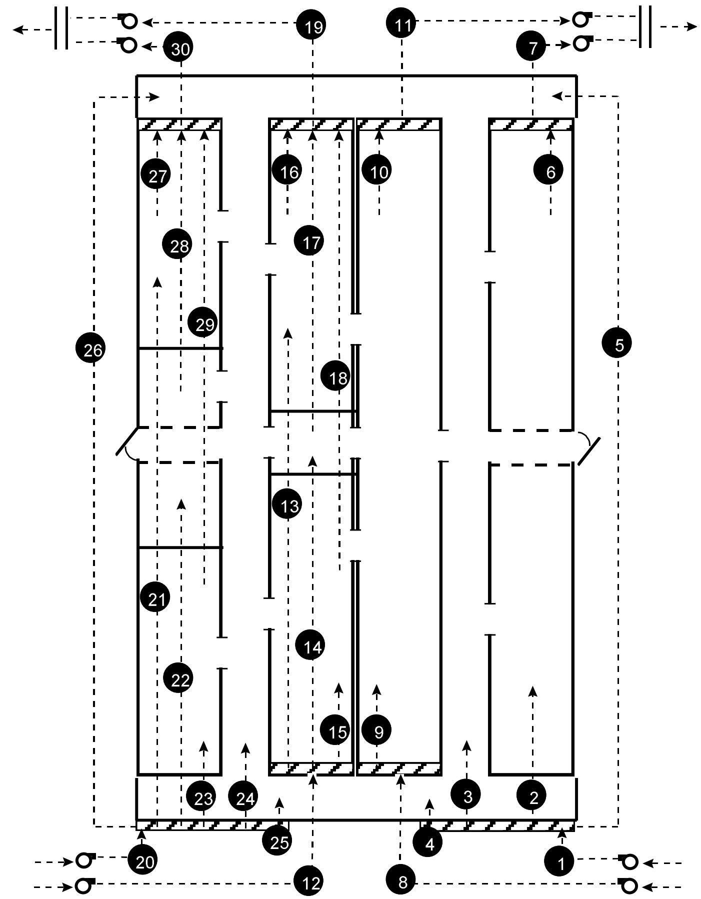
Building layout

MELCOR model



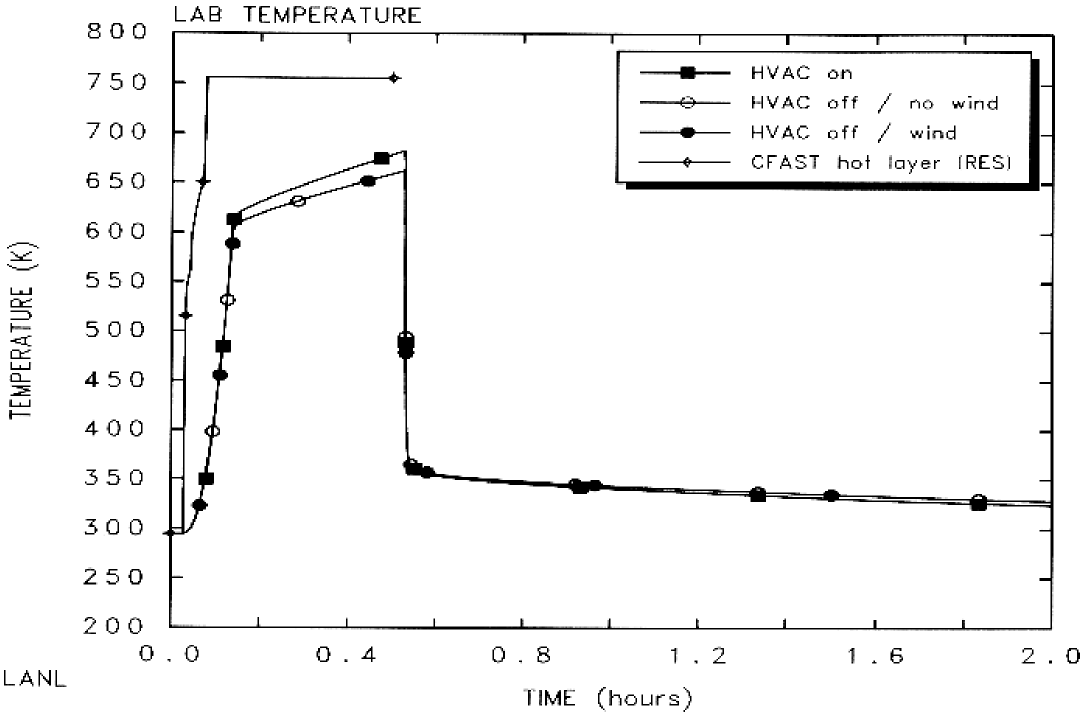
MELCOR Decomposes Facility into ‘Control Volumes’ and ‘Flow Paths’



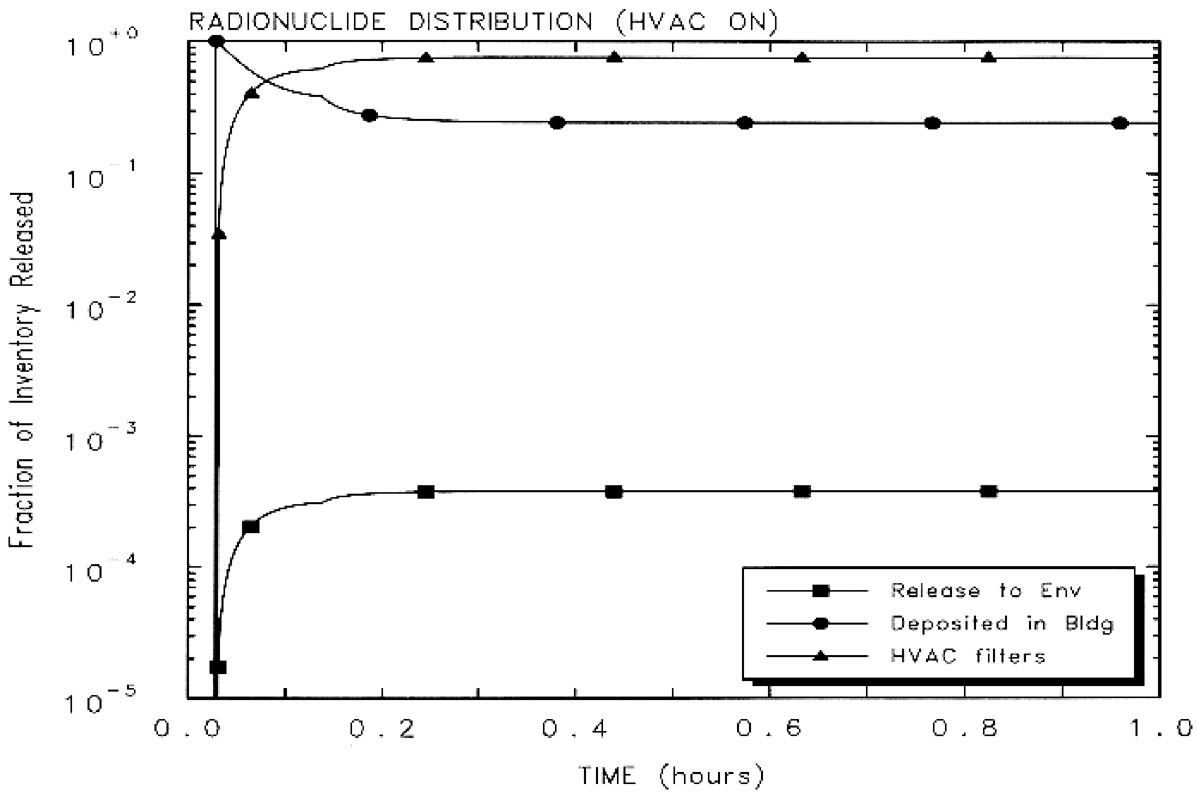


Example 1: LPF Calculation, Laboratory Fire Accident Scenario

- Scenario involves:
  - 1 lb/ft^2 combustible load in a single laboratory
  - 2MW heat release for 30 min.
- Lab temperature response compared to CFAST

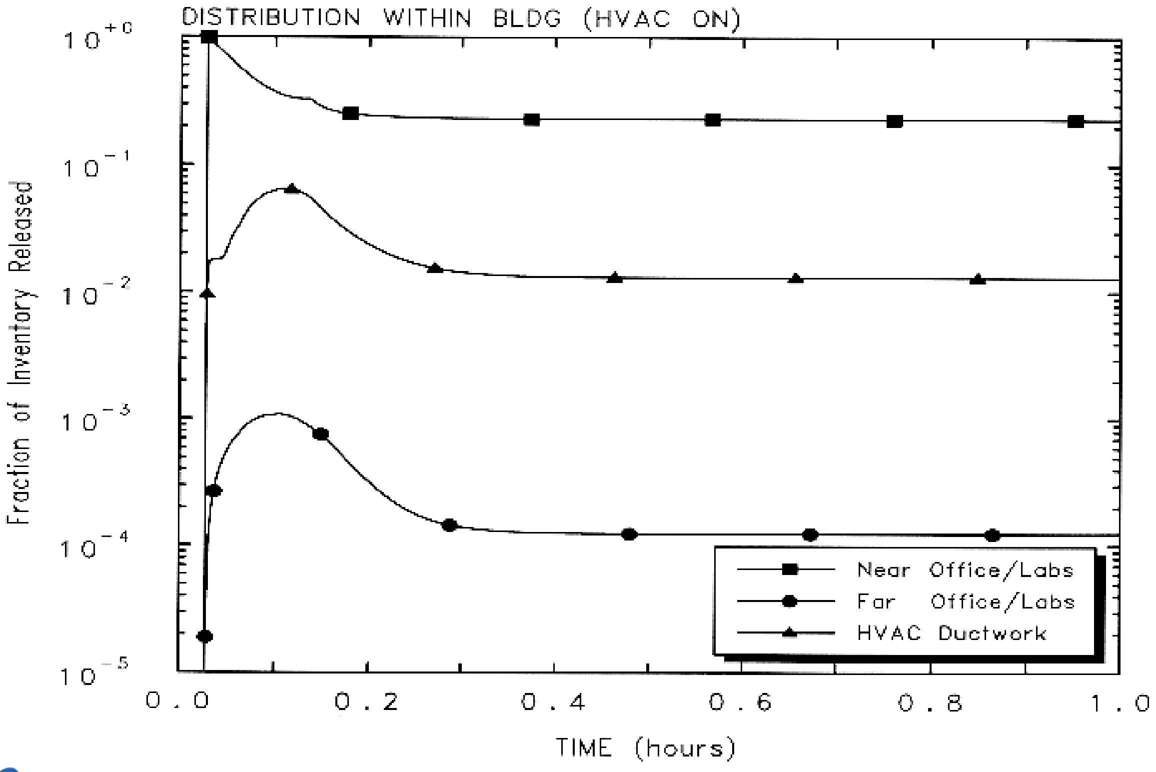


Release of Contaminant Materials (Particulate) Tracked by MELCOR



In addition to calculating the quantity released to the environment, the code tracks the amount captured in HVAC system (HEPA filters), and the amount that settles to the floor of the building.

Calculated Distribution of 'Deposited' Material Useful for Other Purposes



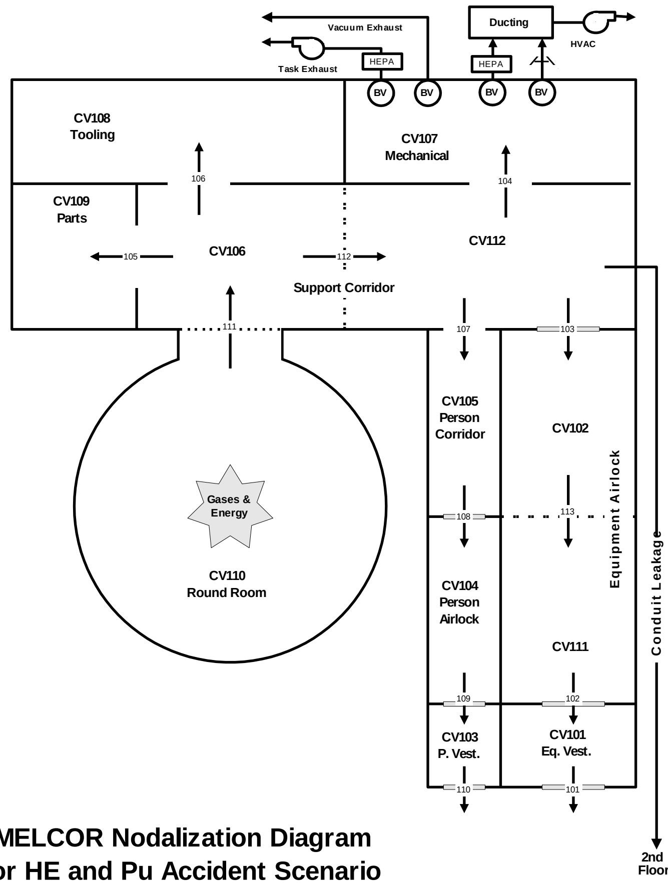
- Extent of contaminant dispersal within the facility is a natural by-product of the MELCOR analysis.
- Can be used for evaluating optimum accident mitigation or evacuation strategies.

Sensitivity Analysis Evaluates the Relative Importance of Safety Features

Case #	HVAC Active	Wind-Enhanced Leakage	Corridor door open	HVAC Inlet Open Fully	Larger Fire (2 lb/ft^2)	Leak Path Factor (Fractional Release)	
						1-hour	24 hours
1	X					4.E-4	4.E-4
2	X	X	X			4.E-4	4.E-4
3						0.03	0.05
4		X				0.07	0.13
5		X	X			0.14	0.15
6				X		0.19	0.23
7					X	0.03	0.05

- Possibility of direct leak path to the environment (open evacuation door).
- Operation of filtered ventilation system (on/off).
- Effect of external wind on driving force for transport without operating HVAC.

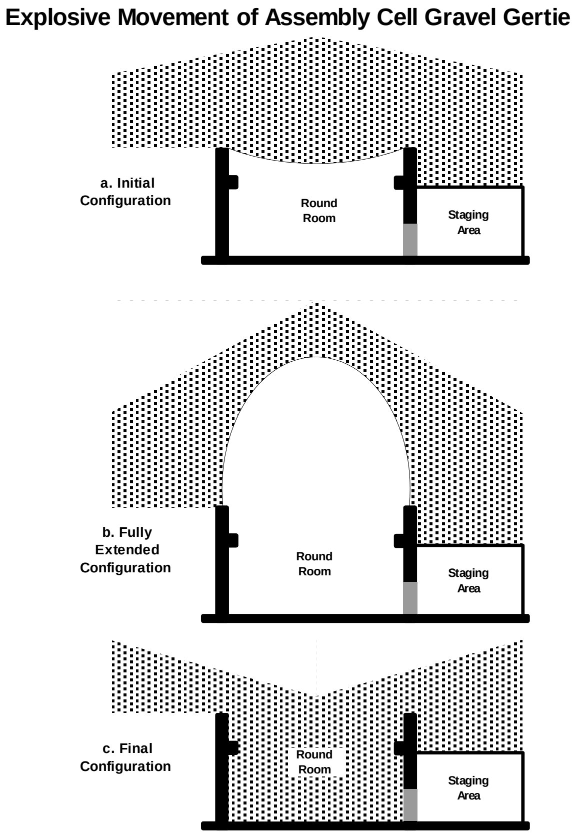
Example 2: Dynamic Accident Behavior



MELCOR Nodalization Diagram for HE and Pu Accident Scenario

- Explosion Accident Scenarios Very Difficult to Evaluate by Hand
  - Short-lived, energetic release is followed by protracted cooling and depressurization of the building.
- A MELCOR model was developed for the to study high-explosive detonation accident releases.
- Model benchmarked against full-scale experimental data for HED ‘accident’ with gravel gertie actuation.

‘Gravel Gertie’ Designed to Mitigate Explosion Involving Large Quantity HE

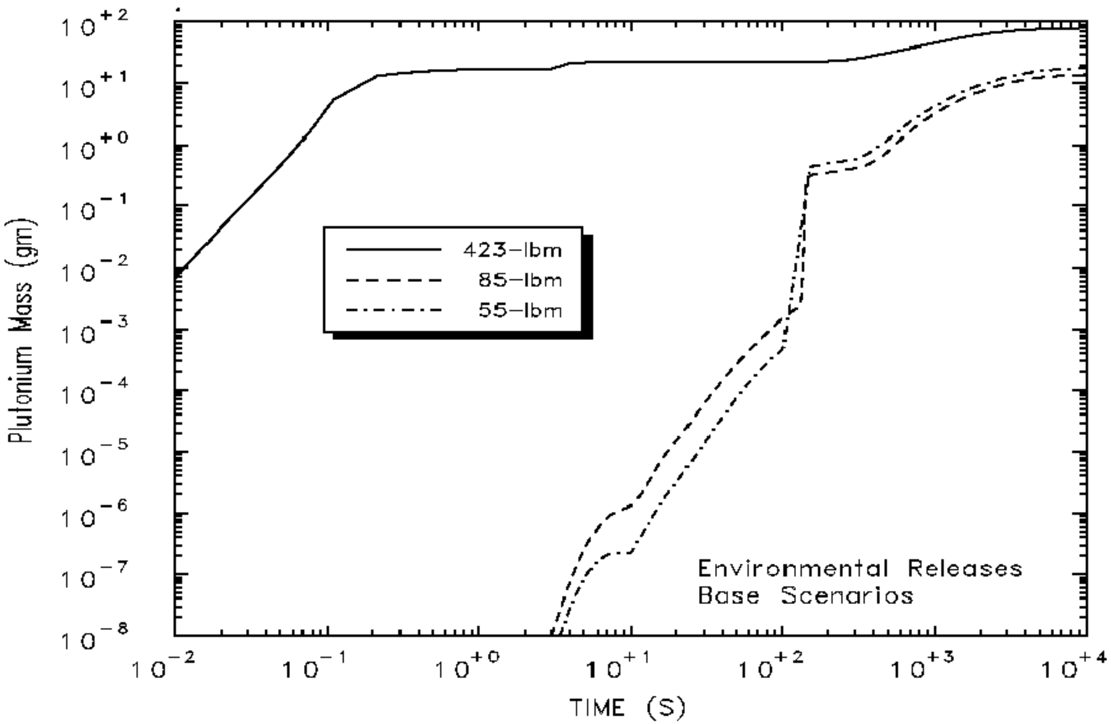


Normal Configuration

Lifting of Gravel Gertie During Pressure Expansion

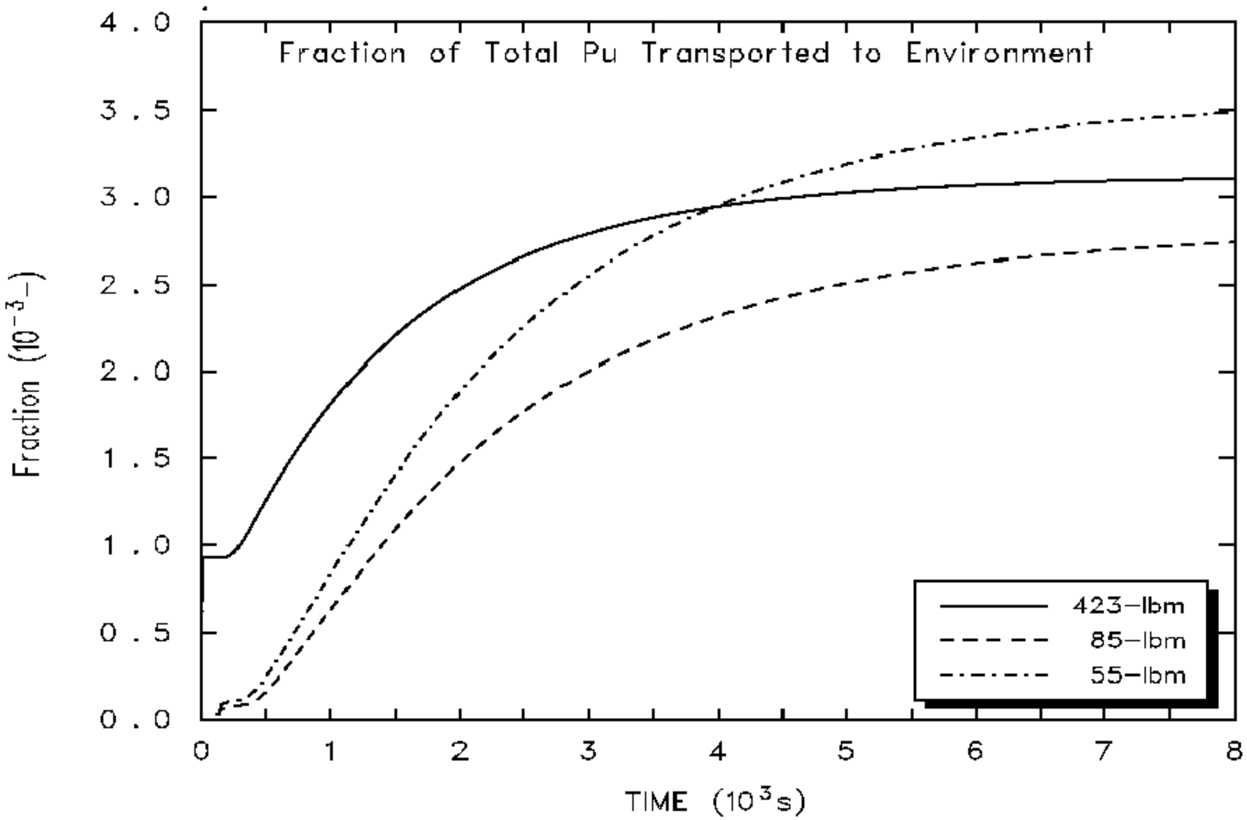
Collapse of Gravel Bed into Cell after Pressure Relieved

Magnitude of Explosion Strongly Affects Building Response & LPF



- Gravel Gertie lifts for case with very large HE mass
- Cell remains essentially intact for explosions involving smaller HE masses

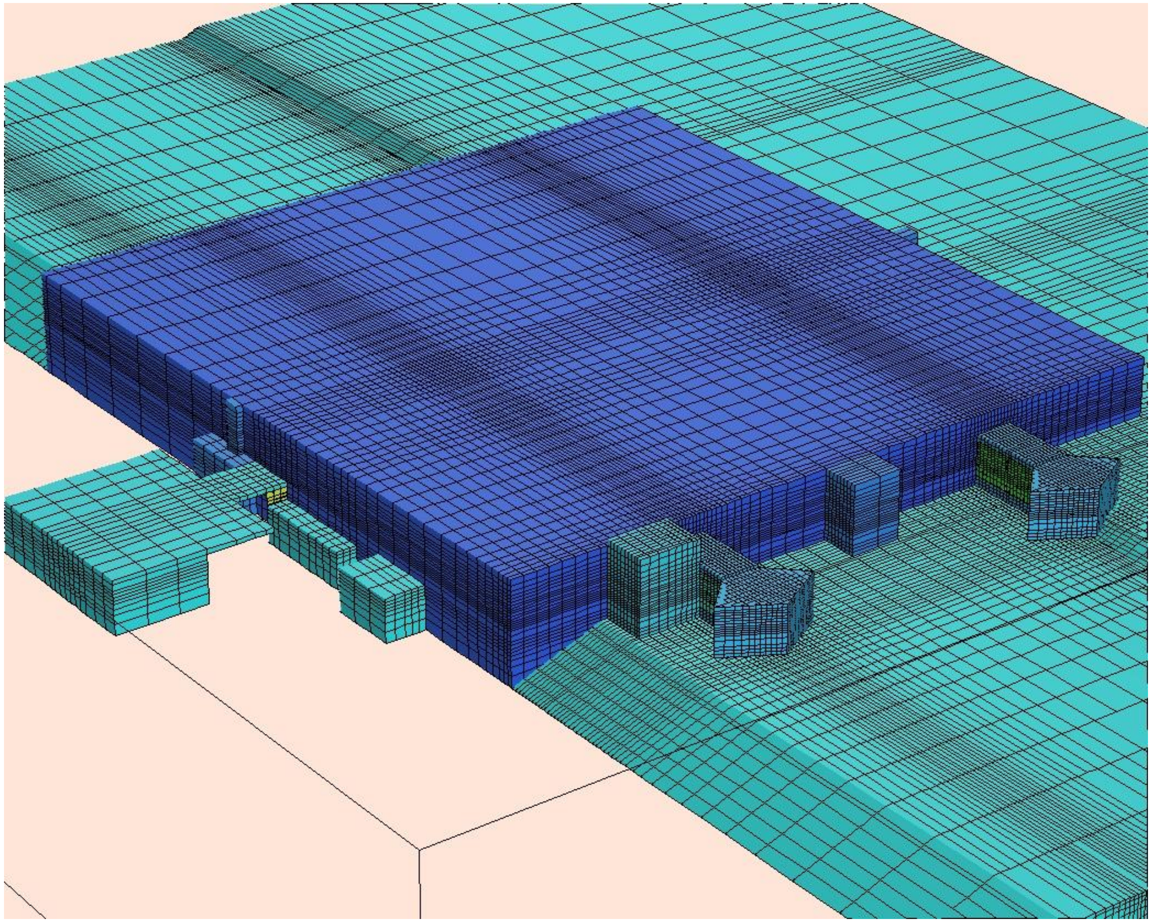
LPF Varies Considerably with Time



Example: More 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

Rendering of Facility



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

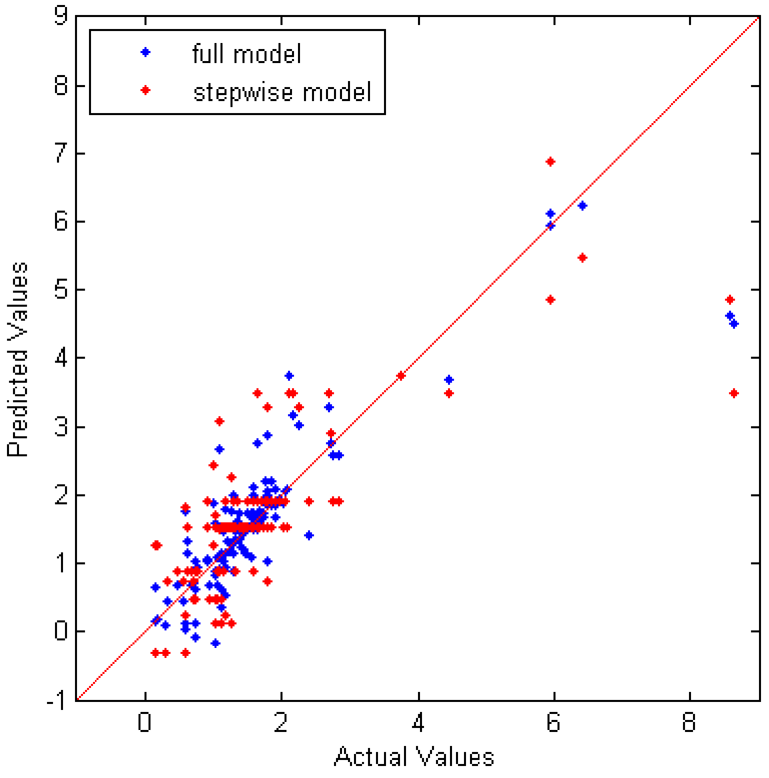
A	B	C	D	W	R	S	F	LPF95		
A1	B1	C1	D2	W1	R1	S1	F1	7.20E-01	1.39E+00	0.14
A1	B1	C1	D3	W1	R1	S1	F1	7.10E-01	1.41E+00	0.15
A1	B1	C1	D1	W1	R1	S1	F1	6.70E-01	1.49E+00	0.17
A2	B1	C1	D3	W1	R1	S1	F1	5.00E-01	2.00E+00	0.30
A2	B1	C2	D3	W1	R1	S1	F1	4.70E-01	2.13E+00	0.33
A2	B1	C1	D3	W2	R1	S1	F1	3.35E-01	2.99E+00	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

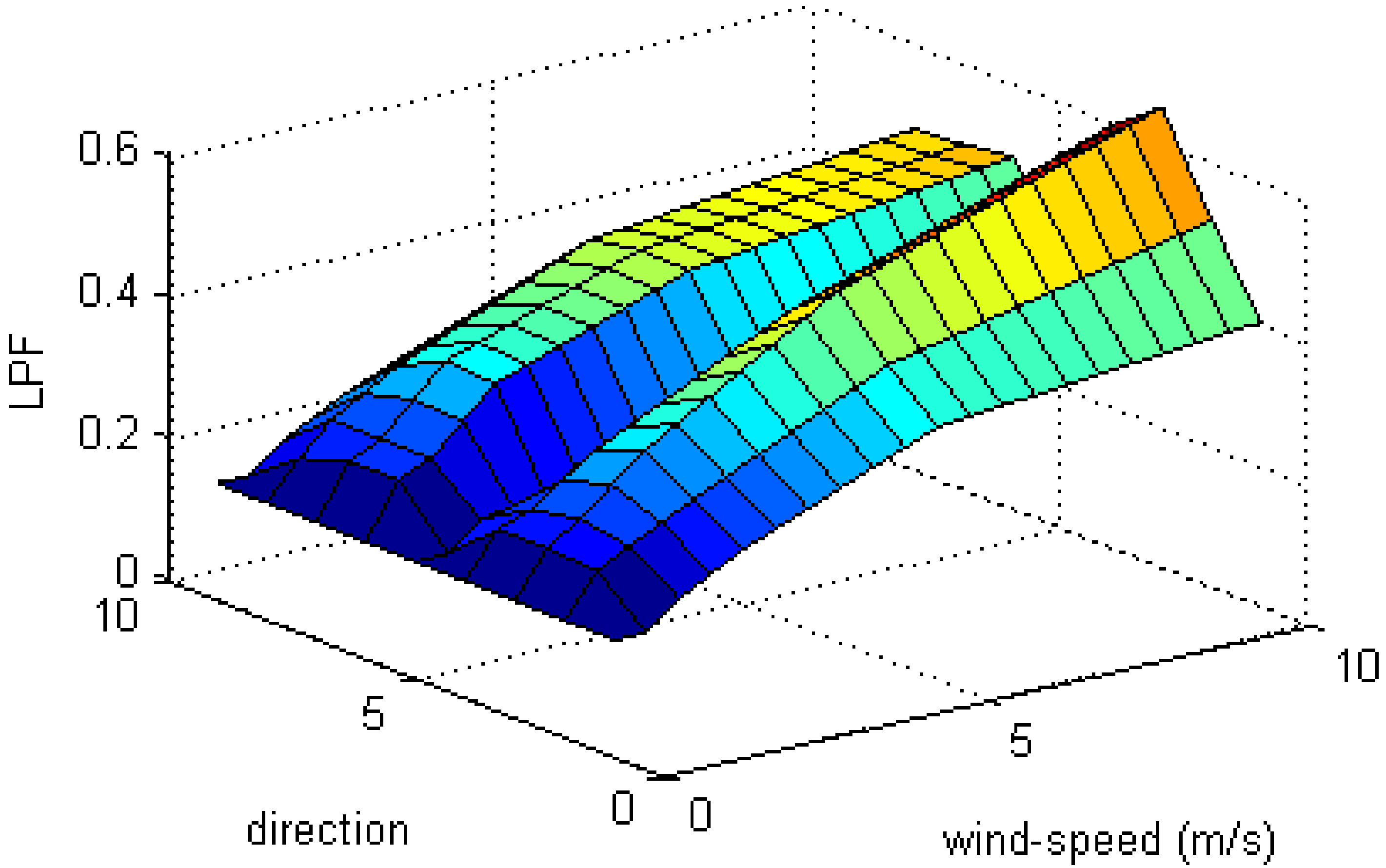
Category		Parameter Tag	Definition
Door Condition	1	A1	Both E and W doors always open
	2	A2	Both E and W doors closed at 10 min
	3	A3	Both E and W doors closed at 5 min
	4	A4	Both E and W doors always closed
	5	A5	E door closed, W door closed at 5 min
	6	A6	Both E and W doors closed at 2 min
	7	A7	E 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 enhance (although not completed mitigated) but 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.

Summary

- LPF analysis is often required and an important part of facility accident analysis.
- Simple, hand calculations often adequate for purposes of DSA (bounding scenarios).
- Simple calculations are not realistically possible for complex situations.
- More sophisticated tools (computer codes) are being used to provide refined estimates of LPF, with added value of broader insights into accident behavior.