SAND2017-2550C

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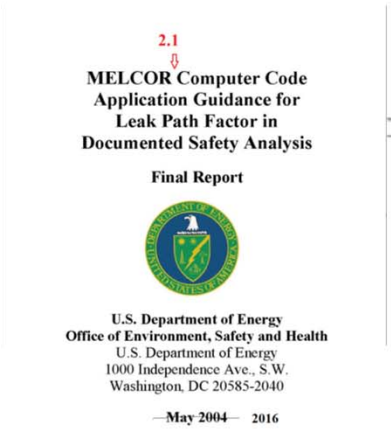
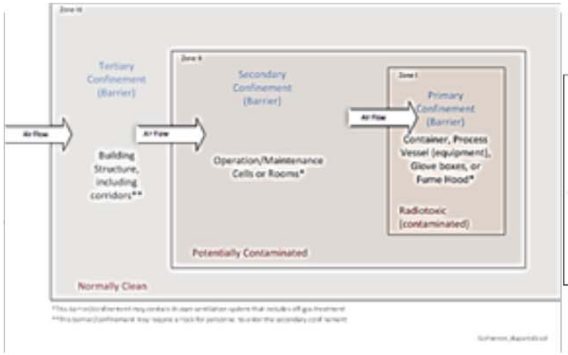
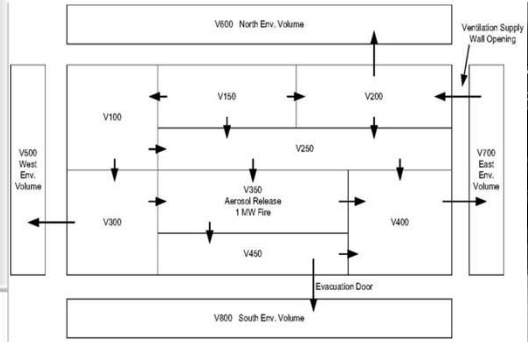






NSRD-10: Leak Path Factor Guidance Using MELCOR

Presented by David Louie , Ph.D.

dllouie@sandia.gov

2017 EFCOG NFS Workshop – NSR&D Subgroup

March 14, 2017

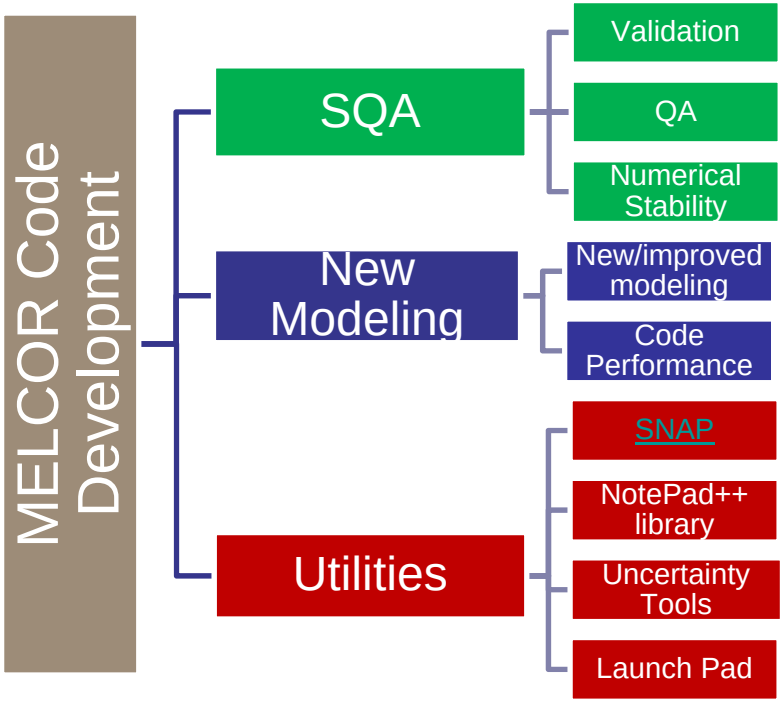
SAND2017-XXXX

Acknowledgement

We are gratefully that DOE consistently fund Sandia to work on Nuclear Safety Research & Development (NSR&D) Program at DOE Office of Nuclear Safety under Dr. Alan Levin and Mr. Patrick Frias. This work is funded under WAS Project# 2015-AU30-SNL-MELCOR.

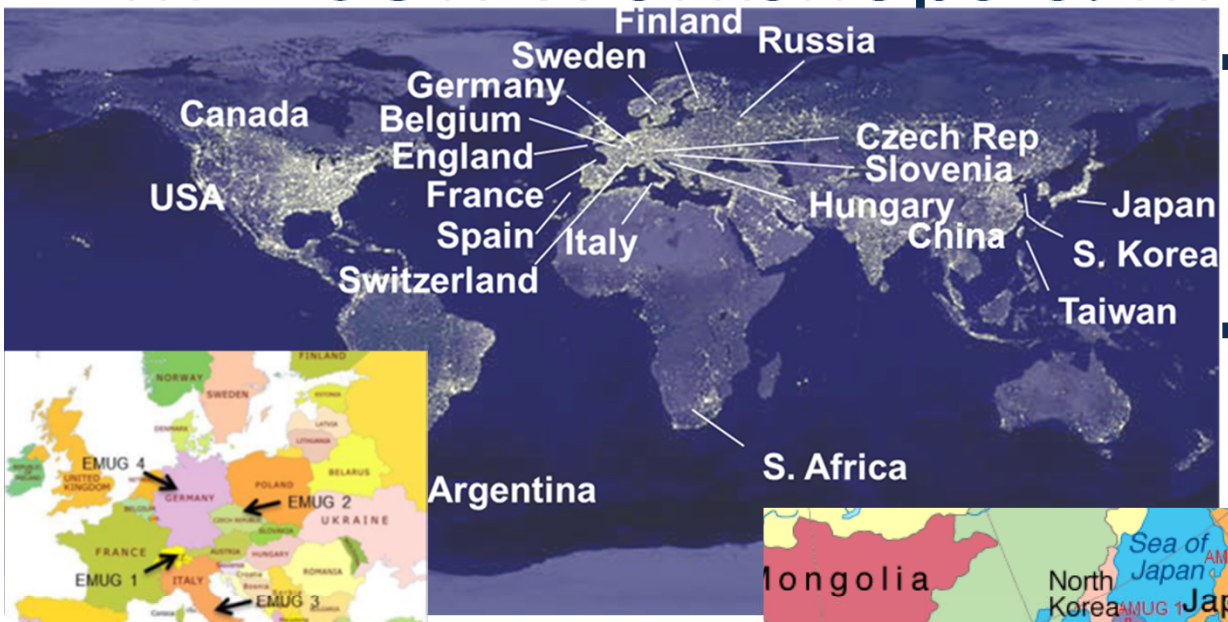
MELCOR Code Development

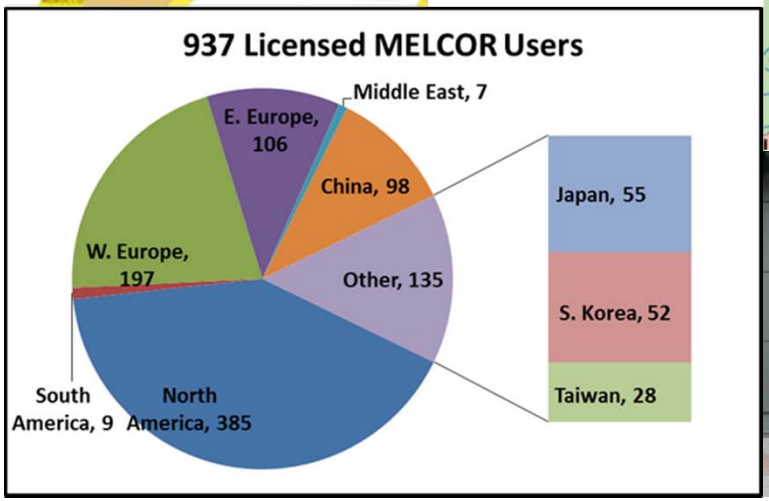
- MELCOR is developed by SNL for
  - US Nuclear Regulatory Commission
  - Division of Systems Analysis
  - Since early 1980s
- MELCOR Development is also strongly influenced by the participation of many International Partners through CSARP
  - Development Contributions – New models
  - Development Recommendations
  - Validation
- Other cooperation also may influence the development of MELCOR:
  - Sodium fast reactors – CONTAIN-LMR implementation, TerraPower
  - Small moderator reactors – NuScale
  - Source term Spent Fuel Reprocessing Project



- MELCOR code version:
  - 1.8.5, 1.8.6 – Legacy
  - 2.x – Current
  - 3 – Coming soon

MELCOR Workshops & Meetings





- 2016 European MELCOR User Group (EMUG)
  - Hosted by Imperial College London & AMEC
  - April 6-7, 2016
- MELCOR User's Workshop in Ukraine
  - Hosted by SSTC in Kiev
  - April 25-28, 2016
- 2016 CSARP/MCAP
  - September 12, 2016
  - Bethesda, MD
  - No Workshop
- 2016 Asian MELCOR User Group (AMUG)
  - Hosted by SPICRI & NRSC (Beijing)
  - October 17-21, 2016
  - MELCOR/MACCS Workshop

Major Objectives

- Replace the obsolete MELCOR 1.8.5 LPF Guidance Report in the DOE Repository
  - MELCOR 1.8.5 or 1.8.6 is not supported by Sandia
  - Only verification tests included
- 2016 MELCOR Guidance Report development include:
  - Validation tests
    - reactor and non-reactor experiments, particularly for aerosol physics
    - Analytical tests
  - Verification tests
    - Version to version comparison - MELCOR 1.8.5, 1.8.6 and 2.1
    - Additional verifications other than those in MELCOR 1.8.5 guidance report
  - Best practices for common accident scenarios encountered at DOE facilities

MELCOR Code Validation

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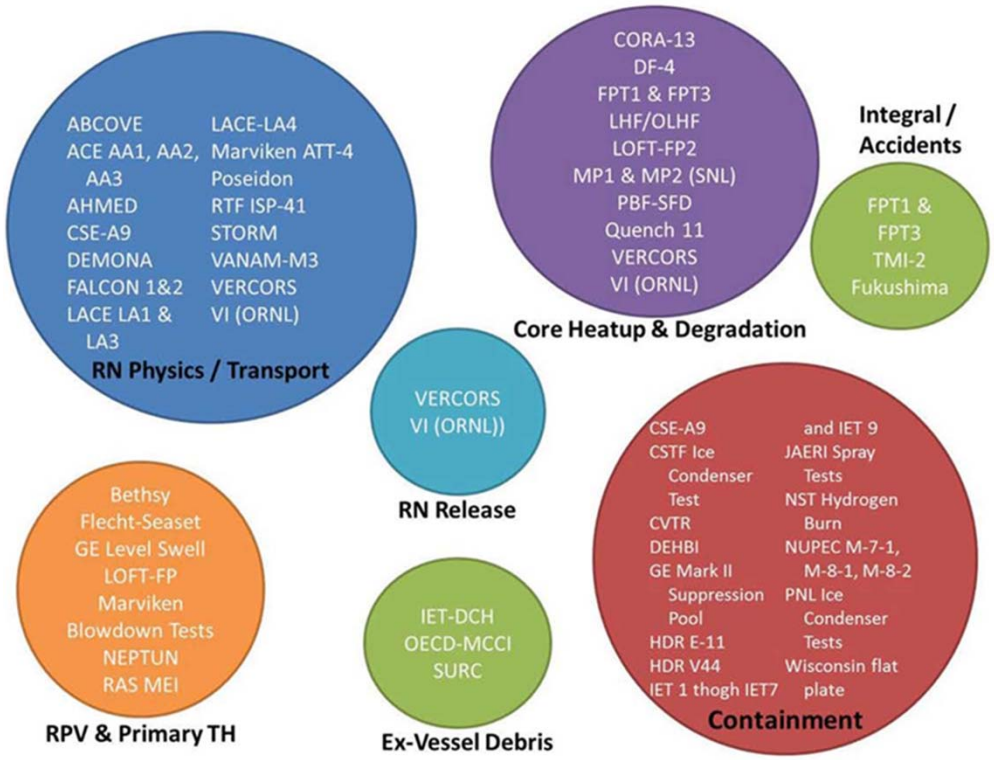
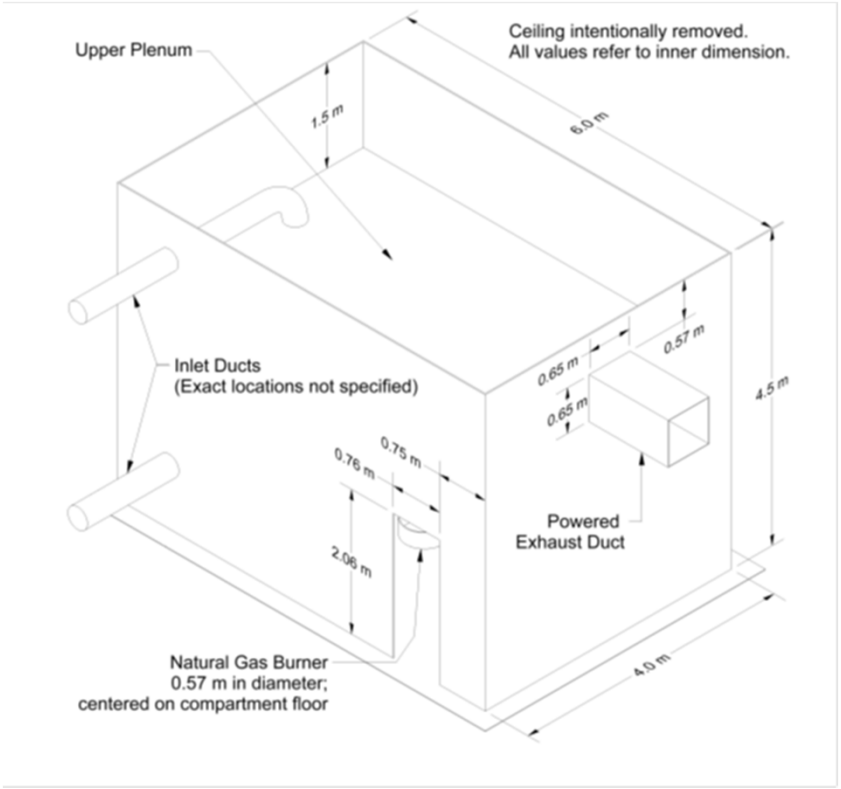
- Separate effects tests
  - More tightly controlled conditions
  - Limited or specific range of phenomena
- Integral tests
  - Combine many simultaneous physics aspects
  - Often less precisely characterized test conditions
  - Broader range of phenomena investigated
- Actual Accident Studies: TMI-2, Fukushima
  - Combines all relevant physics at full scale
  - Least well instrumented and characterized "experiment"
  - An ultimate basis for code validation
    - Bearing in mind, not every accident should be expected to be the same as TMI-2
- Participation in multiple International Standard Problems
- SAND2016 6693R MELCOR 2.1 Assessment Report has been published

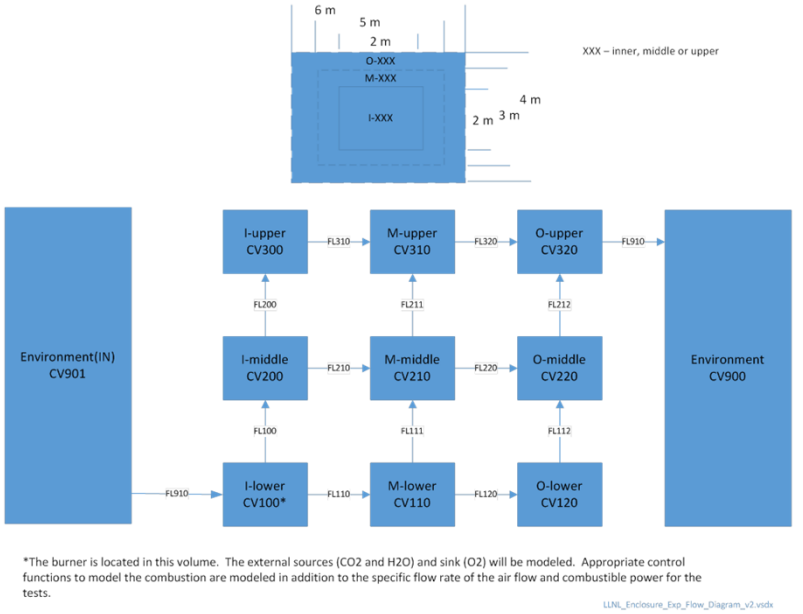


Verification and Validation Tests

- In addition to those identified from MELCOR Assessment Report
- We have identified:
  - Fire test –LLNL Enclosure Fire – from Validation document of CFAST
  - Aerosol resuspension test – STORM SR-11 Test
  - Additional experiments from DOE-HDBK-3010-94
    - Wind Tunnel Gasoline pool fire tests conducted at the RART facility
    - Spills and Pressurized Release Tests conducted in RART
- Verification tests
  - Sample problems in Obsolete MELCOR 1.8.5 guidance report
    - Version-to-version comparison: MELCOR 1.8.5, 1.8.6 and 2.1

LLNL Enclosure Fire Test (CFAST)





Test 9

Time (s)	Air Flow (kg/s)	Fuel Flow (kg.s)	O_2 Fraction	ΔP (Pa)	CO_2 Fraction	West Upper TC (K)	West Middle TC (K)	West Bottom TC (K)
0	0.565	0.0	0.208	-398	0.0005	302.15	302.15	302.15
500	0.491	0.0041	0.185	-297	0.0140	399.15	386.15	332.15
1000	0.474	0.0040	0.1822	-292	0.0156	413.15	398.15	339.15
2000	0.463	0.0042	0.1809	-287	0.0159	425.15	413.15	346.15
3000	0.464	0.0039	0.1824	-278	0.0154	427.15	413.15	399.15
4000	0.461	0.0040	0.1819	-261	0.0157	434.15	419.15	405.15

Test 11

Time (s)	Air Flow (kg/s)	Fuel Flow (kg.s)	O2 Fraction	ΔP (Pa)	CO_2 Fraction	West Upper TC (K)	West Middle TC (K)	West Bottom TC (K)
0	0.240	0.0	0.2098	-75	0.0004	292.15	292.15	292.15
500	0.222	0.0040	0.1705	-42	0.0220	408.15	394.15	339.15
1000	0.221	0.0040	0.1546	-39	0.0289	422.15	408.15	349.15
2000	0.210	0.0040	0.1486	-45	0.0325	437.15	421.15	360.15
3000	0.207	0.0040	0.1473	-38	0.0326	444.15	429.15	366.15
4000	0.204	0.0040	0.1460	-31	0.0335	452.15	436.15	373.15

LLNL Fire Test Results

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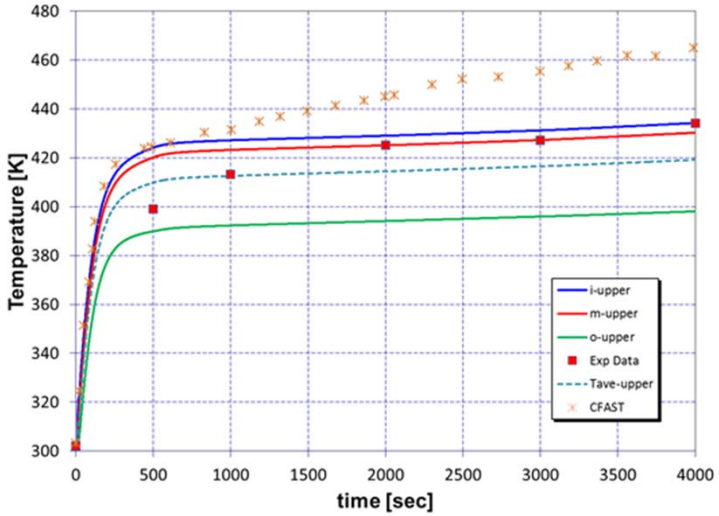
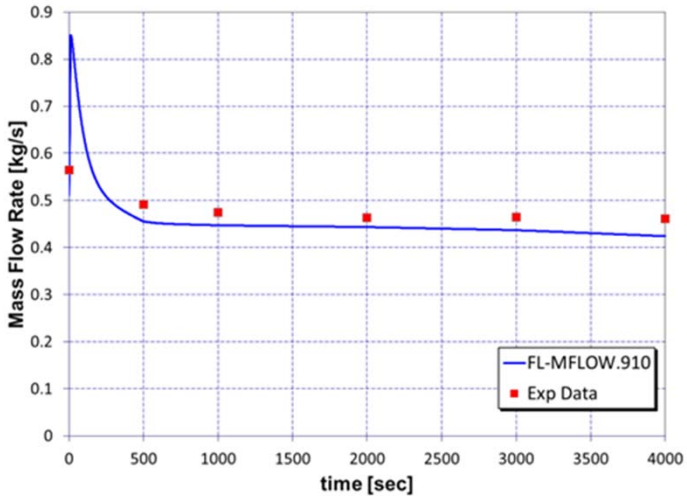
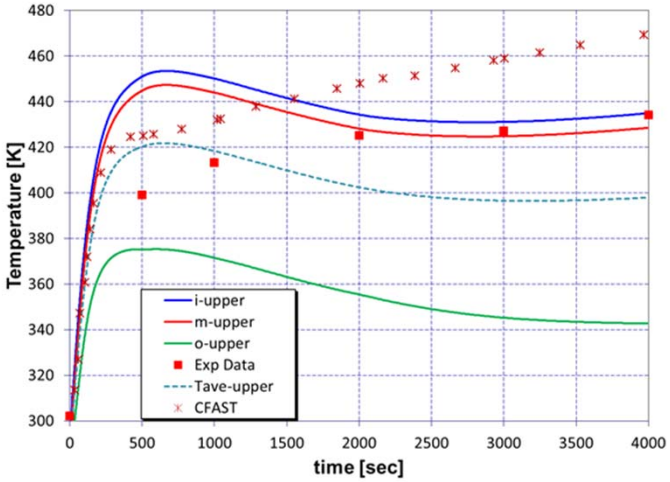
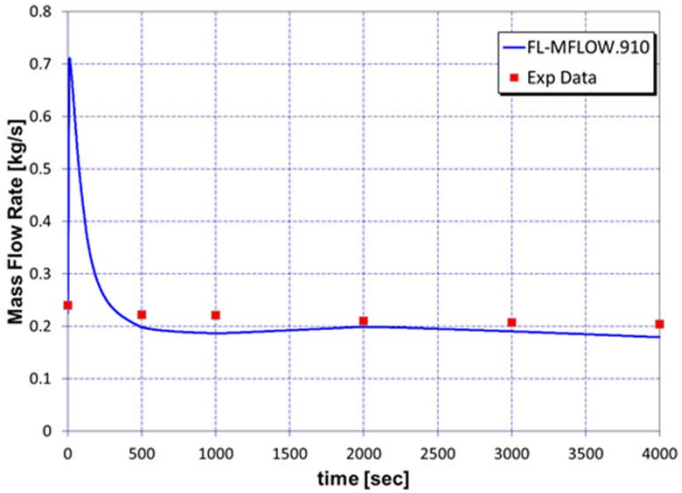
Test 9



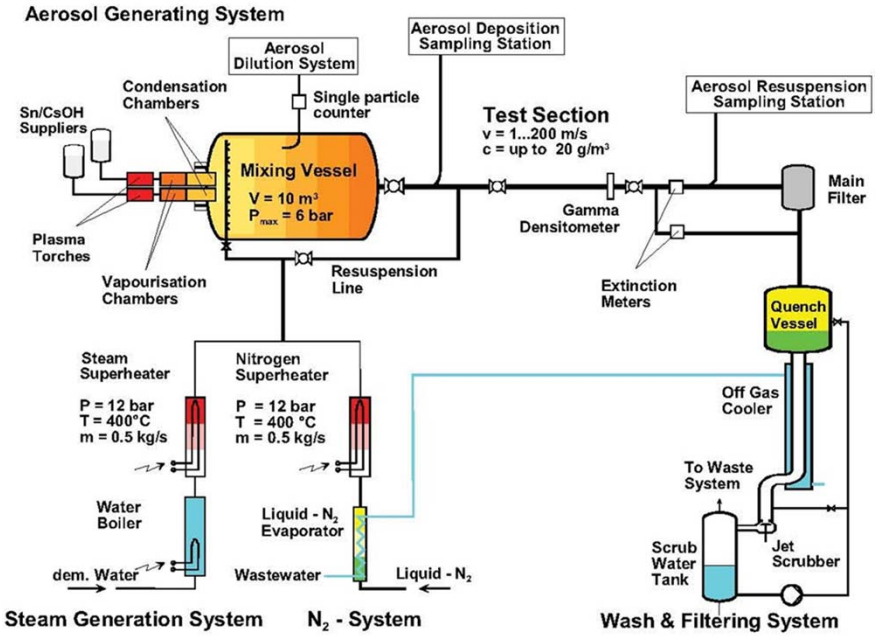


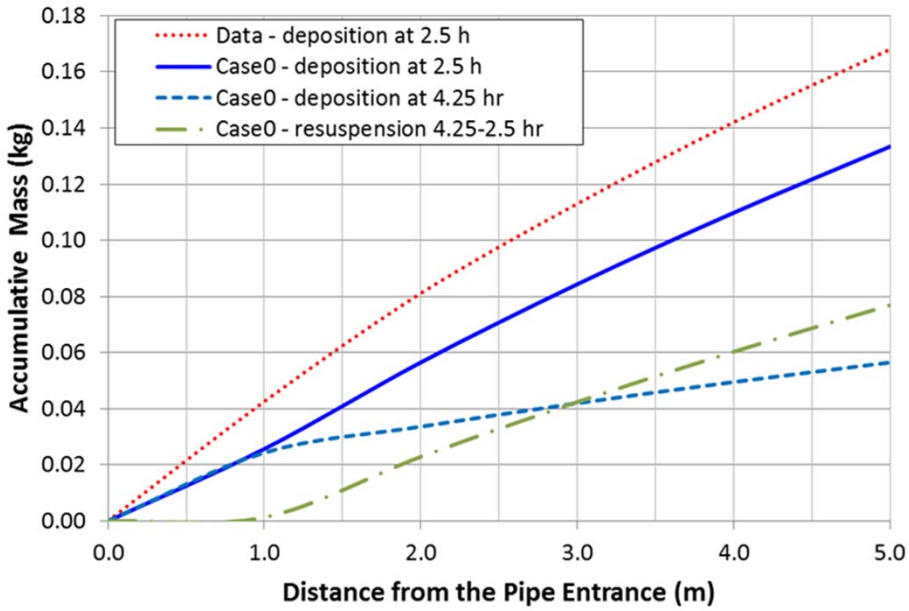
Test 11

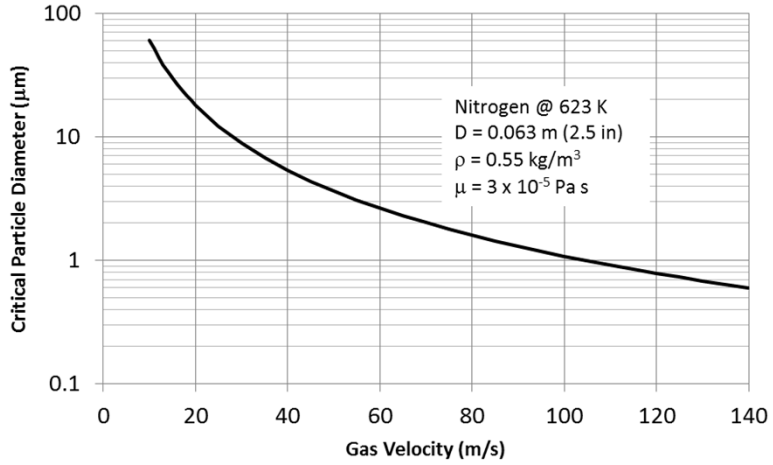




STORM SR-11 Resuspension Test

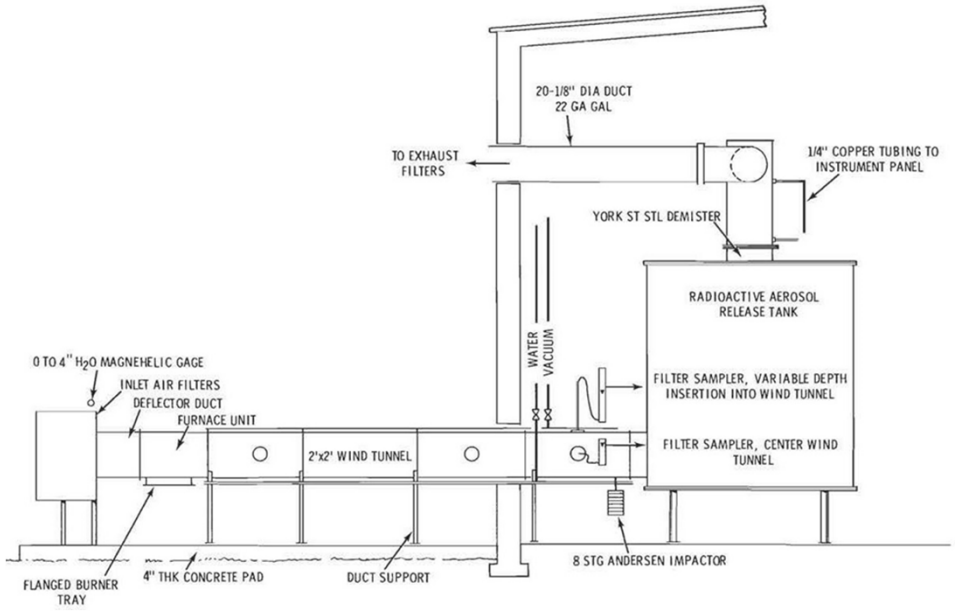


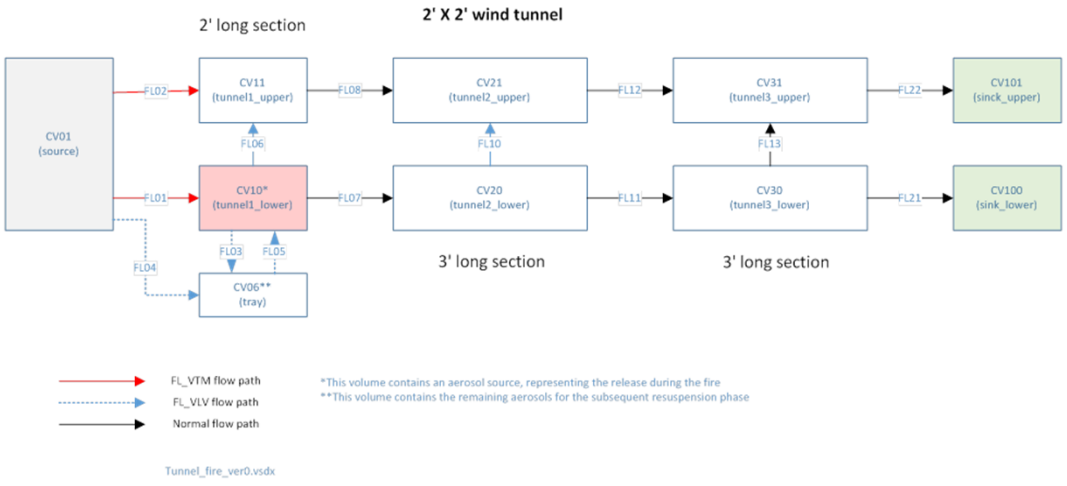


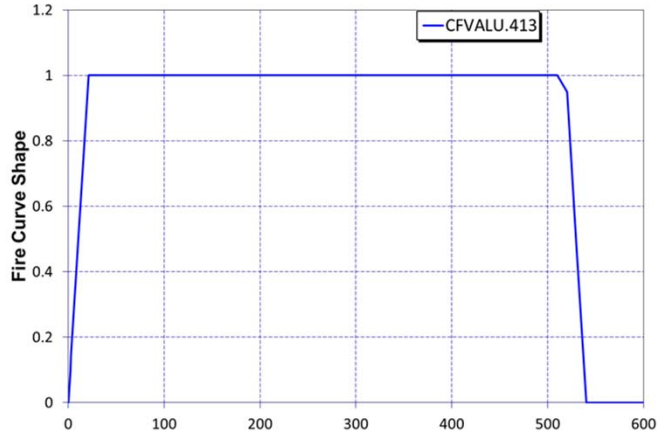


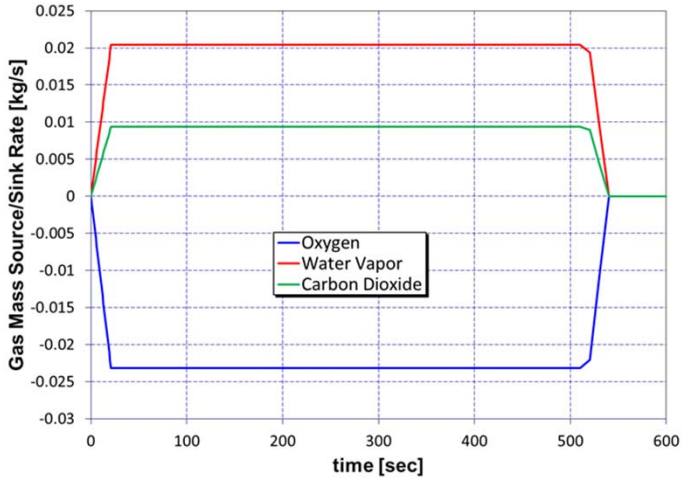
MELCOR predicted ~80 g versus experimental result of 113.3 g for SnO_2

Gasoline Pool Fire in Wind Tunnel







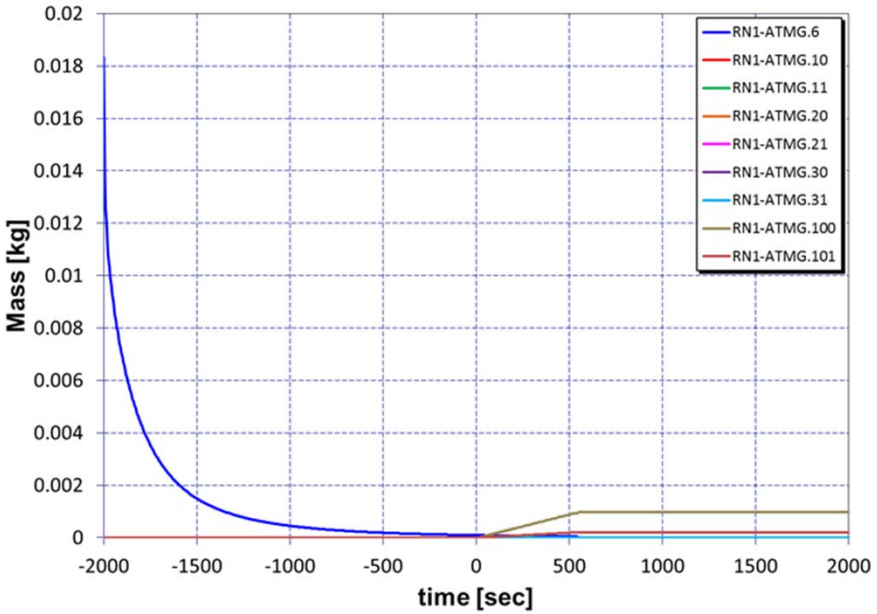


Gasoline Pool Fire Results

- 19.5 g UO2 in 1 Gallon gasoline
  - 6% sourced into tunnel at 0 s according to Fuego
  - 94% sourced into pan before start of resuspension phase

Bin #	Mass Fraction
1	0.008086
2	0.051213
3	0.09973
4	0.107817
5	0.161725
6	0.161725
7	0.107817
8	0.107817
9	0.086253
10	0.107817

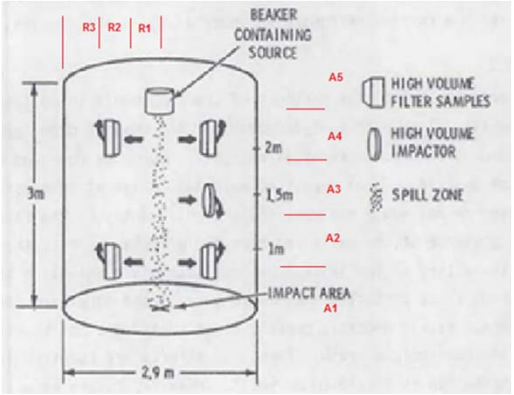
UO_2 Airborne Release Masses in Volumes



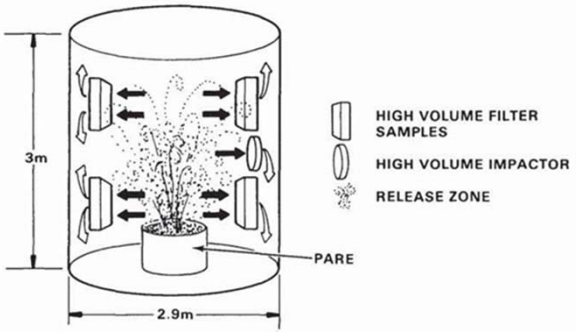
Experimental Data	MELCOR 2.1
During Fire – ARF=0.0012 Mass=2.34E-05 kg	During Fire – ARF= 0.0606 1.1836E-03 kg (Adjust to total area of the sampling*) Mass=2.94E-05 kg
During Resuspension- ARF=9.0E-4 Mass=1.755E-05 kg	During Resuspension (after fire gone) ARF=0.0 Mass=0.0 kg

*Total sampling cross section fraction to the wind tunnel cross section area of 0.025

Power Release Experiment from PNL

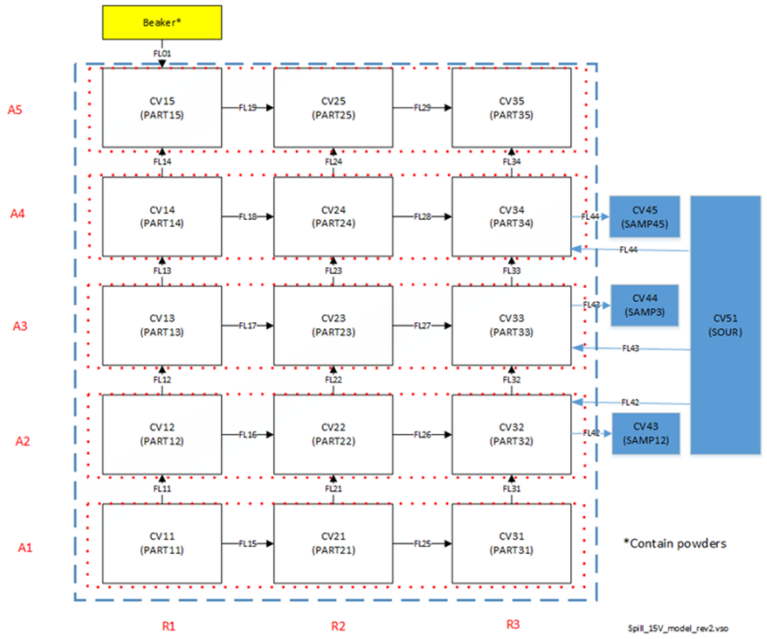


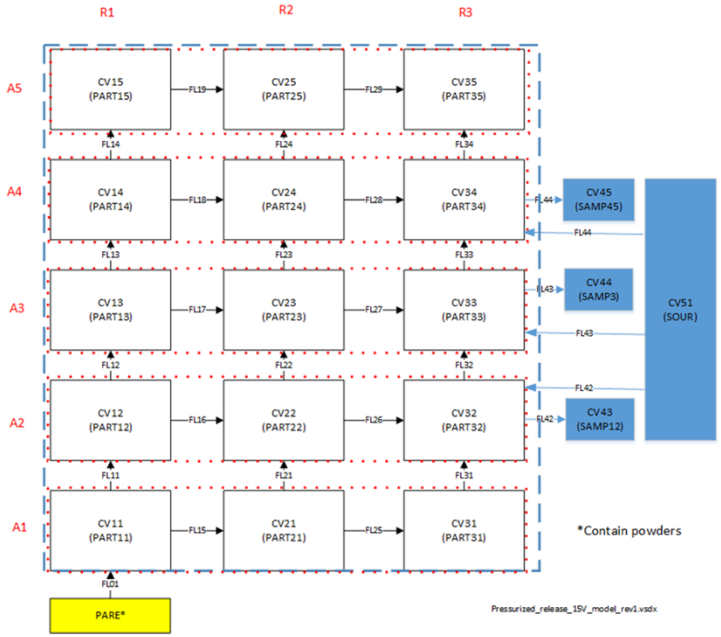
[Sutter 1981]

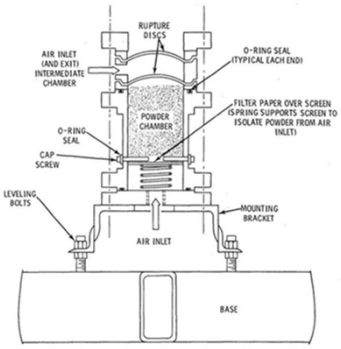


[Sutter 1983]

Parameter	MELCOR
Dimension	
PARE or beaker volume	862 cm^3
RART model	3 m × 2.9 m dia.
1-volume (1V)	1V
5-vol: A1 to A5 in Fig. 1	5V
15-vol: A1 to A5 × R1 to R3 in Fig. 1	15V
Assumptions	
Aerosol min and max diameters	0.8 and 50 µm
Pressurized Case	
Rupture disk timing	0.001 s
Aerosol source timing	< 0.001 s
Spill Case	
Aerosol source timing	0.05 s







[Sutter 1983]

Power Release Results

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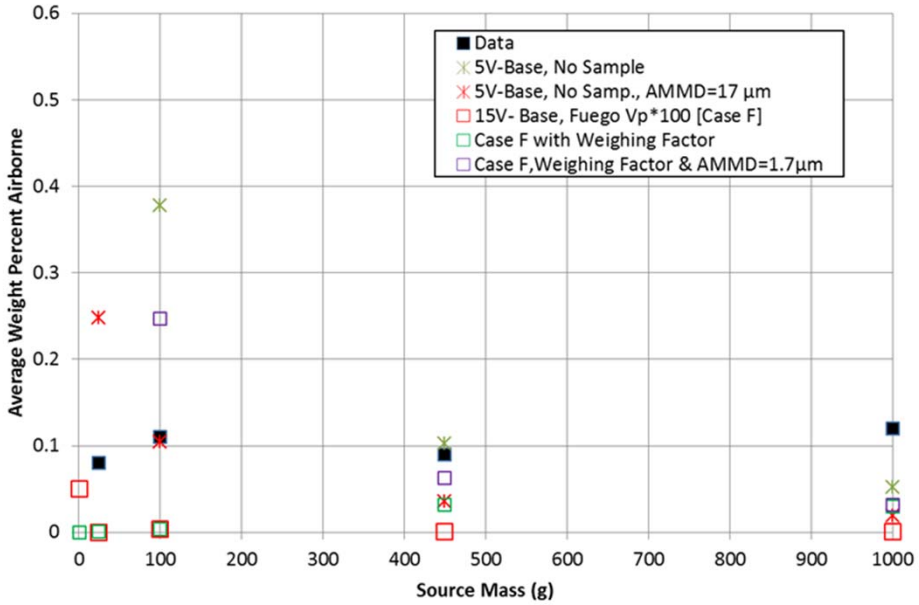
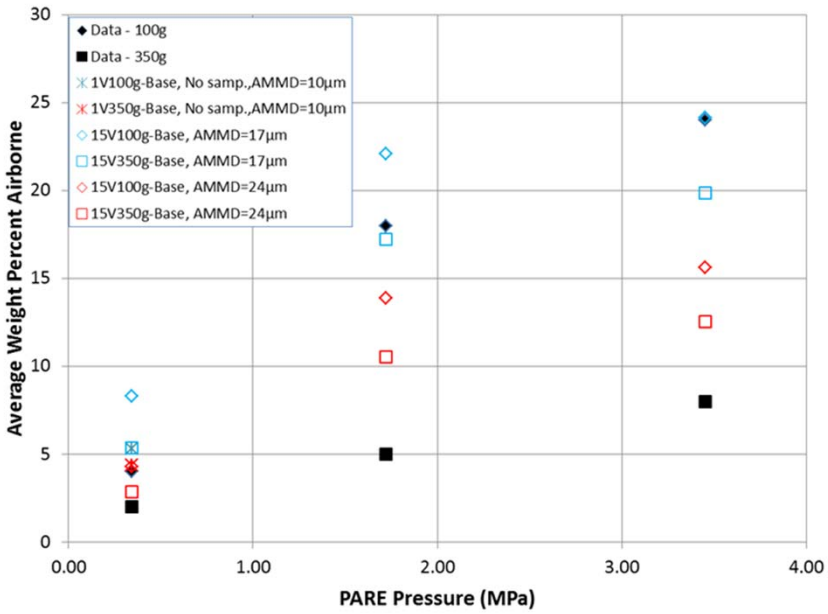
Gravitational Spill at 3 m



Pressurized Release at 50 psig (0.345 MPa), 250 psig (1.72 MPa) and 500 psig (3.45 MPa)

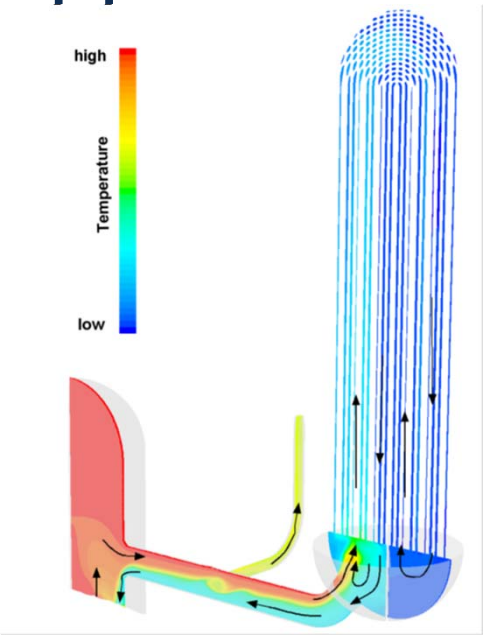


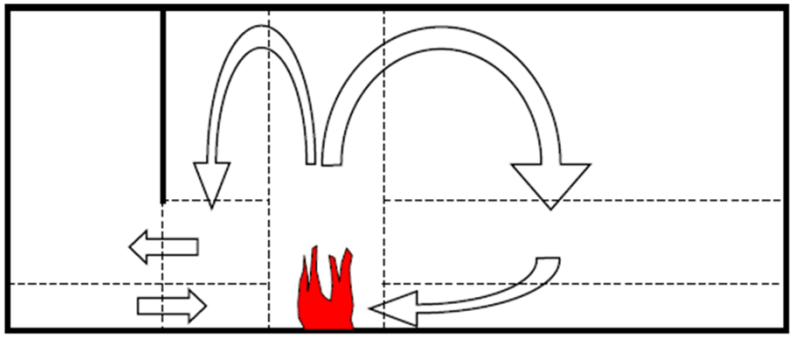
Best Practices

- Cover major accident scenarios in using MELCOR
  - Explosions
    - Analytical approach using control functions
    - Computational approach using BLASTX
    - Proper accounting for product gas generation and energies
  - Fires
    - Use Control function package to fire (demonstrated in here)
    - Results are encouraging, compared well with CFAST
  - Inadvertent of nuclear criticality
    - Similar approach as in explosion, except no by-product gas generation
    - 10^{18} fissions ~ 32 MJ.
  - Spills
    - Demonstrated in the validation tests shown here
- Specified models
  - Default values
  - Environment volume modeling – time-independent volume
  - Aerosol modeling
  - Counter-Current Flow Model for Fire

Counter Current Flow Model Applications

- It has been applied to model natural recirculation of hot and cold gas exchange during a severe accident condition
  - With the use of CFD results, the results should match better
- Similarly, it can be applied to model the doorway between the fire room and a cooler corridor
  - It is only applicable for the horizontal flow paths





Summary

- A draft report of MELCOR 2.1 guidance for LPF applications has been completed, and has been reviewed externally.
  - Document applicable reactor experiment data, and additional validation experiments from DOE-HDBK-3010
  - Provide additional specific validations:
    - Fire experiment with CFAST – LLNL Enclosure Fire
    - STORM Resuspension Phase Experiment
    - Gasoline pool fire experiment at PNL
    - Powder release experiments
  - Develop a number best practice on modeling explosion, fire, nuclear criticality and spill accidents

Future Expectations

- MELCOR 2.X is ready to be used in DOE LPF analysis, replacing the old LPF analysis using obsolete versions of MELCOR
- Create DMUG (DOE LPF MELCOR user group)
  - Conduct MELCOR workshop
    - MELCOR 1.8.5/1.8.6 conversion to MELCOR 2.1 or later version
  - LPF analysis exchange
- Any Question????

Back up slides or hyperlink

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Visualization and Graphical Interface

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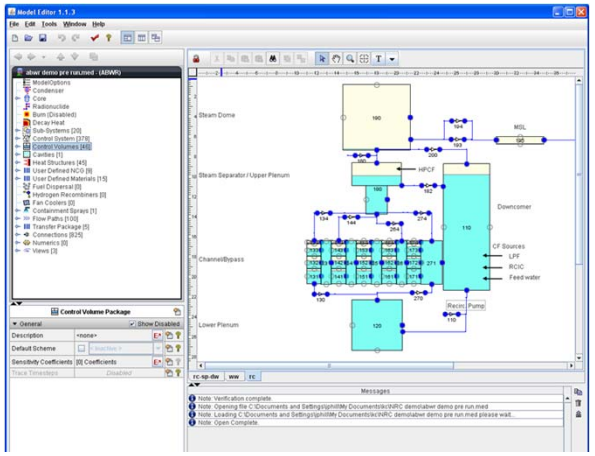
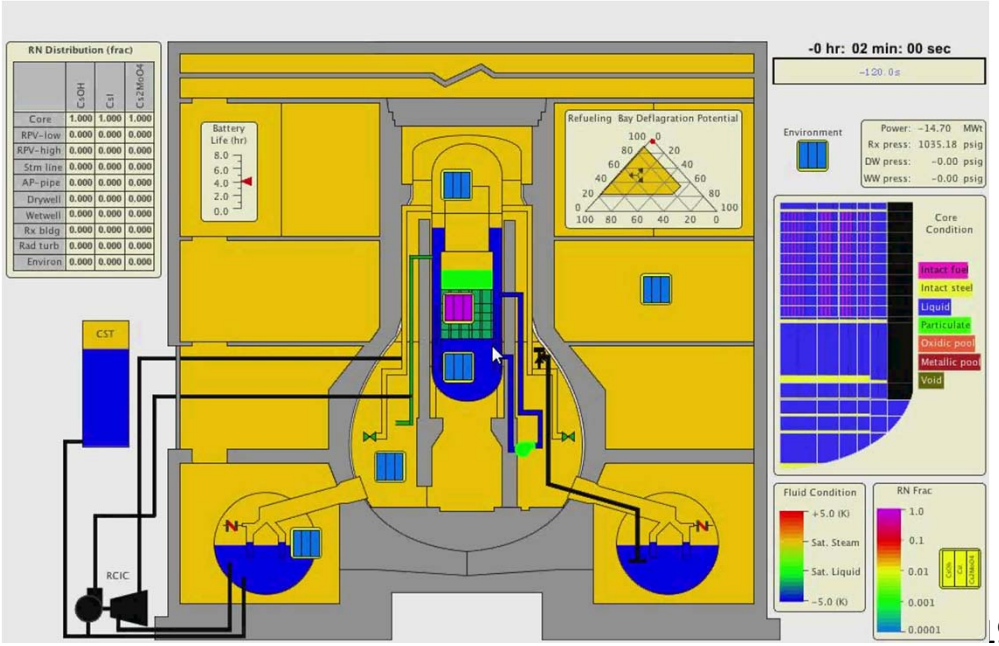
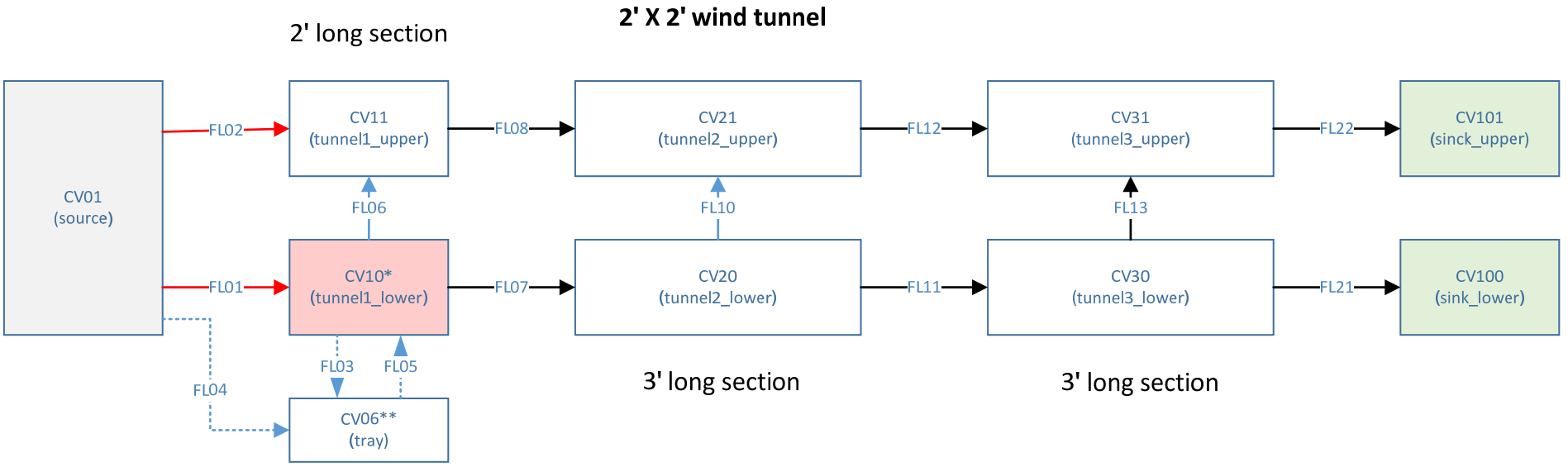
- Visualization is important for improving quality of calculations
  - Identification of modeling errors and issues
- Graphical user interface
  - Can reduce input errors
  - Simplifies input for new users
- SNAP MELCOR 2.1 Plugin
  - Version 1.0.0 - Released 7/17/09
  - Current version 2.1.1 – Released 2/24/12
  - Will convert a 1.8.6 input deck to 2.1 and back to 1.8.6
  - Sandia is working with SNAP developers to recommend enhancements for MELCOR plug-in
- 2011 workshop focused on the use of SNAP
- Model Editor -Components
  - Tree Structure organization
  - Arranged according to MELCOR package
  - ASCII view of object available
  - Organize components
  - DIFF capability for components
- Views
  - Trend plots
  - Custom animations
  - Others





Gasoline Pool Fire MELCOR Model



FL_VTM flow path
FL_VLV flow path
Normal flow path

*This volume contains an aerosol source, representing the release during the fire
**This volume contains the remaining aerosols for the subsequent resuspension phase

Tunnel_fire_ver0.vsdx