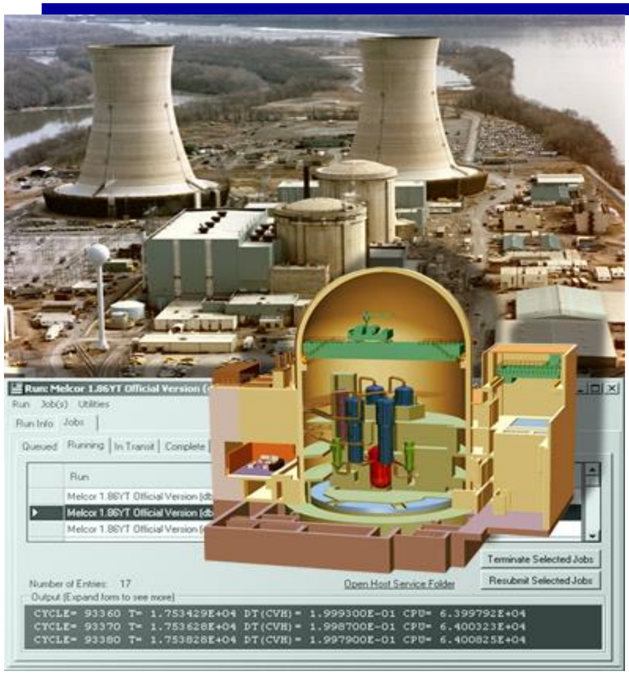

Engineer Safety Features of the RN Package

Presented by

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RN Engineered Safety Features

- Three primary features discussed for this talk
  - –Pool Scrubbing –SPARC-90 Model
  - –Spray – HECTR Model
  - –Filters – Simple user-specified models

RN ESFs

- The reference manual provides sufficient information and detail to understand these models.
- This presentation reviews the models and provides additional discussion
- Guidance given is the based on the presenter's experience of these models.

RN ESFs – SPARC-90 in MELCOR

- MELCOR implements Thermal-Hydraulics (T-H) and Fission Product (FP) scrubbing for bubbles independently between the control volume hydrodynamics (CVH) and radionuclide package (RN):
  - Mass and energy exchange between bubble NCGs/Water and the Pool is treated within CVH and is activated on FL_JSW for a given flow direction.
  - SPARC-90's FP scrubbing models are enabled through RN2_PLS input.

RN ESFs – CVH Bubble Transport T-H

- MELCOR applies simple efficiency correlations to determine the mass/energy dispositioning associated with bubble transport.
  - Efficiency - submergence depth
  - Efficiency - adequate subcooling
  - Efficiency - condensation

$$\varepsilon_z = \frac{z_P - z_J - 0.01\text{m}}{1.0\,\text{h}}, 0 \le \varepsilon_z \le 1$$

$$\varepsilon_T = \frac{T_{sat}(P) - T_P - 0.1\text{K}}{5.0\,\text{K}}, 0 \le \varepsilon_T \le 1$$

$$\varepsilon = \varepsilon_z \varepsilon_T$$

Zp , Zj=Pool and Flowpath elevations

h = Flowpath junction height

Tsat(P) , Tp = Pool Sat. Temperature and Pool Temperature

Ref: SAND2017-0876 O pg. CVH/FL-RM-60

RN ESFs – SPARC-90 Model

- General SPARC-90 Model
  - Thermal/mechanical equilibration between vapor / pool
    - Assumed instantaneous, i.e., thermophoretic deposition is ignored
  - Mass and energy transfer
    - Between Pool and Bubbles
      - Supersaturation of bubble results from mechanical work due to expansion during bubble rise.
    - Condensation to aerosols
      - Hygroscopic, soluble particle-growth, supersaturation,
    - Vapor released to overlying atmosphere
  - Fission product removal mechanisms

RN ESFs – SPARC-90 FP Capture

- Aerosol Capture
  - Globule, i.e., Pre-Swarm (Vent Exit)
    - Two-Models: pre-detachment and post-detachment of globule
      - Diffusion deposition – Brownian and gravitational
      - Centrifugal
    - Steam Condensation
      - During equilibration of vapor (fraction of gas volume condensed)
    - Impaction
  - Bubble Swarm (Piece Wise Marching Calculation)
    - Calculates bubble T-H and particle growth
    - Deposition velocities are computed: Centrifugal, Brownian, and Gravitational. Hindering velocity also computed: Pool Vaporization
    - Volatile Iodine capture – Limited by slower aqueous reactions and bubble surface renewal, modeled independent of pH in SPARC-90.

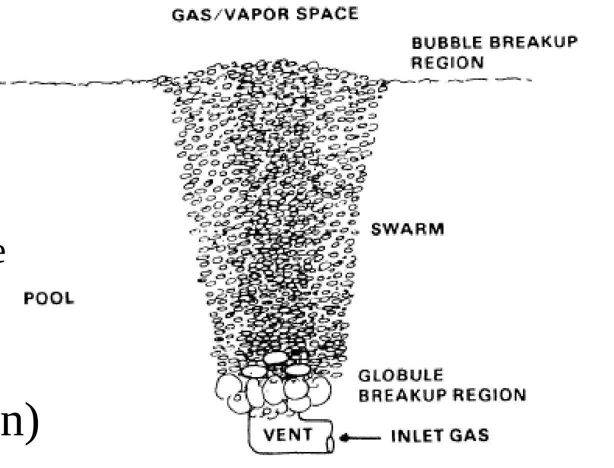


FIGURE 2.1. Schematic of Suppression Pool During Scrubbing of Inlet Gases

2.1

SPARC-90 Parameter Sensitivity Results

Taken from Ref.:

P.C. Owczarski, K.W. Burk, “SPARC-90: A Code for Calculating Fission Product Capture in Suppression Pools,” NUREG/CR—5765, Oct. 1991.

- Most Important
  - Particle size distribution
- Very Important
  - Particle concentration
  - Bubble size/shape
  - Volume fraction of steam in inlet gas
  - Particle density
- Intermediate Importance
  - Pool temperature
  - Pool depth
  - Percent of soluble material in particles
- Least Important
  - Noncondensible gas composition
  - Pressure above pool

RN ESFs – SPARC-90 Modeling Practices

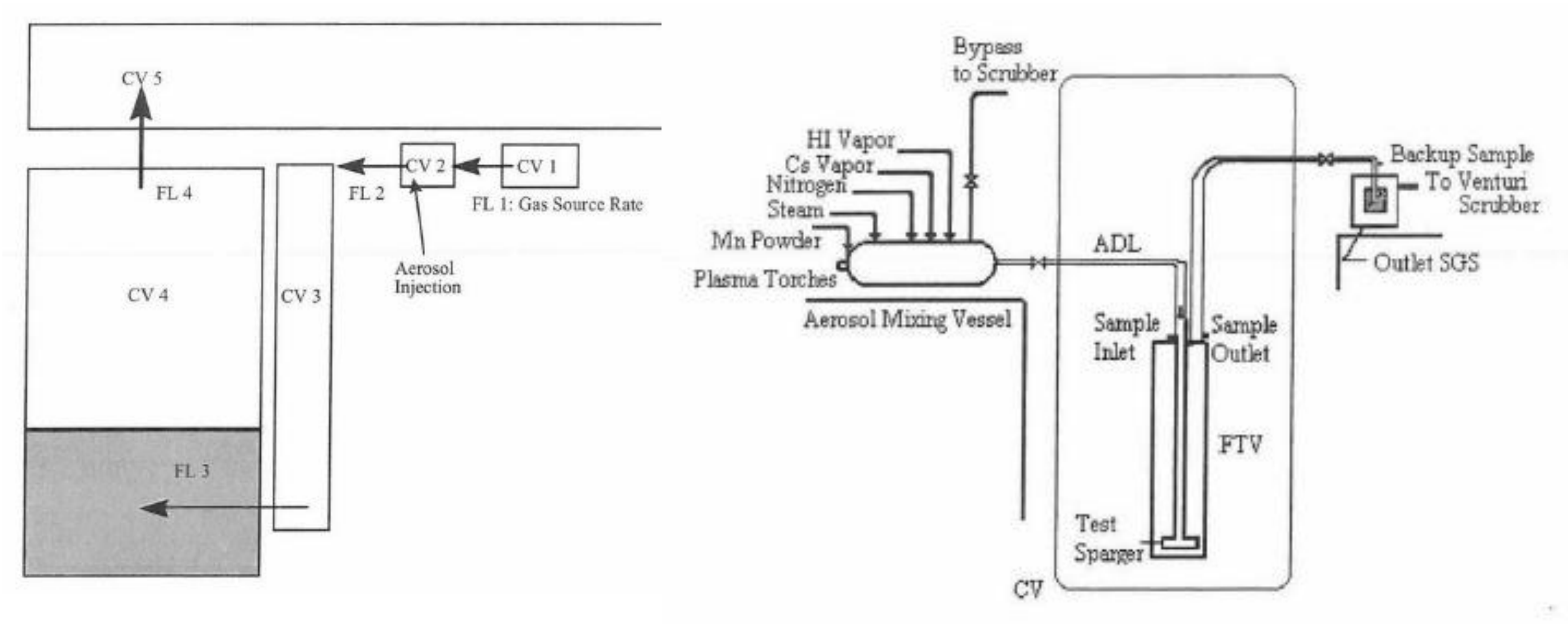
- Using Pool Scrubbing
  - Users must enable the scrubbing model to use SPARC-90 FP decontamination factor (DF) calculations
  - By default SPARC-90 is off:
    - Enable to compute scrubbing of aerosols and/or iodine vapor
    - Additional inclusion made for scrubbing of all vapors
      - SOARCA best practice is to enabled vapor scrubbing (?).
  - Of the important parameter's, most are determined directly by MELCOR.
  - Model has assumed bubble regions: entrance globule and bubble swarm. Therefore, single contiguous pools are recommended when using the model.
    - Otherwise, globule / bubble swarm decontamination will switch and restart with each flowpath in-series.

RN ESFs – SPARC-90 Modeling Practice

- Using Pool Scrubbing (Cont.)
  - All MELCOR assessments presented for pool scrubbing experiments use single control volume for receiving pool. Avoid stacked control volumes for scrubbing pool representation.
  - Missing from the importance list is the vapor temperature of the exit fluid. Decontamination is stronger for aerosols than vapors; therefore, the exit temperature which determines the Cs/I physical state can drive large DFs for aerosols or small DFs for vapors.
    - If your releases to environment significantly varying from one analyses to the next, determine the physical form of Cs/I being passed to the pool.
  - Scrubbing can also be enabled for the Cavity package for core-concrete releases when submerged.

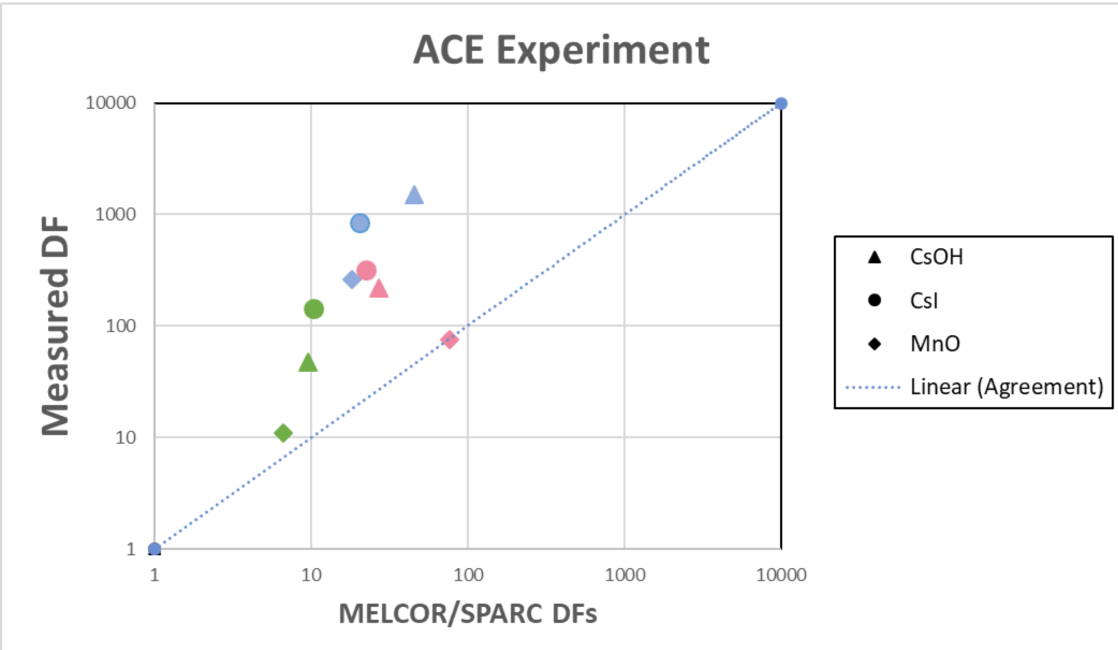
MELCOR Assessments

- ACE AA1-3 Experiments
  - Comparison with MELCOR calculated values.
  - Sourced in HI, Cs, N, and H2O vapor as well as Mn powder.



Ref.: L.L.Humphries, et. al., MELCOR Manual Vol. 3, Sept. 2015.

ACE AA1-3 Experiments

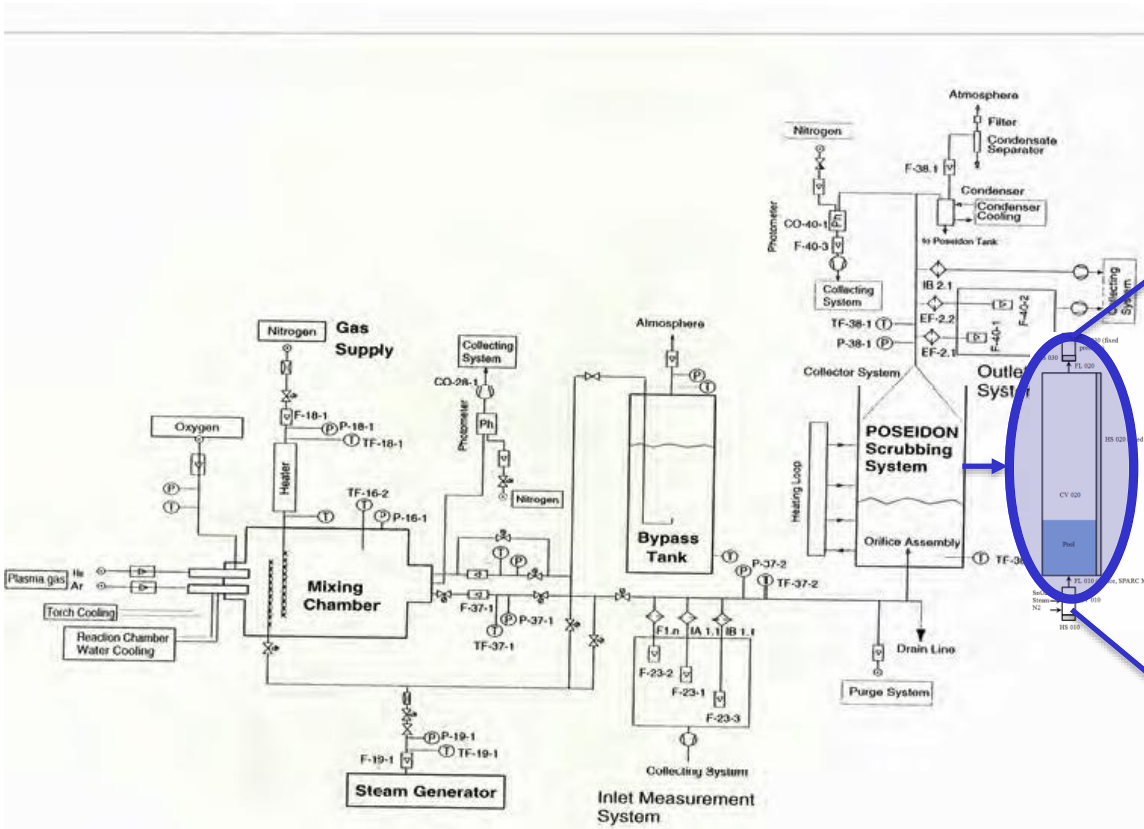


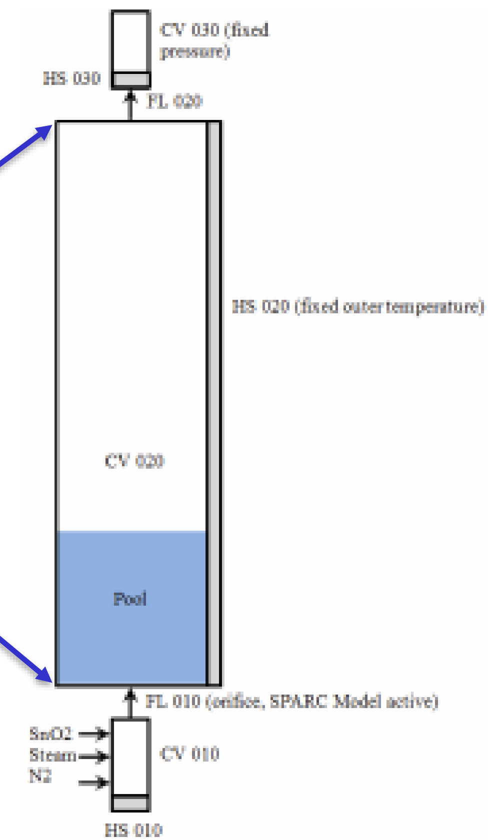
Experiment	Aerosol	Calc. DF	Measured DF
AA1	CsOH	9.6	47
	CsI	10.3	145
	MnO	6.7	11
AA2	CsOH	45.3	1500
	CsI	20.5	840
	MnO	18.2	260
AA3	CsOH	26.9	220
	CsI	22.5	320
	MnO	76.2	75

Ref.: L.L.Humphries, et. al., MELCOR Manual Vol. 3, Sept. 2015.

MELCOR Assessments

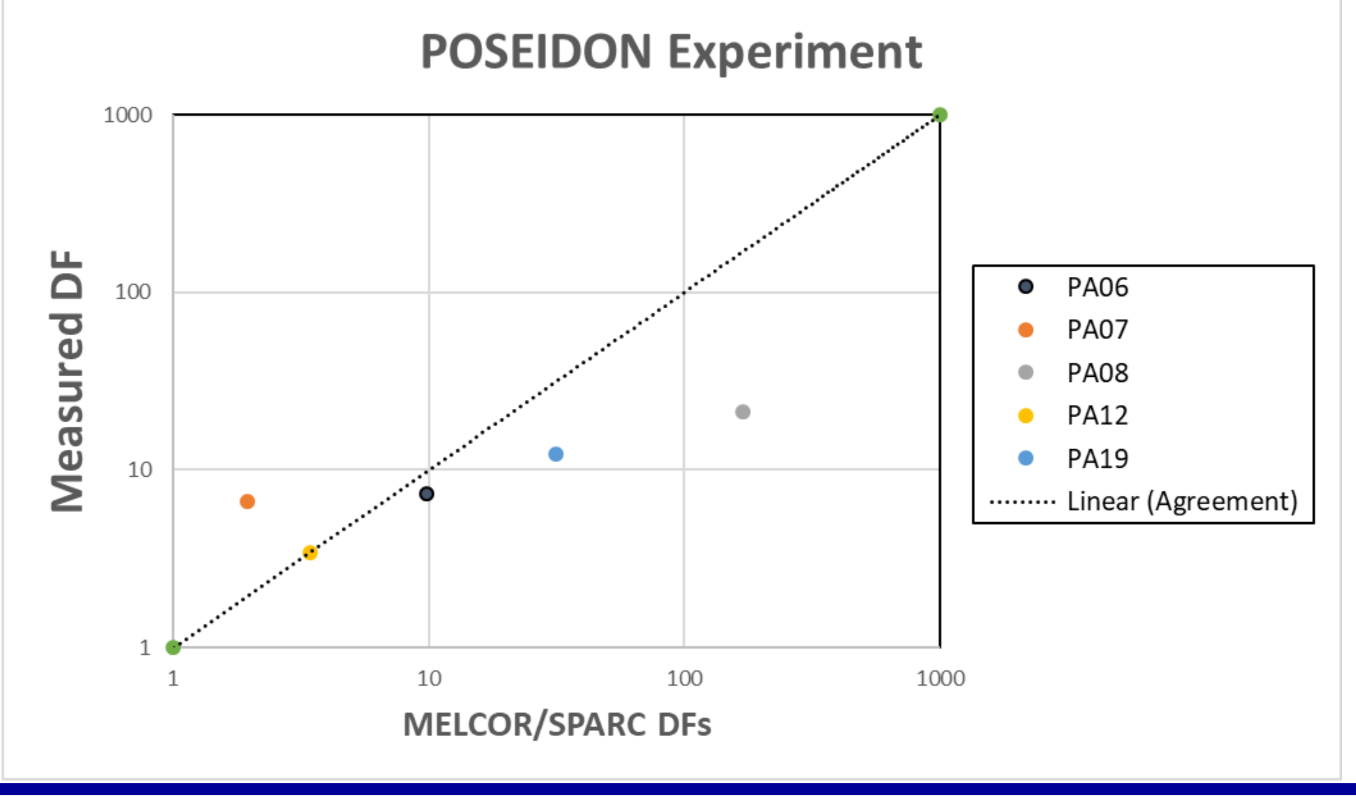
- POSEIDON Experiments





POSEIDON Experiments

- PA07 (Shallower Pool)
- PA08 (Deeper Pool)
- PA12 (No Steam)
- PA17 (High steam fraction and larger particles)



RN ESF - Sprays

- MELCOR models T-H and gas scrubbing for sprays within the SPR package. All associated input is in the SPR package.
  - Mass and energy transfer is modeled with a single droplet fall model for each discrete bin size.
    - Spray Junction (SPR_JUN) define "fall-thru" if droplets reach a control volume base.
  - Radionuclide scrubbing is computed with lamdas (λs) for aerosols and vapors.
    - Single droplet sizes are recommended for sprays when gas scrubbing is being considered

RN ESF – Sprays Input Variables

- User specifies the following information
- Volumetric flow rate and temperature
- Diameter (or size distribution)
  - Effects flow rates around droplet
    - Drag / terminal velocity
    - Mass transfer coefficients
- Fall height
  - Combined with diameter gives exposure time
- Pass through (SPR_JUN)
  - Interface exchange for falling droplets

RN ESF – Sprays Scrubbing

- Vapor / Aerosol removal rate per class

$$\frac{dM_k}{dt} = -\lambda_{k,i} M_k$$

- Vapor removal model is mechanistic and is film/layer diffusion limited.
- User may account for additives (borated, etc.) by adjusting the partition coefficient, ratio of equilibrium densities.

RN ESF – Sprays Scrubbing

- Aerosol removal is calculated primarily by impaction and interception
  - Diffuisophoresis and diffusion also included
  - Similar to aerosol/aerosol interaction
    - Droplets that are "large" (>10micron) sweep up aerosols
    - For "smaller" droplets, diffusiophoresis becomes more significant
  - Aerosol lamda is a function of efficiency (ε)
    - Impaction (velocities/radii disparity) potential/viscous
    - Interception (solely radii disparity) potential/viscous
    - Diffusion
    - Diffusiophoresis

$$E_{i,j} = 1 - \prod_k \left(1 - \varepsilon_{ijk}\right)$$

RN ESF – Sprays Scrubbing

- Vapor

$$\lambda_{k,i} = \frac{F_i E_{k,i} H}{V} \qquad (2.115)$$

where

F_i	= volumetric flow rate for droplets of size *i*
$E_{k,i}$	= adsorption efficiency for vapor class *k*
H	= partition coefficient for partition of the vapor between spray water and gas
V	= volume of control volume

- Aerosol

$$\lambda_{k,i} = \frac{3F_i h E_{i,j}}{4Vr_i}$$

H = fall height,

r_i = drop radius

RN ESF – Filters

- User specified decontamination factors (DFs)
  - No mechanistic model is available in MELCOR
- User specifies
  - Either vapor or aerosol filtration
  - Class specific DFs
    - If aerosol, bin size DFs may be specified
  - Maximum filter deposition
    - Once met, no further decontamination
- Filter losses can be simulated
  - Flow loss should be defined to be laminar within a filter
    - Specify proper laminar loss coefficient (SLAM) and hydraulic diameter
    - User may control loss parameter (SLAM) via control function to simulate aerosol loading
- Decay heat is placed in "downstream" control volume.

Questions