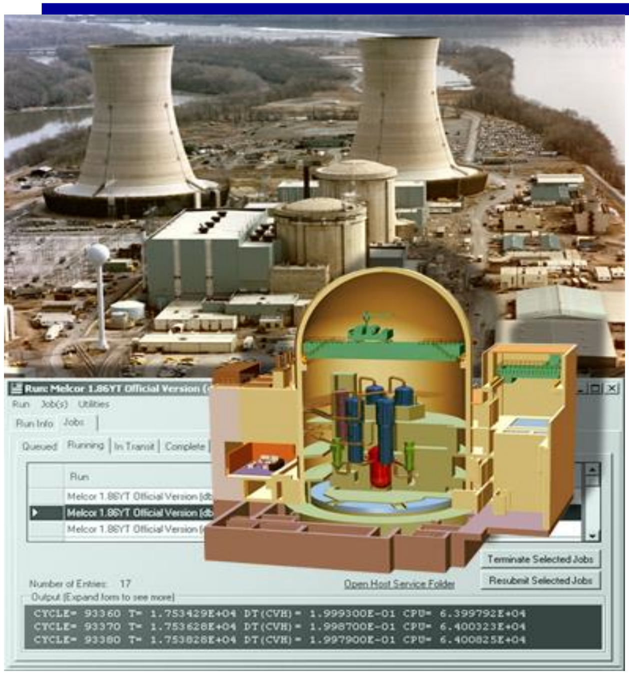

Hygroscopic and Flashing Jet Impaction Models in the RN Package

Presented by

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RN Hygro and Jet Models

- The following topics are discussed
  - –Hygroscopic (Hygro) Model
    - Discussion some functions of the model
    - Nuances that may be overlooked (what else changes when Hygro is on?)
  - –Flashing Jet Impaction Model
    - Flashing, jet expansion, and aerosol deposition

Hygroscopic Model

- Hygro is OFF by default
  - By default, water condensation onto aerosols is a suspension of supersaturation within a control volume
  - Newly created aerosol mass (CVH fog) is dispersed across the existing aerosols distribution, using Mason Equation

- When Hygro is ON
  - RN calculates water vapor condensation/evaporation onto aerosols, not CVH
  - Solute, Kelvin, and Latent Heat effects are considered in condensation/evaporation rate equation, Mason Equation

Hygro – Solute Effect

- Aerosol growth by vapor diffusion is given by the Mason Equation.
- Aerosols are mixtures of soluble and in-soluble material
- Soluble fission products (CsOH, CsI, NaOH, etc.) enhance water adsorption
  - In solution, equilibrium vapor pressure at the surface of a droplet is modified
- A_r is limited by maximum solubility

$$\frac{dr}{dt} = \frac{1}{r}\frac{(S - S_r)}{a + b}$$

$$S_r = A_r \cdot \exp\left(\frac{2M_w\sigma}{RT_\infty \rho_w r}\right)$$

$$A_r = \exp\left[-\sum_i \frac{\nu_i n_i}{n_w}\right]$$

n_s, n_i	=	moles of dissolved solute in wet particle (may be less than total)
n_w	=	moles of water on wet particle
ν_i	=	ionization factor for solute molecule (usually 2).

Pruppacher, H.R. and J.D. Klett, *Microphysics of Clouds and Precipitation*, D. Reidel Publishing Co. Dordrecht, Holland (1980).

Murata K. et.al. CONTAIN Manual 2.0, NUREG/CR-653, SAND97-1735, June 1997.

Hygro – Kelvin Effect

- Kelvin effect account for surface tension increasing water vapor pressure.
- Increasing the surface tension, or reducing the radius of the droplet promote evaporation
- Small droplets may evaporate in saturated environments due to the Kelvin effect

$$\frac{dr}{dt} = \frac{1}{r} \frac{(S - S_r)}{a + b}$$

$$S_r = A_r \cdot \underbrace{\exp\left(\frac{2M_w \sigma}{RT_\infty \rho_w r} \right)}_{\text{KE}}$$

Hygro – Latent Heat Effect

- Surface temperature expression relates heat and mass transfer at the surface
- T(r) is a function of the mass exchange at the surface and conduction rate of the atmosphere
- Surface saturation considers the mass exchange in the temperature evaluation

$$\frac{dq}{dt} = -\Delta h_{fg} \frac{dm}{dt}$$

$$\frac{dq}{dt} = 4\pi rk\left(T_\infty - T(r)\right)$$

$$T(r) = T_\infty + \frac{\rho_d \Delta h_{fg}}{k^*} \frac{rdr}{dt}$$

$$\frac{rdr}{dt} = \frac{D_v M_w}{R\rho}\left(\frac{P_{sat,\infty}}{T_\infty} - \frac{P_{sat,Tr}}{T(r)}\right)$$

$$\frac{rdr}{dt} = \frac{S - Sr}{a + b}$$

$$a = \left(\frac{\Delta h_f^2 M_w \rho_w}{RT_\infty k_a^*}\right)$$

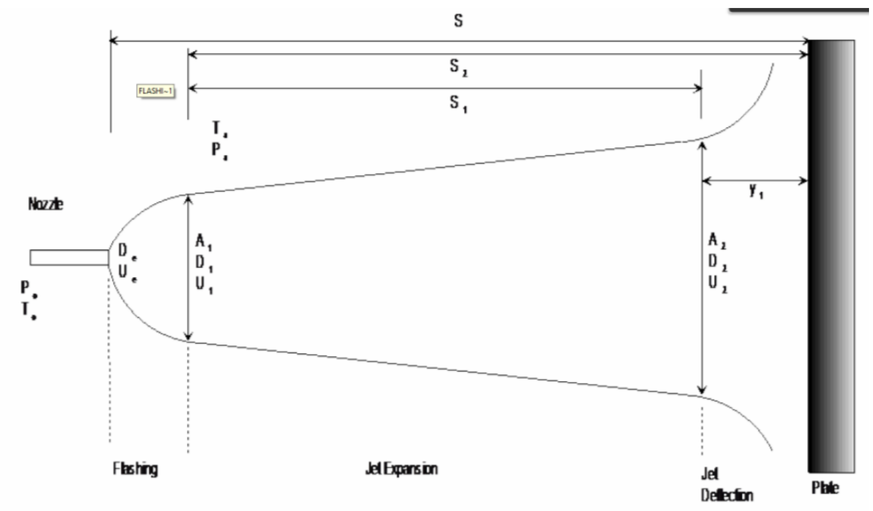
$$b = \left(\frac{RT_\infty \rho_w}{D_v^* M_v p_{sat}(T_\infty)}\right).$$

Hygro – RN Components

- Reminder on RN Components
  - RN Components group RN Classes and share a size distribution
  - If soluble RN Classes are grouped with insoluble Classes within a Component then growth will impact size distributions of insoluble Classes.
  - Water must be assigned to its own Component (and is by default)

Flashing Jet Impaction Model

- Models impingement of flashing water on a plate
  - –Flashing
    - Isenthalpic pressure flashing model
  - –Jet expansion
    - Conservation of mass
  - –Aerosol deposition
    - Cutoff diameter



FJIM – User Input

- The user specifies sufficient information to provide the enthalpy of the entering fluid, area jet of the entrance, the local ambient pressure and density, and the distance to and name of the heat structure.
- Limitations for a given Jet Impaction
  - Only one jet is permissible
  - Only one HS may be identified
  - The definition of the target CV (ambient condition volume) impacts conditions at should be specified appropriately

Jet Impaction – Flashing Model

- User is required to identify the flowpath (FL_FLSH) or water source (WM on CV_SOU) as flashing
- Isenthalpic transformation evaluated from stagnate pressure to the recipient control volume pressure (explicit)

$$f = \frac{h_w - h_f(P)}{h_{fg}(P)}$$

Where,

h_w = *specific enthalpy of the water source*

$h_f(P)$ = *specific sat. enthalpy of liquid in recCV*

$h_{fg}(P)$ = *latent heat of vaporization at recCV*

Flashing Model w/ RN

- Partitioning liquid water between Aerosol and Pool
- w/ RN a Rosin-Rammler distribution greater than the user defined (or default) maximum aerosol size

$$\frac{M(d > d_P)}{M_{Total}} = \exp\left\{ -\left[\Gamma\left(\frac{k-1}{k}\right)\right]^{-k} \left(\frac{d_p}{d_S}\right)^{k} \right\}$$

Where,

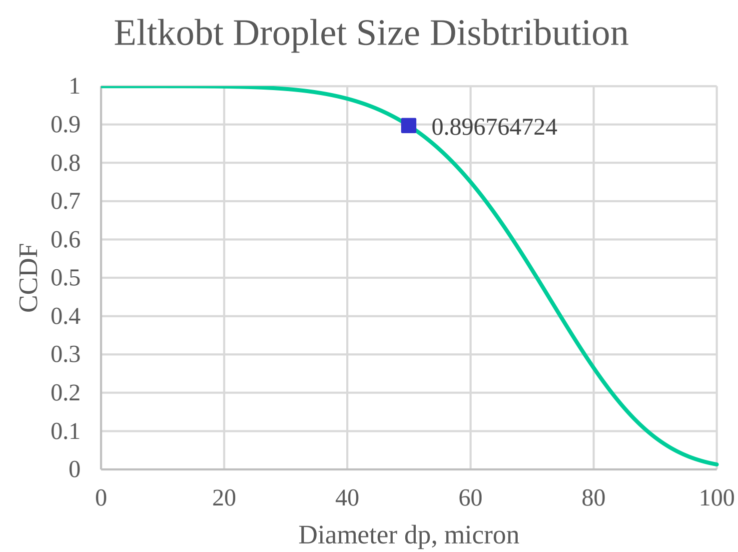
Γ gamma function

d_p is a given particle diameter

M is mass of particles

d_s Sauter mean diameter as 65micron

k is set as 5.32



- At 50micron maximum size aerosol, ~90% of unflashed water is placed into the Pool.

FJIM – Jet Expansion

- Exit conditions, e, are obtained from available FL information $U_e = \frac{G v_e}{A_e}$
- Using the momentum equation

$$U_1 = U_e + (P_e - P_a)\frac{A_e}{G} \qquad A_1 = \frac{G v_m}{U_1}$$

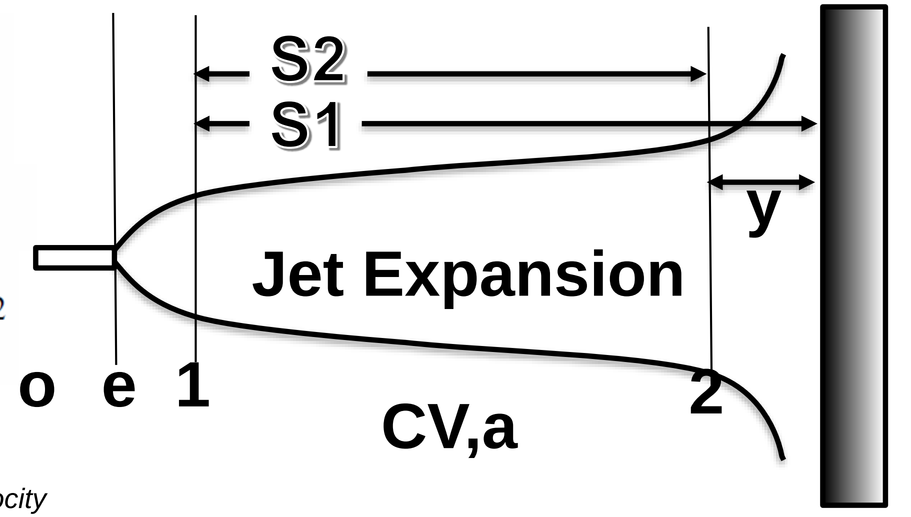
$$\rho_m A_1 U_1^2 = \rho_m A_{2m} U_2^2 + \rho_a (A_2 - A_{2m}) U_2^2$$

$$A_{2m} = A_1 \left\{ -\left(-1 + \frac{\rho_a}{\rho_m}\right) + \left[\left(-1 + \frac{\rho_a}{\rho_m}\right)^2 + 4\left(\frac{A_2}{A_1}\right)\frac{\rho_a}{\rho_m}\right]^{1/2} \right\} / 2$$

$$y_1 / D_1 = 1.2 \quad for \quad S_1 / D_1 < 6.8,$$

$$y_1 / D_1 = 0.153(1 + S_1 / D_1) \quad for \quad S_1 / D_1 > 6.8$$

$$D_2 = D_1\left(1 + \frac{2S_2}{D_1}\tan(10^\circ)\right)$$



U = velocity
G = Mass flow rate
v = sp. density
A = Area
P = Pressure
D = Diameter
S1 = Standoff Distance UserSpc.
S2 = Distance to deflection
y = deflection distance

m = mixture
e = entrance
o = origin
a = ambient conditions
A1 representing only jet
A2m represents only jet
A2 represents entrainment+jet

FJIM – Stokes Cutoff

- Aerosol impaction and removal is determined from a using a stokes cutoff criterion.
- The Jet velocity, U_2, is used to determine the departure from the slip stream leading to impaction

$$St_{m,50\%} = \rho_p d_{p,50\%}^2 U C_u / (9 \mu D_e) = 0.268$$

$d_{p,50\%}$, diameter corresponding to 50% removal efficiency

$St_{m,50\%}$, Stokes number evaluated at $d_{p,50\%}$

C_u, Cunningham factor (size bin dependent)

0.268, represents circular break $St_{m,50\%}$ cutoff

- Fraction of particles greater than $d_{p,50\%}$ are available for capture (<u>Linear?)</u>
- Scaled by min(heat structure area / A_2 , 1.0)

Questions