South Texas Project
Models and Methods Used for CASA Grande

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Overview

- **Required Inputs to CASA Grande**
- **Topical Approach and Implementation Plan**
  - Debris Generation
  - Debris Transport
  - Head Loss
  - Air Intrusion
  - Debris Bypass
- **Interface With PRA**
- **Example Calculations to Illustrate Physics Models**

REQUIRED INPUTS TO CASA GRANDE

Debris Generation

- Containment geometry
- Pipe break (LOCA) frequencies
- ZOI size/shape for plant materials
- Debris characteristics for plant materials
- Qualified coatings quantity for LOCA categories
- Unqualified coatings quantity
- Latent debris quantity
- Miscellaneous debris quantity

Chemical Product Generation

- **None required for initial quantification effort (initially assuming negligible impact for chemical effects)**

Debris Transport

- Blowdown transport fractions for LOCA categories
- Washdown transport fractions for LOCA categories
- Pool fill transport fractions for LOCA categories
- Recirculation transport fractions for LOCA categories
- Fiberglass erosion fractions for non-transporting pieces of debris
- No inputs required for upstream blockage in initial quantification

Head Loss

- Strainer area/geometry
- Flow rate
- ECCS/CS pump NPSH margin

Air Intrusion

- **Vortexing**
  - Flow conditions (water level and flow rate) that would result in vortexing based on prototypical strainer testing (may not be an issue for PCI Sure-Flow design)
- **Gas desorption**
  - Containment pressure
  - Containment pool temperature
  - Strainer submergence depth

Debris Bypass

- **No additional input required for initial quantification effort.**

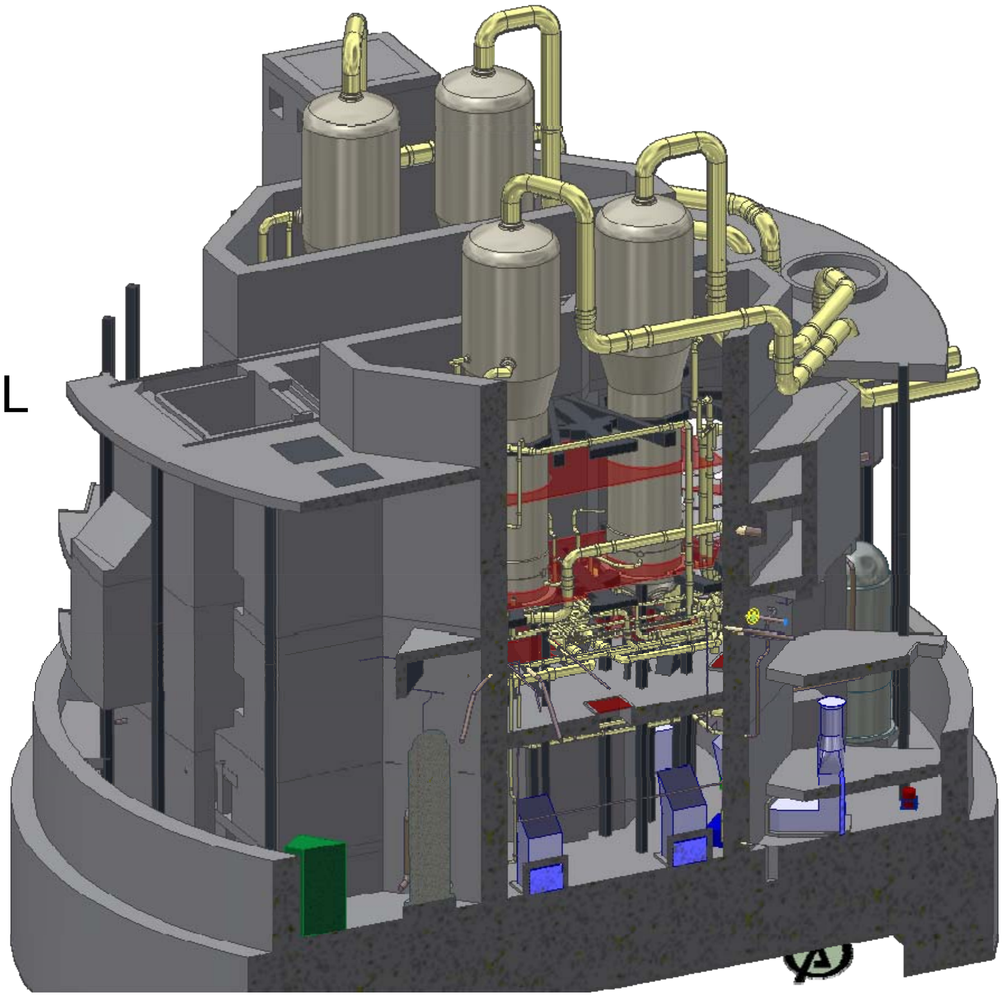
TOPICAL APPROACH AND IMPLEMENTATION PLAN

Debris Generation Calculations

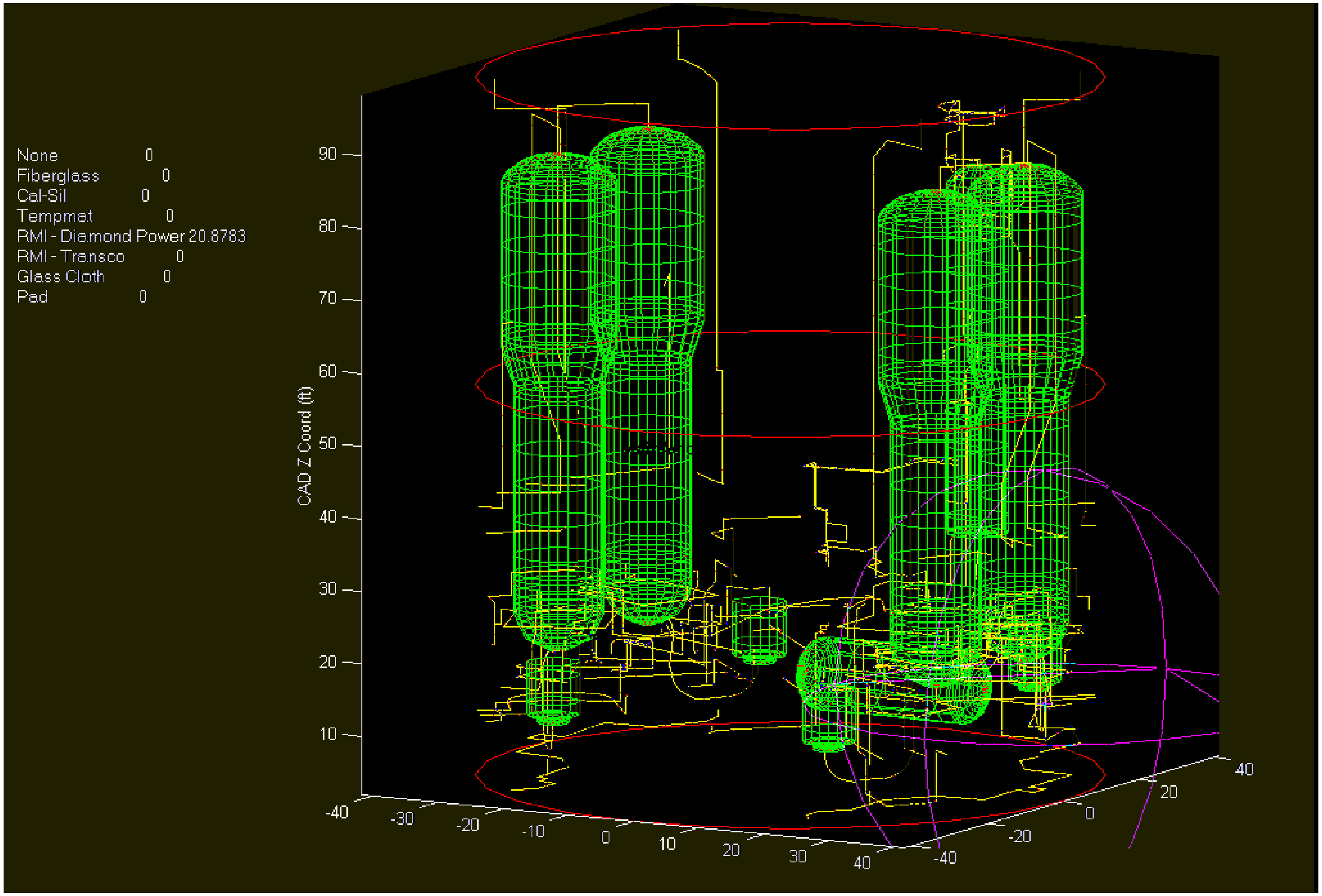
- **CASA Grande will calculate debris quantities generated within given ZOIs for:**
  - Multiple break locations (welds on RCS pipes, wall rupture)
  - Multiple break sizes at each location (2” to DEGB)
  - Multiple jet orientations (if a non-spherical ZOI is used)
  - Each type of insulation material in the vicinity of the break

Input for Containment Geometry

- **Import containment geometry from CAD model**
  - Concrete walls (robust barriers) imported using STL files
  - Piping insulation imported through text files
  - Weld locations imported through text files
  - Equipment insulation recreated using primitive shapes

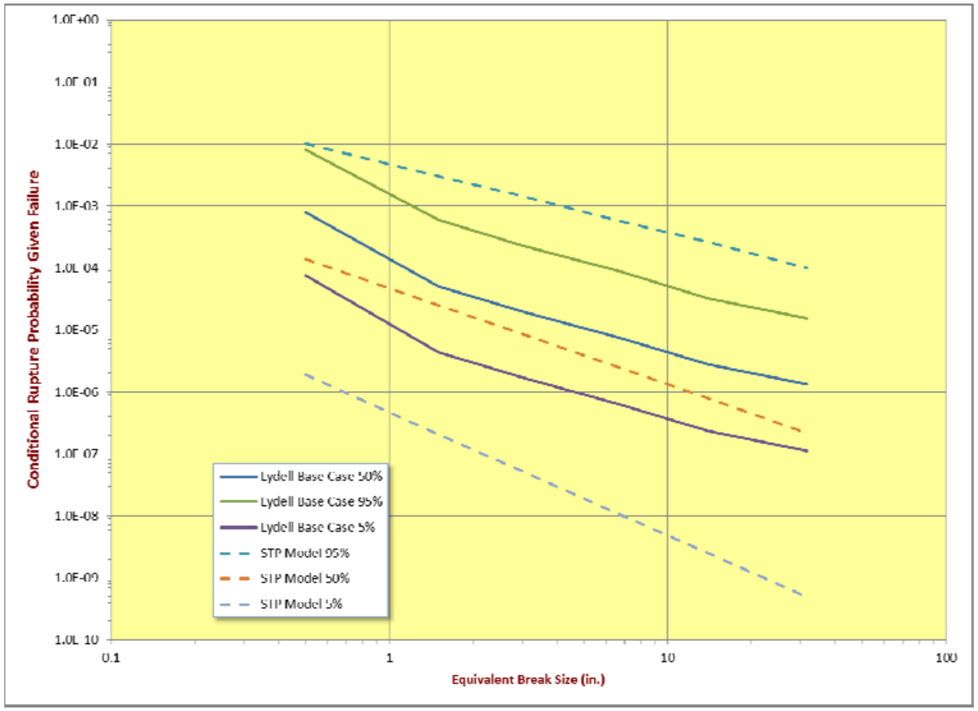


CASA Grande Prototype

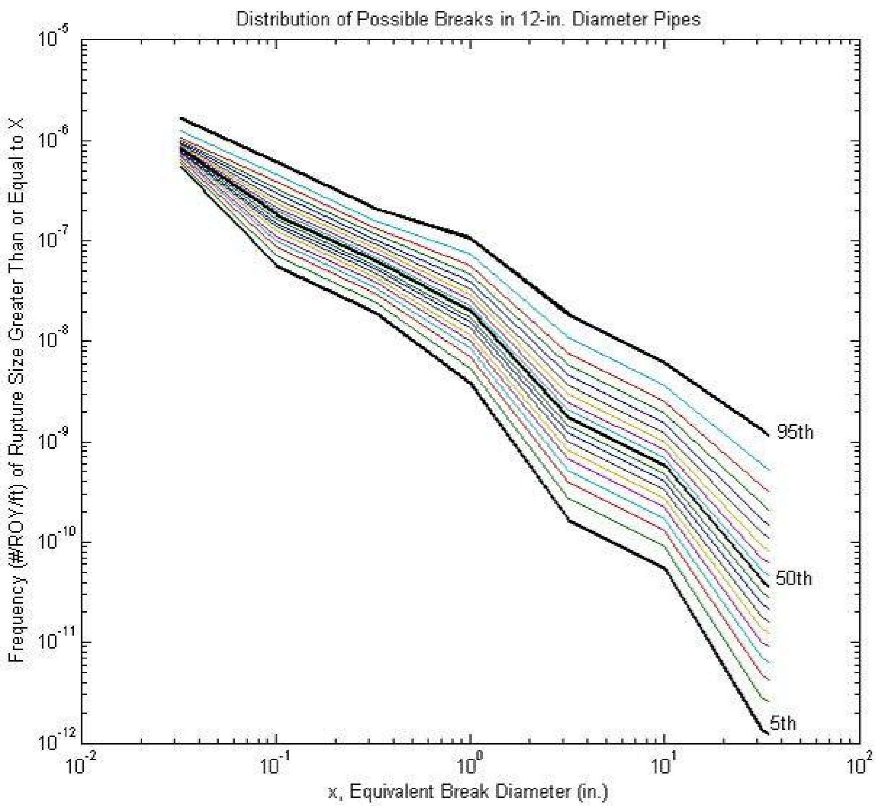


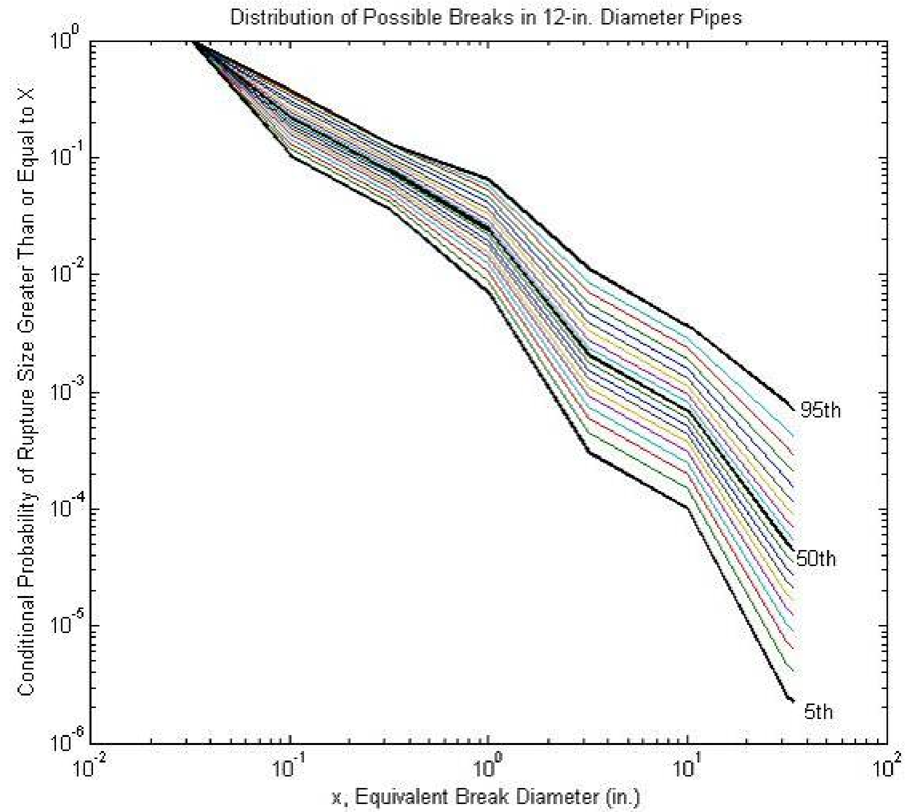
Input for LOCA Frequencies

- **Import LOCA frequency curves for each weld or other potential break location**



Normalized Freq ⇨ Conditional Prob

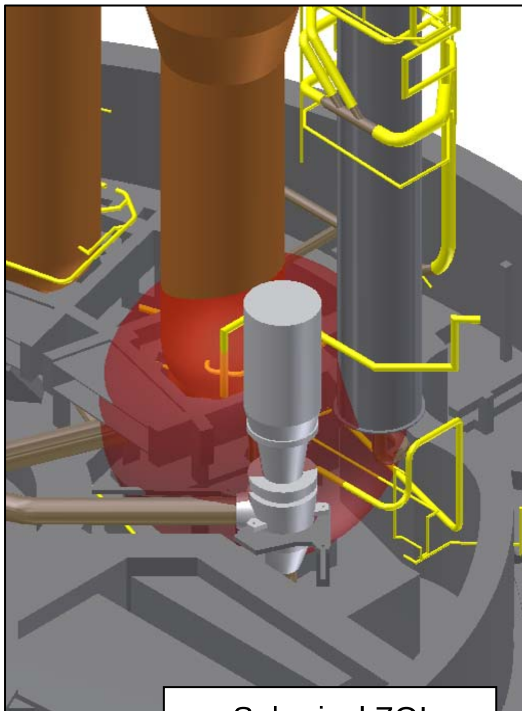




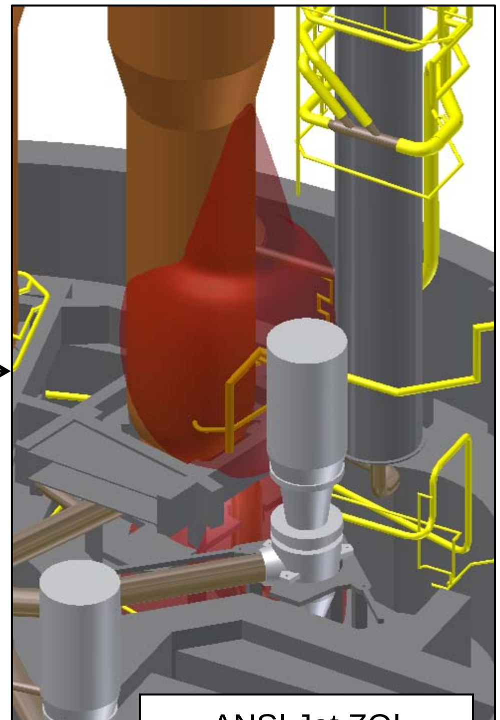
- CASA Grande will *only* sample conditional probabilities
- Epistemic uncertainties on break frequency can be propagated if needed but no further epistemic factors will be segregated

Input for ZOI Sizes and Shapes

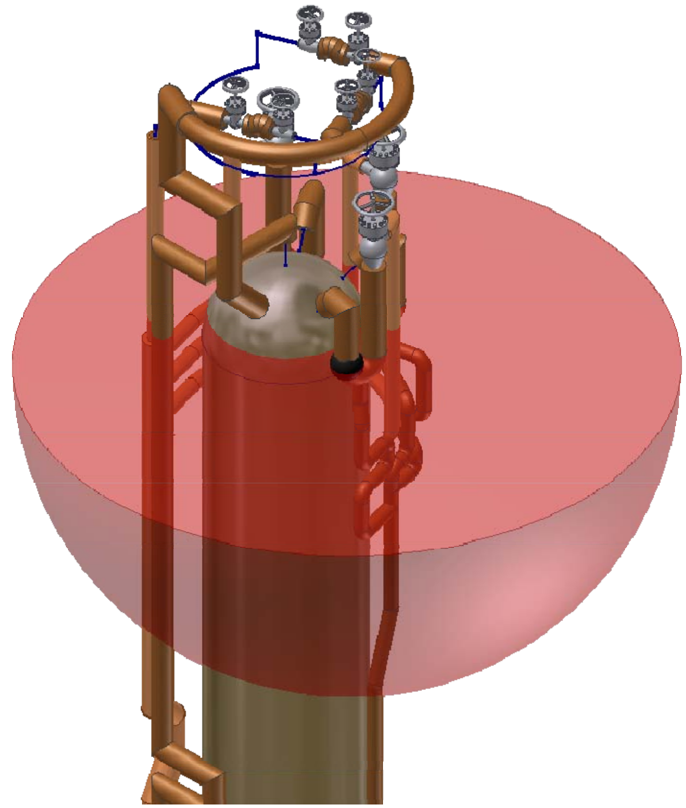
- **Define ZOI size and shape for each insulation material**



Spherical ZOI
Insulation Debris
Volume = 13.4 ft^3

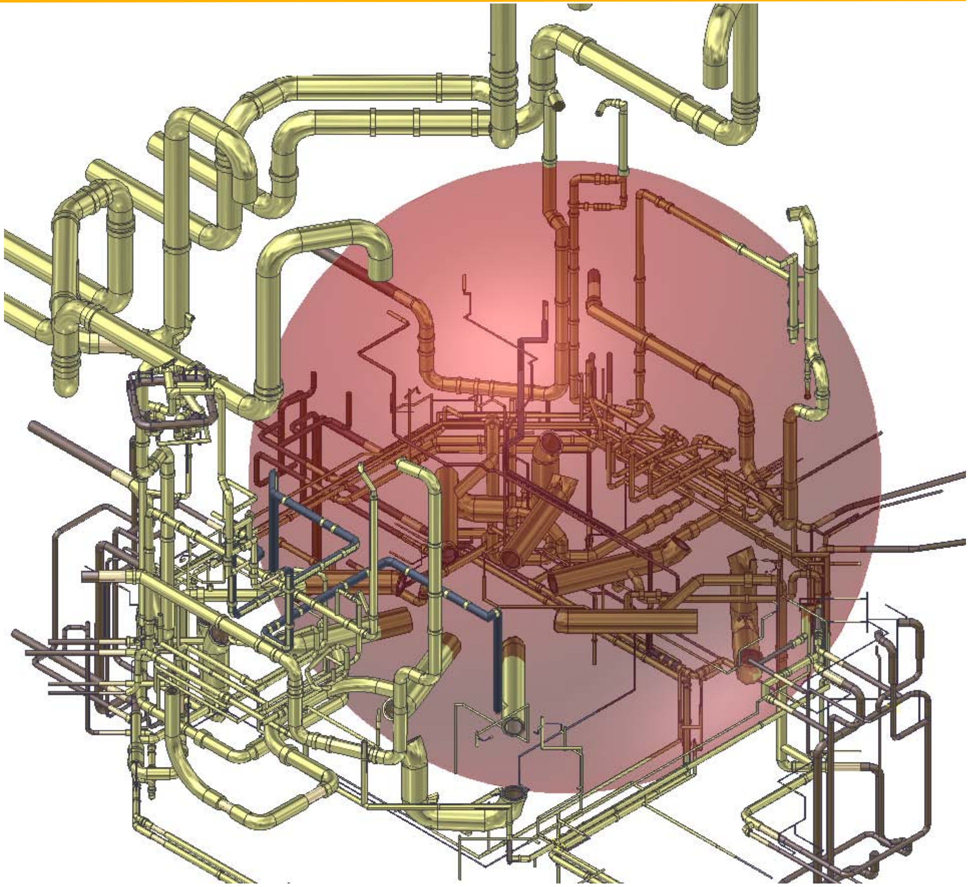


ANSI Jet ZOI
Insulation Debris
Volume = 10.2 ft^3



Implementation Plan for ZOIs

- **Plan for initial quantification effort:**
  - Use standard spherical and hemispherical ZOIs
  - Use standard ZOI sizes (i.e. 17D ZOI for Nukon) scaled to appropriate break sizes
- **Options for 2012 refinements:**
  - Modify ZOI shape using ANSI jet model, results of CFD modeling, etc.
  - Modify ZOI size using PWROG blast testing, more realistic interpretation of AJIT data, CFD modeling, etc.



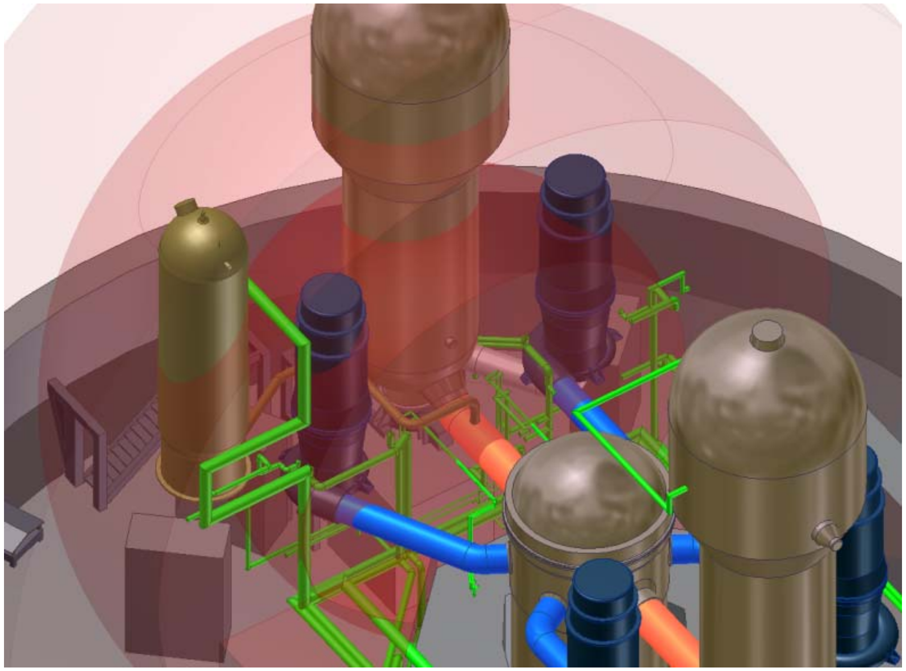
17-D ZOI for 31" DEGB at STP encompasses approximately half of Nukon insulation in SG compartments

Input for Debris Characteristics

- **Input appropriate debris characteristics:**
  - Insulation size distribution (fines, small pieces, large pieces, intact blankets)
  - Coatings size distribution (particulate, chips)
  - Latent debris distribution (fiber, particulate)
  - Bulk and material densities for debris
  - Characteristic size of fine material

Implementation Plan for Characteristics

- **Plan for initial quantification effort:**
  - Use NEI 04-07 baseline size distribution (fines and large)
  - Assume all unqualified coatings fail as 10 micron particulate
  - Use standard NEI 04-07 guidance for size and density
- **Options for 2012 refinements:**
  - Alion refined size distribution (fines, small, large, and intact)
  - Partial unqualified coatings failure based on EPRI report
  - Unqualified epoxy fails as chips based on CPSES report



Proprietary Alion debris size distribution methodology is used to determine quantity of fines, small pieces, large pieces, and intact blankets based on distance of insulation from the break

Input for Unqualified Coatings

- **Input unqualified coatings debris quantity:**
  - Total quantity of 3,366 lb_m based on STP unqualified coatings logs
  - Epoxy, IOZ, phenolic, alkyd, baked enamel

Generic example of unqualified coatings debris following a DBA test

Input for Qualified Coatings

- **Input qualified coatings debris quantity for bounding LBLOCA:**
  - Total quantity of 586 lb_m based on STP debris generation calculation
  - Epoxy, IOZ, Polyamide Primer
- **Options for 2012 refinements:**
  - Calculate bounding coatings quantities for various LOCA categories (i.e. large, medium, and small breaks)

Blast testing of qualified coatings system

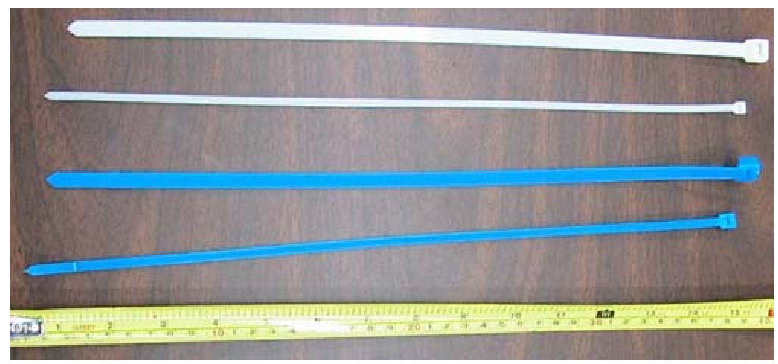
Input for Latent Debris

- **Input latent debris quantity:**
  - Total quantity of 200 lb_m based on STP debris generation calculation (latent debris survey showed 152 lb_m)
  - 85% dirt/dust, 15% fiber

Generic example of latent debris collected from containment

Input for Miscellaneous Debris

- **Input miscellaneous debris quantity:**
  - Total assumed quantity of 100 ft^2 based on assumption in STP debris generation calculation
  - labels, tags, plastic signs, tie wraps
- **Options for 2012 refinements:**
  - Evaluate transport potential for miscellaneous debris based on existing test data.



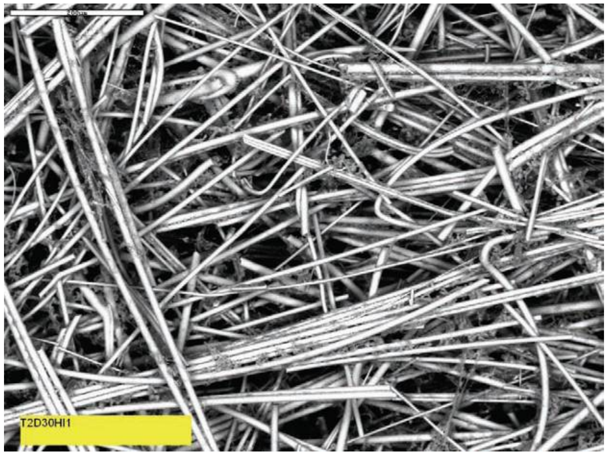
Generic examples of labels and tie wraps

Chemical Product Generation Calculations

- **If necessary, CASA Grande will automatically calculate chemical debris quantities generated based on:**
  - Quantity of fiberglass debris in containment pool
  - Quantity of aluminum or other chemically reactive materials exposed to sprays or submerged in the pool
  - Buffer type and time dependent pH in containment pool
  - Time dependent temperature in containment pool
  - Containment spray duration

Input for Chemical Products

- Plan for initial quantification effort:
  - Assume negligible impact from chemical effects for STP based on initial review of applicable ICET results
- Options for 2012 refinements:
  - Implement WCAP-16530 method if it is determined not to be overly conservative for STP
  - Implement alternative method depending on approach used to account for chemical effects on the debris bed head loss

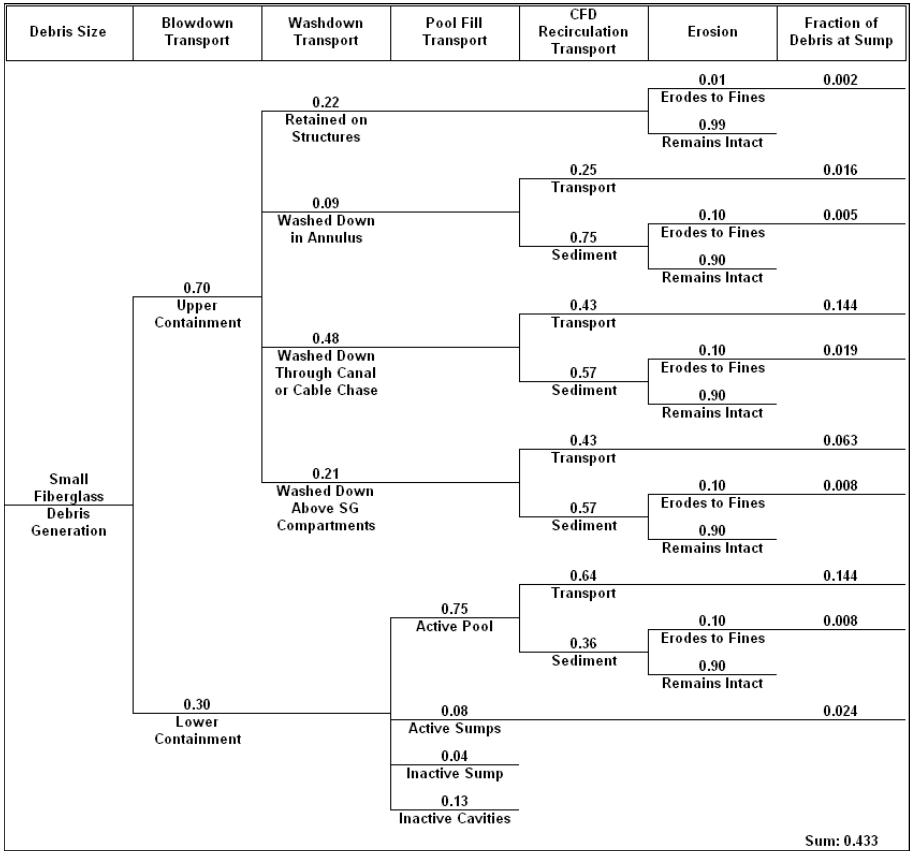


SEM photo from ICET Test #2 (TSP with Fiberglass)

Example of chemical "goo" produced using WCAP-16530 recipe for STP test

Debris Transport Calculations

- **CASA Grande will use logic trees to calculate debris transport fractions with branches for:**
  - Blowdown transport
  - Washdown transport
  - Pool-fill transport
  - Recirculation transport
  - Erosion

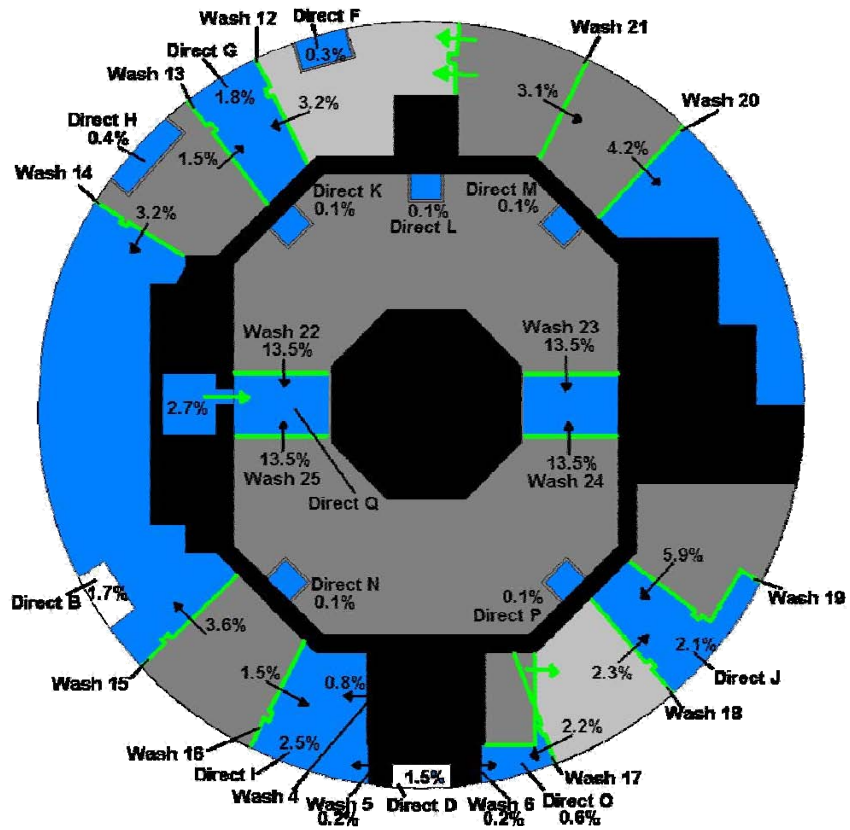


Implementation Plan for Blowdown

- **Plan for initial quantification effort:**
  - Assume 100% of fine/small debris blown to pool
  - Assume large pieces retained on grating based on STP debris transport calculation
- **Options for 2012 refinements:**
  - Incorporate methods used in STP debris transport calculation for LOCA categories
  - Refine blowdown calculations based on drywell debris transport study (DDTS) and other methods

Implementation Plan for Washdown

- **Plan for initial quantification effort:**
  - Assume 100% of fine/small debris washed to pool
  - Assume large pieces retained on grating based on STP debris transport calculation
- **Options for 2012 refinements:**
  - Incorporate methods used in STP debris transport calculation for LOCA categories
  - Refine washdown calculations based on drywell debris transport study (DDTS) and other methods

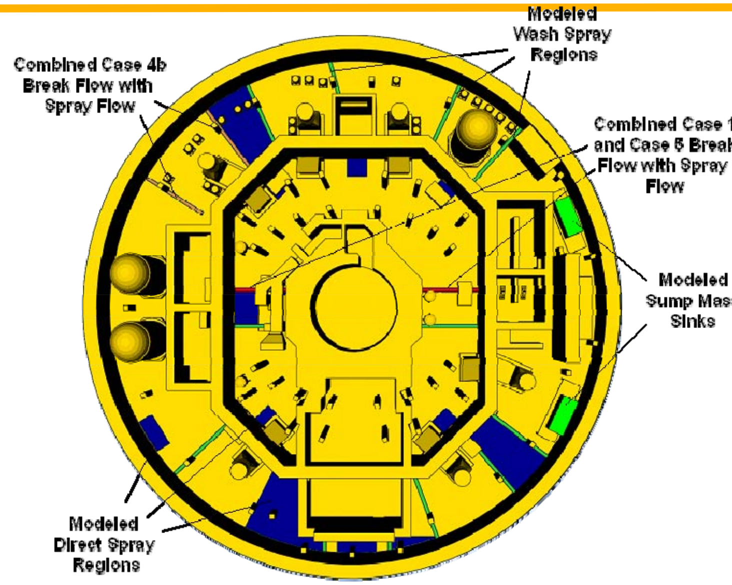


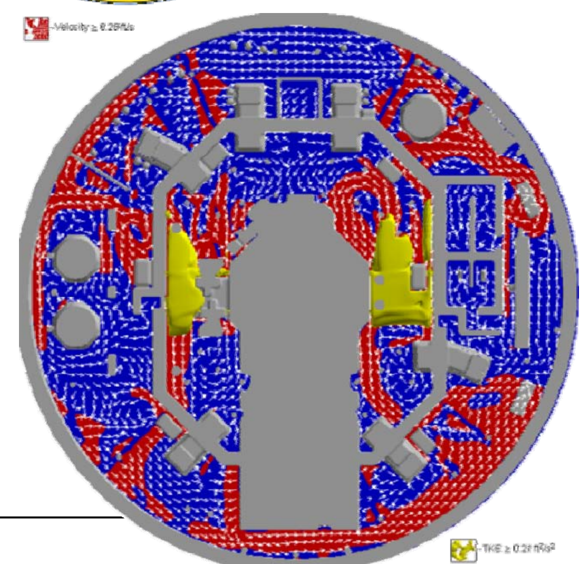
Implementation Plan for Pool-Fill

- **Plan for initial quantification effort:**
  - Assume 100% of small debris remains in active pool
  - Assume fine debris transports with flow (small amount transported to strainer and inactive regions)
- **Options for 2012 refinements:**
  - Perform CFD analysis to more accurately quantify pool-fill transport for small pieces of debris

Implementation Plan for Recirculation

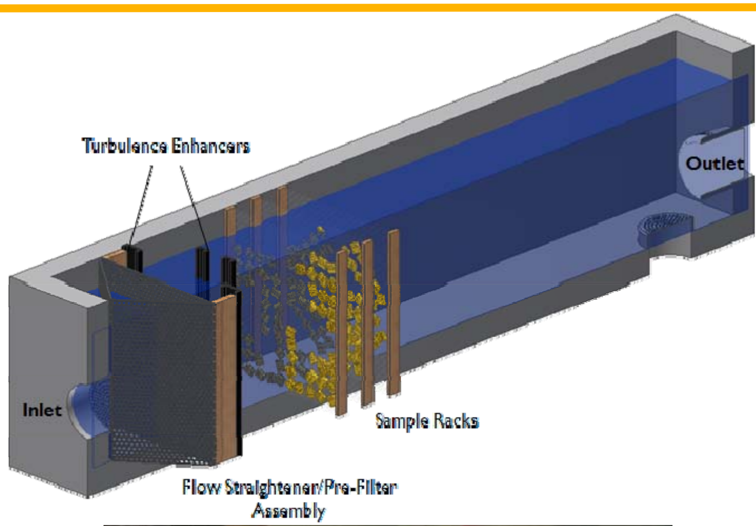
- **Plan for initial quantification effort:**
  - Assume 100% transport of debris in active recirculation pool
- **Options for 2012 refinements:**
  - Incorporate methods used in STP debris transport calculation for LOCA categories
  - Perform additional CFD runs to address realistic flow conditions (water level and flow rate)
  - Modify assumed debris distribution
  - Modify conservative transport metrics
  - Incorporate time dependence in the transport analysis

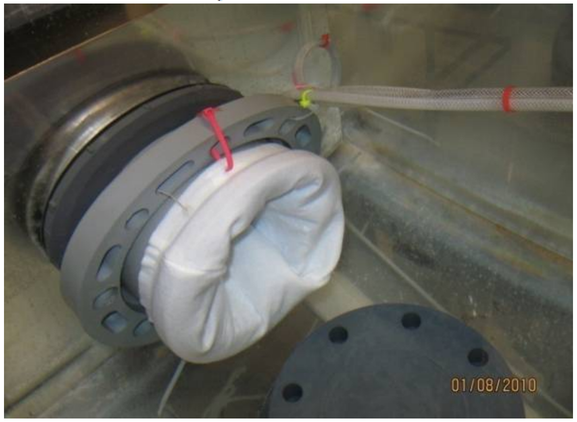




Implementation Plan for Erosion

- **Plan for initial quantification effort:**
  - Assume 1% spray erosion for small and large fiberglass debris held up on gratings above containment pool
  - Erosion for non-transporting small fiberglass debris in pool is N/A since this debris is all assumed to transport
- **Options for 2012 refinements:**
  - Apply proprietary Alion erosion test results for realistic recirculation pool erosion fraction

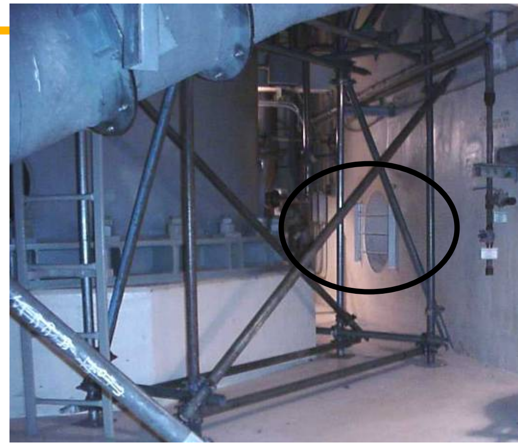




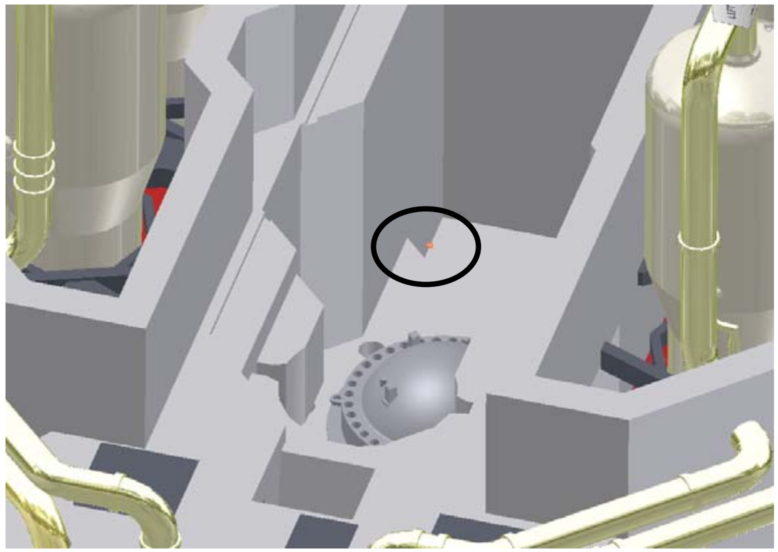
Setup for Alion fiberglass erosion test with filter in flume suction pipe

Implementation Plan for Upstream Blockage

- **Plan for initial quantification effort:**
  - Assume negligible based on STP debris transport calculation
- **Options for 2012 refinements:**
  - Further evaluate potential for upstream blockage including blockage associated with a reactor nozzle break and any uncertainties associated with the current analysis



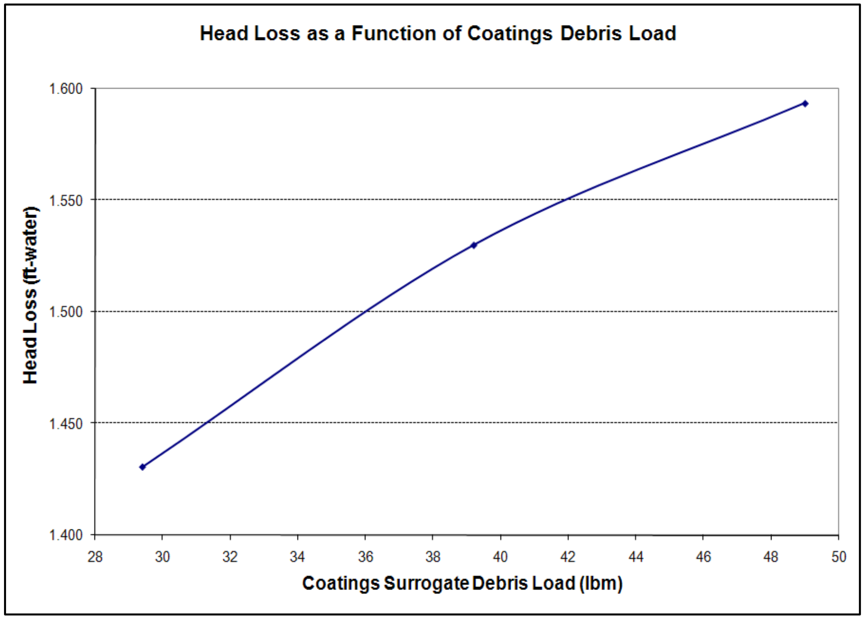
One of the four 30 inch vent holes in STP secondary shield wall



One of the two 6 inch drains in STP refueling canal

Head Loss Calculations

- **CASA Grande will use a correlation to determine head loss over the range of relevant conditions:**
  - Strainer geometry
  - Debris loads
    - Fiber
    - Particulate
    - Microporous
    - Chemical
  - Flow rate
  - Temperature
  - NPSH margin



Implementation Plan for Head Loss Correlation

- **Plan for initial quantification effort:**
  - Use NUREG/CR-6224 correlation for fiberglass, particulate, and chips
  - Assume microporous debris (minimal at STP) behaves similar to other particulate
  - Assume chemical debris has negligible impact on head loss
  - Assume uniform debris deposition and flow through strainer
  - Calculate time dependent head loss
- **Options for 2012 refinements:**
  - Perform tests to validate and/or refine head loss correlation for STP:
    - Perform tank testing to determine head loss reduction from non-uniform deposition on a complex geometry strainer, etc.
    - Perform vertical loop testing to determine head loss characteristics for Microtherm, WCAP-16530 chemical debris surrogate, etc.
    - Perform integrated chemical effects tests to more accurately quantify chemical effects
    - Develop a bump-up factor or correlation to account for chemical debris

NUREG/CR-6224 Correlation

- **NUREG/CR-6224 correlation was developed based on flat plate vertical loop head loss testing with Nukon, iron oxide sludge, and paint chips:**

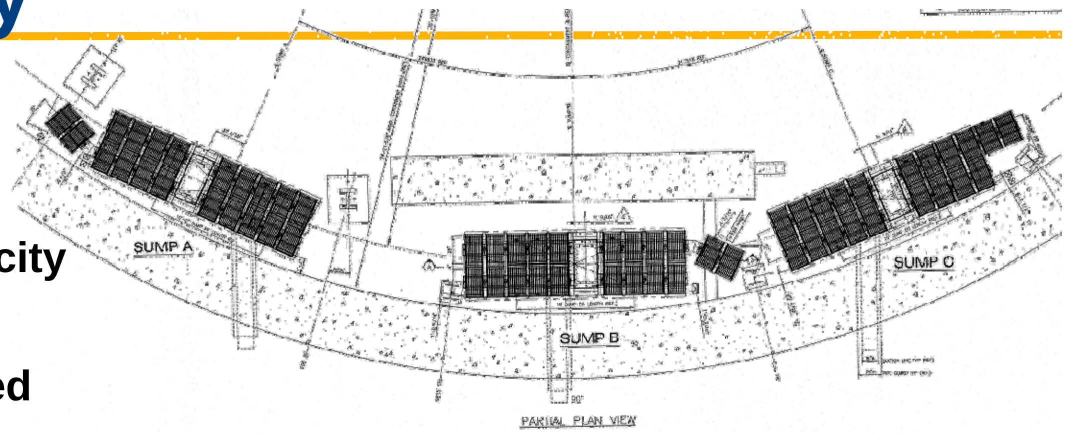
$$\Delta H = \Lambda \left[3.5 S_V^2 \alpha_m^{1.5} \left(1 + 57 \alpha_m^3\right) \mu U + 0.66 S_V \frac{\alpha_m}{(1 - \alpha_m)} \rho U^2 \right] \Delta L_m$$

Where:

ΔH = head loss (ft-water)
S_v = surface-to-volume ratio of the debris (ft^2/ft^3)
μ = dynamic viscosity of water (lbm/ft/sec)
U = fluid approach velocity (ft/sec)
ρ = density of water (lbm/ft^3)
α_m = mixed debris bed solidity (one minus the porosity)
ΔL_m = actual mixed debris bed thickness (in)
$\Lambda = 4.1528 \times 10^{-5}$ (ft-water/in)/($lbm/ft^2/sec^2$); conversion factor for English units

Strainer Geometry

- Input strainer area and gap dimensions based on strainer drawings
- Calculate average approach velocity based on total strainer area
- Calculate interstitial volume based on gap dimensions
- Calculate increased approach velocity for large debris loads based on circumscribed strainer area



Photos and layout of STP PCI strainer

Strainer Dimensions

- Strainer area (per train) = 1,818.5 ft^2
- Circumscribed area (per train) = 419.0 ft^2
- Interstitial Volume (per train) = 81.8 ft^3

Photos of STP PCI strainer

Strainer Debris Loads

- **Use debris generation and transport calculations for quantity and characteristics of debris on strainer for each postulated break at STP:**
  - Fiberglass
  - Coatings particulate/chips
  - Microtherm
  - Dirt/dust
  - Miscellaneous debris
  - Chemical debris

STP head loss test with fiber and particulate debris

Flow Rate and Temperature

- **Input total flow rate through each ECCS strainer for the specific case analyzed (maximum of 7,020 gpm per train at STP based on 1,620 gpm per HHSI pump, 2,800 gpm per LHSI pump, and 2,600 gpm per CS pump)**
- **Calculate debris accumulation on each strainer based on relative flow split**
- **Input pool temperature to determine fluid density and viscosity**

NPSH Margin

- **Input NPSH margin for each safety injection and containment spray pump**
- **Compare calculated debris bed head loss to the pump NPSH margin to determine whether the pump would fail**
- **NPSH Required**
  - LHSI Pumps = 16.5 ft
  - HHSI Pumps = 16.1 ft
  - CS Pumps = 16.4 ft
- **NPSH Available (excluding clean strainer and debris losses)**
  - Start of Recirculation (267 ˚F) = 22 ft
  - 24 hours (171 ˚F) = 42 ft
  - 30 days (128 ˚F) = 51 ft

Time Dependence

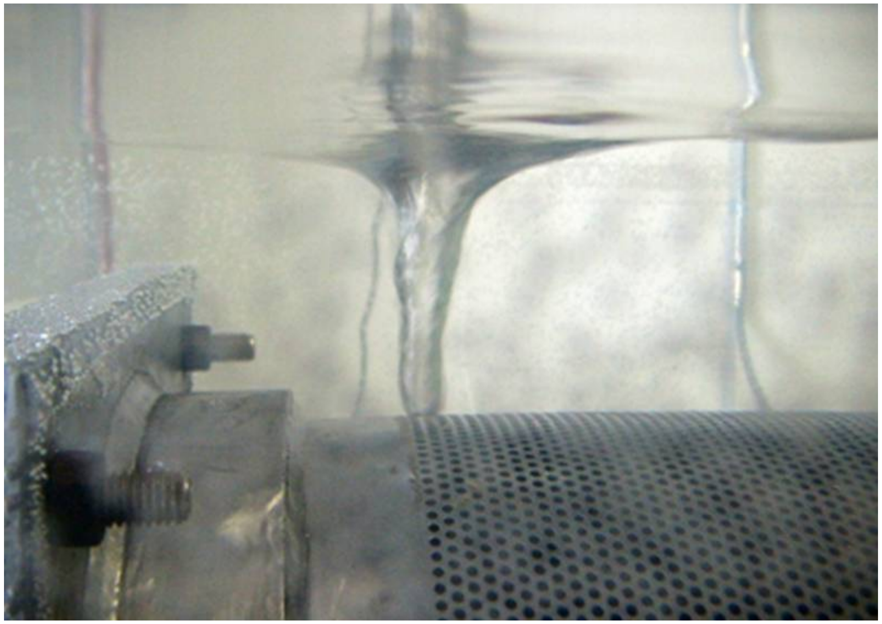
- **A number of parameters used to determine ECCS strainer head loss are time dependent:**
  - Unqualified coatings failure
  - Chemical product generation
  - Debris transport and accumulation
  - Total ECCS sump flow rate
  - Pool temperature
- **Due to changes in pool temperature, NPSH margin is also time dependent**
- **Some aspects of time dependence will be factored into CASA Grande to avoid over-conservatisms**

Air Intrusion Calculations

- **CASA Grande will use test results and correlations to determine conditions that result in vortexing and gas desorption, along with the corresponding void fractions**
- **Froude numbers will be calculated to determine whether gas bubbles would accumulate or be drawn into sump suction piping**
- **Void fractions will be evaluated to determine:**
  - Potential for gas binding of ECCS pumps
  - Effect of void fraction on NPSH
  - Reduced efficiency of pumps, heat exchangers, etc. due to void fraction and resulting effects on system performance

Vortexing

- **Air intrusion due to vortexing is not an issue for STP since strainer design and configuration (under bounding water level and flow rate conditions) preclude vortex formation**



Generic strainer vortex test

Gas Desorption

- **Gas desorption void fractions will be calculated based on the strainer head loss, pool temperature, strainer submergence, and containment pressure based on Henry's Law**

$$C_G = K_G(T) \cdot P_G$$

Where

C_G = Saturation concentration of air

K_G = Henry's constant for air at a given temperature

T = Temperature

P_G = Partial pressure of air

Debris Bypass Calculations

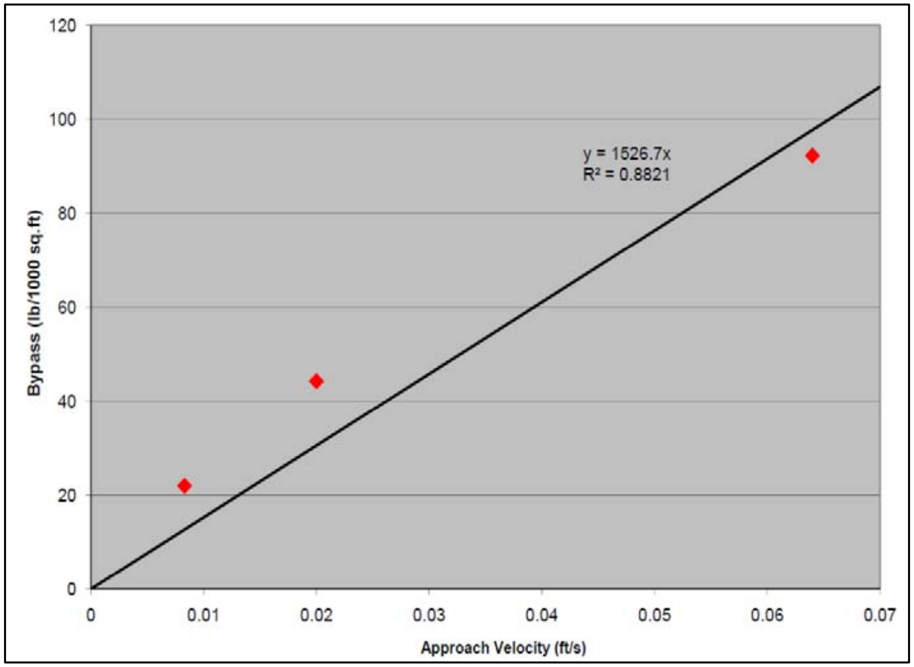
- **CASA Grande will calculate debris bypass quantities based on test data and flow conditions**
- **The bypass debris quantities will be an output of CASA Grande used as an input for downstream effects calculations**

Implementation Plan for Bypass

- **Plan for initial quantification effort:**
  - Use correlation of fiber bypass vs. flow rate developed by Gil Zigler :

    $BP_{\mathbf{total}}$ (g) = 1.538 * Q (gpm)

- **Options for 2012 refinements:**
  - Conduct bypass testing to evaluate bypass over the range of flow and debris load conditions for STP



INTERFACE TO PRA

CASA Interface to PRA

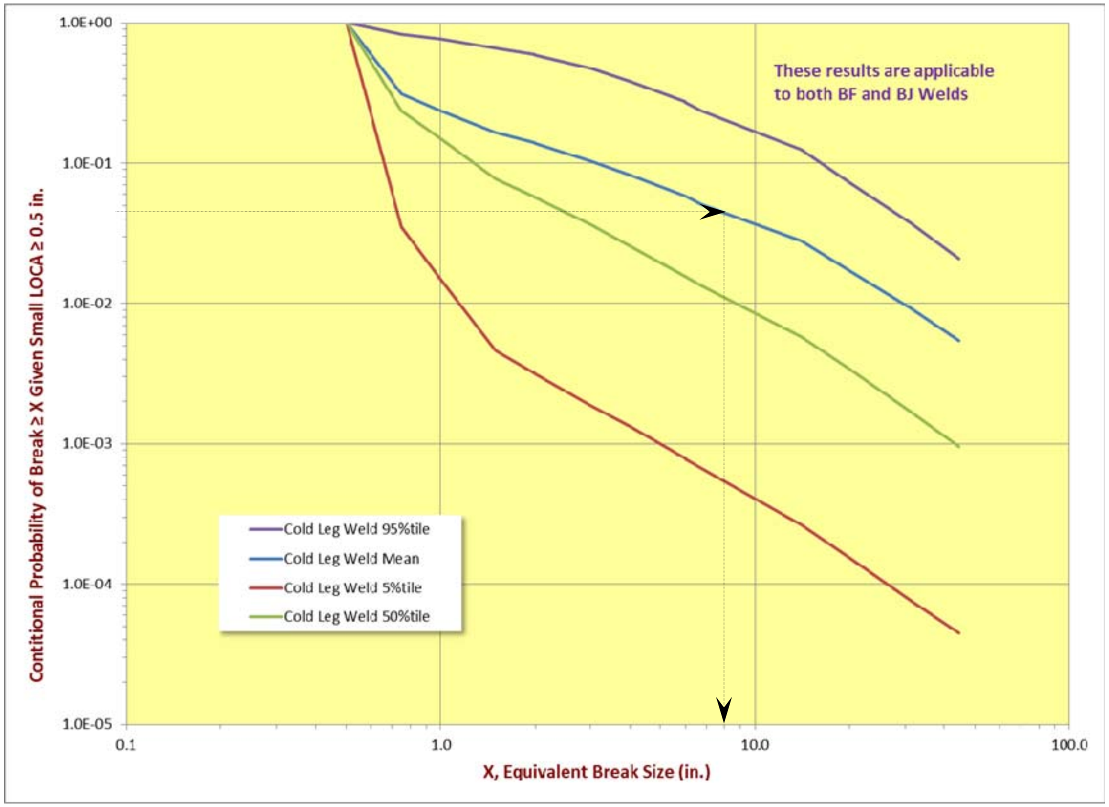
- **Separate results will be compiled for each standard LOCA size (small, medium, large)**
  - Breaks below 2” diam will be assigned zero impact in the PRA
  - All rupture opening sizes will be examined before binning
  - Containment histories computed for conservative representatives of each size
- **Conditional probabilities will be utilized to avoid confusion with PRA time-rate frequency assignments**
- **Alternative sump configurations will be assessed to match mechanical failure branches**
  - Later basis for possible operator mitigative action

EXAMPLE CALCULATIONS TO ILLUSTRATE PHYSICS MODELS

Break Frequencies for Cold Leg Welds

Location		Anywhere in Plant	Each BF in Cold Leg	Each BJ in Cold Leg
Probability SLOCA at Specific Location		1	3.55E-05	6.56E-07
Cumulative Conditional Rupture Probability Given at Least a 0.5in. Break	0.5	1.00E+00	3.55E-05	6.56E-07
	0.8	3.10E-01	1.10E-05	2.03E-07
	1.0	2.37E-01	8.40E-06	1.55E-07
	1.5	1.65E-01	5.85E-06	1.08E-07
	1.99	1.39E-01	4.95E-06	9.13E-08
	2.0	1.38E-01	4.91E-06	9.07E-08
	3.0	1.04E-01	3.69E-06	6.81E-08
	4.0	8.17E-02	2.90E-06	5.36E-08
	5.99	5.80E-02	2.06E-06	3.80E-08
	6.0	5.80E-02	2.06E-06	3.80E-08
	6.8	5.07E-02	1.80E-06	3.33E-08
	14.0	2.79E-02	9.91E-07	1.83E-08
	20.0	1.71E-02	6.06E-07	1.12E-08
	31.5	9.18E-03	3.26E-07	6.02E-09
	44.5	5.40E-03	1.92E-07	3.54E-09

Based on total SLOCA Frequency of 2.04E-3 from NUREG/CR-6928
Excludes SGTR



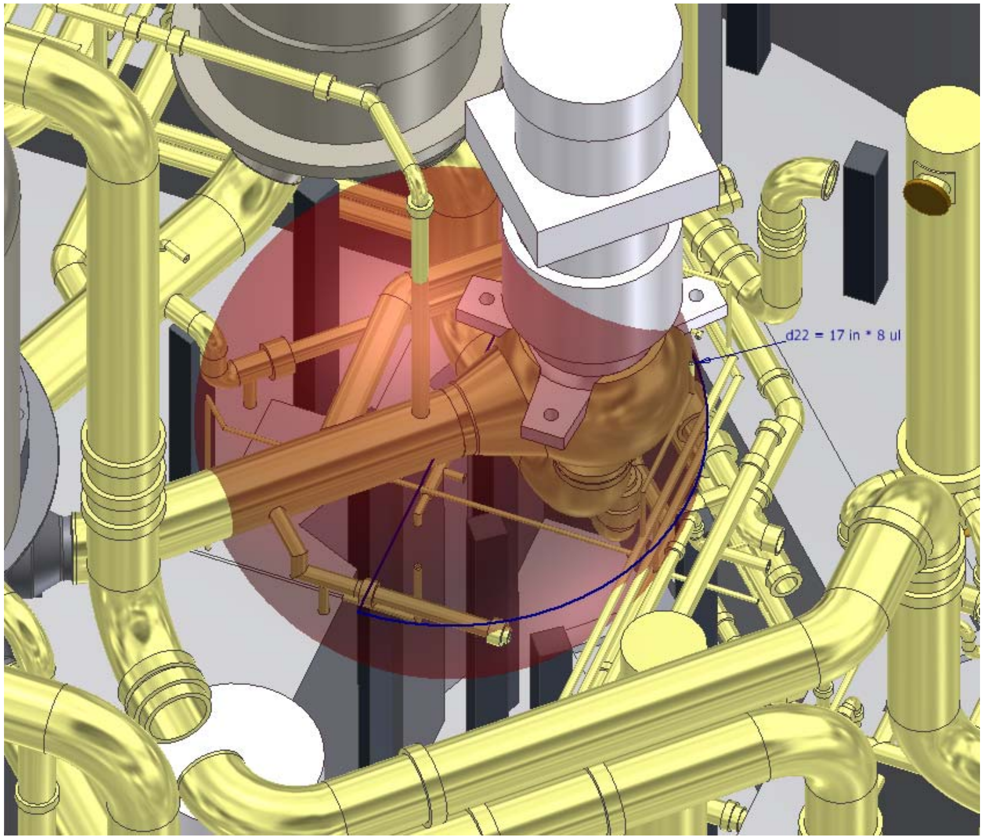
Example Break Case

- Cold leg break at BF weld next to RCP
- Break size equivalent to an 8 inch pipe break (i.e. an 8 inch hole in the side of the cold leg)
- 17D Spherical ZOI for Nukon*
- 28.6D Spherical ZOI for Microtherm*

*Since the break would result in a single sided jet (rather than two jets from a double ended guillotine break), the ZOI would be half the volume of the spherical ZOIs and could be modeled as a hemisphere per the NEI 04-07 guidance. To simplify the analysis, however, this example calculation conservatively uses the spherical ZOI.

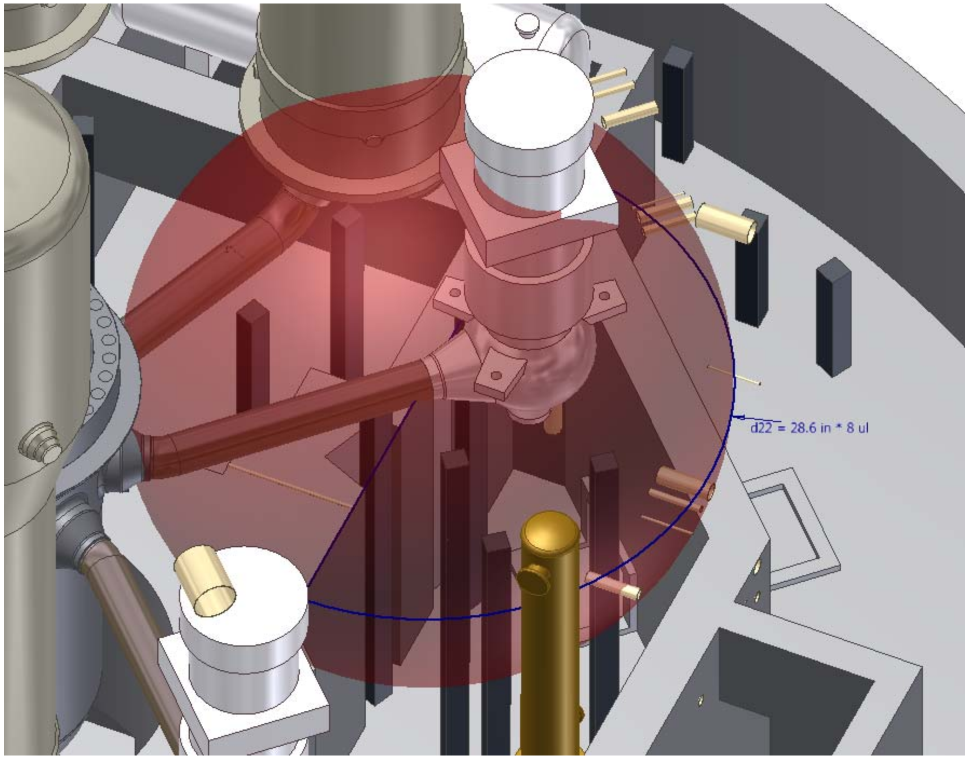
Nukon Debris Generation

- **17D ZOI x 8 inch diameter break = 11.3 ft radius sphere**
- **Quantity of Nukon = 141.0 ft^3**
- **Fines (7 μm diameter) = 0.60 * 141.0 ft^3 = 84.6 ft^3**
- **Large (>4 inch pieces) = 0.40 * 141.0 ft^3 = 56.4 ft^3**
- **Density**
  - Bulk = 2.4 lb_m/ft^3
  - Material = 175 lb_m/ft^3



Microtherm Debris Generation

- **28.6D ZOI x 8 inch diameter break = 19.1 ft radius sphere**
- **Volume = 1.2 ft^3 = 18 lb_m**
- **Bulk Density = 15 lb_m/ft^3**
- **Mass = 1.2 ft^3 * 15 lb_m/ft^3 = 18 lb_m**
- **Fines = 1.00 * 18 lb_m = 18 lb_m**
- **Microtherm Distribution**
  - 3% fiber = 6 µm diameter, 165 lb_m/ft^3
  - 58% SiO_2 = 20 µm, 137 lb_m/ft^3
  - 39% TiO_2 = 2.5 µm, 262 lb_m/ft^3



Coatings Debris Generation

- **586 lb_m qualified coatings debris for bounding LBLOCA from STP debris generation calculation (based on 5D ZOI):**
  - 33 lb_m epoxy = 10 μm, 94 lb_m/ft^3
  - 553 lb_m IOZ= 10 μm, 457 lb_m/ft^3
- **3,366 lb_m unqualified coatings debris from STP debris generation calculation:**
  - 247 lb_m alkyd = 10 μm, 97-195 lb_m/ft^3
  - 843 lb_m IOZ = 10 μm, 97-256 lb_m/ft^3
  - 268 lb_m baked enamel = 10 μm, 82-187 lb_m/ft^3
  - 294 lb_m epoxy dispersed through containment = chips*, 75-118 lb_m/ft^3
  - 1,714 lb_m epoxy in reactor cavity = chips*, 130-140 lb_m/ft^3

*Epoxy chips will be assumed to be 10 μm particulate for initial quantification

Latent and Misc. Debris Generation

- **200 lb_m latent debris from STP debris generation calculation:**
  - 170 lb_m dirt/dust = 17.3 μm, 169 lb_m/ft^3
  - 12.5 ft^3 fiber = 7 μm diameter, 175 lb_m/ft^3
- **100 ft^2 miscellaneous debris from STP debris generation calculation**

Blowdown and Washdown Transport

- **100% blowdown and/or washdown transport to pool at t = 0 hours assumed for following debris:**
  - Nukon fines
  - Microtherm
  - Qualified coatings
  - Latent debris
- **Large pieces of Nukon retained on grating in SG compartments or upper containment; erosion fines assumed to reach the pool at t = 24 hours**
- **Unqualified coatings in reactor cavity would not transport**
- **Other unqualified coatings assumed to fail and reach containment pool at t = 24 hours**
- **Miscellaneous debris assumed to reach strainer at t = 0 hours**

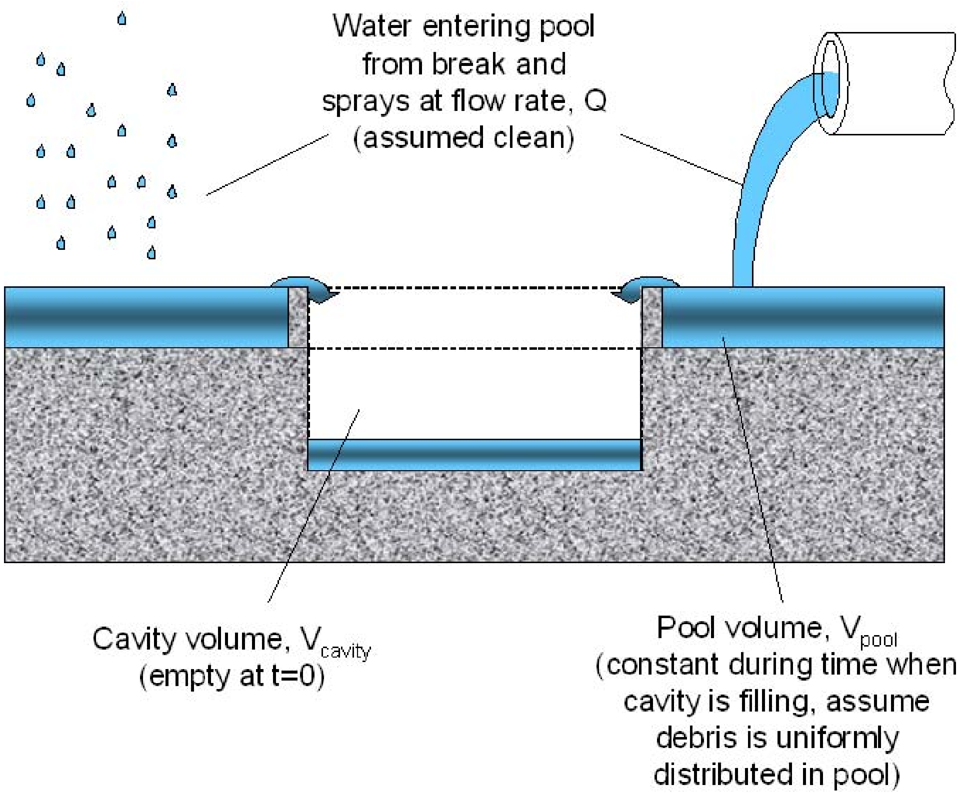
Pool Fill Transport

$$x(t) = x_i e^{-t \cdot (Q / V_{pool})}$$

Where

- $x(t)$ = Time dependent concentration of debris in pool
- x_i = initial concentration of debris in pool
- t = time
- Q = Flow Rate
- V_{pool} = Pool Volume

$$F_{fill-up} = 1 - e^{-\frac{V_{Cavity}}{V_{Pool}}}$$



Pool Fill Transport, Cont.

- **Pool volume inside secondary shield wall at 18 inch depth = 5,046 ft³**
- **Cavity volume for each sump = 240 ft³**
- **Inactive cavity volume (containment sump and elevator pit) = 749 ft³**

$$F_{fill-up(ECCS\,Sump\,Cavity)} = 1 - e^{-\frac{3 \cdot 240\,ft^3 + 749\,ft^3}{5{,}046\,ft^3}} = 0.25$$

- **Split proportional to volumes:**
  - 8% to two active sumps
  - 4% to inactive sump
  - 13% to inactive cavities

Erosion of Large Pieces of Nukon

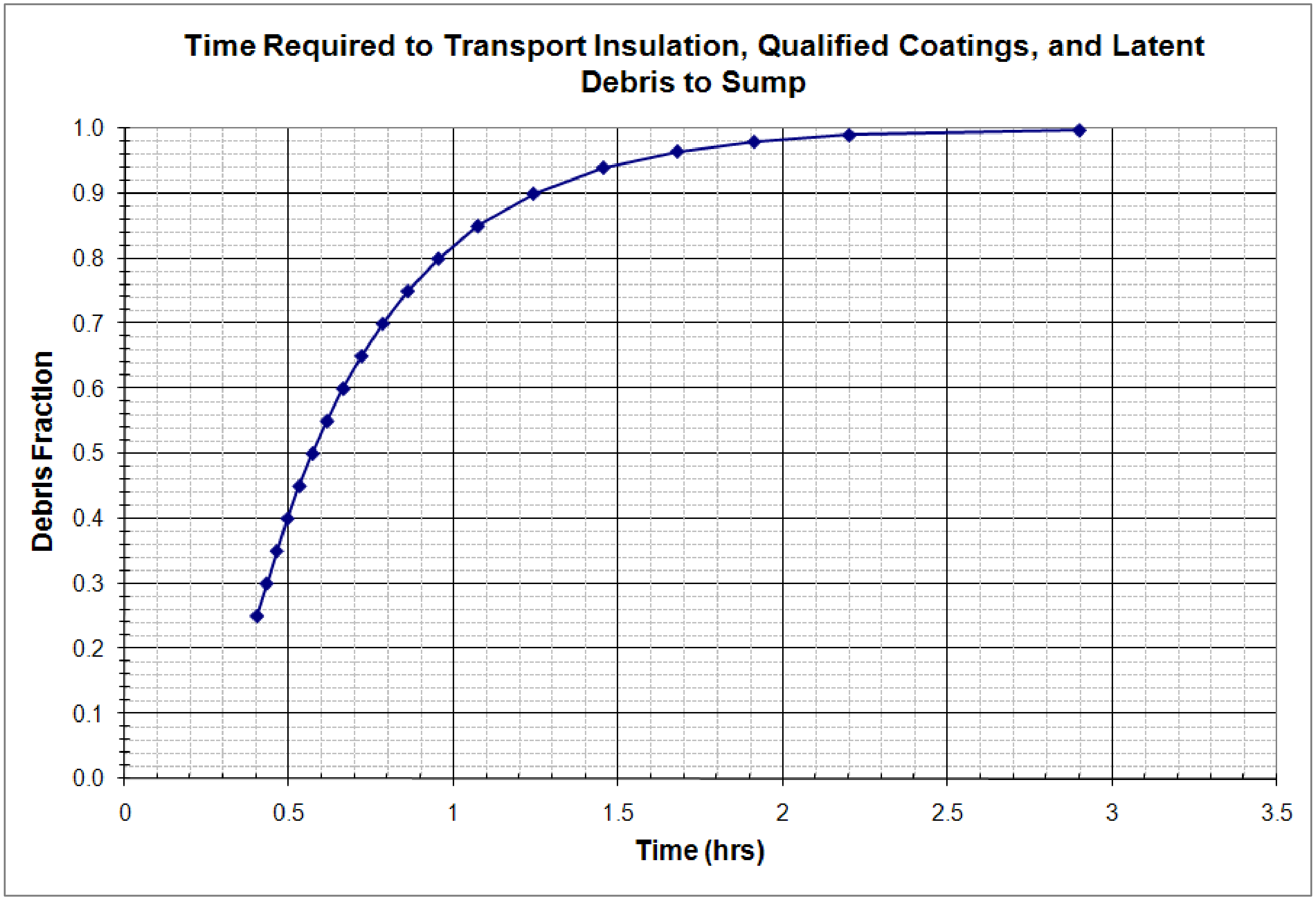
- **An erosion fraction of 1% was used for large pieces of Nukon retained in upper containment: 56.4 ft^3 * 0.01 = 0.6 ft^3**

Time Dependent Recirculation Transport

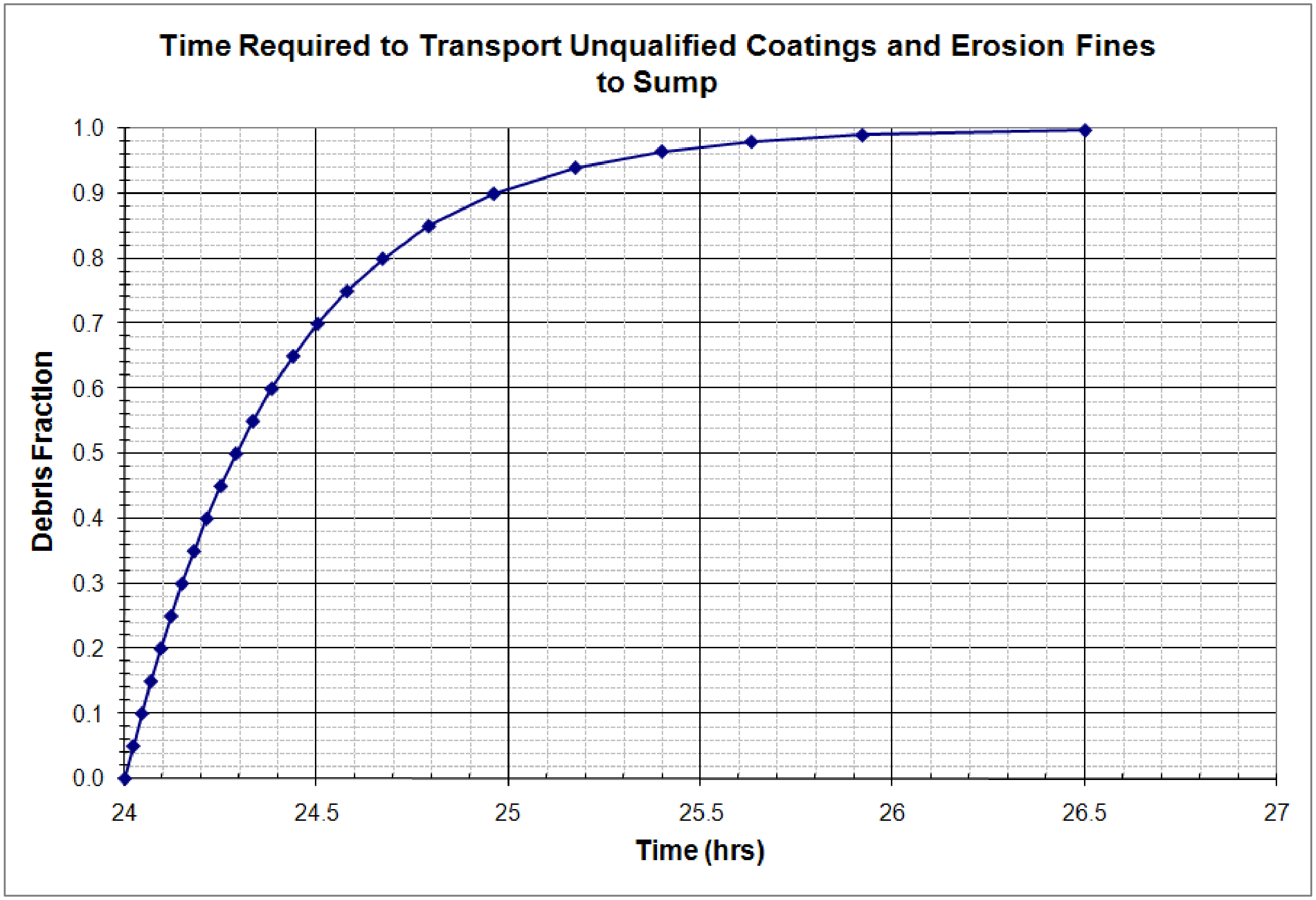
$$x(t) = x_i e^{-t \cdot (Q / V_{pool})}$$

- **Total sump flow rate for two train operation = 14,040 gpm**
- **Total pool volume corresponding to 3.19 ft minimum LBLOCA water level: 46,955 ft^3**
- **Initial concentration of debris at the beginning of recirculation (t = 24 minutes) includes 75% of the Nukon, Min-K, qualified coatings, and latent debris fines. At t = 24 hours, the concentration will be increased to include 100% of the unqualified coatings and Nukon erosion fines.**
- **Pool turnover time = 25 minutes**

Time Dependent Recirculation Transport, Cont.

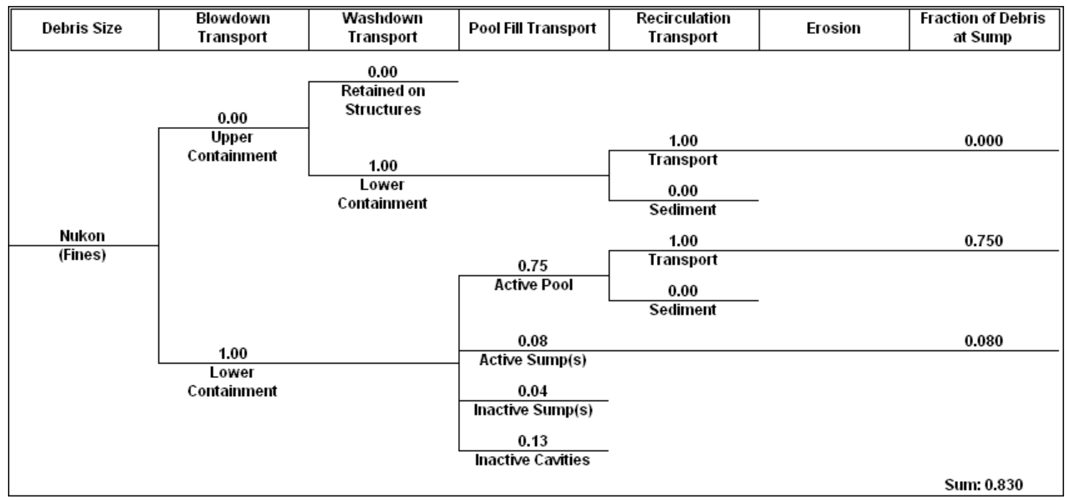


Time Dependent Recirculation Transport, Cont.



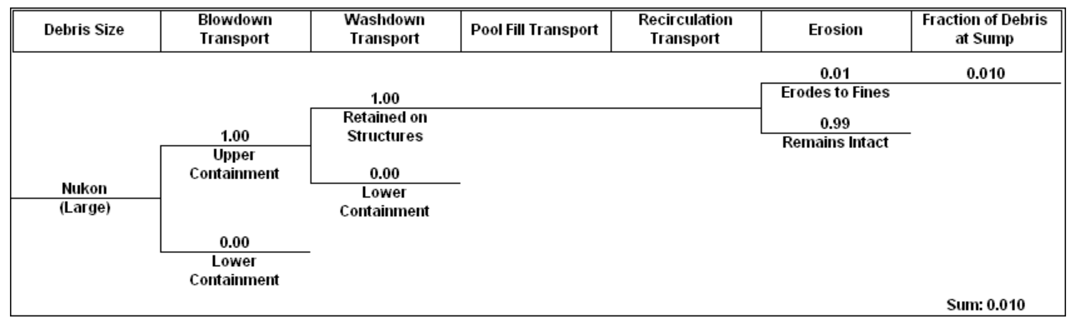
Nukon Debris Transport (Fines)

- **Blowdown to pool: 100%**
- **Washdown to pool: 100%**
- **Pool fill:**
  - 4% to each strainer
  - 13% to inactive regions
- **Recirculation to strainers:**
  - 0% to inactive strainer
  - 50% to each active strainer
- **Erosion: N/A**
- **Overall Transport: 83%**



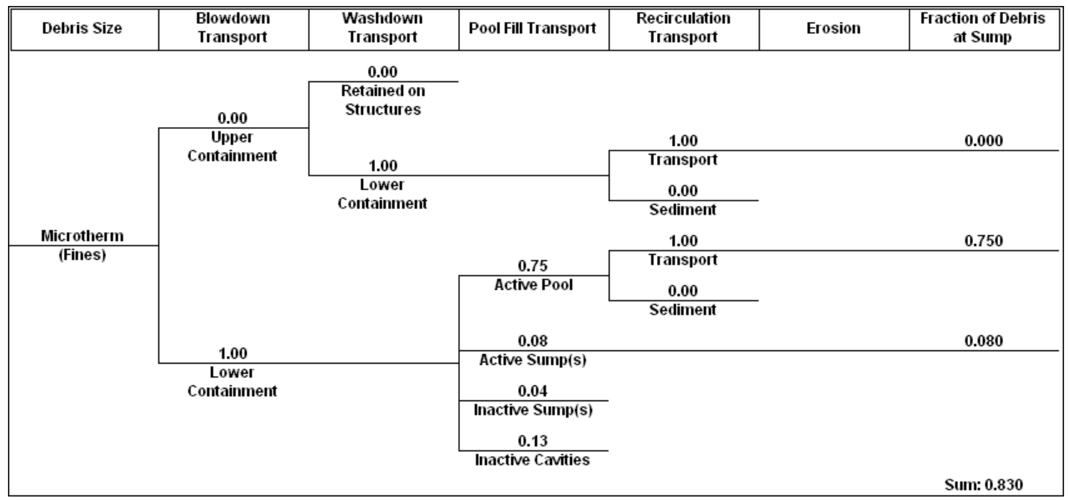
Nukon Debris Transport (Large)

- **Blowdown to pool: 0%**
- **Washdown to pool: 0%**
- **Pool fill: N/A**
- **Recirculation to strainers: N/A**
- **Erosion:**
  - Spray: 1%
  - Pool: N/A
- **Overall Transport: 1%**



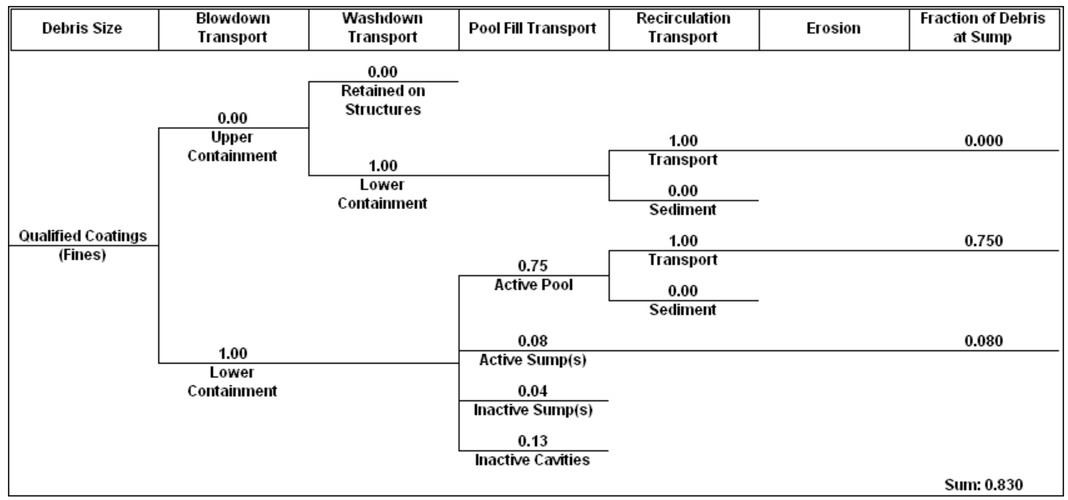
Microtherm Debris Transport (Fines)

- **Blowdown to pool: 100%**
- **Washdown to pool: 100%**
- **Pool fill:**
  - 4% to each strainer
  - 13% to inactive regions
- **Recirculation to strainers:**
  - 0% to inactive strainer
  - 50% to each active strainer
- **Erosion: N/A**
- **Overall Transport: 83%**



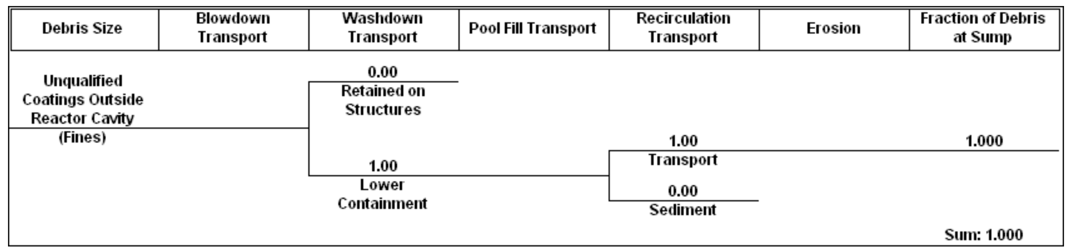
Qualified Coatings Debris Transport (Fines)

- **Blowdown to pool: 100%**
- **Washdown to pool: 100%**
- **Pool fill:**
  - 4% to each strainer
  - 13% to inactive regions
- **Recirculation to strainers:**
  - 0% to inactive strainer
  - 50% to each active strainer
- **Erosion: N/A**
- **Overall Transport: 83%**



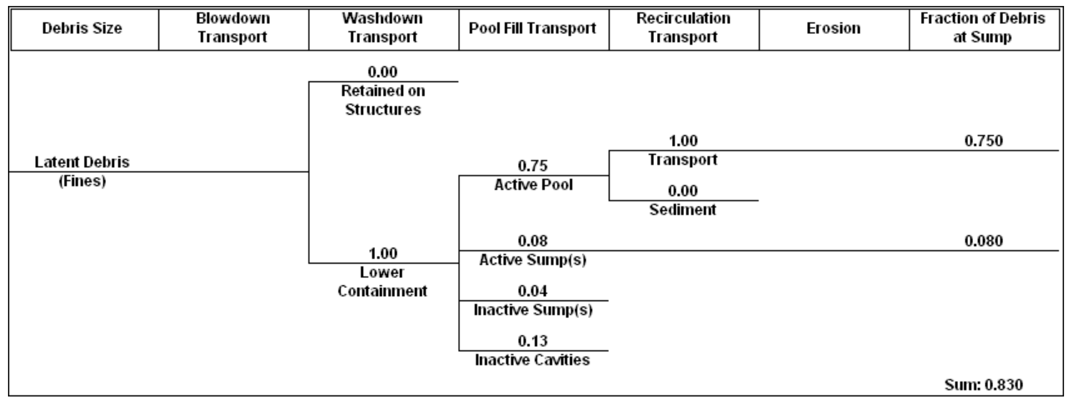
Unqualified Coatings Debris Transport (Fines)

- **Blowdown to pool: N/A**
- **Washdown to pool: 100%**
- **Pool fill: N/A**
- **Recirculation to strainers:**
  - 0% to inactive strainer
  - 50% to each active strainer
- **Erosion: N/A**
- **Overall Transport: 100%**
- **Transport for Unqualified Coatings in Reactor Cavity: 0%**



Latent Debris Transport (Fines)

- **Blowdown to pool: N/A**
- **Washdown to pool: 100%**
- **Pool fill:**
  - 4% to each strainer
  - 13% to inactive regions
- **Recirculation to strainers:**
  - 0% to inactive strainer
  - 50% to each active strainer
- **Erosion: N/A**
- **Overall Transport: 83%**



Time Dependent Transport Quantities

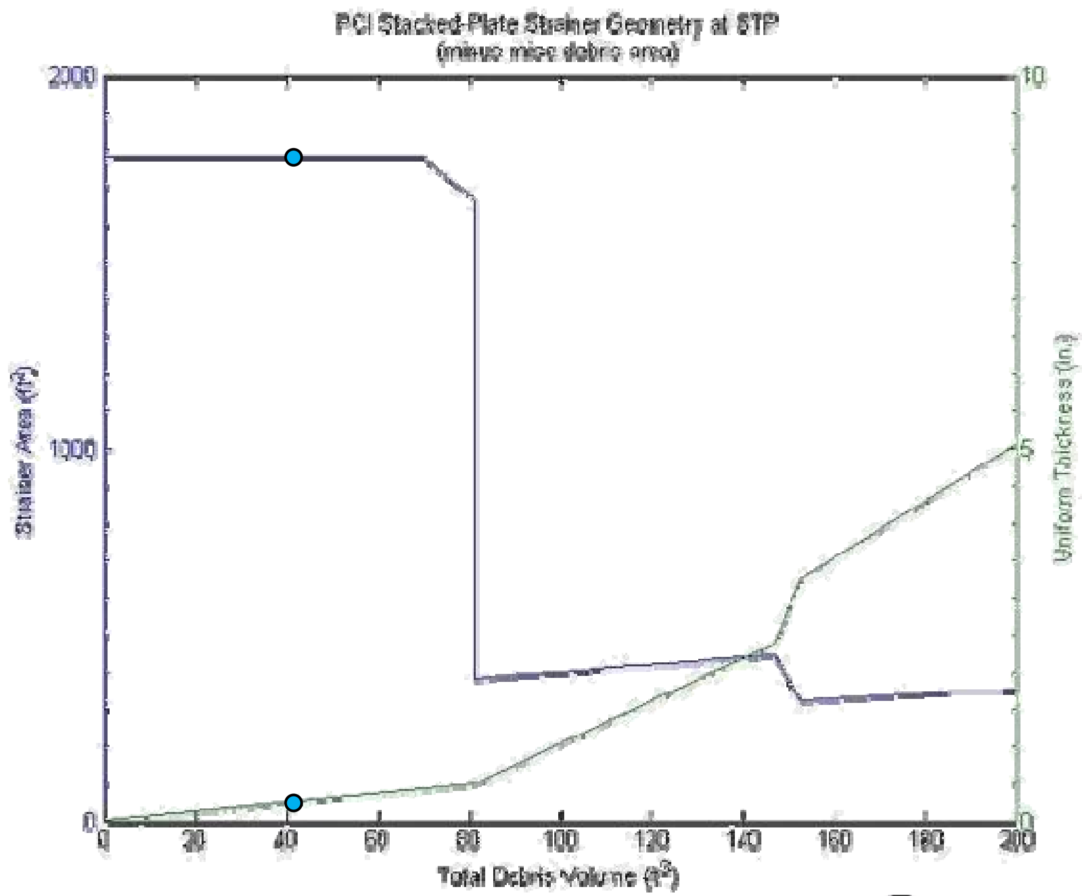
Debris	t = 24 min	t = 3 hr	t = 24 hr	t = 27 hr
Nukon Fines	6.8 ft^3	70.2 ft^3	70.2 ft^3	70.2 ft^3
Nukon Large	0.0 ft^3	0.0 ft^3	0.0 ft^3	0.6 ft^3
Microtherm	1.4 lb_m	14.9 lb_m	14.9 lb_m	14.9 lb_m
Qualified Epoxy	3 lb_m	27 lb_m	27 lb_m	27 lb_m
Qualified IOZ	44 lb_m	459 lb_m	459 lb_m	459 lb_m
Unqualified Alkyd	0.0 lb_m	0.0 lb_m	0.0 lb_m	247 lb_m
Unqualified Epoxy	0.0 lb_m	0.0 lb_m	0.0 lb_m	294 lb_m
Unqualified IOZ	0.0 lb_m	0.0 lb_m	0.0 lb_m	843 lb_m
Unqualified Baked Enamel	0.0 lb_m	0.0 lb_m	0.0 lb_m	268lb_m
Latent Dirt/Dust	14 lb_m	141 lb_m	141 lb_m	141 lb_m
Latent Fiber	1.0 ft^3	10.4 ft^3	10.4 ft^3	10.4 ft^3
Miscellaneous Debris	100 ft^2	100 ft^2	100 ft^2	100 ft^2

Head Loss Calculations

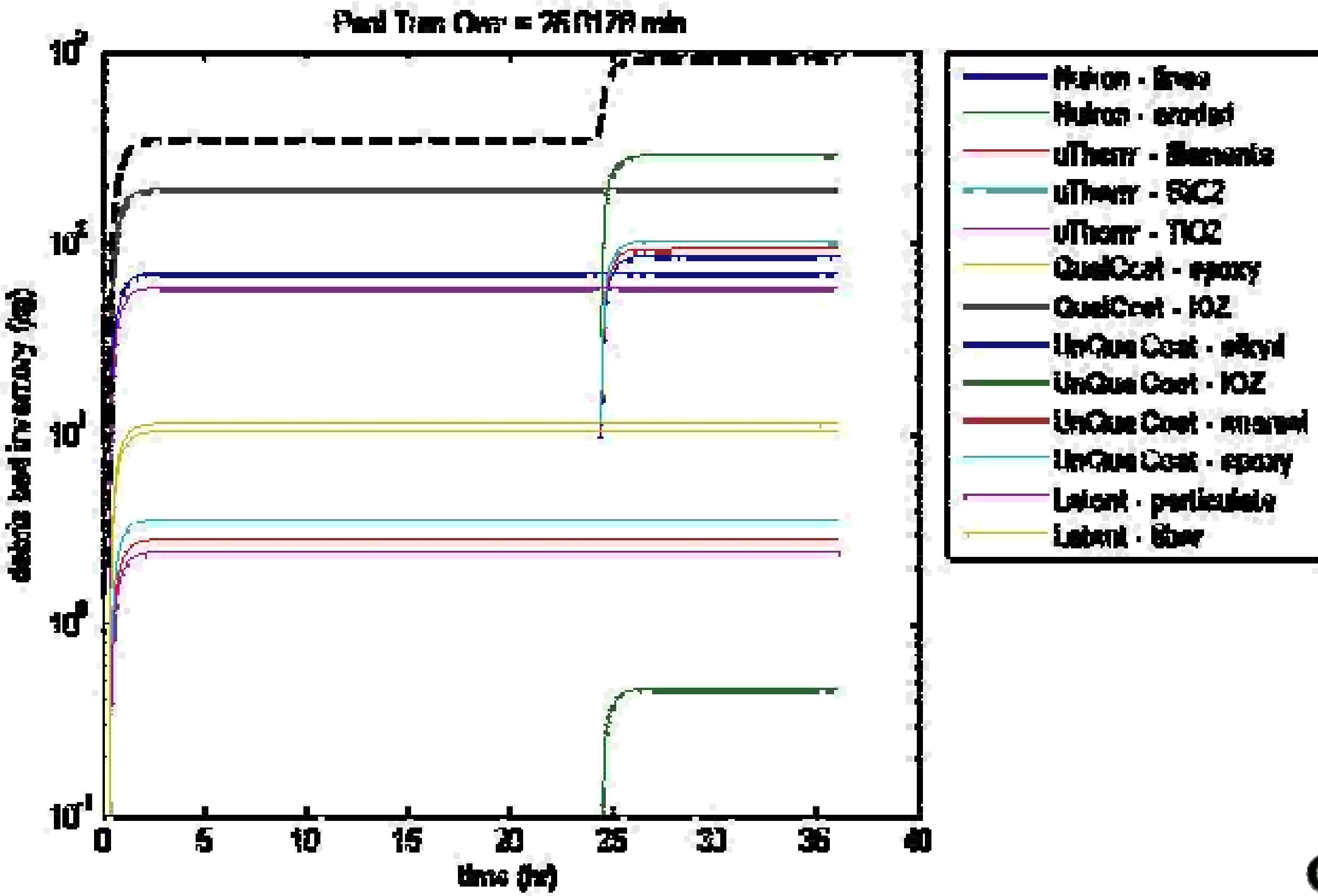
- **Basic assumptions for example calculation:**
  - Homogeneous and contiguous bed at every composition and all times
  - No chemical product formation
  - Particulate limited bed compression
  - Equal debris to each of the two operating trains
  - Debris transported during pool fill-up placed uniformly on strainer despite later submergence history

Geometric Loading Table

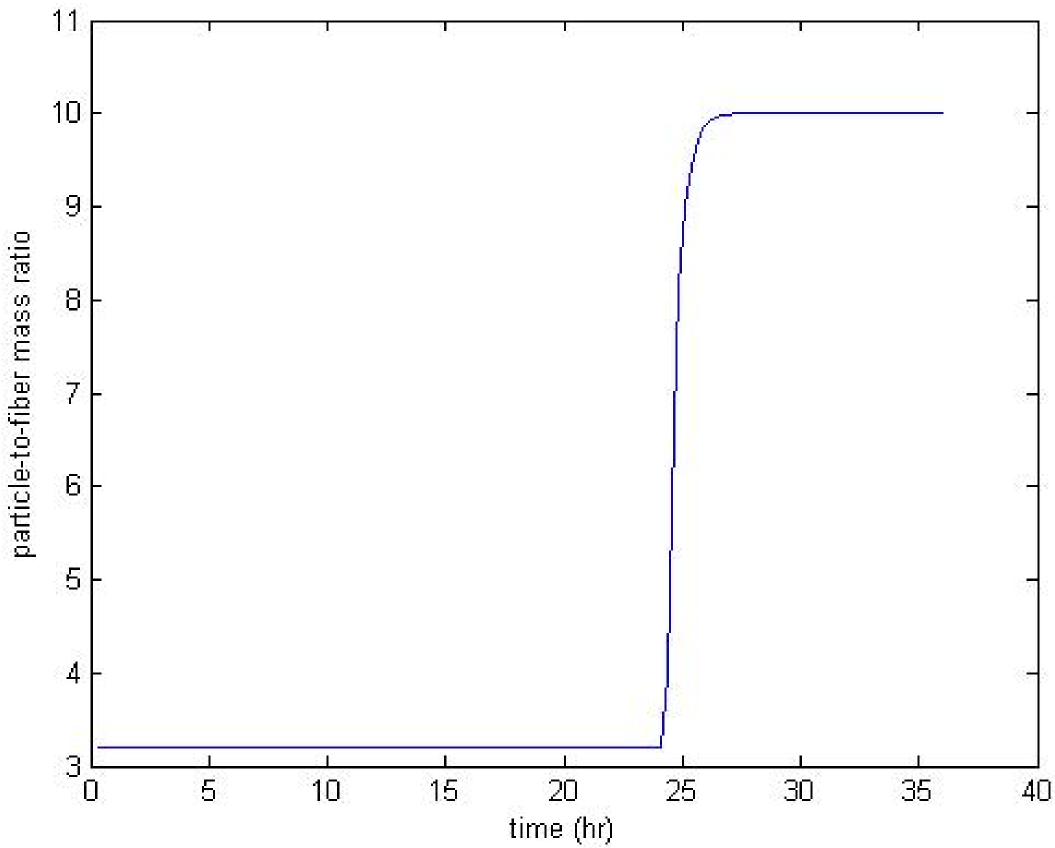
- Clean strainer area of 1818.5 ft^2
- Circumscribed area of 419 ft^2
- Circumscribed debris load of 0.5 in and 82 ft^3
- Fiber loading shown as blue dots



Bed-Inventory History



Particle-to-Fiber Mass Ratio (η)



Head Loss Summary

Time (hr)	Temp (°F)	LHSI $NPSH_R$ (ft)	$NPSH_A$ (ft)	NPSH Margin (ft)	Strainer HL (ft)
0.4	267	16.5	22.1	5.6	0.0
3	246	16.5	22.0	5.5	0.2
24	171	16.5	41.9	25.4	0.4
27	169	16.5	42.0	25.5	3.3
720	128	16.5	50.9	34.4	4.4

Gas Desorption Calculations

- **The gas void fraction can be calculated using the flow rate (7,020 gpm), time dependent temperature and head loss, and the following assumptions:**
  - Saturated equilibrium conditions in the containment pool
  - 100% relative humidity in containment
  - Containment pressure of 14.7 psia when temperature is less than 212˚F
  - Average strainer submergence of 22 inches

Time (hr)	Temp (˚F)	Strainer HL (ft)	Air Released (ft^3/hr)	Void Fraction (%)
24	171	0.4	0	0.00
27	169	3.3	66	0.12
720	128	4.4	87	0.15

Debris Bypass Calculations

- **Fiber bypass fraction is calculated using the correlation: BP_{total} (g) = 1.538 * Q (gpm)**
- **Total sump flow rate for two train operation is 14,040 gpm with 8,840 gpm through the SI pumps and 5,200 gpm through the CS pumps**
- **STP reactor vessel: 193 fuel assemblies**
- **BP_{total} = 1.538 * 14,040 gpm = 21,600 g (47.6 lb_m; 19.8 ft^3)**
  - Split to SI pumps: 21,600 g * (8,840 /14,040) = 13,600 g
  - Split to CS pumps: 21,600 g * (5,200 / 14,040) = 8,000 g
- **Incore fiberglass debris load: 70.5 g / fuel assembly**