Calvert Cliffs GSI-191 Program

Strainer Head Loss Testing and Option 2b Closure Approach

December 2015

Exelon Generation®

Agenda

- Introductions
- Objectives for Meeting
- Discussion of Strainer Chemical Effects Head Loss Testing
- Discussion of Option 2b Simplified Risk-Informed Closure Plan
- Status of Calvert Cliffs Work
- Staff Questions & Concerns
- Schedule for Future Periodic Meetings

CCNPP Attendees

- Mike Gahan – Engineering Manager
- Andre Drake – Lead Responsible Engineer GSI-191
- Jim Landale – Lead PRA Engineer
- Ken Greene – Licensing Engineer
- Craig Sellers – Project Manager GSI-191
- Steve Kinsey – Strainer Chemical Effects Head Loss Testing
- Eric Federline – Project Support & Testing
- Patrick Romine – Project Support & Testing

Objectives of this Meeting

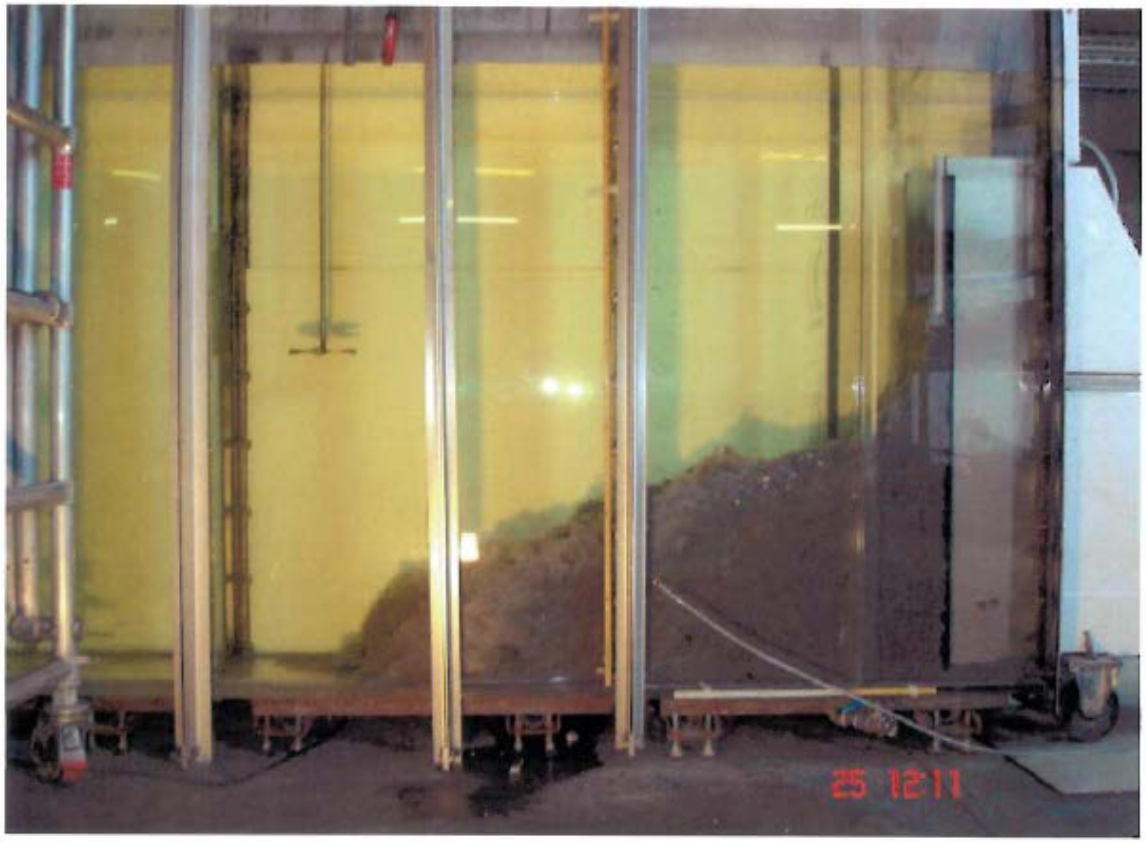
- Discussion of Strainer Chemical Effects Head Loss Testing
- Presentation of Calvert Cliffs Simplified Risk-Informed Approach
- Capture Staff Issues and Concerns
- Discuss Next Steps

Strainer Head Loss Testing

- CCNPP Conducted 7 Strainer Head Loss Tests in 2010
  - Performed in CCI Multi-Function Test Facility (MFTF) in Switzerland
  - Debris Preparation in Accordance with CCI Protocols
    - Fiber disintegrated into Fines using high pressure jet
      - NRC observed CCI debris preparation protocols
  - Debris introduced in 5 batches
    - Each batch 20% of particulate followed by 20% of fiber
    - First batch included 100% of Marinite
  - Tests included WCAP-16530 Chemical Precipitate Surrogate
    - WCAP surrogate prepared in accordance with WCAP guidance
    - WCAP surrogate introduced via metering pump
  - Flow Rate
    - 5000 gpm equivalent prior to chemical addition (Design)
    - 2400 gpm equivalent for chemical addition
      - 820 gpm HPSI, 600 to 1000 gpm per EOP-5
      - 1580 gpm CS (One CS Pump)
        - One CS pump secured at containment pressure < 2.8 psig
        - Containment Response calculation shows sump temperature > 150°F at 2.8 psig
        - Sodium Aluminum Silicate does not precipitate until sump temperature < 140°F
    - Optional flow sweep prior to test termination

Strainer Head Loss Testing (continued)

- Test #1 Included Fine and Small Fibrous Debris
  - Maximum Head Loss 1.75 inches of water
  - Non-Uniform Debris Deposition
  - Conclusion: Testing with Small Pieces is Non-Conservative
  - Results of Test #1 were Rejected as Non-Conservative



Strainer Head Loss Testing (continued)

- Remaining Tests Used Only Fine Fibrous Debris
  - Full load of particulates and precipitates
  - Test for Success Campaign
  - Break-throughs experienced during each test

Picture 27: Debris layer without precipitate


Picture 28: Debris layer at approximate 75 mbar head loss


Picture 30: Underwater picture of breakthrough

Strainer Head Loss Testing (continued)

- Test 6 Rejection
  - Test 6 was rejected in 2010
  - Documented basis for rejection was limited
  - Email archives from period searched
    - Significant discussion of improper agitation observed
    - Use of the hand held drill was lifting the debris within the Test Bed and creating a new profile that was considered not to be consistent with previous and subsequent testing.
    - A formal evaluation of the test was performed and additional guidance on agitation control was prepared.
    - After communication with the CCNPP project team the results of Test 6 were rejected.
    - This rejection was performed before proceeding with Test 7.
  - This has been documented and added to test files at CCNPP

Strainer Head Loss Testing (continued)

- Test Debris Types & Equivalent Quantities

Debris Type	Test			
	3	4	5	7
Nukon	167 ft^3	36 ft^3	88 ft^3	61.5 ft^3
Thermal Wrap	154 ft^3	227 ft^3	227 ft^3	227 ft^3
Temp-Mat	3.61 ft^3	3.61 ft^3	3.61 ft^3	3.61 ft^3
Generic LDFG	44.5 ft^3	4.1 ft^3	4.1 ft^3	0 ft^3
Mineral Wool	0 ft^3	0 ft^3	0 ft^3	0 ft^3
Lead Blanket Cover	0 ft^3	0 ft^3	0 ft^2	564.5 ft^2
Epoxy Particulate	2 ft^3	1.5 ft^3	2 ft^3	1.5 ft^3
IOZ Particulate	5.9 ft^3	4.8 ft^3	5.9 ft^3	4.8 ft^3
Unqual Part	2 ft^3	1.3 ft^3	2 ft^3	1.3 ft^3
Latent Particulate	1.275 ft^3	1.275 ft^3	1.275 ft^3	1.275 ft^3
Marinite	0.2 ft^3	0.2 ft^3	0.2 ft^3	0.2 ft^3
$NaAlSi_3O_8$	59.48 lbs	47.70 lbs	54.1 lbs	56.8 lbs

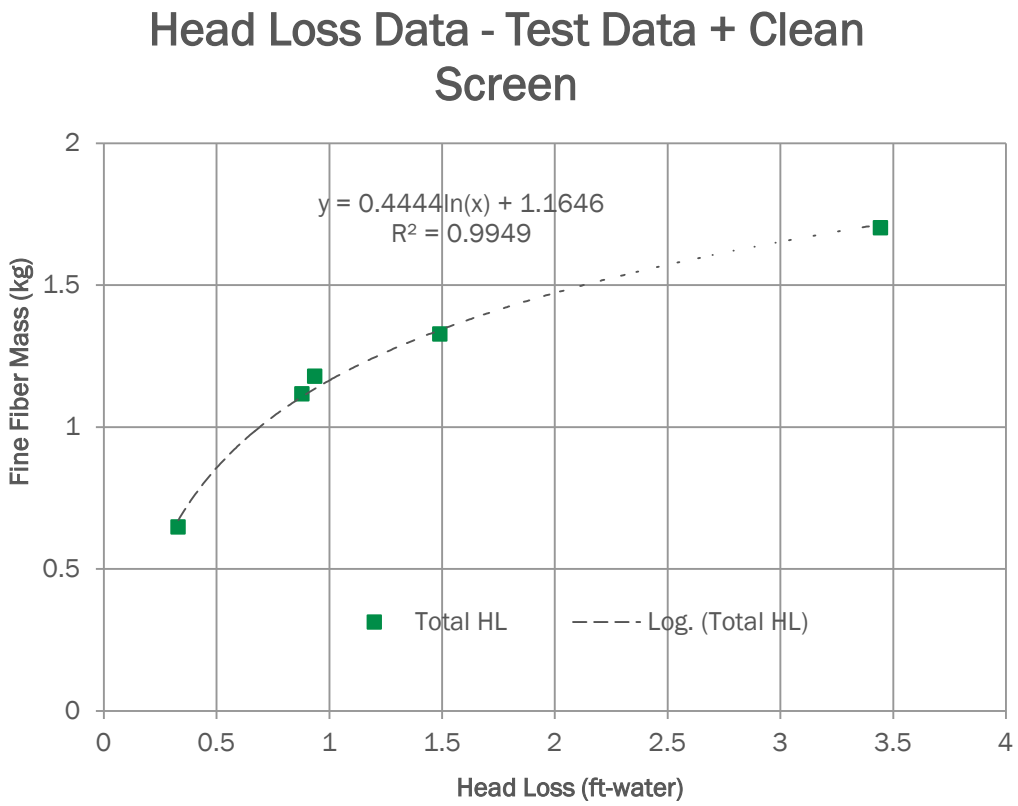
- Test Head Loss Results (ft-water)

Test	Debris HL	CS HL	Total HL
2	0.05	0.28	0.33
3	3.165	0.28	3.445
4	0.599	0.28	0.879
5	1.211	0.28	1.491
7	0.656	0.28	0.936

- Maximum Allowable Strainer Head Loss
  - Currently Under Development
  - Limiting Failure Mode is Deaeration
  - Will range 1.75 to 2.5 ft-water
- Test 5 Test with Highest Acceptable Head Loss

Strainer Head Loss Correlation Demonstrates Head Loss Proportional to Mass of Fine Fiber

- Plot of Head Loss –vs- Fiber Mass produces well correlated curve fit
- Plot includes clean strainer head loss
- Empirical Correlation based on Calvert Cliffs Prototypical Strainer Head Loss Testing



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Simplified Risk-Informed Approach
Define Threshold Break Size

- Identify Applicable Strainer Chemical Effects Head Loss Test
  - WCAP-16530 Chemical Surrogates

- Identify Smallest Break(s) that Generate Equivalent Quantity of Fine Fibrous Debris as used in Applicable and Acceptable Head Loss Test
  - Also key criteria
    - Quantity of Particulate for Each Break
    - Quantity of WCAP-16530 Precipitate for Each Break

- Breaks That Produce Less Debris Than Tested are Acceptable Through Deterministic Analysis

- Breaks That Produce More Debris Than Tested are Addressed Probabilistically (Risk-Informed)
  - The ID of the smallest break that produces more debris than tested is defined as the Threshold Break Size

Simplified Risk-Informed Approach
Calculate ΔCDF & ΔLERF

- CDF and LERF are taken from the Calvert Cliffs PRA Model of Record.
- ΔCDF Determined from LOCA Frequency for Threshold Break Size
  - Apportion LOCA Frequency Across Welds ≥ Threshold Break Size
  - Interpolate within NUREG-1829 Intervals as needed for Break Size
  - ΔCDF = ∑Apportioned LOCA Frequency for Breaks that produce more debris than tested
  - Sensitivities on interpolation and LOCA Frequency Aggregation Methods
- ΔLERF approach is to obtain a CDF multiplier from the Calvert Cliffs LERF model that is bounded by a worst case accident sequence for the Threshold Break Size for non SBO conditions.
- Compare CDF, ΔCDF, LERF, and ΔLERF results against Reg Guide 1.174 criteria for Region III.
- Verify other requirements (safety margin, defense in depth) of Reg Guide 1.174 are met.

Simplified Risk-Informed Approach (Continued) Deterministic Analysis

- Breaks Acceptable Through Deterministic Analysis
  - Bounding Analyses
    - NEI 04-07
  - Limiting Single Failure
    - All HPSI pumps running
    - Credit for Operator Actions in EOPs
      - Secure one CS pump
    - Failure of LPSI pump to trip being resolved through plant modification
  - Safety Related Calculations
    - Calvert Cliffs GSI-191 calculations prepared in accordance with Appendix B QA program

Simplified Risk-Informed Approach (continued)
Identify Applicable Head Loss Test

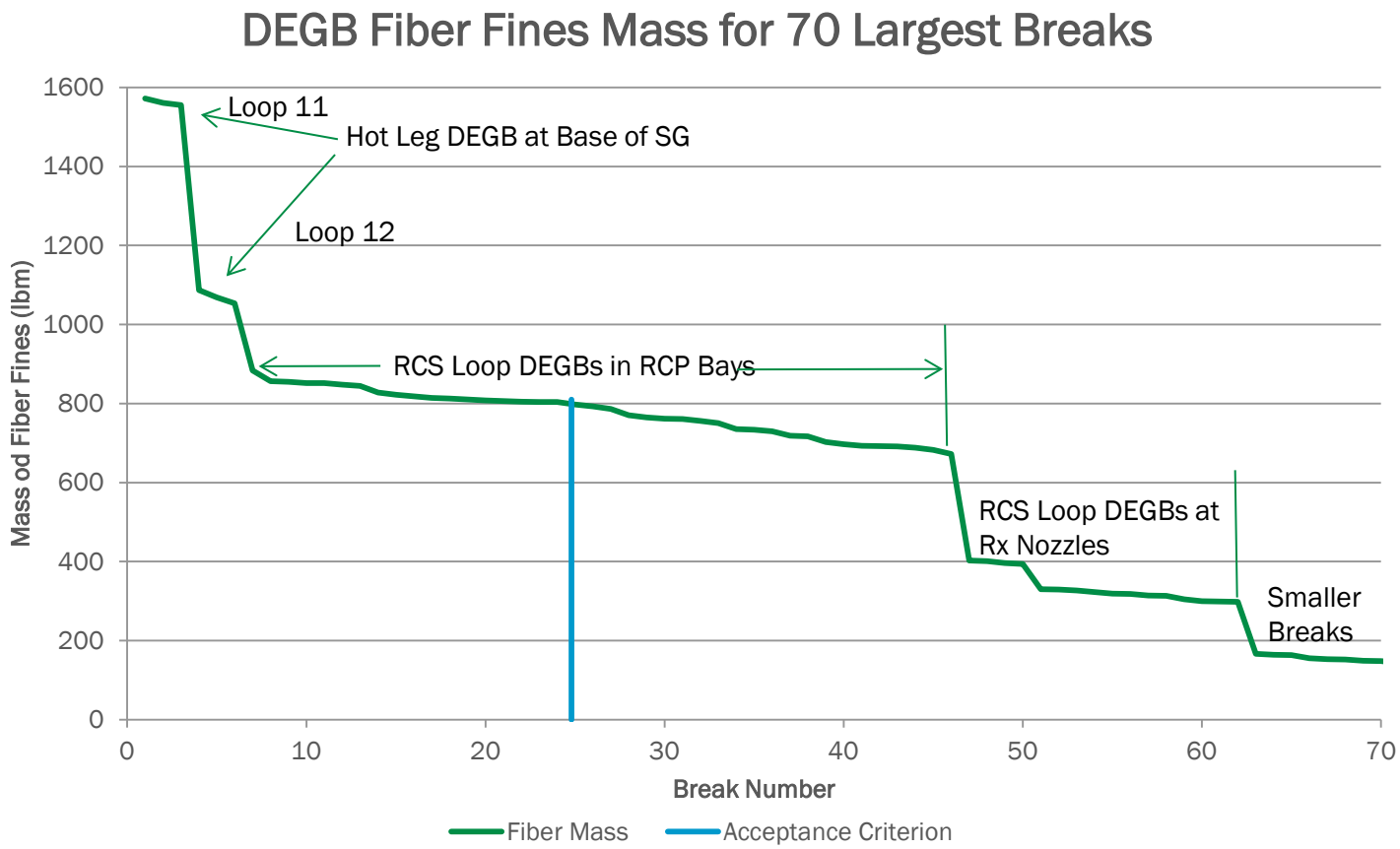
- Test 5 and DEGB @ ISI 30-RC-11A-6 (Crossover Leg at RCP Suction Elbow)
  - Test 5 used equivalent of 825.7 lbm Fiber Fines
  - Use 800 lbm Acceptance Criterion
  - DEGB @ ISI 30-RC-11A-6 generated 797.8 lbm Fiber Fines

	Material											
	Nukon	Thermal Wrap	Temp-Mat	Generic LDFG	Mineral Wool	Lead Blanket Cover	Epoxy Part.	IOZ Part.	Alkyd Part.	Latent Part.	Marinite	$NaAlSi_3O_8$
Test 5	210.9#	543.2#	42.9#	28.6#	0#	0#	2 ft^3	5.9 ft^3	2 ft^3	1.275 ft^3	0 ft^3	54.1 lbs
	E-Glass	825.7 lbm					9.9 ft^3					
ISI 30-RC-11A-6	309.6#	249.8#	30.2#	179.9#	22.58#	0#	1.21 ft^3	2.22 ft^3	1.74 ft^3	1.275 ft^3	0.12 ft^3	65.8 lbs
	E-Glass	769.5 lbm					5.17 ft^3					

- Test 5 had
  - 56 lbm more E-Glass fiber fines
  - 22.58 lbm less mineral wool
    - Mineral wool 2.8% of fine fiber quantity
    - CHLE investigatory tests showed no notable head loss impact from mineral wool
  - 73% more failed coatings & latent particulate
  - 0.12 ft^3 less Marinite
  - 82% of $NaAlSi_3O_8$ precipitate
    - All tests experienced debris bed break-throughs relieving ΔP before 100% WCAP-16530 surrogate precipitates introduced

Simplified Risk-Informed Approach (continued)
Identify Small Breaks that Produce Sufficient Debris

- Risk-Informed Debris Generation Calculation Results
  - Breaks Analyzed at 437 Circumferential Welds
  - Longitudinal Welds Currently Being Analyzed
  - ISI 30-RC-11A-6 is break #25 below



Simplified Risk-Informed Approach (continued)
Calculate ΔCDF – Preliminary Results

- Use Conservative Approach
  - Smallest break that threatens strainer performance – 30” DEGB
  - NUREG-1829 LOCA Frequencies
  - Equally Apportion LOCA Frequency Across RCS Welds
    - Degradation mechanisms are Design and Construction for all 126 RCS welds
    - PWSCC also on 8 RCS welds

LOCA Category	Break Size (in.)	Geometric Mean[1]	Arithmetic Mean[2]
1	≥ 0.5	1.90E-03	1.00E-02
2	≥ 1.5	4.20E-04	3.00E-03
3	≥ 3	1.60E-05	7.30E-05
4	≥ 6.75	1.60E-06	9.40E-06
5	≥ 14	2.00E-07	2.40E-06
6	≥ 31.5	2.90E-08	1.50E-06
Notes:			
[1] Taken from Table 7-19 of NUREG-1829 [2] Taken from Table 7-13 of NUREG-1829			

  - 126 Welds ≥ 30”
  - 24 Welds ≥ 30” Threaten Strainer Performance

- Linear Interpolation

LOCA Category	Break Size (>in.)	Geometric Mean	Arithmetic Mean
1	≥ 0.5	1.90E-03	1.00E-02
2	≥ 1.5	4.20E-04	3.00E-03
3	≥ 3	1.60E-05	7.30E-05
4	≥ 6.75	1.60E-06	9.40E-06
5	≥ 14	2.00E-07	2.40E-06
5.5	≥30	4.37E-08	1.58E-06
6	≥ 31.5	2.90E-08	1.50E-06
# Welds	#Failed	ΔCDF GM	ΔCDF AM
126	24	8.32E-09	3.00E-07

- Log-Log Interpolation

LOCA Category	Break Size (>in.)	Geometric Mean	Arithmetic Mean
1	≥ 0.5	1.90E-03	1.00E-02
2	≥ 1.5	4.20E-04	3.00E-03
3	≥ 3	1.60E-05	7.30E-05
4	≥ 6.75	1.60E-06	9.40E-06
5	≥ 14	2.00E-07	2.40E-06
5.5	≥30	3.93E-08	1.55E-06
6	≥ 31.5	2.90E-08	1.50E-06
# Welds	#Failed	ΔCDF GM	ΔCDF AM
126	24	7.48E-09	2.96E-07

Differences STP – VOGTLE – CCNPP

- Physical

Item	STP	VOGTLE	CCNPP
NSSS	Westinghouse	Westinghouse	CE
RCS Piping Welds	Circumferential Welds	Circumferential Welds	Circumferential & Longitudinal Welds
RCS Piping ID	31”	31”	42” & 30”
ECCS Trains	3	2	2
Strainer Config.	3 combined	4 separate	1 combined
Strainer Design	PCI Flow Control	GE Stacked Disc	CCI Pocket
Strainer SA	~1800 ft^2/Train	~800 ft^2/Pump	~6000 ft^2 Total
CS Setpoint	9.5 psig	~21.5 psig	2.8 psig

Differences STP – VOGTLE – CCNPP

- Analytical

Topic	STP	VOGTLE	CCNPP
Debris Generation	Casa Grande	BADGER	
Break Size/Orientation	Search Algorithm	2”, 45° increments	
Debris Transport	Casa Grande	NARWHAL	
Chemical Precipitate Qty	Bounding Test	NARWHAL Break-Specific Analysis	
Precipitation Timing	Not Credited	ANL Solubility	Precipitate ≤140°
Aluminum Passivation	Not Credited	Credited	Not Credited
Core Flow / Blockage	FIDOE/RELAP5-3D	WCAP-17788	WCAP-16793
GSI-191 Risk Quantification	Critical Break Size Frequency	CFP Entered into PRA	Critical Break Size Frequency
Strainer HL Protocol	Flume	Tank	CCI MFTF

Status of Calvert Cliffs Analysis

- Calculation Revisions
  - In Owner Acceptance Review
    - Debris Generation – 4 size distribution for Mineral Wool debris
  - In process
    - Revised Debris Transport Calculation
    - Revised WCAP-16530 Chemical Precipitate Calculation
    - Revised LOCADM Calculation
    - Maximum Allowable Strainer Head Loss Calculation
    - Revised Strainer Bypass Calculation
  - Scheduled
    - Formal Risk-Informed Analysis Calculations
    - Update Ex-Vessel Downstream Effects Calculations

- Plan for GL 2004-02 Response
  - Commitment Change Letter
  - Perform Risk-Informed Analyses: March to June 2016
  - Prepare Final Submittal: October 2015 to July 2016
  - Submit Final Response: August 2016

Questions/Concerns

- Jointly Review Issues, Questions, and Concerns for Future Communication

Next Steps

- Finalize Update of Deterministic Calculations
- Present Formal Risk-Informed GSI-191 Analysis and Results
- Desire Next Meeting – April 2016