Harris Realistic LBLOCA Question Response Meeting

January 11, 2012

Rockville, MD

~~Slides contain material proprietary to AREVA~~

NGG
Think Fleet.

Progress Energy

AGENDA

- Introductions
- Overview of Status
- Response to Individual questions from December 13th Meeting
- Schedule
- Concluding Remarks

Participants

Progress Energy

- Mike Blom
- John Caves
- Dave Corlett
- Dean Tibbitts

AREVA

- Bob Baxter
- Bert Dunn
- Mireille Cortes
- Nithian Nithianandan
- Gayle Elliott

PGN Reload Summary

	Current	Cycle 18
Feed Assembly Clad	Zircaloy 4	M5
LBLOCA Method	EMF-2087	ANP-3011 based on EMF-2103
PCT	2081 °F	1919 °F
Transient Oxidation	7%	<3%
Safety Analysis Core Power (MW)	2958	2958

LOCA History

Method	Method Type	Core Power (MW)	Clad	PCT	Transient Local Oxidation (%)
EMF-2087	Appendix K	2958	Zircaloy 4	2081	7.0
EMF-2103 Rev 0	Best Estimate	2993	Zircaloy 4	1887	2.02
EMF-2103, Rev 0 + Trans Pkg	Best Estimate	2958	Zircaloy 4	1930	1.95
ANP-3011	Best Estimate	2958	M5	1919	2.94

Overview of Question Response

- Additional Sensitivity Cases Run (Response to Question 1)
- Discussions of Questions 2 to 6 refined and responses prepared

Question #1

- Characterize droplet shattering model without modeling the fuel relocation
- Show the sensitivity of the fuel relocation to fuel relocation packing factor
- Consider including a range of packing factors 30 - 80%
- Utilize the Harris Nuclear Plant (HNP) limiting-peak clad temperature (PCT) case

Question #1
Droplet Shattering w/o Relocation

Question #1
Expand Sensitivity Study

Table 1: 0.5 Packing Fraction Cases with Hot Assembly Rupture

Question #1
Expand Sensitivity cont'd

Table 2: 0.6 Packing Fraction Cases with Hot Assembly Rupture

Question #1
Expanded Sensitivity cont'd

Table 3: 0.7 Packing Fraction Cases with Hot Assembly Rupture

Question #1
Summary of Expanded Sensitivity Study

Question #1 cont'd

Histogram of PCT with Droplet Shattering Activated - 0.7 Packing Fraction

Question #1 cont'd

Rupture node cladding temperature response for limiting Case-57

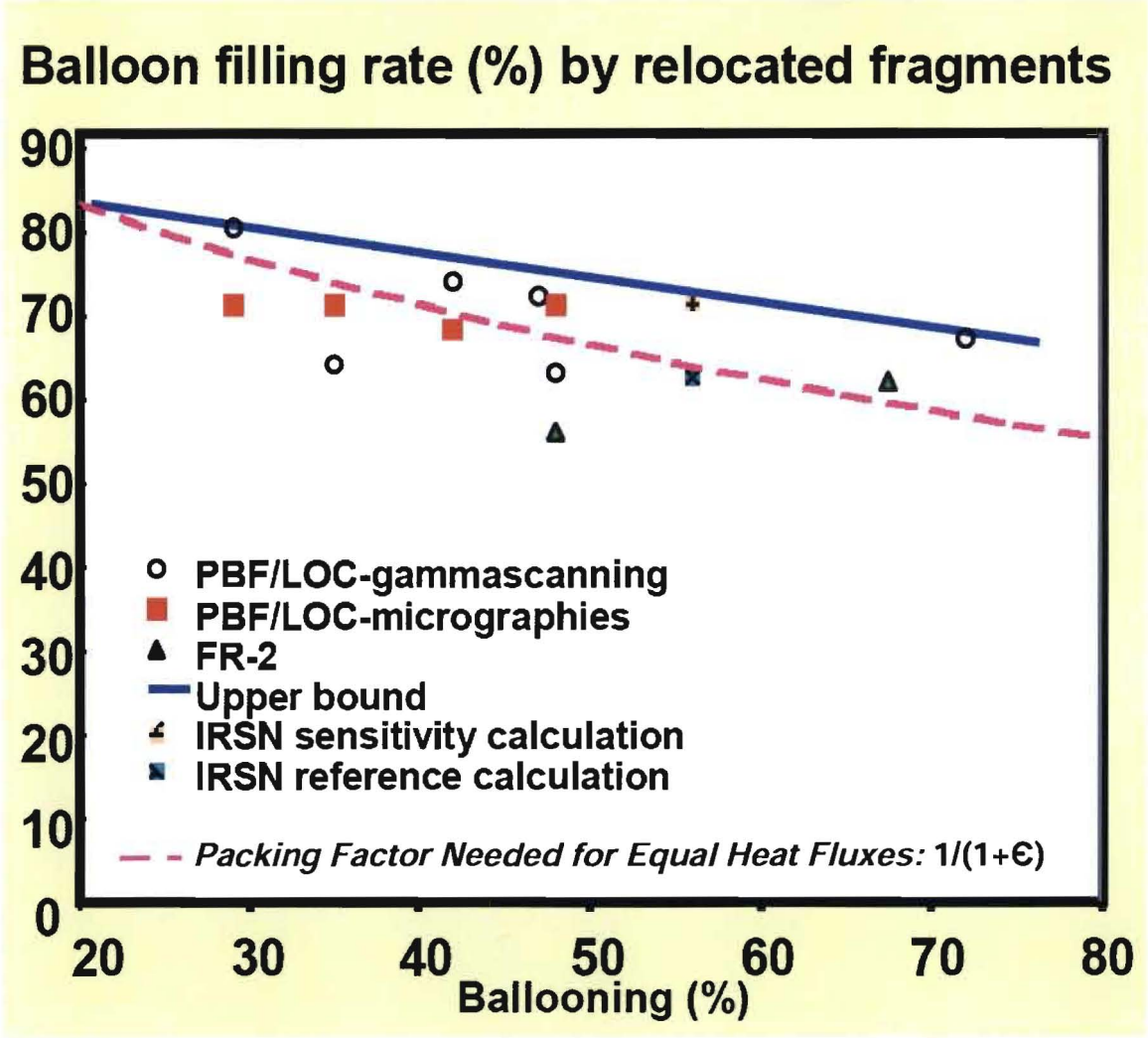
Question #1
Maximum Packing Factor [PF] Considerations

PBF – Power Burst Facility

- Only 1 gamma scanning data point at 80% packing fraction and it is at 30% strain
- Data results are in question due to material movement during the handling of the test rods
- Micrographies measurement is more accurate compared to gamma scanning
- PBF micrographic data shows 70% PF for rupture strain below 50%
- AREVA estimates 45% PF for strains near 70%

Question #1
Maximum PF Considerations cont'd

Packing Fraction vs. Rupture Strain



Note: The balloon filling rate is interpreted as packing fraction.

Question #1
Maximum PF Considerations cont'd

Test	Measured PF	Comments
FR-2 (E-5)	61.5%	Test maximized rupture strain and had very small rupture opening
Halden IFA-650.4	53%	92 GWd
Halden IFA-650.9	Not measured, but observed as similar to 650.4 (NEA report)	~ 90 GWd
Halden Test IFA-650.10	No relocation (no strain)	60 GWd

Question #1
Maximum PF Considerations cont'd

- Studsvik Tests – Provide results for burn-ups at 70 GWd, show no fuel in the ruptured region as it was all lost out of the rupture
- KfK/FR2 Tests – Only rod E5 showed a PF of 61.5%. During the swelling and rupture of the rod, the cladding expanded to make a seal around the ID of the container tube, thus invalidating any other results

Question #1
S-RELAP SRR Conservatism

Question #1
HNP Rupture Strain vs. Rupture Temperature

Question #1
S-RELAP Faster Cladding Heatup

Question #1 Summary

- 50%, as in ANP-3011P, is an appropriate PF based on the Halden test results, which are the most reliable information available
- 70% PF is an upper limit (based on older PBF data) for the strain range seen in the HNP plant cases
- Sensitivity study concludes base case is conservative and no bias is proposed (with droplet shattering)

Question #2
Droplet Shattering Model

Address whether droplet shattering is calculated on all flow blockage (non-vertical) surfaces in the S-RELAP5 calculation. If not, provide the flow blockage surfaces which are assumed to cause droplet shattering.

Question #2
Droplet Shattering Model cont'd

Question #3

Page 122 of ANP-3011(P), "Harris Nuclear Plant Unit 1 Realistic Large Break LOCA Analysis" states, In the present model, the rupture blockage ratio [which is correlated to the number of droplets to yield a maximum atomization factor], ϵ, is taken from the swelling and rupture correlation.

- Address whether droplet shattering is calculated only against the hot pin rupture, or the additional flow blockage areas (i.e., balloon/burst regions, spacer grids, etc.) assumed to be present upstream of the hot pin rupture location.
- If the additional flow blockage areas are not based on pre-transient core geometry, discuss how the locations and sizes of flow blockages are distributed.

Question #3 cont'd

Question #3 cont'd

Question #3 cont'd

Question #4
Benchmark to Swell/Rupture [SR] Data

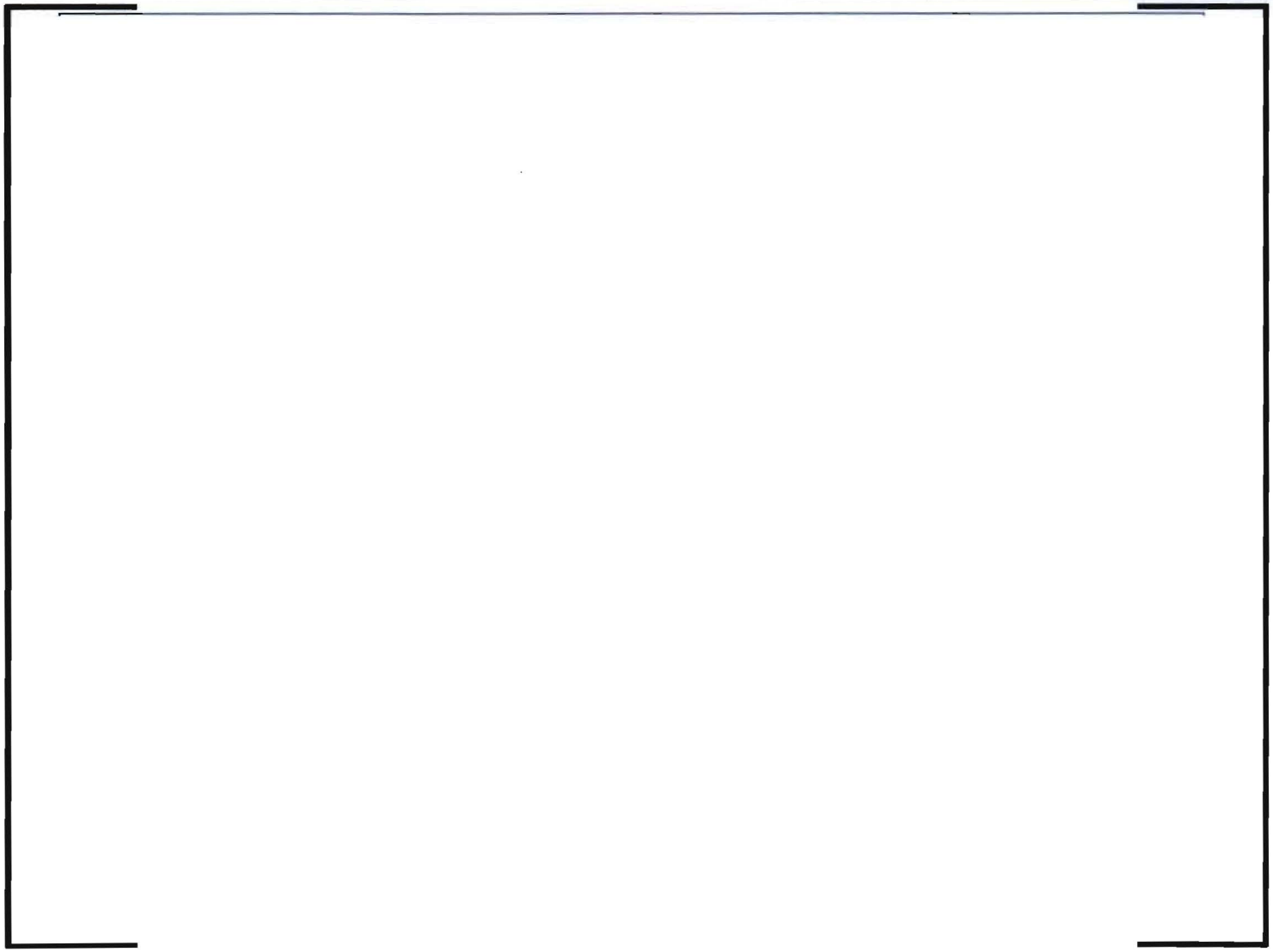
On page 123 of ANP-3011(P), it is stated, It can be seen that the code predicted the peak cladding temperature variation well. The data is so tightly clustered that the degree of agreement is difficult to ascertain. Please tabulate the data to provide a more quantitative indication. Address how well the S-RELAP5 modification predicted the data.

Question #4
Benchmark to SR Data cont'd

- An Excel spreadsheet that contained blockage Test 61607 data has been placed in PGN FTP site for NRC to retrieve for further evaluation
- Figures 6-14 and 6-15 in ANP-3011P show S-RELAP5 conservatively predicted PCT compared to blockage test data for the FLECHT-SEASET and REBEKA-6 tests
- Additional FLECHT-SEASET test benchmarks, 61509 and 61607, are presented on the next two slides
- COBRA-TF (NUREG/CR-4166) modeled all expected multi-dimensional flow phenomena at rupture location, including flow diversion
- The figures show that S-RELAP5 conservatively predicts cladding response compared to the COBRA-TF results

Question #4
Benchmark to SR Data cont'd

Question #4
Benchmark to SR Data cont'd



Question #5
Application of Sugimoto/Murao correlation

Comparative data demonstrate the global effects of the droplet shattering phenomena; however, the correlation as implemented discriminates between large and small droplets and the behavioral differences between the two. Validate droplet size distribution as implemented in model. Explain how the Sugimoto/Murao correlation applies to the scenario in which it is applied.

Question #5
Application of Sugimoto/Murao Correlation cont'd

Question #6
Droplet shattering impacts on Heat Transfer

Explain how droplet shattering model incorporates the following droplet-dependent heat transfer effects:

- Inter-phase heat transfer
- Fluid-structural interactions including cladding, balloon, and spacer heat transfer to coolant
- Validate heat transfer modeling for these separate effects

Question #6
Droplet shattering impacts on Heat Transfer cont'd

Question #6 cont'd

Question #6 cont'd

Question #6 cont'd

REBEKA-6 Test: Rupture rod cladding temp. & pin pressure

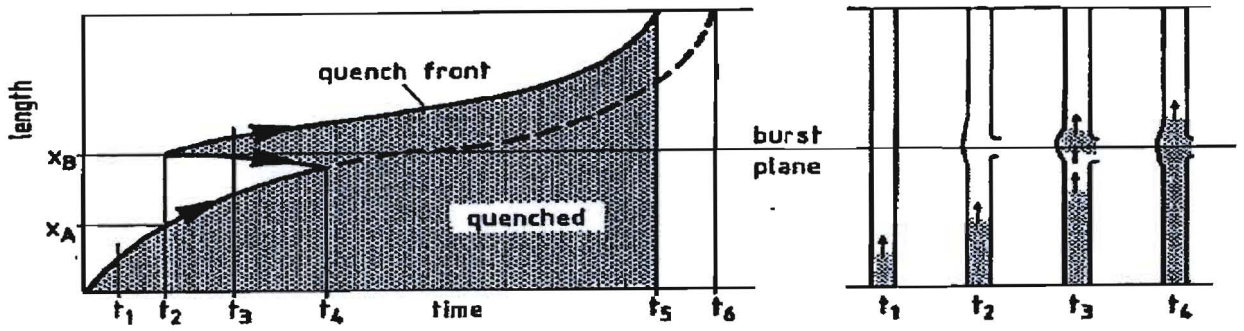
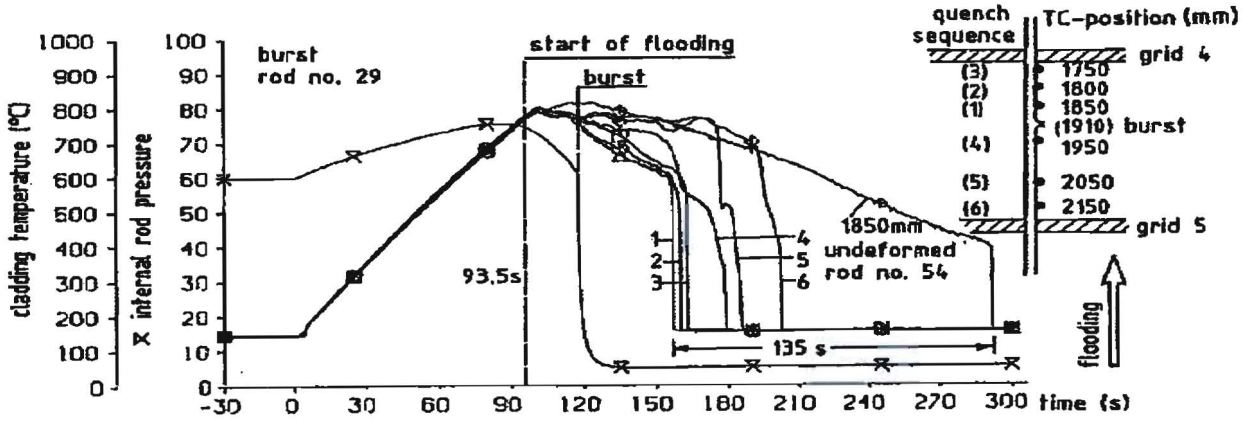


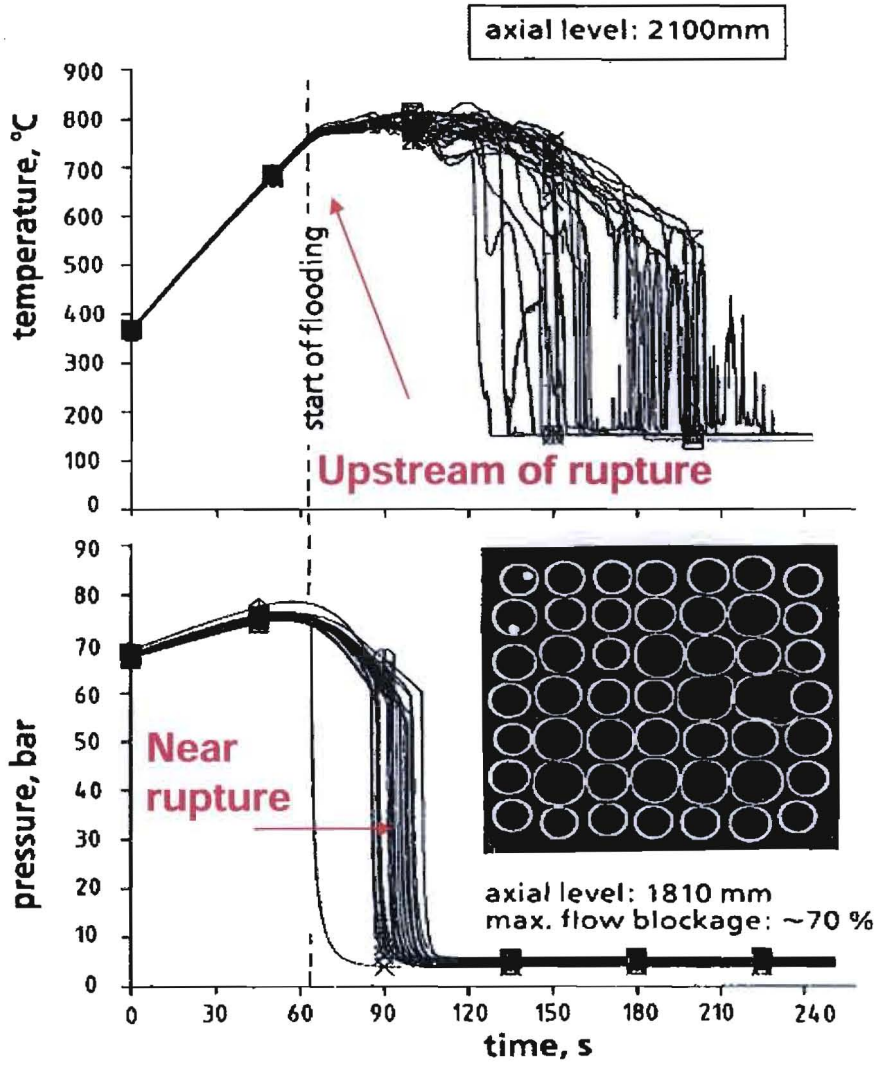
Fig. 7 Premature quenching of burst Zircaloy claddings (schematic)



Question #6 cont'd

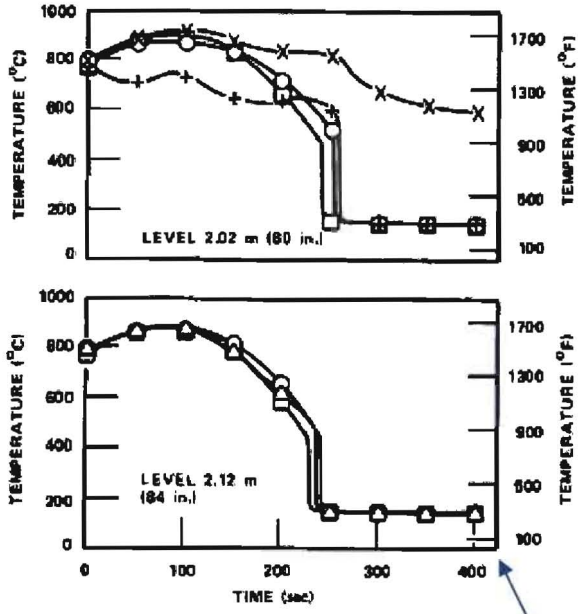
REBEKA-7 Results:

Maximum blockage ~ 70 %



Question #6 cont'd

FEBA Tests Results



FLOODING RATE = 0.038 m/sec (1.5 in./sec)
PRESSURE = 0.40 MPa (58 psig)

SERIES II:

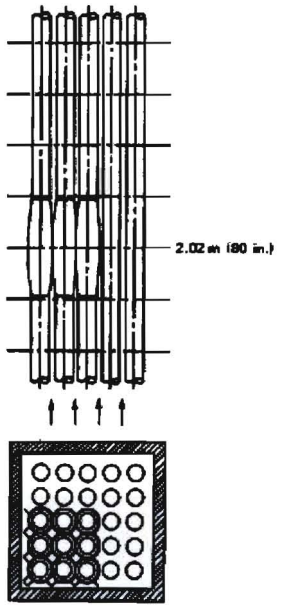
TEST Z29
6 GRID SPACERS
UNBLOCKED BUNDLE

□ CLADDING

SERIES III:

TEST Z39
6 GRID SPACERS
BLOCKED BUNDLE (3 X 3 RODS)
BLOCKAGE AT LEVEL 2.02 m (80 in.)
BLOCKAGE RATIO 80%

○ BYPASS REGION
△ BLOCKED REGION
+ SLEEVE
X UNDERNEATH SLEEVE



Upstream of blockage

Summary of Questions 2 - 6

- Droplet shatter model is implemented in a conservative manner
- Benchmarking demonstrates that sensitivity study model provides conservative predictions

Conclusions

- Best estimate to upper bound packing factor is 50% to 70%
- The response of PCT over a range of PF shows a smooth response to changes
- AREVA's sensitivity method has been successfully benchmarked against applicable research
- AREVA's treatment of the SRR phenomenon is applied in a conservative manner within ANP-3011
- A PCT of 1919 from base case is therefore defensible

New Round of Questions

Discussion of questions received on January 10th, 2012.

Schedule

- Progress Energy will docket the responses
- Projected docket date is January 20, 2012
- Target date for new round of questions to be docketed is the week of February 13th

Supplemental Slides

Supplemental Slides Question #5

Supplemental Slides Question #5