Updated Leakage Analysis

Industry/EP/NRC/ANL Meeting

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Topics For Discussion

- Review of Modified B* Approach
- Resolution of Concerns Identified with Modified B* Approach from October 29 Meeting at ANL
- Conclusions

Modified B* Approach

- Two options are available to address primary to secondary leakage with implementation of the PARC:
  - Leakage Analysis Limited H* Length
  - An increased leakage factor can be addressed by a reduction in primary coolant activity
- The H* distance must always be greater than 3 inches to stay within the leakage testing data base

Background

•Assuming loss coefficient does not change between NOP and DBA conditions, using the Darcy equation for flow through a porous medium, the ratio of leak rate between the limiting design basis accident and normal operating conditions can be expressed as:

$$\frac{Q_{DBA}}{Q_{NOP}} = \frac{\Delta P_{DBA}}{\Delta P_{NOP}} \frac{m_{NOP}}{m_{DBA}} \frac{l_{NOP}}{l_{DBA}}$$

Background

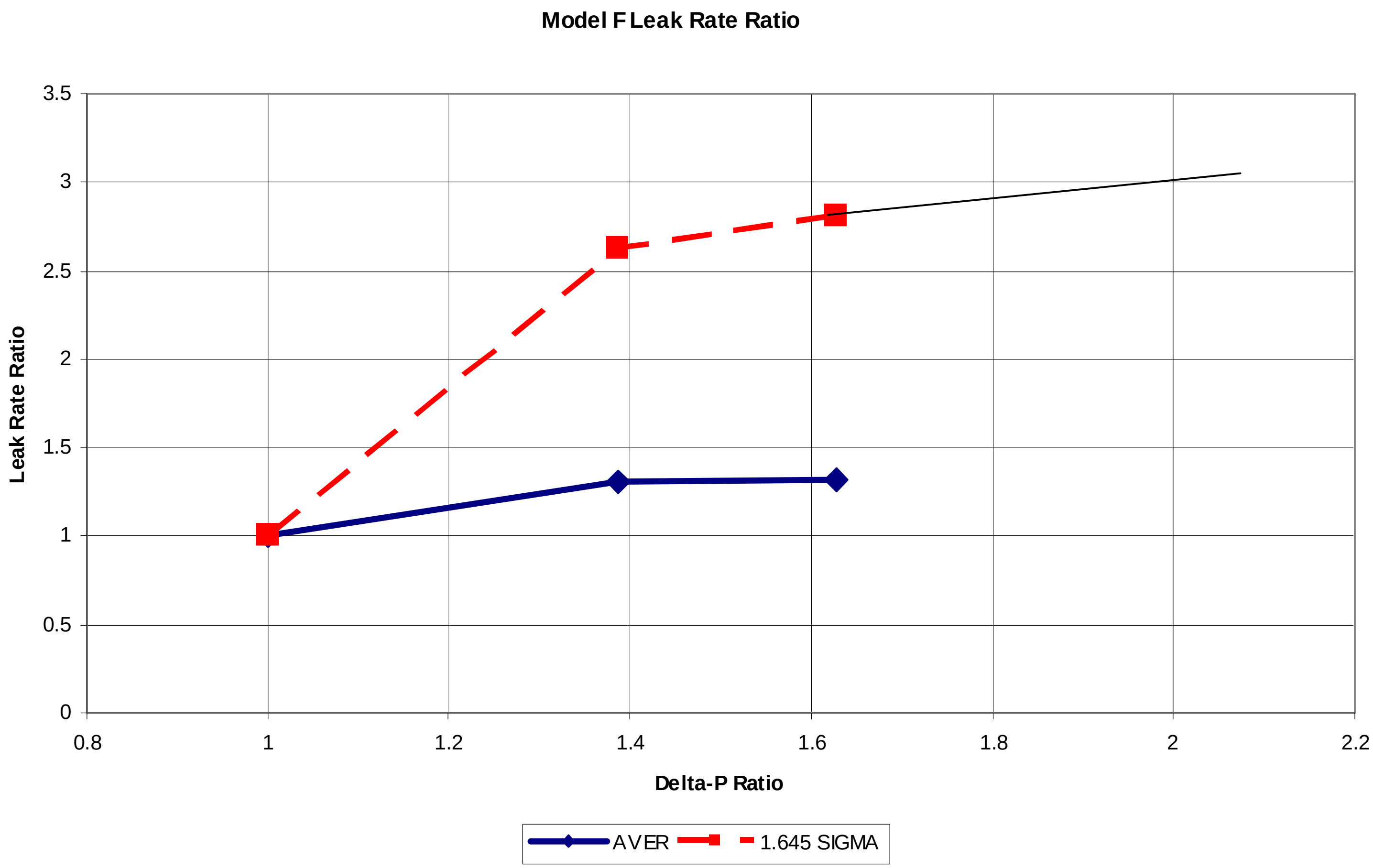
$$\frac{Q_{DBA}}{Q_{NOP}} = \frac{\Delta P_{DBA}}{\Delta P_{NOP}} \frac{m_{NOP}}{m_{DBA}} \frac{l_{NOP}}{l_{DBA}}$$

- Three “subfactors’ need to be evaluated to define the overall “leakage factor”:
  - Impact of pressure differential increase
  - Impact of change in dynamic viscosity
  - Impact of effective crevice length
- Leak test results are used to address leakage factor uncertainty:
  - Via an adjustment to the differential pressure ratio

Modified B* Approach

Peak Pressure Ratio for Plant Transients that Model Primary-to Secondary Leakage	
Transient	Delta-P Ratio
FLB/SLB	1.96
Locked Rotor (Dead Loop)	1.49
Locked Rotor with Stuck Open PORV	1.57
Control Rod Ejection	1.66

Modified B* Approach



Modified B* Approach

- To address the change in dynamic viscosity between the DBA and NOP conditions requires:
  - maximum primary side pressure and temperature increases need to be defined for the H* Plants for design basis accidents that model primary to secondary leakage
    - Steam line break
    - Feedwater line break
    - Locked rotor w/o stuck open PORV
    - Control rod ejection

Modified B* Approach

Maximum Temperature Increase for Design Basis Accidents				
SG Model	SLB	FLB (HL/CL) °F	Locked Rotor (HL/CL) °F	Control Rod Ejection (HL/CL) °F
F and F-Type	0	(6.5/66)	(4/29)	(85/5)
D5	0	(50/120)	(3/5)	(85/5)

Modified B* Approach

Maximum RCS Pressures for Design Basis Accidents				
SG Model	SLB (psi)	FLB (psi)	LR (psi)	CRE (psi)
F and F Type	2560	2672	2765	3030
D5	2560	2850	2711	3030

Modified B* Approach

- For Option 1, an inspection depth can be defined from the top of the tubesheet that limits the increase in primary-to-secondary leakage during the DBA
  - For a postulated FLB, setting the overall leakage factor to 2; using $\Delta P_{DBA}/\Delta P_{NOP}=2.93$; $\mu_{NOP}/\mu_{FLB}=2.31$
  - Setting l_{NOP} equal to the minimum expansion length (i.e., effective crevice length of 3 inches) shown by Westinghouse test data to follow the Darcy flow equation results in:
  - l_{DBA} = ***10.16 inches*** (maximum) for the H* plants
  - l_{DBA} *is defined as the **"Modified B* Length"***

$$\frac{Q_{DBA}}{Q_{NOP}}=\frac{\Delta P_{DBA}}{\Delta P_{NOP}}\frac{m_{NOP}}{m_{DBA}}\frac{l_{NOP}}{l_{DBA}} \longrightarrow 2=\frac{\Delta P_{DBA}}{\Delta P_{NOP}}\frac{m_{NOP}}{m_{DBA}}\frac{3}{l_{DBA}}$$

- *Plant specific "Modified B* lengths" will be defined for each H* plant*

Modified B* Approach

- A <u>second option is available</u> if a leakage analysis limited H* length is not acceptable to a utility:
  - The l_{NOP}/l_{DBA} ratio can be set equal to 1; using $\Delta P_{DBA}/\Delta P_{NOP}$=2.93; μ_{NOP}/μ_{FLB}=2.31

$$\frac{Q_{DBA}}{Q_{NOP}} = \frac{\Delta P_{DBA}}{\Delta P_{NOP}} \frac{m_{NOP}}{m_{DBA}} \frac{l_{NOP}}{l_{DBA}} \qquad 6.78 = \frac{\Delta P_{DBA}}{\Delta P_{NOP}} \frac{m_{NOP}}{m_{DBA}} \bullet 1$$

  - The increased leakage factor can be addressed by a reduction in the primary coolant activity
    - This proposed action is in line with the actions taken for the voltage based plugging criteria for tube support plate ODSCC and is outlined in DG-1074
    - Preliminary results show a maximum leakage factor of greater than 6 for FLB for one plant.
  - H* distance must always be greater than 3 inches

Application of the Modified B* Approach

- A similar approach for either Option 1 or 2 is used to establish expected leakage during accident conditions
  - Plant Specific "leakage factors" will be provided in tabular form for each H* plant for both options
- For example, for a postulated FLB, for option 1 (i,.e., where a modified B* length has been defined) a factor of 2.0 will be applied to the condition monitoring (CM) and operational assessment (OA) as follows:
  - For the CM, the component of leakage from the prior cycle below the H* distance will be multiplied by a factor of 2.0 and added to the total leakage from any other source and compared to the allowable limit
  - For the OA, the difference in the leakage from the allowable leakage limit and the accident leakage from other sources will be divided by 2.0 and compared to the observed leakage and that an administrative limit (for operating leakage) will be established not to exceed the calculated value

Modified B* Approach

Two concerns were raised about the modified B* approach at ANL:

1. Whether or not loss coefficient remains constant when changing from NOP and DBA conditions
   - Loss coefficient is judged to be a function of contact pressure by ANL
2. Preliminary results show contact pressure may reduce from NOP to SLB conditions

Resolution of Concerns

- Addressing Concern No. 1, it was suggested by ANL that if the Westinghouse leakage data was evaluated on a sample to sample basis that it would reveal a relationship between contact pressure and loss coefficient
  - Westinghouse has conducted such a review
  - The results suggest that there is <u>not a significant</u> relationship between contact pressure and leakage loss coefficient

Resolution of Concerns

- Analysis assumptions:
  - Crevice pressure profiles were matched to plant initial pressure and temperature conditions to the extent possible
- The Model D5 conditions used to calculate test sample contact pressure are: Normal Operation (2250 psi) and FLB (2800 psi), the corresponding average crevice pressures are 1517 psi for NOp and 1800 psi for FLB
- The Model F conditions used to calculate test sample contact pressure are: SLB (2560 psi) and “Other” (Hydrotest) (3100 psi), the corresponding average crevice pressures are 1404 psi for SLB and 1800 psi for “Other”
- A composite plot of the regression analyses results for the Model D5 and F test samples show that, for the most part, loss coefficient <u>is essentially constant or decreases with increasing contact pressure</u>

Resolution of Concerns

- Regression analysis results from the test data reveal:
  - Model D5 test data results in a positive linear relationship between loss coefficient and contact pressure in only 2 of the 5 samples tested at elevated temperatures
  - Model F leak test data results in a positive linear relationship between loss coefficient and contact pressure in only two 2 of 9 samples tested at elevated and room temperatures

Resolution of Concerns

MODEL D5 Samples

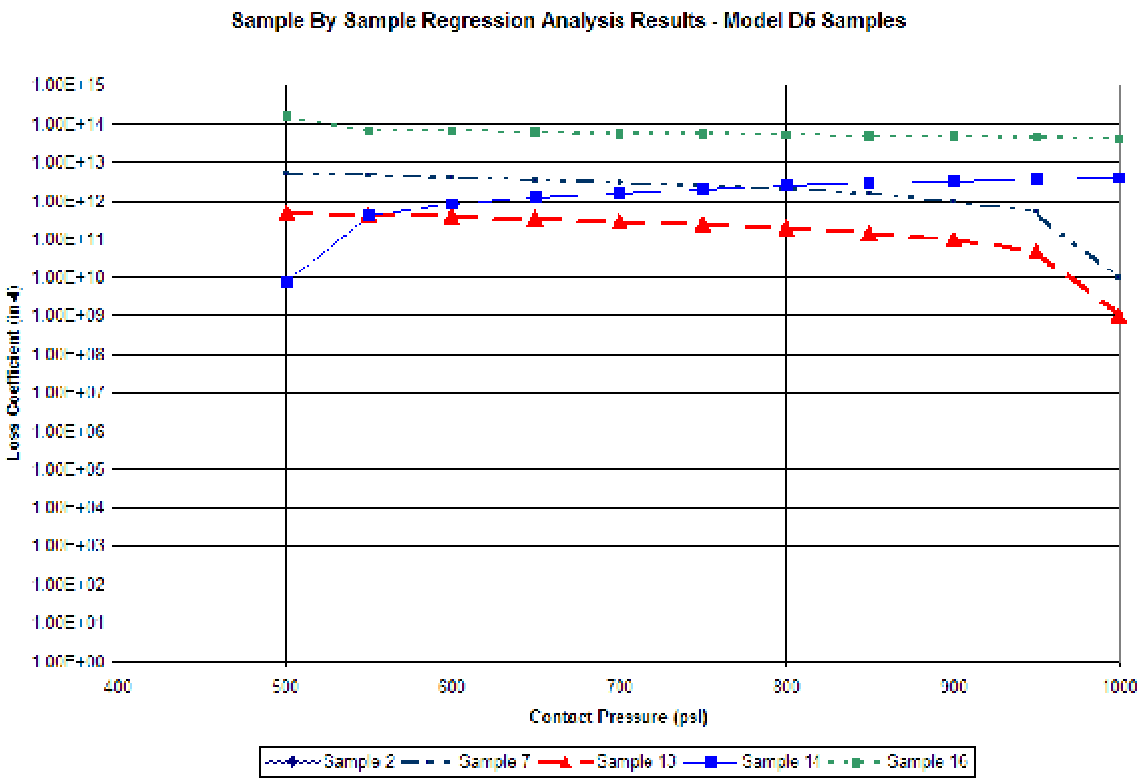
Linear Correlation	Psec at Exit			
Sample No.	Slope	Intercept	R-Squared	Expansion Length (in)
S2	1.00E+10	-1.00E+13	0.2991	12
S7	-1.00E+10	1.00E+13	0.5246	9
S13	-1.00E+09	1.00E+12	0.4533	6
S14	8.00E+09	-4.00E+12	0.9013	6
S16	-3.00E+11	3.00E+14	0.0926	3

Resolution of Concerns

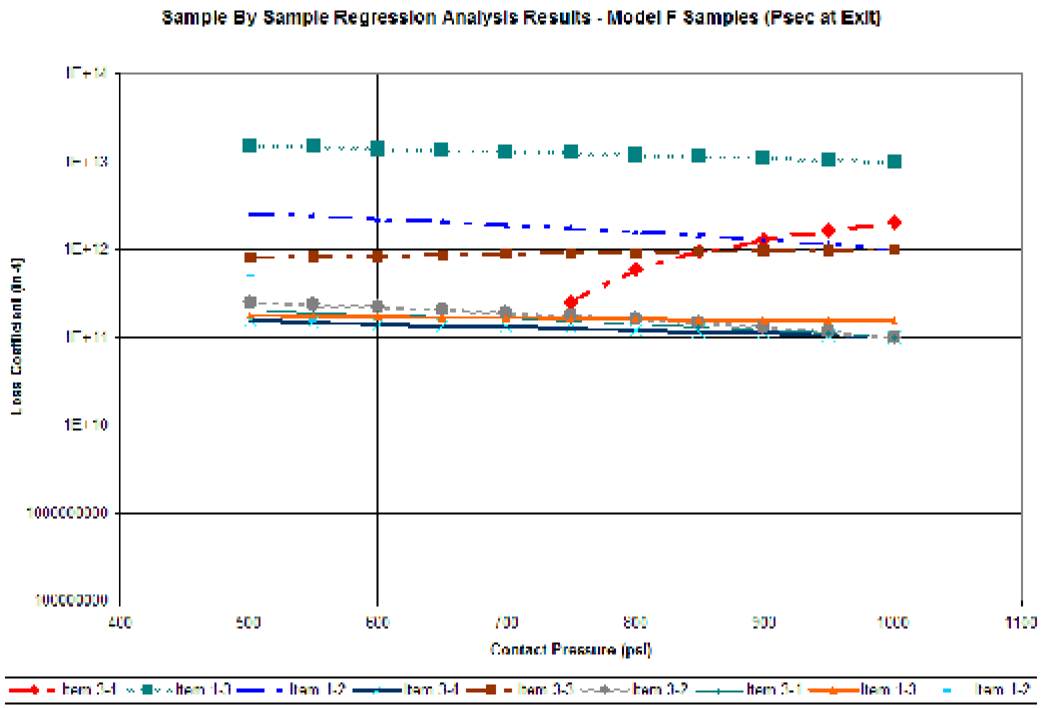
Model F Samples

Linear Correlation		Psec At Exit		
Sample No.	Slope	Intercept	R-Squared	Expansion Length (in)
ITEM 3-4	7.00E+09	-5.00E+12	0.0874	16.5
ITEM 1-3	-1.00E+10	2.00E+13	0.1349	16.5
ITEM 1-2	-3.00E+09	4.00E+12	0.2453	16.5
ITEM 3-4	-1.00E+08	2.00E+11	0.355	16.5
ITEM 3-3	4.00E+08	6.00E+11	0.017	16.5
ITEM 3-2	-3.00E+08	4.00E+11	0.2744	16.5
ITEM 3-1	-2.00E+08	3.00E+11	0.5715	16.5
ITEM 1-3	-5.00E+07	2.00E+11	0.0012	16.5
ITEM 1-2	-7.00E+09	4.00E+12	0.0474	16.5

Resolution Of Concerns
Model D5 Sample Results



Resolution of Concerns
Model F Sample Results



Resolution of Concerns

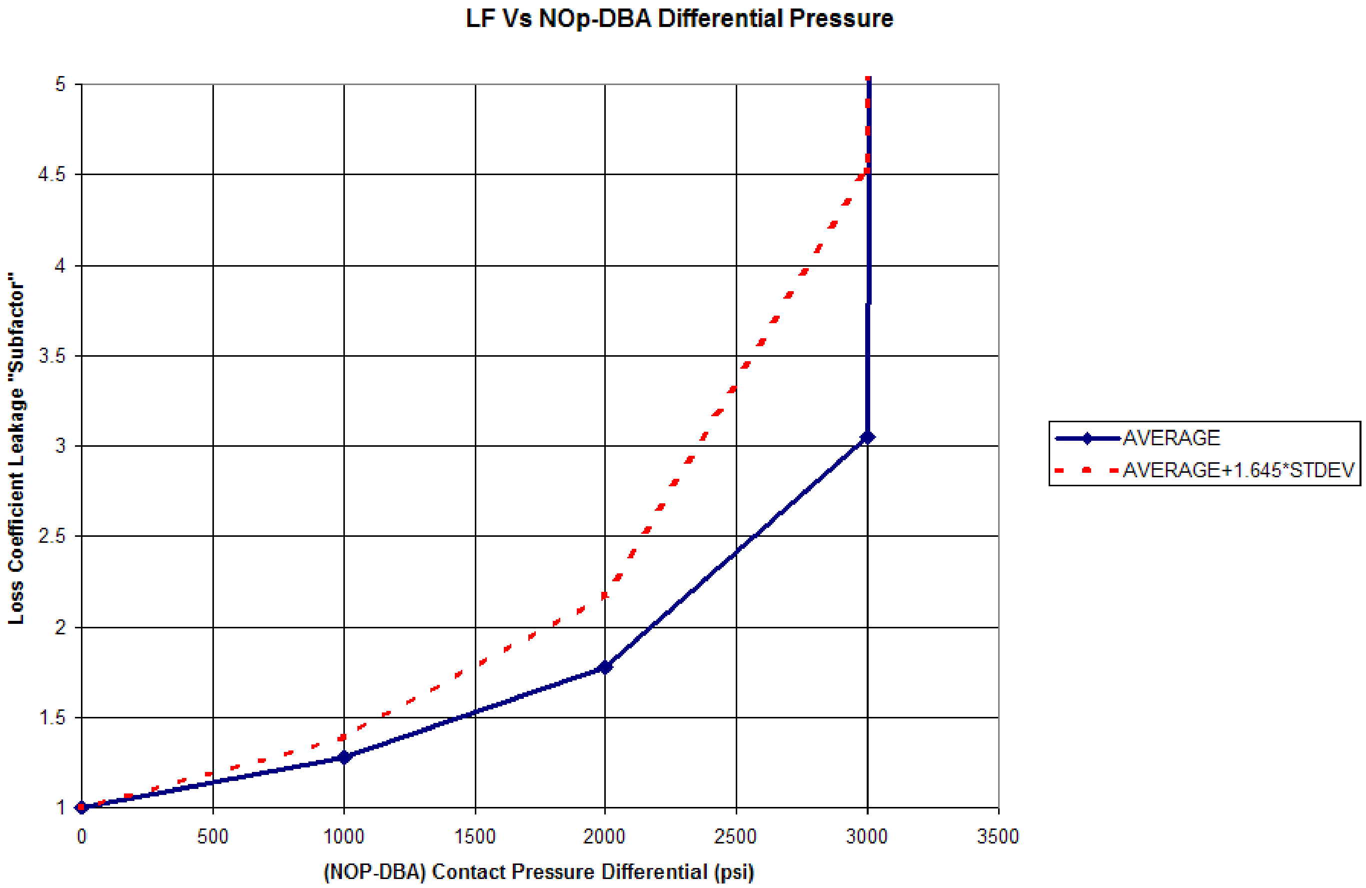
- Addressing concern No. 2, how will the issue that a possible reduction in contact pressure between NOP and DBA conditions can occur be addressed?
  - A "subfactor" for loss coefficient can be *conservatively* re-introduced into the expression for determining overall leakage factor to address the potential reduction in contact pressure during a design basis accident

$$\frac{Q_{DBA}}{Q_{NOP}} = \frac{\Delta P_{DBA}}{\Delta P_{NOP}} \frac{m_{NOP}}{m_{DBA}} \frac{l_{NOP}}{l_{DBA}} \frac{K_{NOP}}{K_{DBA}}$$

Resolution of Concerns

- The linear regression analysis results for individual tests with a positive slope from the leak test data are used to develop a loss coefficient versus contact pressure leak rate subfactor
  - The 4 cases for the Model D5 and F leak test samples that resulted in a slightly positive slope are used to calculate the ratio K_{NOP}/K_{DBA} as function of pressure differential
- A sensitivity study has been completed which evaluates the effect of a potential reduction in contact pressure during a design basis accident
  - The K ratio subfactor is not needed if DBA contact pressure is demonstrated to meet or exceed NOP contact pressure through the entire thickness of the tubesheet
- A 1.645 Sigma leakage “subfactor” can be defined based the difference (reduction) in contact pressures between NOP and the DBA condition

Resolution of Concerns
Loss Coefficient Subfactor



Resolution of Concerns

- The impact of the loss coefficient leakage factor can be compensated for by adjusting the effective crevice length inspected using the ratio technique
  - If the reduction in contact pressure is less than 1700 psi from NOP to DBA, the maximum 1.645 Sigma leakage subfactor for loss coefficient is less than 2
  - For a Model F plant that has been inspected to 17 inches below the top of the tubesheet, any increase in leakage due to a possible decrease in loss coefficient would be negligible as the expected decrease in contact pressure would be small (< 500 psi); <u>overall leakage factor would be less than 2.5</u>

Conclusions

- The Modified B* approach (Options 1 and 2) remains a viable approach for addressing potential primary-to-secondary leakage following implementation of the PARC
- Both options address
  - All design basis accidents that model primary to secondary leakage (consistent with RIS 2007-20)
  - Leakage uncertainty (consistent with NEI 97-06, Rev. 2 Guideline documents)
- When it can be demonstrated that contact pressure increases during a postulated DBA, then the assumption that K=constant remains valid
- If contact pressure decreases during any DBA, a leakage subfactor can be defined for loss coefficient as a function of maximum difference in contact pressure between NOP and DBA conditions
  - Inspection to 17 inches below the top of the tubesheet assures that any leakage increase that may occur due to a reduction in contact pressure during a design basis accident would be negligible; i.e., an overall leakage factor of 2.5 remains conservative