NRC/ANL INDUSTRY MEETING

Dated: November 6, 2008

Leakage Analysis

NRC/ANL/Industry Meeting

10/29/08

Gary Whiteman

Topics for Discussion

- Background Information on B*
- Modified B* Approach
- Application of the Modified B* Approach
- Conclusions

Background

- The objective of this presentation is to show how the leakage integrity performance criterion of NEI 97-06, Rev. 2 is met with implementation of the PARC
- Plant specific leakage factors are developed to predict the increase in leakage that occurs during a design basis event versus normal operating conditions using a ratio of the Darcy flow equation
- Two options are discussed for implementation
  - leakage analysis length limited H* or <u>not</u>

- Consistent with RIS 2007-20, all design basis accidents that model primary to secondary leakage are considered in this analysis
- More likely than not, the limiting accident for the H* plants is a postulated feedwater line break event
  - Highest pressure differential
  - Highest temperature

Background Information

- The leakage analysis for Final H* will continue to be based on Darcy's equation for flow through a porous medium

- Volumetric flow, Q, is a function of the differential driving pressure, Δp, and the respective inverse values of viscosity, μ, loss coefficient, K, and the length of hydraulic expansion, l

$$Q = \frac{\Delta P}{\mu K l}$$

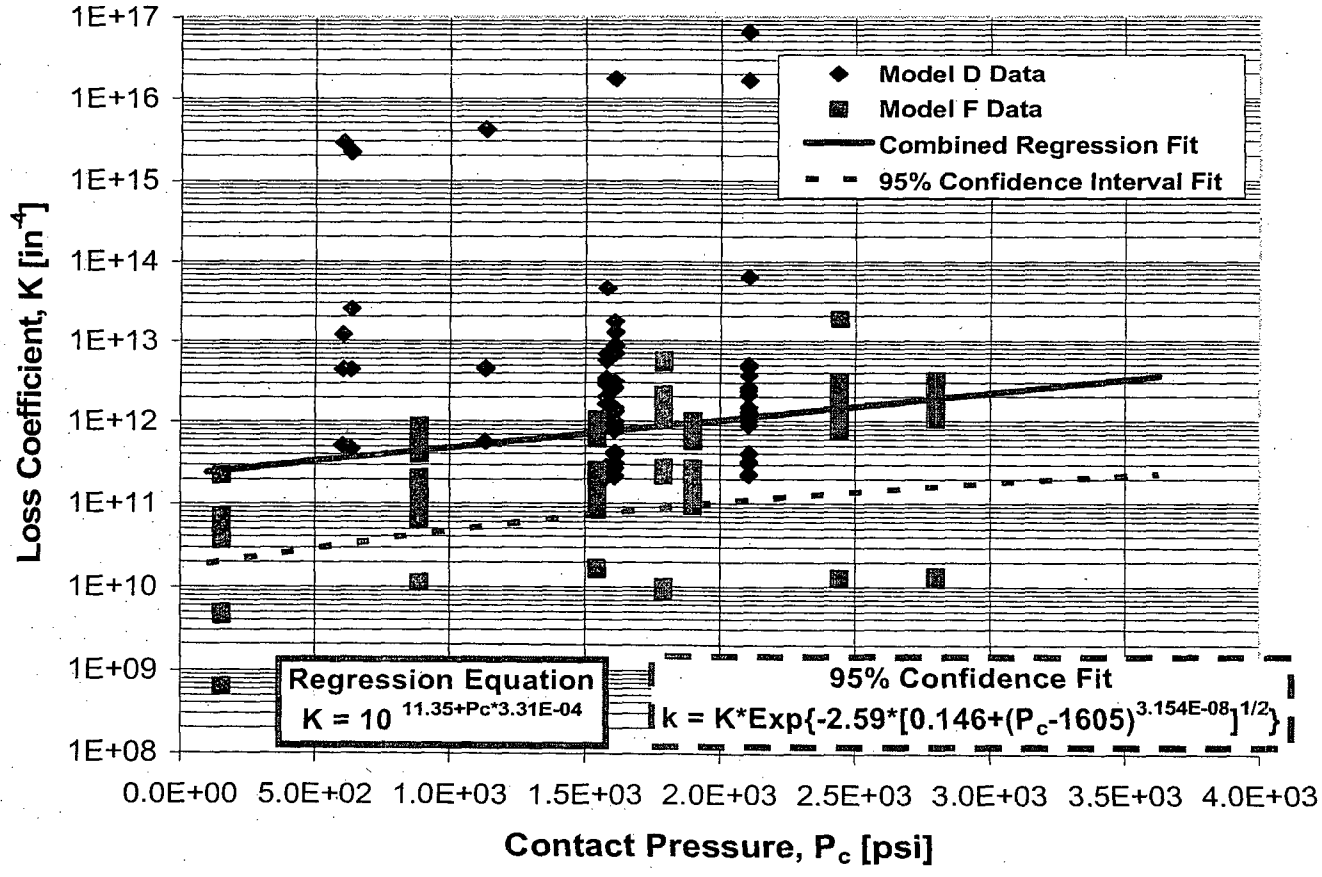
Background Information

- Westinghouse used multiple testing programs to define a log-linear relationship between loss coefficient and contact pressure
- The B* length was dependent on defining loss coefficient as a function of contact pressure
- B* was the length of engagement in the tubesheet needed for the leak rate for a postulated SLB to be bounded by a factor of 2 greater than the leakage during normal operating conditions

Background Information (Cont)

- The NRC staff raised concerns about the correlation of leak loss coefficient (LLC) with contact pressure (CP)
  - The Model F LLC vs. CP regression analysis slope and intercept properties are different than Model D5
  - Model D5 loss coefficient data is spread out in range and results in a negative log-linear correlation

Loss Coefficient For Model F



Background Information (Cont)

- Original B* length, based on K=f(contact pressure), will no longer be used for final ARC leakage basis
- The loss coefficient is conservatively assumed to be constant between design basis accident and normal operating condition
  - Tube follows bore, 3-D FEA shows no gap exists
  - A porous medium is a porous medium during all plant conditions
  - Leakage decreases during DBA because of increased tightening of the joint; resistance to leakage would increase

Modified B* Approach

- The ratio of leak rate between the limiting design basis accident and normal operating conditions can be expressed as:

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

Modified B* Approach

- Based on a review of the expression, three "sub-factors" need to be addressed to define "leakage factor":
  - Pressure differential increase
  - Impact of 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

- The leakage factor approach:
  - Requires maximum pressure differentials across the tubesheet, and maximum primary side pressure and temperature increases 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

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

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

Leak Rate Limit Requirement

- In accordance with NEI 97-06, Rev. 2, the projected total leak rate from all degradation within the steam generator has to be less than the leakage performance criteria with 0.95 probability at 50% confidence

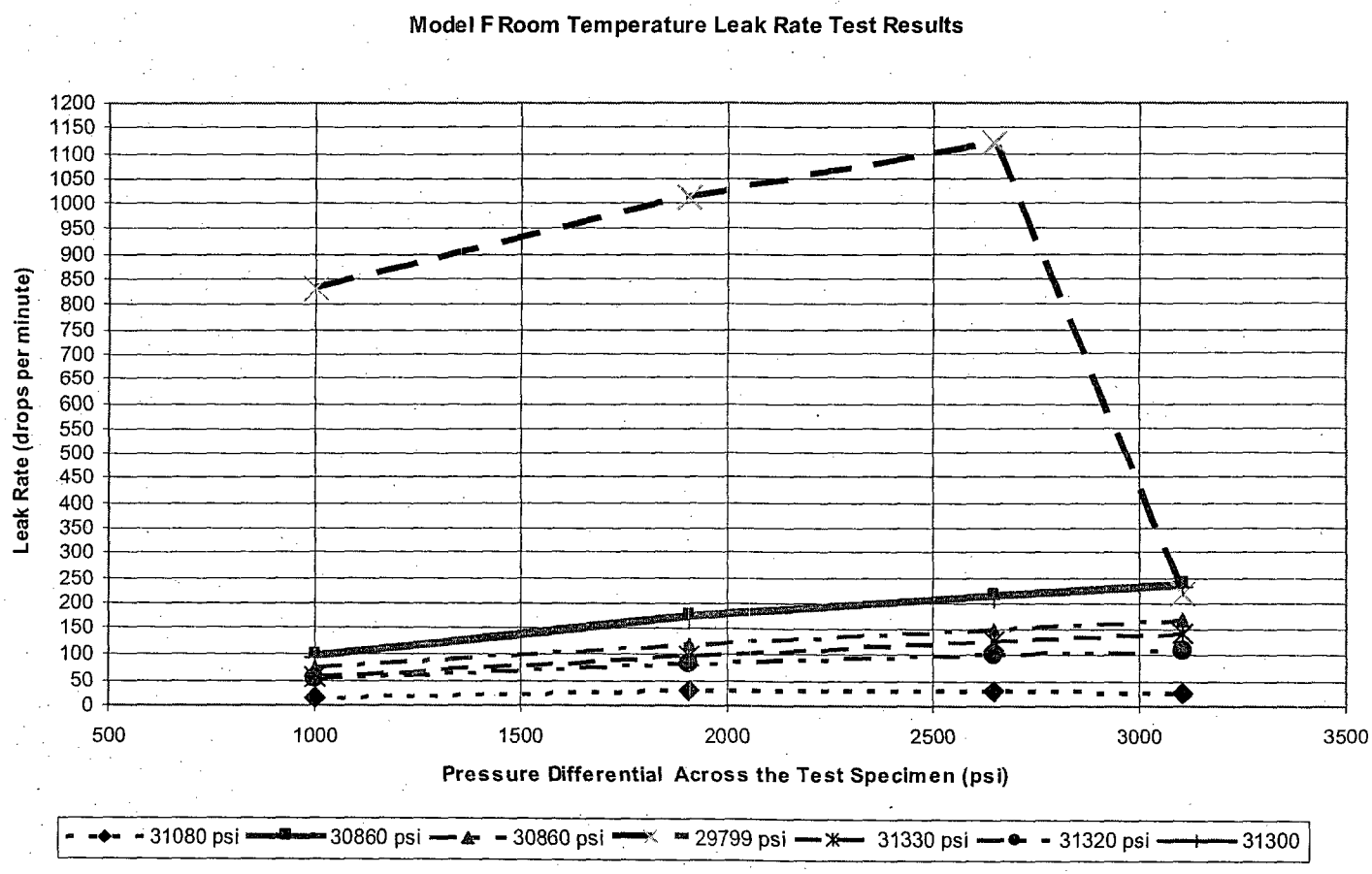
Modified B* Approach

- Previous leak rate test results are used to confirm use of Darcy Formula and establish leakage uncertainty
- 1.645 sigma values for leakage ratios used for final leakage factors for all design basis transients

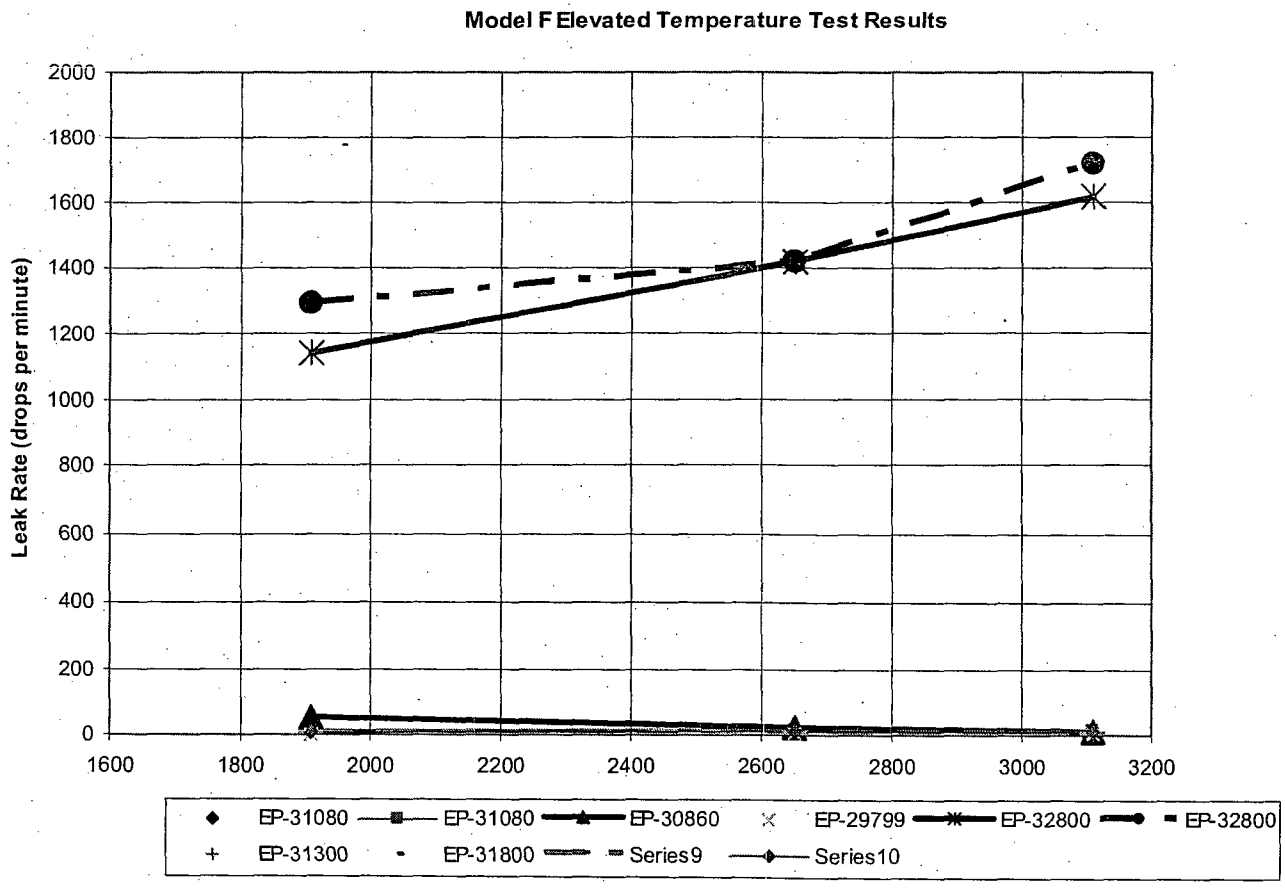
Modified B* Approach

- Leak rate test results demonstrate that it is conservative to assume that a linear relationship exists between leak rate and differential pressure across the tubesheet
  - Model D5 and F leakage test data used hydraulic expansion lengths of 12 and 16.5 inches, respectively
  - Some Model D5 expansion lengths as short as 3 inches tested (with similar results)
  - Nominal and large diameter (out of tolerance by 6 mils – noted as EC on the following slides) collar inner diameters tested
  - Hydraulic expansion pressures were within the original SG manufacturing specification limits

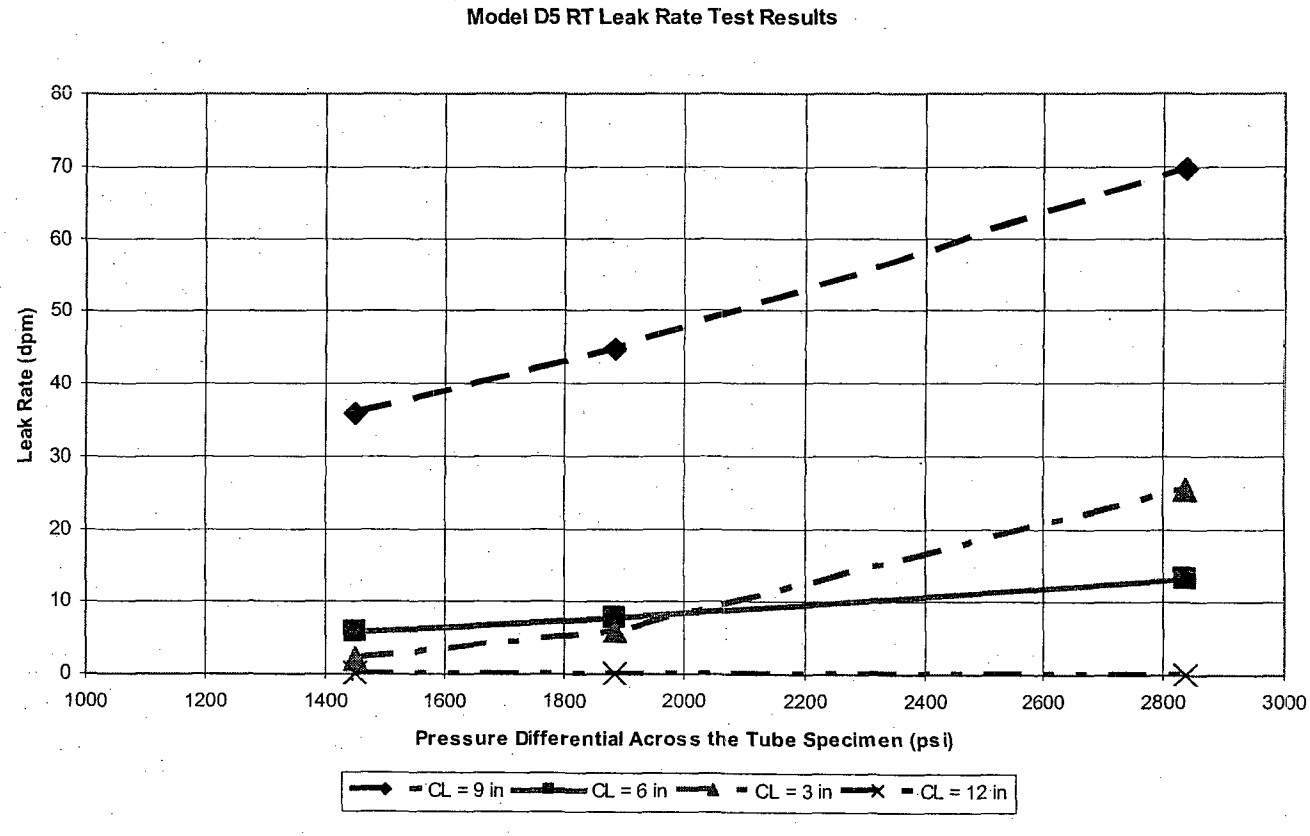
Modified B* Approach



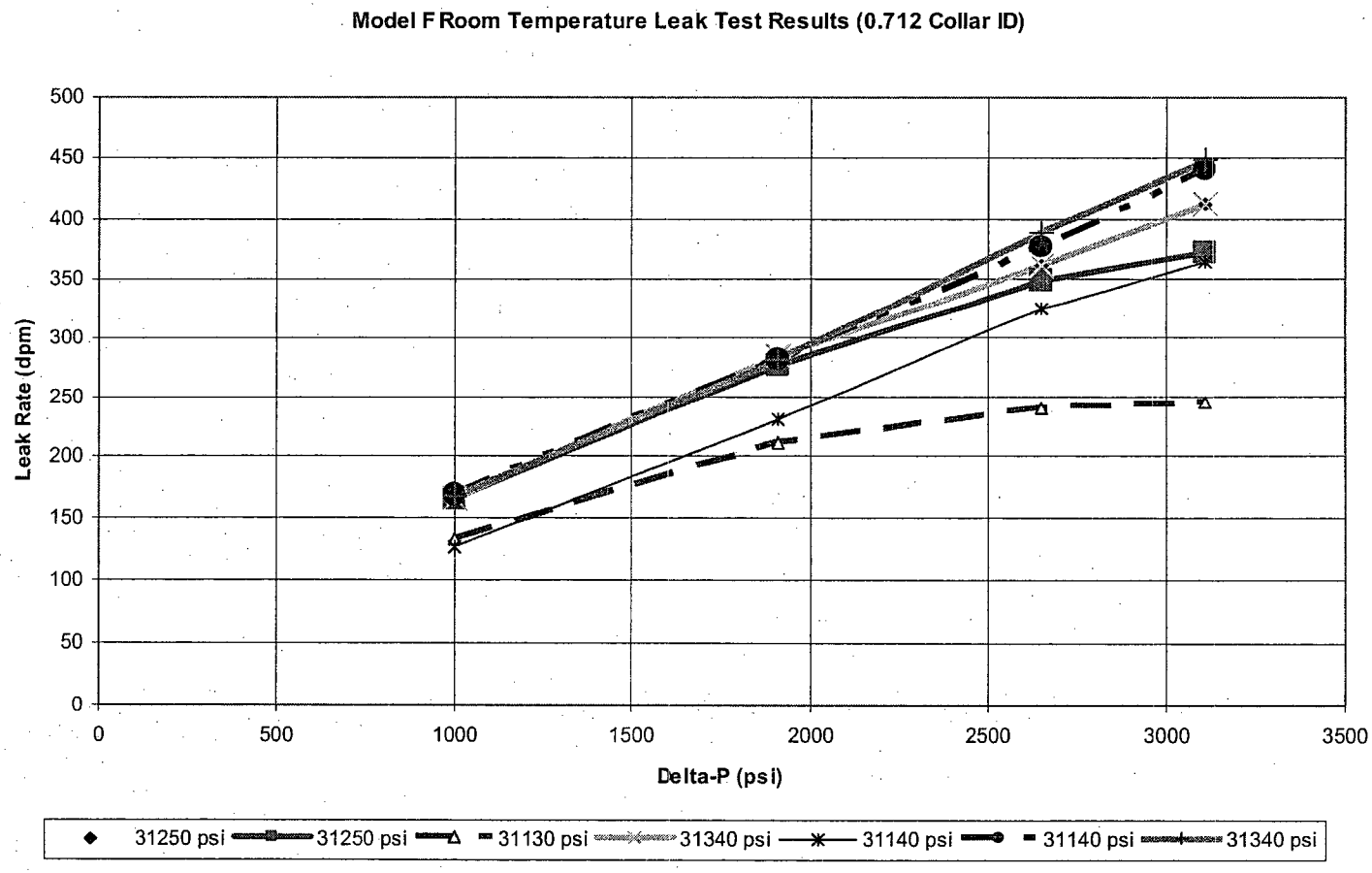
Modified B* Approach



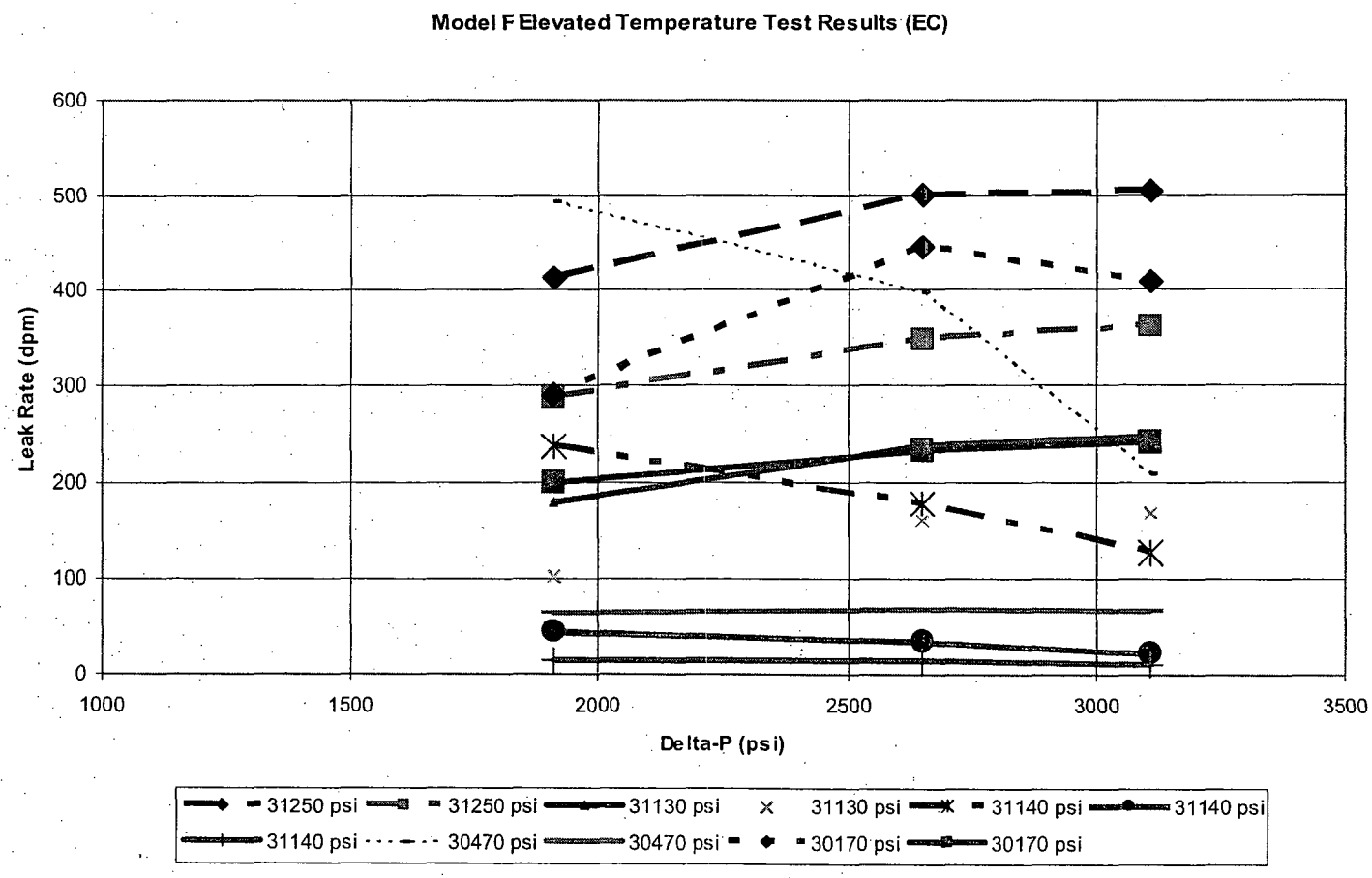
Modified B* Approach



Modified B* Approach



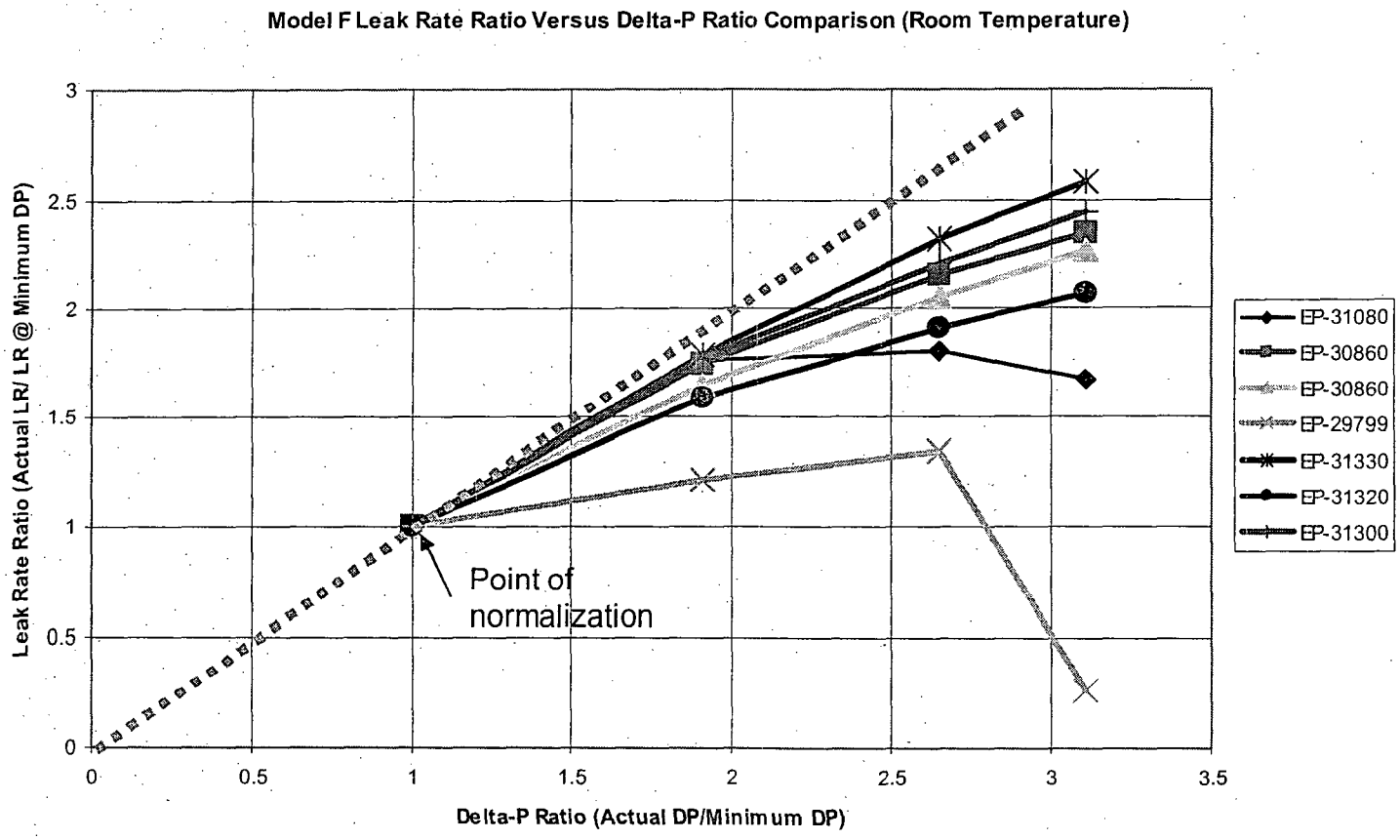
Modified B* Approach



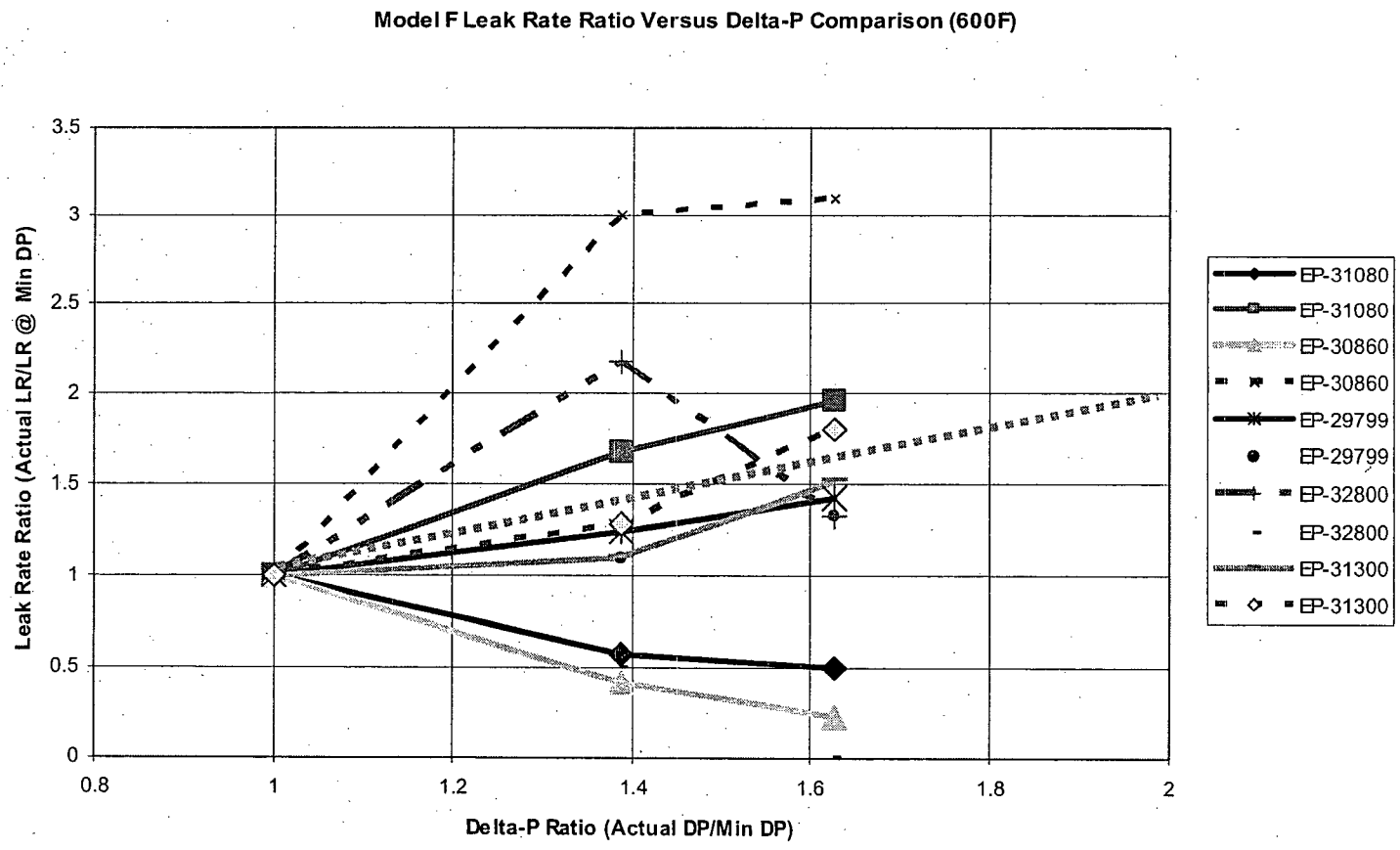
Modified B* Approach

- Leak rate ratio increase tends to be less than pressure differential ratio increase
- In the following slides, all plots are normalized to a minimum pressure
  - 1000 psi – Model D5, F specimens
  - 1900 psi – Elevated Temperate Model F specimens

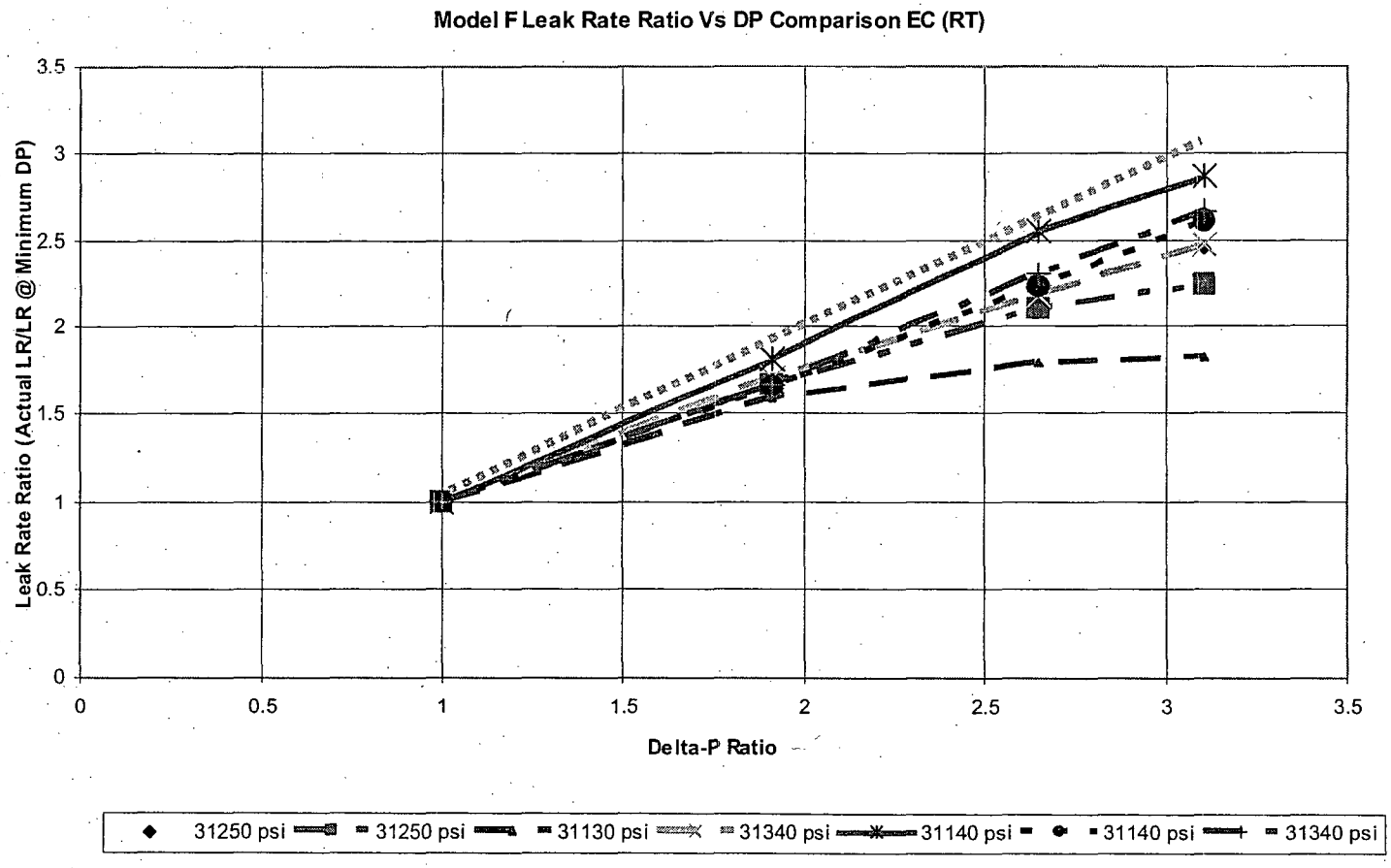
Modified B* Approach



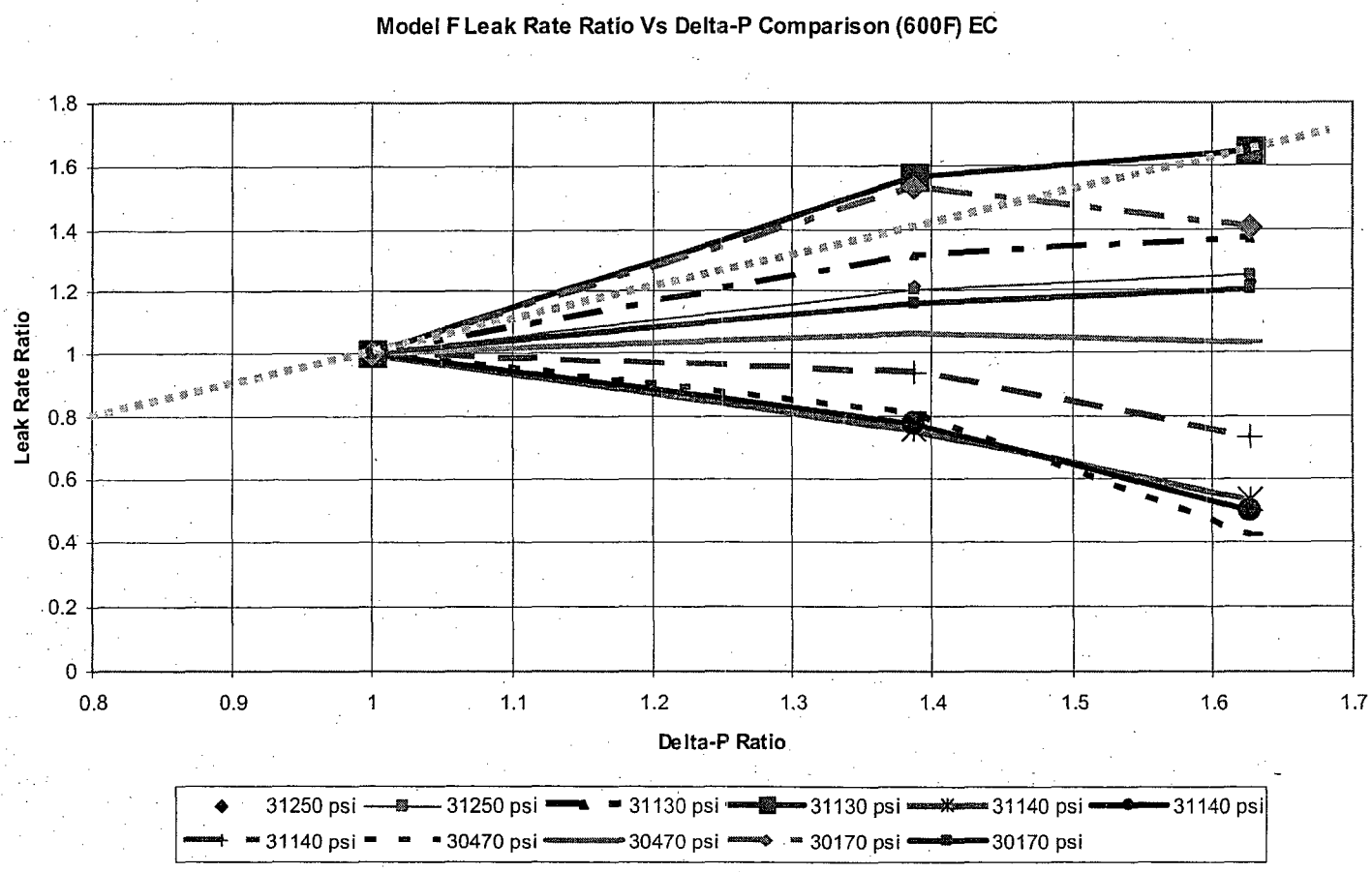
Modified B* Approach



Modified B* Approach



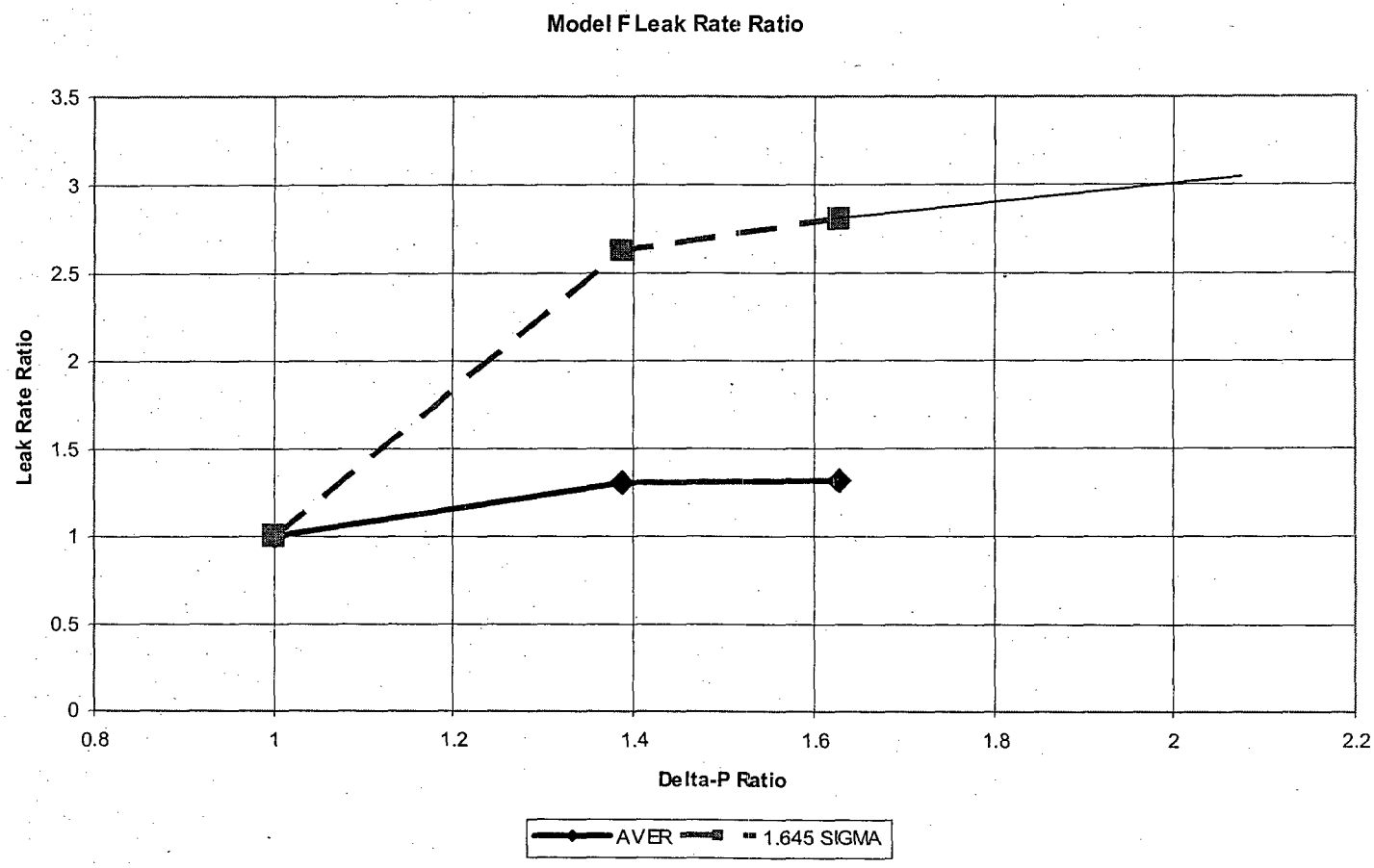
Modified B* Approach



Modified B* Approach

- The leakage test results are then used to adjust the pressure differential ratio
- The curve for the Model F SG for mean + 1 sigma result is used to correct the pressure differential ratio
  - The methodology for adjusting the pressure differential ratio is under review by the expert panel

Modified B* Approach



Modified B* Approach

- Finally, the ratio of effective crevice length during normal operating conditions to the effective crevice length during design basis accidents can be used to define a <u>modified B* length</u> that precludes an increase in leakage greater that a ratio equal to the increase in pressure differential ratio that occurs during each design basis accident

Modified B* Approach

- Recall that: $$\frac{Q_{DBA}}{Q_{NOP}} = \frac{\Delta P_{DBA}}{\Delta P_{NOP}} \frac{\mu_{NOP}}{\mu_{DBA}} \frac{l_{NOP}}{l_{DBA}}$$
- Setting

$$\frac{Q_{DBA}}{Q_{NOP}} = 2$$

$$l_{NOP} = 3\ inches$$

- l_{NOP} is equal to the minimum expansion length (i,.e., effective crevice length of 3 inches) shown by test data to result in a linear increase in leakage with increasing pressure differential
- To achieve a leakage factor of 2, l_{DBA} = 10.16 inches
- l_{DBA} is defined as the "Modified B* length"
- Plant specific "Modified B* lengths" will be defined for each H* plant

Modified B* Approach

- Modified B* length for FLB event bounds the modified B* length for a locked rotor or control rod ejection event
  - Results in a reduced "leakage factor" for these transients for the Condition Monitoring and Operational Assessment
  - Demonstrates more margin for current accident analysis leakage assumption

Modified B* Approach

- A <u>second option is available</u> if a leakage analysis limited H* length is not acceptable to a utility:
  - The I_{NOP}/I_{DBA} ratio can be set equal to 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 will always be greater than 3 inches to stay within the leak testing data base

Application of the Modified B* Approach

- A similar approach for both 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

Conclusions

- Two equally viable options are available to address primary-to-secondary leakage upon implementation of H*
  - Option 1 – leakage analysis limited H*
  - Option 2 – structural H* with reduction in primary coolant activity level
- 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)
- Methodology to implement either option is the same as the IARC