Accident Induced Leakage Performance Criterion

SGTF/NRC Meeting

August 12, 2005

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Presentation Topics

- SGMP Study on Bending Load Effect on AILPC
- Effect on SG Generic License Change Package
- Status of NEI 97-06 Revision 2

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SG Technical Issue

- NRC draft Generic Letter asks plants to verify "leakage integrity" in the presence of non-pressure related loads
  - GDC-2, *Design bases for protection against natural phenomena*, requires that the safety function be maintained with consideration of "*appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena*"
- Integrity assessment for AILPC does not consider bending loads associated with external events

SG Technical Issue

- SGMP is conducting a study to determine the effects of bending loads on leakage and how to evaluate them
  - Initial results for seismic loads
    - RSGs are affected in high row U-bends
    - Only a concern for significant circ cracks on extrados and intrados of tube
    - May increase leakage during seismic event by a factor of 4 maximum
    - May increase long term leakage after the seismic event by a factor of 2 due to plastic deformation

SG Technical Issue

- Scoping study found, as with SIPC, not a safety issue –
  - •Limited to circumferential flaws
  - •Ind ustry has not experienced circumferential degradation capable of leaking in high bending stress areas
- Further studies planned to benchmark results and to provide evaluation guidance

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Leakage Integrity Under Combined Loads
Summary of Phase I Evaluation

J. A. Begley.

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Phase 1 Scoping Study

- SGMP Phase 1scoping studies were performed independently by Westinghouse, Babcock & Wilcox Canada and Areva to determine the significance of non-pressure loads on leakage integrity.
- This presentation summarizes the results of the three scoping studies.

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General Leakage Integrity Issues

- Mechanical tearing of partial-depth degradation under accident conditions
  - •Pos sible development of 100% through-wall (TW) cracks and
  - •Su bsequent leakage through the cracks (pop-through conditions)
- Prediction of the 100%TW crack length including further elongation due to mechanical tearing
- The influence of bending loads on pop-through conditions, final through wall leaking crack lengths and final crack opening areas.

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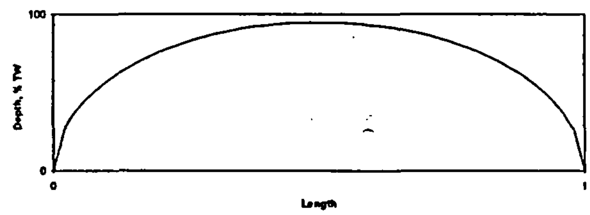
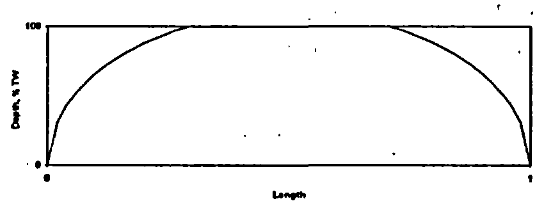
Pop-Through and Tearing





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Main Questions of Scoping Study

- Do bending loads lead to the development of leakage sites not presently considered in tube integrity evaluations?
- If leakage sites exist, what is the magnitude of the increase in leak rates with the addition of bending loads?

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Answers to Main Questions

- Existing information was used in the scoping studies to answer the questions of interest. Scoping study found
  - No additional leakage sites beyond those evaluated in current CMOAs
  - The maximum calculated long term effect of bending loads is about a factor of 2 increase in leak accident leak rates for the worst case circumferential degradation location
  - There are no current or projected degradation states where bending load effects increase projected accident leak rates

Conclusions and Status

- There is no current safety concern relative to the impact of bending loads on leakage integrity.

- An experimental program is being implemented to verify the conclusions of the scoping studies and provide the basis for extending the presently documented leakage assessment methodology to incorporate the effect of bending loads.

Scoping Study Results

- Degradation Geometries and Loads of Interest
- Pop Through Conditions
- Leak Rates Under Combined Pressure and Bending

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Degradation Geometries and Loads of Interest

- Axial Cracking
- Circumferential Cracking
- Volumetric Degradation
  - Axial Failure Mode
  - Circumferential Failure Mode
- Differential Pressure
- Axial Loads (End Cap Pressure, Seismic, Thermal)
- Bending Loads (Seismic, LOCA shaking, Crossflow)

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Degradation Geometries and Loads of Interest

- Axial loads and bending loads have essentially no effect on pop-through or crack opening areas of axial cracking or volumetric degradation that fails in an axial mode based on burst test results and ovality measurements under bending loads.
- Circumferential cracking and volumetric degradation that fails in a circumferential mode require consideration of both axial and bending loads. Axial loads are routinely considered.
- Circumferential degradation under bending loads is therefore the primary focus of the scoping study.

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Locations of Interest

- Top span of original OTSG's
  - Very high bending loads from cross-flow accident loading
  - Occasional instances of circumferential degradation
  - Bounding size on the order of 50% TW and 90° arc
- Larger radius u-bends in RSG's
  - High in plane seismic bending loads
  - Circumferential PWSCC detected but at flank locations and only out to row 10 in 51's and row 13 in D4

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Top Span of Original OTSG Designs

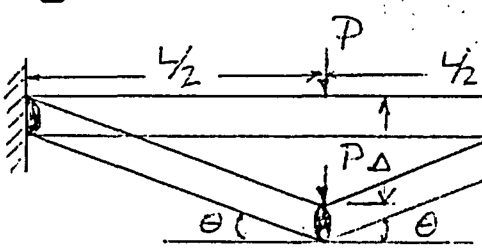
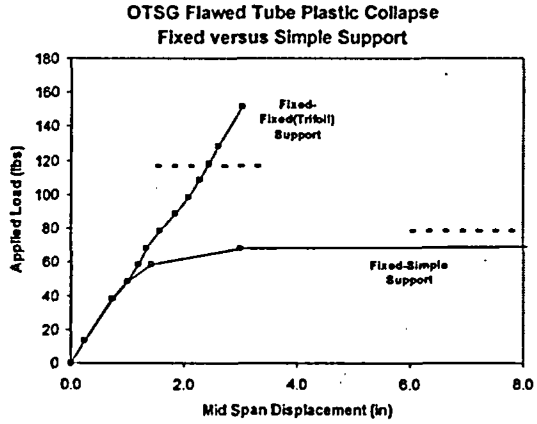


Illustration of Plastic Hinges Required for Plastic Collapse in Bending

Top Span of Original OTSG Designs

- A plastic bend angle of 3.6° is needed to create the $ctod_c$ required for pop-through
- Tube lock-up occurs at a rotation of 0.5° preventing plastic collapse and the development of the needed plastic bend angle



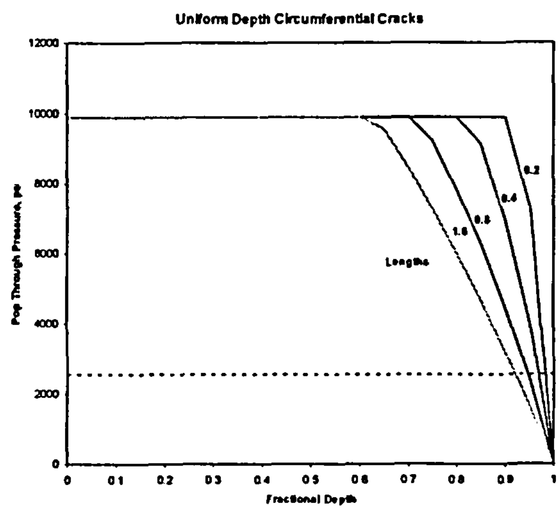
Pop-Through Under Axial Loads Generated by End Cap Pressure

- For a circumferential crack of uniform depth, d, the pressure differential required to develop 100% TW tearing is given by:

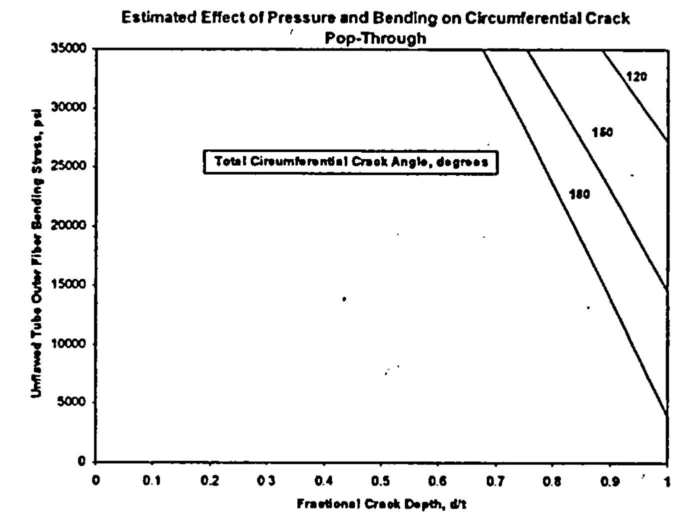
$$p = 1.2\,(\sigma_y + \sigma_u)\,M_{cp}\,t / Rm$$
$$M_{cp} = (1 - d/t)/[1 - d/(t\ M_c)]$$
$$M_c = 0.887 + .1312\,\lambda + 0.1125/\exp(\lambda)$$
$$\lambda = L/\sqrt{(R_m\,t)}$$

- Here p is the differential pressure in psi, d is the circumferential crack depth, and L is the total circumferential crack length

Pop-Through Under Axial Loads Generated by End Cap Pressure



Plastic Collapse Under Tension and Bending



Pop-Through Conclusions

- Consideration of bending loads does not lead to additional leakage sites.
- The conclusions of current leakage assessment methodologies dealing with pressure and axial force loading remain valid.
- At present there have been no observed circumferential degradation sites that are both capable of leaking and located in high bending stress regions.

Leak Rates under Combined Pressure and Bending

- A leaking circumferential crack in a high bending stress region is assumed.
  - This is a "what if scenario"
- Two independent techniques were used to calculate crack opening areas. (Westinghouse and B&W Canada)
- For a given crack opening area, the leak rate calculations used essentially the same approach.
- The two independent analysis techniques arrived at very comparable results

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Leak Rates under Combined Pressure and Bending

- Accident bending loads are transitory
- Leak rate increases under bending loads when crack opening area increases more than it decreases
- Residual plastic opening after the bending transient is completed leads to an increased leak rate under pressure only loading
- Calculated leak rates as affected by bending are bounding since maximum crack opening is considered rather cyclic opening and closing

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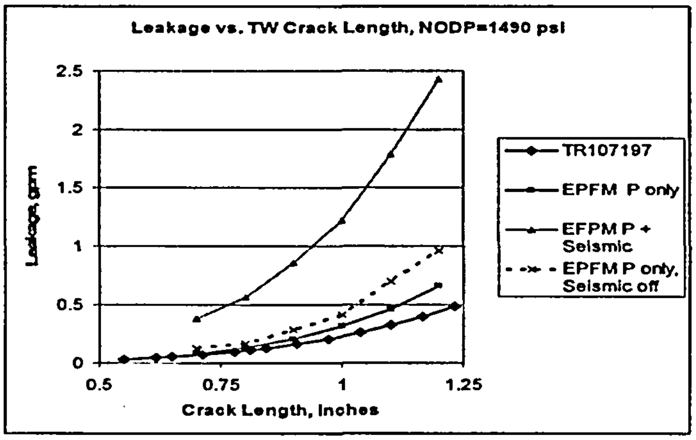
Leak Rates under Combined Pressure and Bending

- ► Westinghouse NOP/Seismic Results with Outer Fiber Bending Stress of About 8800 psi



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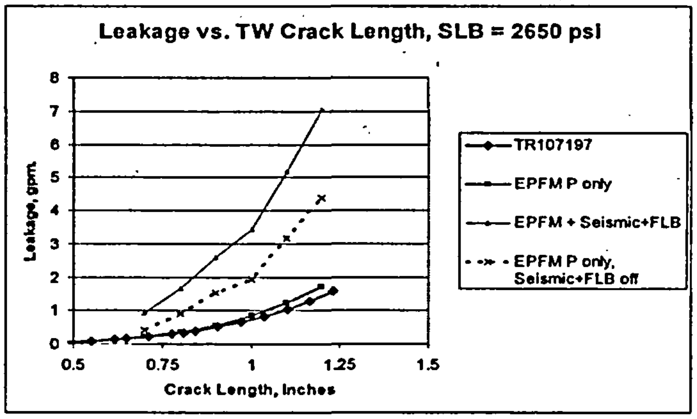
Leak Rates under Combined Pressure and Bending

- Westinghouse FLB/Seismic Results with Outer Fiber Bending Stress of About 14750 psi



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Leak Rates under Combined Pressure and Bending

- B&W Canada Results with Outer Fiber Bending Stress of About 21,000 psi and a 15% Smaller Tubing Size
- Leakage Result – 50° Throughwall Circumferential Crack

Event	Leakage due to MSLB Pressure Differential Loading only [gpm]	Leakage during Seismic Event – Combined Loading [gpm]	Leakage after Seismic Event – Combined Loading [gpm]
Main Steam Line Break + Seismic	0.013	0.065	0.018
Main Steam Line Break following Normal Operation + Seismic	0.013	0.061	0.013

Leak Rates under Combined Pressure and Bending

- B&W Canada Results with Outer Fiber Bending Stress of About 21,000 psi and a 15% Smaller Tubing Size
- Leakage Result – 110° Throughwall Circumferential Crack

Event	Leakage due to MSLB Pressure Differential Loading only [gpm]	Leakage during Seismic Event – Combined Loading [gpm]	Leakage after Seismic Event – Combined Loading [gpm]
Main Steam Line Break + Seismic	0.20	0.85	0.33
Main Steam Line Break following Normal Operation + Seismic	0.20	0.73	0.20

Bending Effects On Leak Rates, Conclusions

- The long term effect of high transient cyclic bending loads is about a factor of 2 increase in the accident leak rate
- During the high load cyclic bending transient the accident leak rate may be increased by somewhat more than a factor of 2
- Low bending loads have a negligible effect on accident leak rates
- At present there have been no observed circumferential degradation sites that are both capable of leaking and located in high bending stress regions

Pop-Through Conclusions

- Consideration of bending loads does not lead to additional leakage sites for current and projected degradation states
- The conclusions of current leakage assessment methodologies dealing with pressure and axial force loading are valid.

Status

- There is no current safety concern relative to the impact of bending loads on leakage integrity
- An experimental program is underway to verify the conclusions of the scoping studies and provide the basis for extending the presently documented leakage assessment methodology to incorporate the effects of bending loads

SG GLCP

- CLIIP notice of availability issued May 6th
  - 12 month window
- Draft NRC Generic Letter on SG tech specs still in process
  - Addressed to plants that have not received (submitted?) the new tech specs
  - Issue date uncertain
  - Wording resulted in a technical issue regarding the inclusion of bending loads on the AILPC
- Some plants are hesitant to request the GLCP with the subject outstanding technical issue

SG Technical Issue

- Submittal of GLCP
  - Some plants desire a way of clearly identifying the issue in their submittal. Approach:
    - Acknowledge existence of the issue
    - Assert that it is not safety significant
    - Indicate that SGMP is studying the effects and will incorporate the results into guidelines as appropriate
    - Commitment to follow SGMP guidance is inherent in TSTF-449
  - Not all plants will elect to identify the issue in their LAR

NEI 97-06 Revision 2

- Revision will incorporate changes identified during the development of the GLCP:
  - Identification of "Mandatory" and "Shall" requirements
  - Revised structural integrity and accident induced leakage performance criteria
  - Reduced detail in the DA and IA sections and reference to the guidelines
  - Made the requirements for NRC reports consistent with TSTF-449
  - Expanded industry reporting requirements
  - Contractor oversight
  - Consolidation of "Integrity" and "Support" element sections
  - Reference to TSTF-449

NEI 97-06 Revision 2

- NEI 97-06 revision 2 approved by SGMP
  - Implement revision 2 within 6 months of final approval
- MEOG endorsement on July 19
- Expect NSIAC approval on August 18
- Distribute later in August