ELECTRIC POWER RESEARCH INSTITUTE

NRC / EPRI Steam Generator Task Force Meeting
August 21, 2012

Agenda

8:30 am ***Introductions*** ***NRC and Industry***

Opening Remarks ***NRC and Industry***

EPRI SGMP Steam Task Force Update

- Noise Monitoring
- Anti-Vibration Bar Position Verification
- Divider Plate Cracking
- Tube-to-Tubesheet Weld
- Guidance for Auto Analysis
- Degradation of Secondary Side Internals
- Pending Interim Guidance
- Nuclear Safety Advisory Letter 12-01
- Potential Generic Implications of Sequoyah 2 Probe Issue

11:30 am ***Lunch***

ELECTRIC POWER RESEARCH INSTITUTE

Agenda

12:30 pm ***SGMP Steam Generator Task Force Update (continued)***

- Technical Specification Task Force 510
- Development of Appendix I Examination Technique Specification sheet (ETSS) for Axial Outside Diameter Stress Corrosion Cracking Datasets
- Interpretation of In-Situ Pressure Test Guidelines for Long Axial ODSCC Cracks
- Upcoming Changes to Industry Documents
- Recent Steam Generator Operating Experience
- NEI 03-08 Deviations Since February 16, 2012

2:30pm ***NRC Discussion/Items of Interest***

- *e.g., essential variable tolerance, time dependent leak rate, performance standards for tube integrity, review of ETSS reports, channel head cladding degradation, Information Notice on tube-to-tube contact, pre-service inspection requirements in Code, industry guidelines pertaining to the use of Nitrogen-16 monitors*

3:00 pm ***Address Public Questions/Comments***

3:30 pm ***Adjourn***

Open Issues

Open Technical Issues - SGTF

- Noise Monitoring
  - Recommendations have been provided to the Examination Guidelines Revision 8 Committee
    - New appendix has been drafted for noise monitoring
- AVB Position Verification
  - White paper developed incorporating information from February meeting
  - Recommendations have been provided to the E&R TAC for consideration for inclusion in the next revision of the Integrity Assessment Guidelines
  - SGMP Project has been proposed for 2013 to determine the level of deposit that would lead to occlusion of TSPs

Open Technical Issues - NRC

- The following topics were presented to the NRC during previous SGTF meetings. NRC Feedback will be provided during the NRC Discussion/Items of Interest portion of this meeting

  - Eddy Current Essential Variable Tolerance
    - The following EPRI Technical Reports were provided to the NRC
      - 1015126, "Development of a Process for Determining Examination Technique Equivalency"
      - 1018557, "Steam Generator Management Program: Development of Standardized Process for Determining Examination Technique Equivalency"
      - 1020992, "Development of Documentation for Examination Technique Equivalencies"

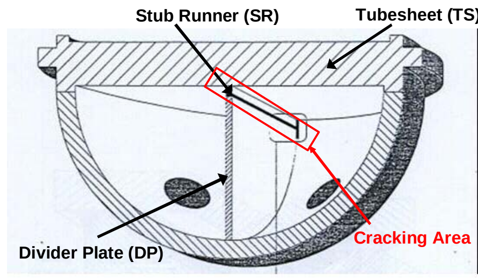
Open Technical Issues - NRC

- Time Dependent Leak Rate
  - EPRI Technical Report 1022831, “Onset of Fatigue Cracking in Steam Generator Tubes with Through Wall Flaws”, provided to NRC
- Performance Standards
  - EPRI Technical Report 1012984, “Technical Basis for SG Tube Integrity Performance Acceptance Standards”, provided to NRC

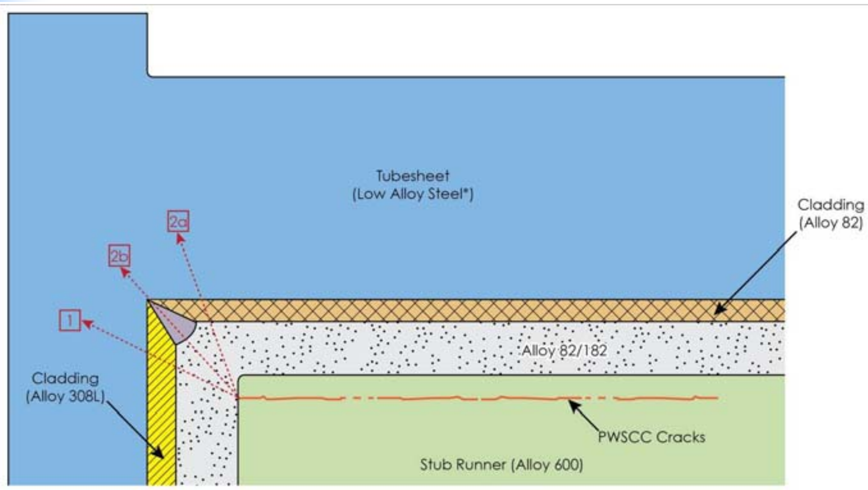
General Discussion Items

Divider Plate & Tube-To-Tubesheet Weld Project Update

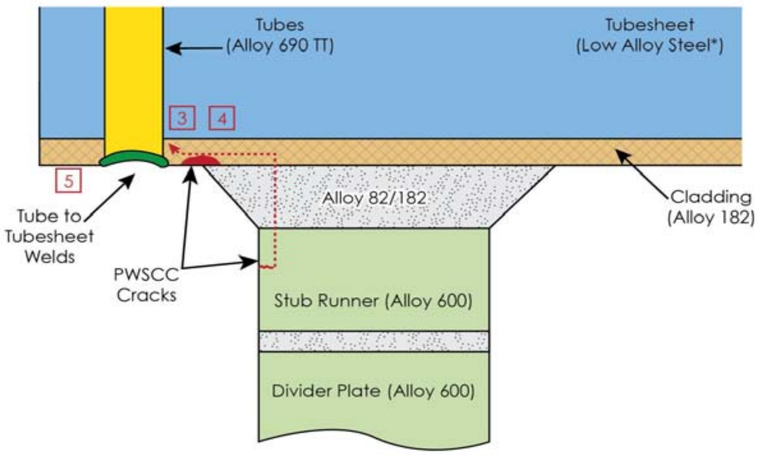
- Potential cracking of the Alloy 600 material in the SG divider plate assembly led the NRC to question crack propagation over extended period of operation
- SGMP began a multi-year project in 2011 to address the concerns of cracks propagating over time to pressure boundary components such as the channel head or the tube-to-tubesheet weld
- Work completed to date are described in the following slides



Divider Plate & Tube-To-Tubesheet Weld Project Update
Postulated Crack Propagation

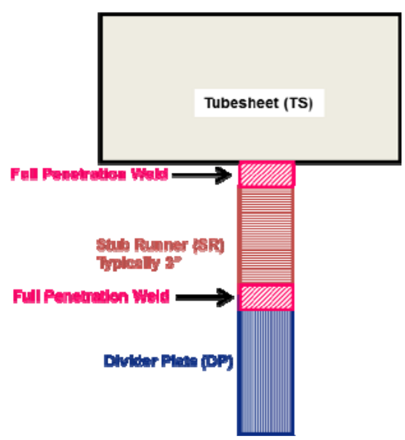


Divider Plate & Tube-To-Tubesheet Weld Project Update
Postulated Crack Propagation



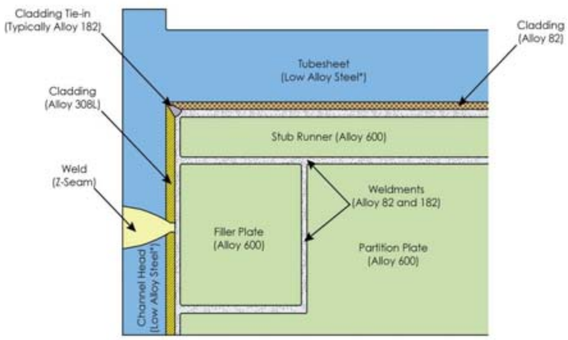
Divider Plate & Tube-To-Tubesheet Weld Project Update
Review of Susceptible SG Channel Head Materials and Fabrication Process

- Channel heads are fabricated using a low alloy steel material clad with two or more layers of stainless steel weld deposit
- The tubesheet is fabricated using a low alloy steel forging clad using a nickel based weld deposit (Alloy 82 or 182)
- The tubesheet and channel head receive a post weld heat treatment
- Alloy 600 divider plate welded to the channel head buttering/cladding
- A short Alloy 600 plate section called a "Stub Runner" is welded directly to the tubesheet cladding
- Divider plate is attached to the stub runner
- The weld connecting the divider plate to the Alloy 600 stub runner is typically a combination of Alloy 82/182 but is conservatively assumed to be Alloy 182



Divider Plate & Tube-To-Tubesheet Weld Project Update Review of Susceptible SG Channel Head Materials and Fabrication Process

The Shielded Metal Arc Welding (SMAW) process is used in locations where welding is performed manually. Locations having restrictions related to either the welding process or space. Filler metal used is Alloy 182 (UNS W86182) which has a specified chromium concentration of 13.0 to 17.0 weight percent.



The Gas Tungsten Arc Welding (GTAW) process is used in locations where welding can be automated. Filler metal used is Alloy 82 (UNS N06082) which has a specified chromium concentration of 18.0 to 22.0 weight percent

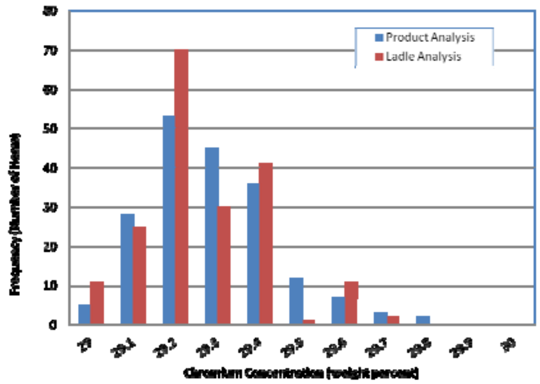
The Submerged Arc Welding (SAW) process is used in flat locations where the flux can be physically managed. Filler metal used is Alloy 309L (UNS S30983) and 308L (UNS S30883) which have a specified chromium concentration of 23.0 to 25.0 and 19.5 to 22.0 weight percent respectively.

Divider Plate & Tube-To-Tubesheet Weld Project Update Review of Susceptible SG Channel Head Materials and Fabrication Process

- Tube-to-tubesheet welds are part of the design primary pressure boundary for the SG tubes
- The tubes are expanded and welded autogenously
- The ends of the tubes are positioned slightly beyond the cladding surface. The top edge of the cladding surrounding the tube is then fused
- The chromium concentration in the tube-to-tubesheet welds will depend on the amount of dilution of the high-chromium Alloy 690 tubing material (29% to 31% Cr) with the lower-chromium 82/182 tubesheet cladding material

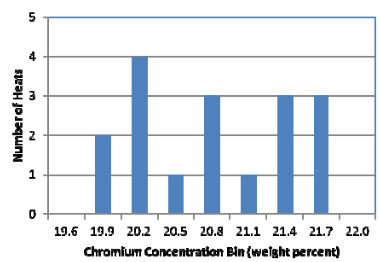
Divider Plate & Tube-To-Tubesheet Weld Project Update Survey to Determine the Chromium Content of the Tube-to-Tubesheet Welds

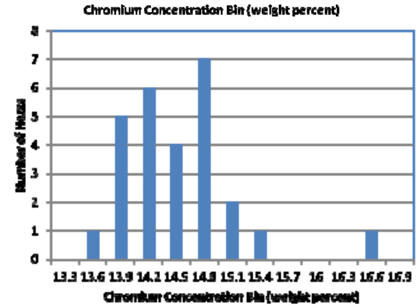
- SGMP Alloy 690TT steam generator tubing specification recommends a minimum chromium concentration of 28.5 weight percent
- 191 heats of Alloy 690 tubing material were reviewed and the minimum concentration is 29 weight percent
  - All three tubing suppliers were represented



Divider Plate & Tube-To-Tubesheet Weld Project Update Survey to Determine the Chromium Content of the Tube-to-Tubesheet Welds

- 27 heats of Alloy 182 and 17 heats of Alloy 82 were reviewed
  - The lowest chromium concentration in the Alloy 82 heats is significantly higher than the minimum specified (19.64 versus 18.0 weight percent)
  - The lowest chromium concentration in Alloy 182 heats is slightly higher than the minimum specified (13.56 versus 13.0 weight percent)





Divider Plate & Tube-To-Tubesheet Weld Project Update
Dilution Calculations for Tube-To-Tubesheet Weld

- A dilution level of 50% is a first approximation for the autogenous weld centered at the tube-to-tubesheet interface
- For 690TT tubes to Alloy 82 welds, 24.32 minimum value was calculated, which is above the industry recognized minimum Cr level for PWSCC resistance (24%)
- For 690TT tubes to Alloy 182 welds, 21.28 minimum value was calculated, which is also considered adequate for PWSCC resistance based on literature review and operational experience

Divider Plate & Tube-To-Tubesheet Weld Project Update
Literature Review

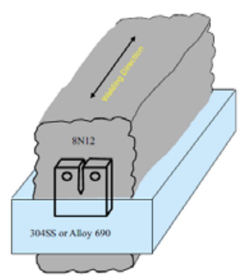
- PWSCC Initiation
  - The relevant available test data plus a mechanistic analysis suggest that the “threshold” chromium content for PWSCC mitigation is something >22% chromium
  - The effects of chromium content regarding crack initiation data is limited because high chromium materials are highly resistant to crack initiation
  - Industry has accepted a 24% chromium content as a conservative threshold for PWSCC initiation
    - Chromium levels down to 20% have excellent resistance to initiation based on testing and operational experience

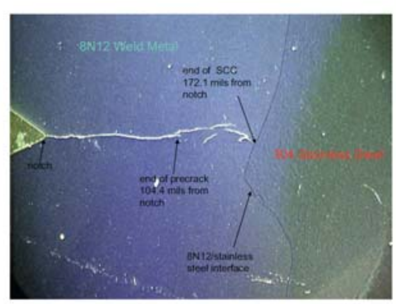
Divider Plate & Tube-To-Tubesheet Weld Project Update
Literature Review

- PWSCC Propagation
  - While high crack growth rates have been produced in the laboratory for welded structural components, there are no examples of such high growth rates in the field
  - Cold working and elevated test temperatures are used to expedite the crack initiation period. The act of speeding up the initiation step may skew results during the propagation stage
  - Recent research using composite arrest specimens has shown cracks initiating and propagating in PWSCC susceptible material can slow or even arrest in resistant material

Divider Plate & Tube-To-Tubesheet Weld Project Update
Literature Review

- Compact tension specimen uses PWSCC susceptible material welded to resistant materials
- Configured to drive crack growth into the resistant material
- Cracks arrested in or around the resistant material interface
- Based on these results and OE, it is considered unlikely that PWSCC initiating in Alloy 600 would grow through 308L cladding and into the LAS channel head

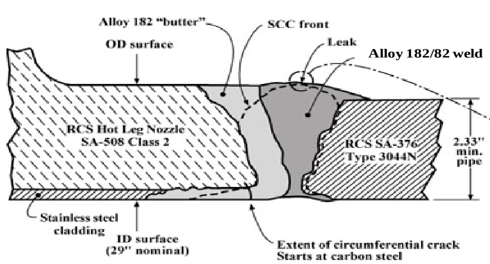


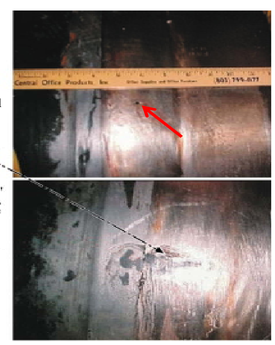


Divider Plate & Tube-To-Tubesheet Weld Project Update
Operating Experience

- Cracking seen in the non-US plants have been restricted to a shallow cold worked surface and remains in the Alloy 600 plate material
  - No cracking has been identified in the welds or the triple point
  - Latest information indicates that cracking is in the heat effected zone of the two welds of the divider plate assembly, is shallow, and remains parallel to the weld
  - The EPRI 2007 report states that as cracks near the triple point, they tend to turn and curve up. This was based on Westinghouse interpretation of original data
    - This has not been observed at the non-US plants
    - DE performed support cracking only in Alloy 600 material

Divider Plate & Tube-To-Tubesheet Weld Project Update
Operating Experience





- Hot Leg Nozzle Cracking
  - Axial extent of the crack traversed the Alloy 182/82 weld and butter between the low alloy steel nozzle and the stainless steel pipe
  - PWSCC did not propagate into the low alloy steel even though the orientation of the crack was favorable to extend in that direction

Divider Plate & Tube-To-Tubesheet Weld Project Update
Operating Experience

- An International plant found indications in nozzle/safe-ends
  - Metallographic examinations from boat samples revealed interdendritic stress corrosion cracking (IDSCC) of Alloy 182
  - Significant branching of some cracks, very tight crack tips and also tight crack sections that were connected to the inner surfaces
  - Indications of some hot cracking and lack of fusion
  - No IDSCC propagation into the reactor pressure vessel low alloy steel or the Type 316 stainless steel

Divider Plate & Tube-To-Tubesheet Weld Project Update
2012-2013 Planned Work for Tube-to-Tubesheet

- Tube-to-tubesheet weld dilution study
  - Determine the actual amount of chromium in tube-to-tubesheet welds
  - Multiple samples are being fabricated using similar base material (SA-508 Class 2), cladding material (Alloy 82/182), and tubes (690TT) as in the field
  - Cross sectioning the welds will facilitate measuring chromium levels using a process such as Energy-Dispersive X-ray Spectroscopy
  - Results of testing will be used to refine weld dilution algorithm

Divider Plate & Tube-To-Tubesheet Weld Project Update 2012-2013 Planned Work for Tube-to-Tubesheet

- Finite element analysis will consider if a crack occurring in the cladding, stub runner-to-tubesheet connection weld material, or stub runner base metal can propagate to a tube end weld
- If the modeling shows that a crack can propagate to the region surrounding a tube end, an assessment will be performed to see if the crack is self arresting or will continue to grow into the tube end weld and/or tube end material
- If this work concludes that specific inspections are necessary to detect degradation in the tube end weld, the divider plate inspection and cladding inspection samples and expansion criteria will be defined

Divider Plate & Tube-To-Tubesheet Weld Project Update 2012-2013 Planned Work for Channel Head

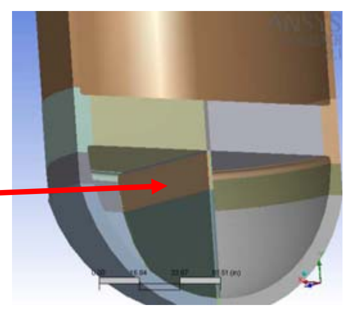
- Finite element modeling is being used to model the stresses in the lower channel head to determine if the stresses are sufficient to propagate PWSCC via fatigue
- A fracture mechanics evaluation is being performed to determine the allowable circumferential flaw size for the SG channel head
- Fatigue crack growth analyses will be performed for the channel head. The operating period required for the postulated initial flaw size to reach the allowable flaw size will be determined. Fatigue crack growth rates for low alloy steels in a PWR environment will be used in the evaluation.

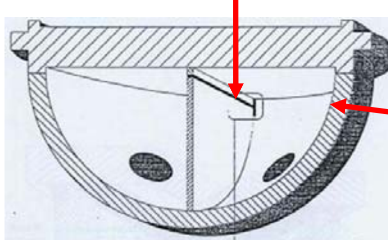
Divider Plate & Tube-To-Tubesheet Weld Project Update
2012 NDE R&D for Channel Head Inspection Technique

- Mockups are being fabricated to simulate the SG channel triple point
  - Demonstrate feasibility to use UT from the outside of the SG bowl to ensure that cracking has not propagated through the clad and into the channel head material

Divider Plate & Tube-To-Tubesheet Weld Project Update
2012 NDE R&D for Channel Head Inspection Technique

Area of Cracking





Concept – Use Ultrasonic Testing (UT) to ensure cracking has not propagated into the channel head material

Divider Plate & Tube-To-Tubesheet Weld Project Update Conclusions

- Data and operating experience suggest the crack propagation scenarios postulated are not credible
  - Further studies are underway that will evaluate the stress in this areas of concern and the susceptibility of the areas to PWSCC
- Report was published in June, "Assessment of Channel Head Susceptibility to PWSCC," 1025133

Auto Analysis

- *The NRC staff asked whether a comparison of single pass eddy current results to those of the traditional eddy current primary and secondary analysis results was available for the staff to become familiar with the comparison technique. The industry stated that the comparison technique is still in the process of being developed so comparison data is not yet available*
  - One utility who has multiple field deployments with a single pass system has performed pre-outage comparisons between the two approaches by running the new system on the prior cycle data and comparing the results to prior cycle traditional two party results
    - This approach was found technically sufficient by the EPRI NDE TAC during a required deviation review
  - As previously reported, the EPRI NDE TAC has a ongoing project to determine the minimum POD/CL needed for a single pass system
    - Scheduled to be completed 1st Qtr. 2013

Auto Analysis

- *Regarding the discovery of tube-to-tube wear at two plants, the NRC staff inquired how a single pass automated analysis protocol would have handled such indications (i.e., indications that were not expected)*
  - The single pass system (currently field deployed) would have detected absolute drift signals which would have led to a refinement of the analyzer parameters to detect both the incipient degradation and precursor tube proximity signals
  - The same system also detected unexpected loose part wear indications in a recent inspection
  - The system also has other tools in the toolbox, such as signal injection, noise visualization and historical data compare that are available to assist in both qualification and detection

Degradation of Secondary Side Internals Requirements

- Section 10 of the EPRI SG Integrity Assessment Guidelines (IAGL) address maintenance of secondary side integrity

  "The SG program shall include measures to maintain the SG secondary-side integrity as required by NEI 97-06. Monitoring and projecting secondary side steam generator conditions for the purpose of developing a strategy for long-term steam generator operability and performance shall be part of the licensee's steam generator program. This strategy will assist in developing inspection intervals, anticipating future maintenance activities, and planning for contingencies."

- The IAGL requires secondary side integrity assessments
  - Degradation Assessment, Condition Monitoring and Operational Assessment

Degradation of Secondary Side Internals
Requirements

- Per Section 10.6 of the IAGL, the inspection frequency of the upper steam drum internals shall be evaluated and documented to verify tube safety functions are not jeopardized by internals degradation
  - The secondary side inspection looks for evidence of corrosion, erosion, chemical deposits or other conditions which may be present in the upper shell internals

- Bottom line: EPRI guidance requires utilities to develop and implement secondary side inspections and secondary side integrity assessments

Degradation of Secondary Side Internals
Reporting of Inspection/Degradation

- Secondary side inspection and degradation is reported to the industry through several processes
  - SGMP TAG Meetings (Utility Experience Reports)
  - INPO Operating Experience Reports
  - SGMP Steam Generator Degradation Database Entries
- These data sources are reviewed by the industry when performing secondary side degradation assessments
- EPRI Technical Report 1022830, Investigation of Steam Generator Secondary-Side Degradation, was published in September 2011
  - Reviews and discusses age-related degradation that has occurred in the carbon steel internal components in the steam drums of Westinghouse original and early replacement SGs
  - Resource for utility engineers to develop secondary inspection plans and provides secondary side degradation experience

Degradation of Secondary Side Internals Inspection

- Review of the referenced data sources indicates that plants are inspecting secondary side internals at various frequencies that are based primarily on
  - Having existing degradation or no degradation
  - SG Design and Materials of construction (chromium content)
  - OEM recommendations
  - Industry experience
- Areas of secondary side inspections typically include:
  - Moisture separators, Riser/Downcomer Barrels
  - Feedring, J-nozzles, spray nozzles, pre-heater waterbox
  - Tube Support Plates/U-Bend Supports
  - Feedwater, Aux Feedwater and Main Steam Nozzles
  - Other miscellaneous secondary side internal component (e.g., hatches, ladders, seal skirts, blowdown piping, internal supports, shroud and shell internal surfaces, etc)
- Plants with degradation typically supplement visual inspections with UT thickness measurements.

Degradation of Secondary Side Internals Reported Degradation

- The referenced data sources were reviewed to determine the types of secondary side degradation reported and the extent of plants that have reported degradation
- Plants have reported degradation in the following areas
  - Primary and secondary moisture separators
  - Feedring and J-Nozzles
  - Impingement from J-Nozzles
  - Batwing support degradation
  - Internal blowdown pipe
  - Misc. fabrication blocks/bars
- Degradation is not widespread or global. Few plants affected
- CONCLUSION: SGMP guidance is sufficient to require utilities to specify secondary side inspections in their Degradation Assessments and SG inspection plans

Pending SGMP Interim Guidance

- Interim Guidance (IG) has been drafted and is currently in the review process
- The IG deals with changing prescriptive requirements to performance based requirements within the SG Examination Guidelines for
  - Inspection requirements following forced outages due to design basis accidents (i.e., seismic events, steam line/feed line breaks, primary to secondary leakage, and loss of coolant accidents)
  - Inspection of tube plugs
- Need for IG for forced outages following DBA was identified following thorough Industry discussions following a seismic event that exceeded OBE and DBE criteria. Guidance for inspections following tube leaks is already addressed in Section 9 of the SG Integrity Assessment G/Ls (IAGL)
- Need for IG for plug inspections following review of SG Exam G/L's for plants with A600TT tube with A600MA welded plugs

Pending SGMP Interim Guidance
Forced Outage Inspection Guidance

- Currently, Section 3.10 of the SG Exam G/L's states:

"Forced outage examinations shall be performed during plant shutdown subsequent to any of the following conditions:

a. SG Primary-to-secondary leakage leading to plant shutdown

b. Seismic occurrence greater than the Operating Basis Earthquake

c. Loss-of-coolant accident requiring actuation of the engineered safeguards

d. Main steam line or feedwater line break

For unscheduled examinations following primary-to-secondary leakage leading to plant shutdown, follow the Operational Leakage guidance in the EPRI Steam Generator Integrity Assessment Guidelines. For the other unscheduled examinations identified above leading to plant shutdown, follow the guidance in Section 3.6."

Pending SGMP Interim Guidance
Forced Outage Inspection Guidance

- It is proposed to eliminate Section 3.10 in its entirety

- The IAGL will be changed to include the following:
  - The guidance will include validation of the inspection interval when the plant has experienced a forced outage following a design basis accident or when the SGs have experienced conditions that may not be bounded by assumptions in the Operational Assessment
  - The review is to consider the need for additional analysis, evaluations and/or primary/secondary side inspections to demonstrate acceptable condition monitoring and operation assessment prior to start-up

- Inspections following periods of operation with primary to secondary leakage is already addressed in Section 9 of the IAGL

Pending SGMP Interim Guidance
Subsequent Inspection of Plugs

- Currently, Section 3.5.3 "Subsequent Inspection of Plugs" of the Exam G/L's states:

  "• Alloy 600 Mill Annealed Plug Material – During subsequent examinations, all plugs in all SGs shall be examined at the end of each fuel cycle. When plug designs preclude a volumetric examination, all installed plugs shall be examined visually in accordance with Section 6.

  • Alloy 600 TT and 690 TT Plug Material - Visual examination shall be performed on all installed plugs in accordance with Section 6.9 when the SG is opened for scheduled primary side examinations."

Pending SGMP Interim Guidance Subsequent Inspection of Plugs

- Currently, Section 3.5.4, "Subsequent Inspection of Other Repairs", of the Exam G/L's state:

  "• Alloy 600 Mill Annealed Material – During subsequent examinations, all other repairs in all SGs shall be examined at the end of each fuel cycle."

  • Alloy 600 TT and 690 TT Materials – For subsequent inspection guidance apply the tubing requirements provided in Sections 3.3 (material specific), 3.6, 3.7, and 3.8. If an inspection is required to be performed on the tubes for reasons unrelated to the repaired sections of the tubes, then the repair(s) may be considered a separate population."

Pending SGMP Interim Guidance Subsequent Inspection of Plugs

- Section 3.5.3 of the SG Exam G/L provides a prescriptive requirement to inspect all A600MA plugs after each refuel cycle
  - There may be cases when there is technical justification to allow two cycles between plug inspections (e.g. welded plugs)
- The IAGL already has requirements to include tube hardware such as plugs during development of the degradation assessment
  - Therefore, the utility is required to evaluate and determine the requirements, methods and frequency of plug inspections
- The IG will provide a minimum prescriptive requirement in the SG Exam G/L to inspect all plugs whenever the primary side is opened for inspection and refers to the IAGL for specific plug inspection scope, technique and periodicity based on plug material and design (i.e., degradation assessment)

Pending SGMP Interim Guidance
Subsequent Inspection of Plugs / Current Status

- Section 3.5.4 of the SG Exam G/L will be modified to be consistent with Section 3.5.3 to refer to the IAGL and degradation assessment to determine inspection and periodicity of other repairs, in addition to any regulatory requirements for approved repairs

- Interim Guidance Current Status:
  - The IG has been approved by the SGMP E&R and NDE TAC's
  - SGMP Integration Committee and PMMP approval is pending

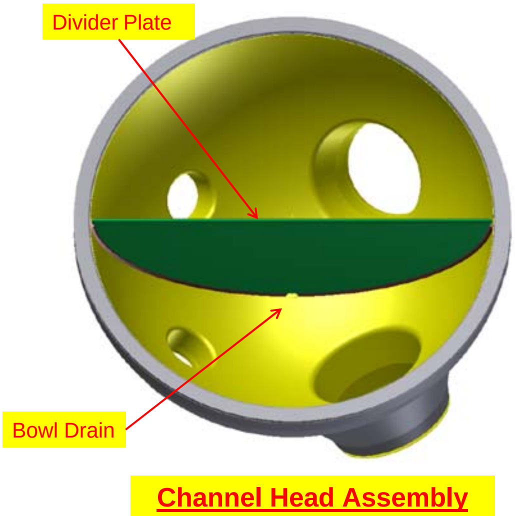
Nuclear Safety Advisory Letter (NSAL) 12-01 Update

- An international utility identified breaches in the cladding in the primary channel head in one of three steam generators

- The plant name has not been formally identified but
  - Steam generator model is known
  - Plant has been in operation since the late 1980s
  - Degraded condition was observed in Fall 2011
  - The flaws were
    - 'Visually-evident' near center bowl drain & divider plate
    - Present only on the cold leg side of the channel head

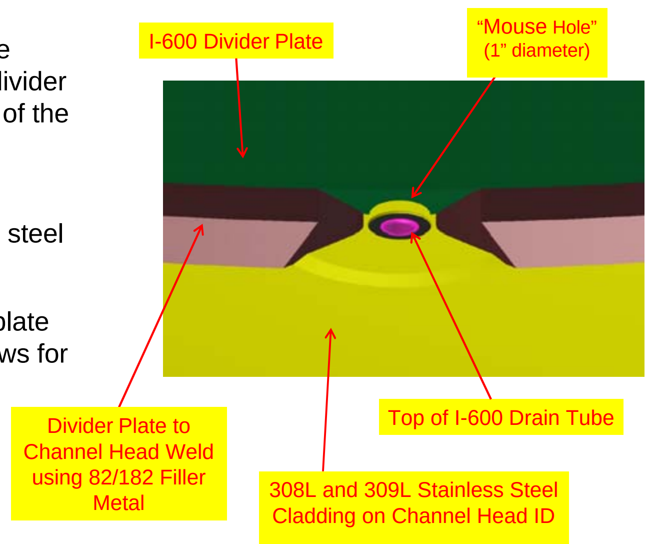
Nuclear Safety Advisory Letter (NSAL) 12-01 Update
Steam Generator Channel Head Geometry

- Westinghouse Model F steam generator design
- Hemispherical SA-487 carbon steel casting
- Partitioned into inlet and outlet chambers by an Inconel divider plate



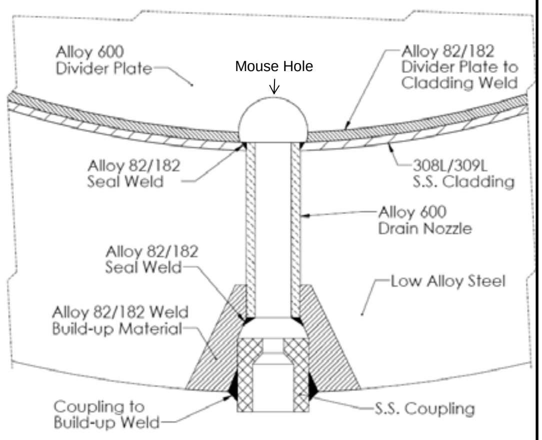
Nuclear Safety Advisory Letter (NSAL) 12-01 Update
Channel Head, Divider Plate and Drain Tube Geometry

- Alloy 600 drain tube located under the divider plate at the bottom of the channel head
- Cladding on the ID surface is stainless steel
- Small semi-circular opening in divider plate ("mouse hole") allows for drainage of both chambers



Nuclear Safety Advisory Letter (NSAL) 12-01 Update Fabrication Sequence (around drain hole) from SG Manufacturing Records

- Weld-deposited cladding
- Drain hole is drilled and machine socket-weld cavity
- Fit divider plate, PT &UT clad
- Drain tube roll-expanded, welded to clad, then PT
- Install divider plate, seal weld, PT, weld out (alternating sides to control distortion), PT
- Post weld heat treatment
- PT clad
- Seal weld lower tube end, PT
- Weld coupling into socket weld prep; PT root and final

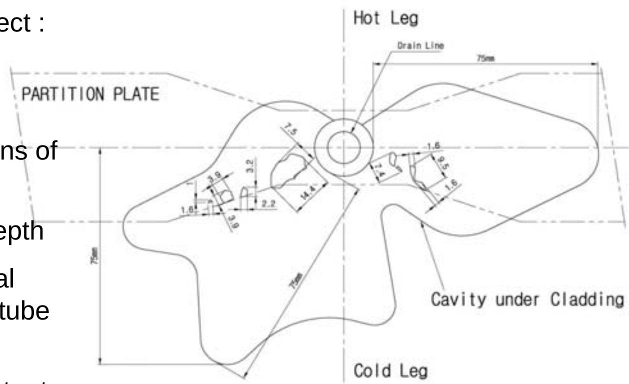


Nuclear Safety Advisory Letter (NSAL) 12-01 Update Field Inspections Performed upon Degradation Discovery

- Visual examinations (VT)
  - Cladding and divider plate-to-clad weld
- Dimensional inspections
  - Flaw size and geometries
- Photographs (to document the as-found conditions)
- Liquid penetrant (PT)
  - Of the adjacent cladded surface and drain tube weld
- Ultrasonic examination (UT)
  - For channel head thickness
    - Carbon steel base material wastage discovered

Nuclear Safety Advisory Letter (NSAL) 12-01 Update Dimensional and UT Inspection Results Provided to Westinghouse for Analysis

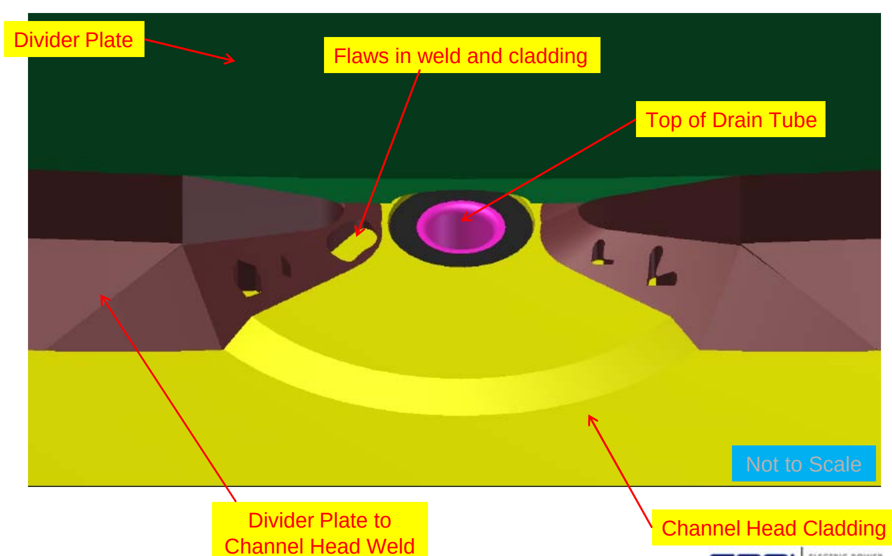
- Largest cladding defect : ~0.3 inch x 0.6 inch
- 5 smaller defects
- UT derived dimensions of apparent cavity:
  - 1.1 inches max depth
  - 3.0 inch max radial extent from drain tube edge
  - 285° azimuthal extent around drain tube



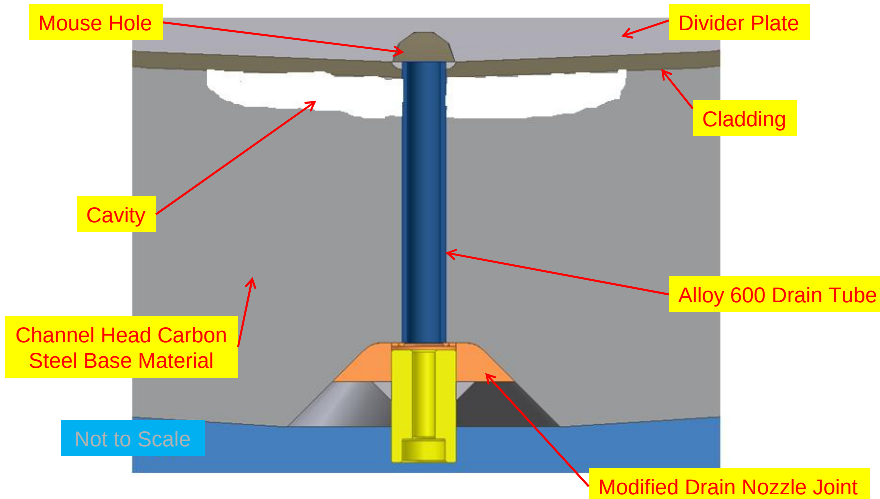
(Note: All dimensions in mm)

Nuclear Safety Advisory Letter (NSAL) 12-01 Update Visual Inspection Results

(Draftsman's Rendition of the Photographs)



Nuclear Safety Advisory Letter (NSAL) 12-01 Update
Channel Head Cavity Around the Drain Tube



Nuclear Safety Advisory Letter (NSAL) 12-01 Update
Westinghouse Evaluation of As-Found Condition

- Westinghouse engineering assessments performed to evaluate as-found conditions for one cycle of operation:
  - Reviewed steam generator manufacturing records
  - Performed structural analysis per ASME Code requirements
  - Evaluated degradation growth rates
  - Assessed base material/corrosion
- Root cause was not part of Westinghouse scope and has yet to be determined
- Designed temporary repair using patch plates to isolate the degraded region of the channel head

Nuclear Safety Advisory Letter (NSAL) 12-01 Update Industry Notification

- Westinghouse issued Nuclear Safety Advisory Letter NSAL-12-1 on January 5, 2012 with the following guidance for the industry:
  - Perform a visual inspection using bowl cameras with dry steam generator condition the next time primary manways are open
    - Inspect the channel head cladding, divider plate to channel head weld, and the weld of the channel head bowl drain tube
    - The inspection limited to a 36 inch radius centered on the very bottom of the channel head bowl
    - Inspect for gross (naked-eye) defects and obvious discoloration (from rusting carbon steel base material)
  - If no degradation is detected, document the inspection results and continue to inspect each time primary manways are open
- This notification was sent to all SGMP members via e-mail
- Utilities are performing this inspection with no degradation reported as described in the NSAL

Nuclear Safety Advisory Letter (NSAL) 12-01 Update EPRI Response as a Potential Generic Issue

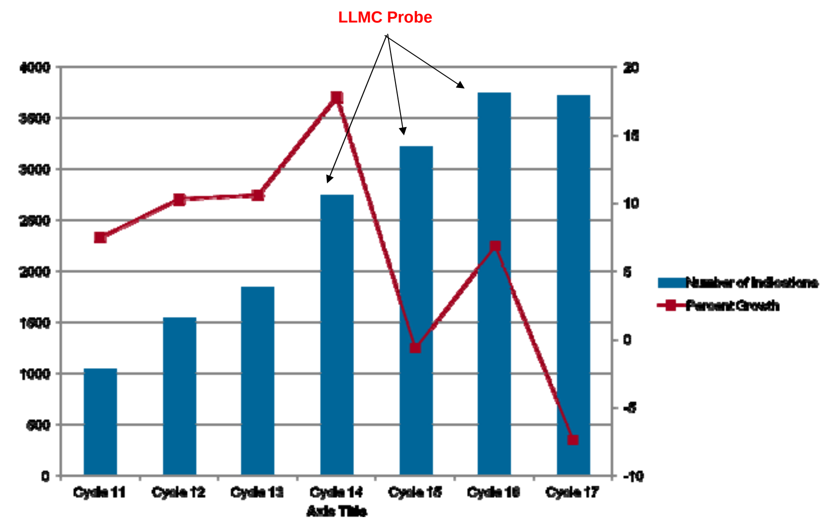
- Joint evaluation effort by Steam Generator, Materials Reliability, and Chemistry Programs
  - Nuclear sector funding
  - Dominion Engineering leading Failure Modes and Effects Analysis (FMEA)
  - Industry experts participated in a meeting July 24-25 to discuss potential degradation mechanisms
  - Team is challenged by limited information
  - Draft report will be completed and industry review will begin mid September

Sequoyah 2 Alternate Repair Criteria Bobbin Probe Issue

- MULC bobbin probes were used at Sequoyah Unit 2 for detection and sizing of axial ODSCC until Cycle 14 when they began using an LLMC probe
- MULC bobbin probes were used again in Cycle 17 inspection
- The different probe designs could result in slightly different bobbin voltage readings

Operating Cycle	Probe Design	Tester	Number of Indications	Percent Growth per EFPY
Cycle 11	MULC	MIZ 30	1045	7.5%
Cycle 12	MULC	MIZ 70	1545	10.3%
Cycle 13	MULC	MIZ 70	1847	10.6%
Cycle 14	LLMC	MIZ 70	2747	17.8%
Cycle 15	LLMC	MIZ 70	3223	-0.7%
Cycle 16	LLMC	OMNI	3747	6.8%
Cycle 17	MULC	MIZ 80	3715	-7.4%

Sequoyah 2 Alternate Repair Criteria Bobbin Probe Issue



Cycle 17 vs Cycle 16 Average Growth Comparison

		SG21	SG22	SG23	SG24	All SGs
Cycle 16	Average BOC Volts	0.671	0.663	0.756	0.707	0.704
	Average Growth per EFPY	0.057	0.033	0.037	0.057	0.048
	Average Percent Growth per EFPY	8.5%	5.0%	4.9%	8.0%	6.8%
Cycle 17	Average BOC Volts	0.666	0.650	0.749	0.688	0.691
	Average Growth per EFPY	-0.059	-0.051	-0.060	-0.042	-0.051
	Average Percent Growth per EFPY	-8.9%	-7.8%	-8.0%	-6.1%	-7.4%
	C16-C17 Voltage Delta	-0.005	-0.013	-0.007	-0.019	-0.013

Generic Implications

- Experience reported at the June SGMP TAG meeting
- Three areas investigated for potential generic implications
  - Bobbin ARC for axial ODSCC
  - Bobbin ETSS(s) used by utilities to size volumetric indications
  - Bobbin voltage screens in the In Situ Pressure Test Guidelines

Generic Implications

- Bobbin ARC
  - The pulled tube database for bobbin ARC includes data from both probe types
- Bobbin ETSS(s) used by utilities to size volumetric indications
  - SGMP is investigating
- Bobbin leakage screens in the In Situ Pressure Test Guidelines
  - The bobbin voltage screens are for volumetric indications only
  - The screening values are conservatively high and would represent indications that would be of sufficient depth to require in situ testing for structural integrity

TSTF-510 Update

- On October 27, 2011, NRC issued the Notice of Availability for TSTF-510 Rev 2, Revision to Steam Generator Program Inspection Frequencies and Tube Sample Selection
- At a May 8, 2012 public meeting between the Technical Specification Task Force (TSTF) and the NRC, the NRC discussed a concern with TSTF Traveler model applications
  - Many Travelers discuss 10CFR50, Appendix A General Design Criteria (GDC).
  - Similar Statements made in the NRC model Safety Evaluation (SE)
  - The model application used by licensees states that the Traveler and model SE were reviewed and are applicable to the plant
    - This creates an inconsistency, because many plants were licensed before 10CFR50 Appendix A GDC were published

TSTF-510 Update

- To resolve the inconsistency, the TSTF proposed the following in a letter to the NRC
  - Future travelers will discuss 10CFR50 Appendix A GDC, as needed
  - Future traveler model applications will instruct licensees not licensed to 10CFR50 Appendix A GDC to discuss in the LAR their plant specific licensing basis that is equivalent to the GDC
  - In future model SE's, the NRC should provide guidance to reviewers to discuss the GDC or the plant specific equivalent requirements
    - This is also applicable to licensees adopting previously approved travelers

TSTF-510 Update

- The NRC accepted the TSTF's proposed approach during an August 8 TSTF/NRC public meeting
  - The NRC is approving plant-specific LARs using the proposed guidance
  - The NRC will prepare a letter to the TSTF to document their acceptance

Appendix I ETSS Datasets for Axial ODSCC at Eggcrates

- Pulled tube data representative of active SGs used to define the NDE signal characteristics and indication morphology that defines acceptable lab specimens
- Datasets to be combined into common POD and sizing correlations have similar NDE responses and indication morphology
- NDE signal characteristics include the features of the plus point coil signals and responses to the tube degradation such as the voltage to indication depth and trends
- Similar morphology relates to comparisons of metallography and fractography from destructive examinations

Appendix I ETSS Datasets for Axial ODSCC at Eggcrates

- Large dataset of pulled tubes
- Pulled tube data representative of active SGs is used to define acceptable lab specimens
  - 100% through wall defect deleted from the regression analysis because length and depth affect voltage response
- Two sizing datasets were developed
  - Tube support plate combined with sludge pile data
  - Eggcrate combined with freespan data

Sizing Dataset ODSCC Axial Data for Eggcrate and Freespan

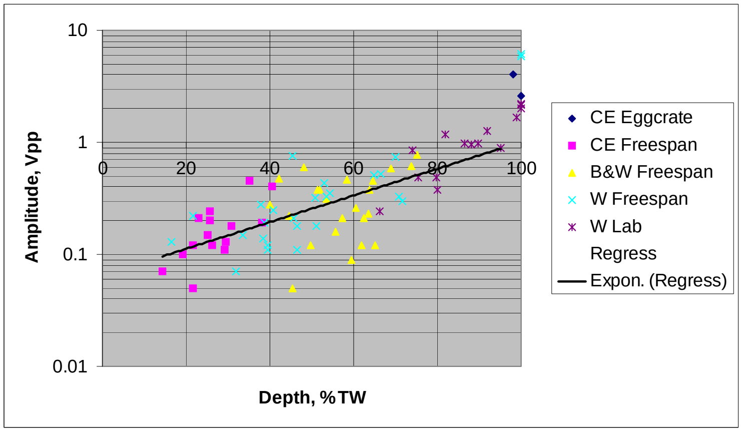
- Total of 81 eddy-current grading units
  - 17 CE plants
    - 2 Eggcrate
    - 15 Freespan
  - 23 B&W plants
    - All Freespan
  - 26 W plants
    - All Freespan
  - 15 W Lab samples
    - All Tube Support Plate
- Excluded by Peer Review
  - 12 NDD
  - 7 Westinghouse lab samples (not needed)

ETSS I28432 +Pt Axial ODSCC Sizing Freespan, Eggcrate, Broached Supports

- Combined W, B&W and CE data to provide a complete dataset spanning the entire range of depths
- CE represents only the lower range of the data
- Statistical tests were not performed because of the number of datasets combined
  - Dataset approved by a peer review of three QDAs and three structural integrity engineers

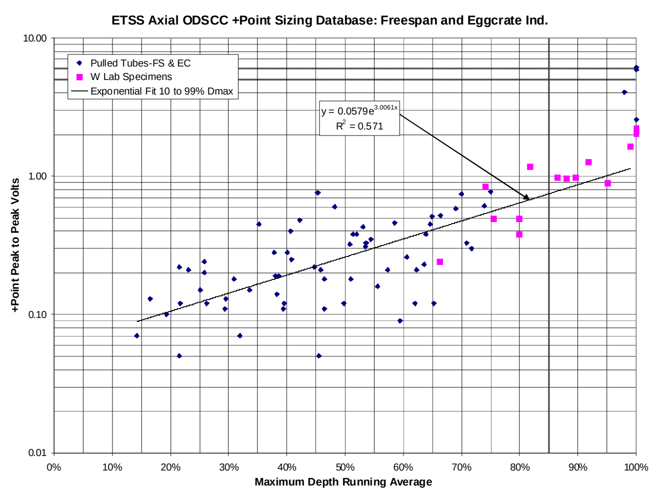
Dataset for Axial ODSCC at Eggcrates

- 100% TW data was not included in the regression analysis



Dataset for Axial ODSCC at Eggcrates

- Ensure the data is normally distributed about the regression line



Guideline Deviation

- A sizing correlation was developed using only the CE data from the Appendix I ETSS

- SGMP reviewed deviation
  - Documentation was considered technically sufficient
  - The deviation process was considered appropriate for this plant
    - No generic implications to Appendix I ETSSs

Interpretation of In Situ Pressure Test Guidelines for Long ODSCC Axial Cracks

- Section 4.4 of the Revision 3 of the In Situ Pressure Test Guidelines provides the proof testing screening criteria for axial ODSCC. The Guideline states :

  "*If VM $\leq$ 0.5 volts, a proof test in not required except for axial ODSCC for which a supplemental screen is required. For axial ODSCC, the voltage must not exceed 0.4 volt for a length >0.6 inch. If VM > 0.5 volts, proceed with screening*"

- This voltage screen requires in situ pressure test screening to continue if the voltage is >0.4 volts for a continuous length of 0.6" or more OR the voltage is >0.5 volts for any length

Interpretation of In Situ Pressure Test Guidelines for Long ODSCC Axial Cracks

- Appendix B of Revision 3 of the ISPT GL provides the technical basis for a lower screening voltage threshold for long axial ODSCC:

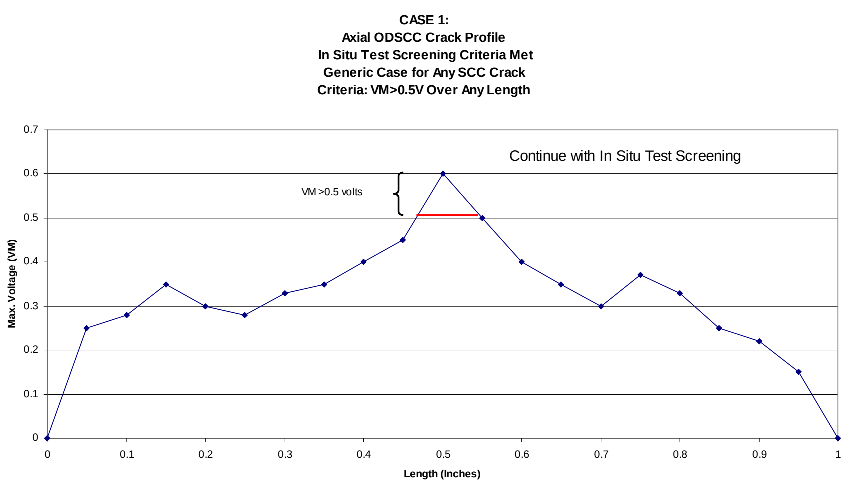
  "It is conceptually possible that a long uniform depth ODSCC flaw could be less than 0.5 volts and not satisfy the 3xNOPD burst pressure limit. When applying the 0.5 volt threshold for long axial ODSCC flaws, the +Point voltage should not exceed 0.4 volt over lengths greater than or equal to 0.6 inch. The voltage profile for the flaw should be checked to confirm that this criterion is satisfied."

- In draft Revision 4 of the ISPT GL, the above Appendix B basis was copied to Section 4, along with the following clarifying sentence*:*

  "For an axial ODSCC flaw that is greater than or equal to 0.6-inches, if all of the voltage readings along any continuous 0.6-inch length are greater than 0.4 volts, then continue with screening."

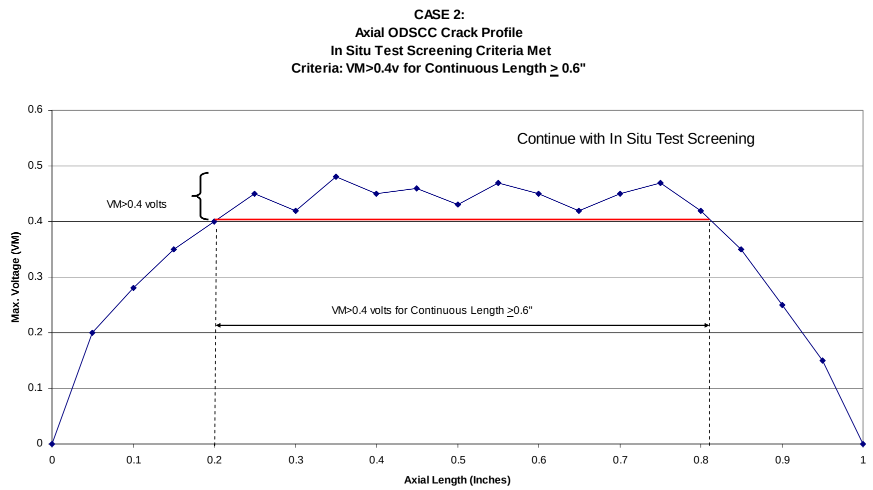
Interpretation of In Situ Pressure Test Guidelines for Long ODSCC Axial Cracks

- Voltage Profile that requires screening to continue:



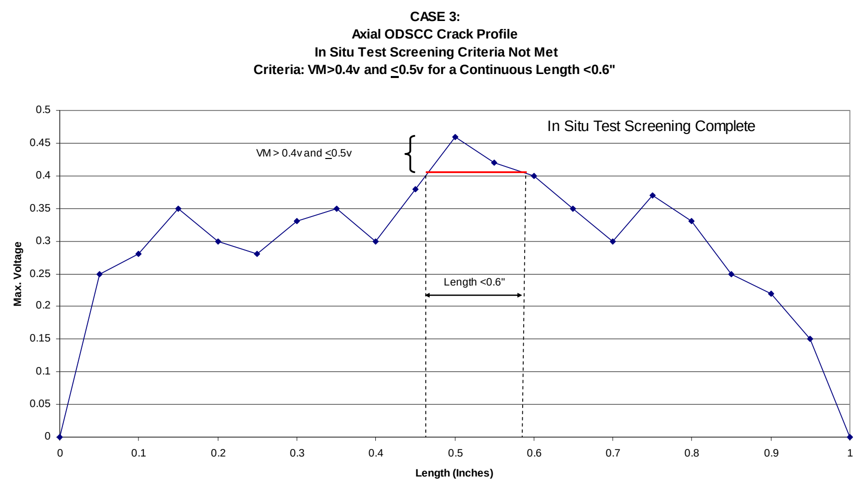
Interpretation of In Situ Pressure Test Guidelines for Long ODCC Axial Cracks

- Voltage Profile that requires screening to continue:



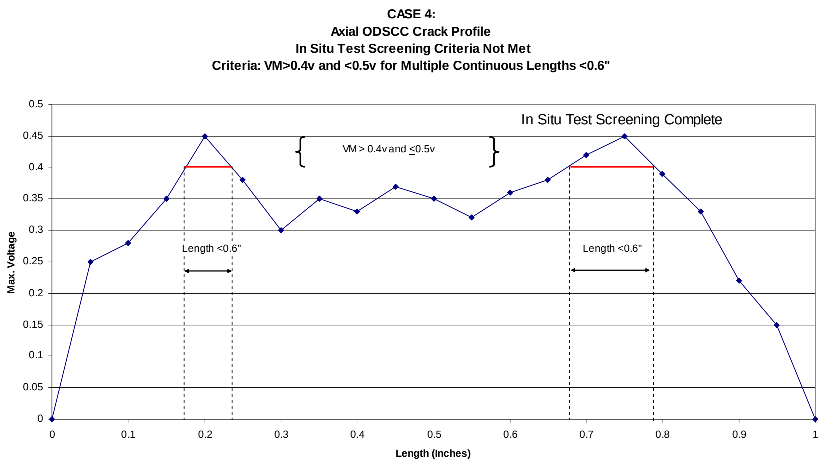
Interpretation of In Situ Pressure Test Guidelines for Long ODSCC Axial Cracks

- Voltage Profile that that does not meet the screening criteria:



Interpretation of In Situ Pressure Test Guidelines for Long ODCC Axial Cracks

- Voltage Profile that that does not meet the screening criteria:



Standing Issues

SGMP Industry Document Status and Revision Schedule

Guideline Title	Current Rev #	Report #	Last Pub Date	Imple-mentation Date(s)	Interim Guidance	Review Date	Comments
Steam Generator Integrity Assessment Guidelines	3	1019038	Nov 2009	9/1/10	SGMP-IG-10-01	2012	Revision 4 will begin January 2013
EPRI Steam Generator In Situ Pressure Test Guidelines	3	1014983	Aug 2007	3/14/08 6/14/08	None		Final Draft in Approval Process
PWR Steam Generator Examination Guidelines	7	1013706	Oct 2007	9/1/08	SGMP-IG-08-04		Rev 8 in progress
PWR Steam Generator Primary-to-Secondary Leakage Guidelines	4	1022832	Sept. 2011	4/11/2012 7/11/2012	None	2013	

SGMP Industry Document Status and Revision Schedule

Guideline Title	Current Rev #	Report #	Last Pub Date	Imple-mentation Date(s)	Interim Guidance	Review Date	Comments
PWR Primary Water Chemistry Guidelines	6	1014986	Dec 2007	6/17/08 9/17/08	SGMP-IG-09-01 SGMP-IG-11-02		Review Board Interpretation CHEM 18 issued Rev 7 in progress
PWR Secondary Water Chemistry Guidelines	7	1016555	Feb 2009	8/20/09 11/20/09	None	2012	Review Board interpretation CHEM 17 issued
Steam Generator Management Program Administrative Procedures	3	1022343	Dec 2010	9/1/11 12/31/11	None	N/A	
Steam Generator Degradation Specific Flaw Handbook	1	1019037	Dec 2009	N/A	None	N/A	Revision 2 will begin January 2013

In Situ Pressure Test Guidelines, R4

- Steam Generator In Situ Pressure Test Guidelines, Revision 3, 1014983
  - Published August 2007
  - Revision 4 is in the approval process
  - Expect to publish fall 2012

In Situ Pressure Test Guidelines, R4 - Major Changes

- Major rewrite of the document focusing on simplification of the screening process and a better understanding of the role of in situ pressure testing in condition monitoring
- Proof test screening
  - Developed +Point threshold voltages for initial screening of volumetric degradation
  - Revised volumetric proof test screening process
- Leak test screening
  - Developed screening process for circumferential degradation under pressure and bending loads.
  - Developed screening process for circumferential degradation to account for large break LOCA loads in OTSGs for circumferential degradation.

In Situ Pressure Test Guidelines, R4 - Major Changes

- Leak test screening
  - Developed screening process for foreign object wear under pressure and bending loads. Development program applied:
    - Industry in situ test results for foreign objects
    - Plus Point voltage measurements for a wide variety of geometries including all of the flaw configurations noted in ETSS 27091
    - Newly performed laboratory pop-through and burst tests
    - Calculations of the pressure levels needed for the onset of 100 %TW tearing.

In Situ Pressure Test Guidelines, R4 - Major Changes

- Updated Appendix B
  - Included in situ pressure test results from May 2006 through September 2011 in the Appendix B data tables. None of the additional data caused the leak test screening values to change
- Updated Chapter 9 leakage calculations to include the effect of bending loads. Calculations validated by independent contractor.
- Updated Appendix A (development of CM limit curves) and validated by an independent contractor
- Updated with current operating experience and to ensure consistency with the latest SGMP guidelines and NEI 97-06

Primary to Secondary Leak Guidelines, R4

- This guideline is used by chemistry and operations departments in developing operational responses to primary-to-secondary leakage, selecting leakage monitoring methods and equipment, performing leak rate calculations, and evaluating data

- This document provides the requirements and suggested procedures for responding to primary-to-secondary leakage to reduce the probability of a tube rupture

Primary to Secondary Leak Guidelines, R4

Overview of Revision 4 Changes

- Technical basis chapter re-organized
- Guidance chapter re-organized
- Two methodologies clearly delineated
  - Rate of Change
  - Constant Leakage
- Some requirements re-worded for clarity so that intent better understood
- All NEI requirements (mandatory, shall, and recommendations) clearly defined and summarized in a Chapter
- Chapters and appendices added or revised to update industry experience or provide additional information

Primary to Secondary Leak Guidelines, R4

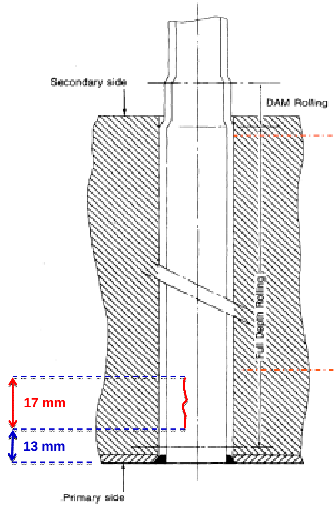
- Guideline published in September 2011
- NEI transmitted hard copies to the NRC on March 1, 2012
- Implementation
  - April 11, 2012 or July 11, 2012
    - If refueling outage within six months, then 9 months from the date of letter.
  - Implementation survey was sent out to industry on July 11, 2012
- Webcasts
  - Purpose: review and discuss guideline changes
  - Dates
    - November 15, 2011
    - February 21, 2012

Recent Foreign OE

- Tube leakage was detected in 2010 in a tube that was known to have a longitudinal crack within the tubesheet
  - 3-loop 900MWe reactor, with AREVA type 51BI steam generators
  - 7/8 inch diameter Alloy 600MA tubes (manufactured by Vallourec)
  - Tubes were mechanically expanded into the tubesheet by hard rolling and included a kiss roll at the top of the tubesheet
  - ~20 steps to achieve mechanical expansion on the full depth of the tubesheet
  - The leakage was identified in tube R19C43 with a Helium leak test

Recent Foreign OE

- Longitudinal crack = 17mm
- A root cause evaluation has shown that the tube was manufactured within the tolerances, but very close to the specified limits
- Tubes with the same configuration were plugged
- 46 tubes identified
  - 32 on 900MWe,
  - 16 on 1300 MWe



US Operating Experience – Alloy 690TT Tubing

- 46 units in the US with 690TT tubing
  - 43 have conducted the first in-service inspection
  - Date of first in-service inspection 1990 – 2011
    - 2012 inspections are not included
- Some plants have experienced a large number of indications in the first inservice inspection
- Some have experienced a large growth in numbers of indications in subsequent inspection

US 690TT Units Affected by Wear

MECHANISM	NUMBER OF DOMESTIC UNITS AFFECTED
Foreign Object Wear	16
U-Bend Support Wear	22
Support Structure Wear	35
Tube-to-Tube Wear	6

Data from Steam Generator Degradation Database as of July 2012

Global Operating Experience – Alloy 600TT Tubing

- Plants are still using temporary alternate repair criteria to limit inspections in the tubesheet
- Cracking continues to be identified in Alloy 600TT tubing

Location	ODSCC		PWSCC	
	Axial	Circ	Axial	Circ
U-Bend			X	
TSP/FDB	X			
TTS/Exp Trans	X	X	X	X
Tubesheet			X	X
Tube End			X	X

NEI 03-08 Deviations

- Three long-term deviations
  - Steam Generator Examination Guidelines, R7
    - Single pass auto analysis
  - Steam Generator Secondary Water Chemistry Guidelines, R7
    - Wet lay up steam generator sample frequency
  - Steam Generator Integrity Assessment Guidelines, R3
    - Use of site-specific sizing indices
- Two short term deviations
  - Steam Generator Examination Guidelines, R7
    - PSI prior to hydro
  - Steam Generator Secondary Water Chemistry Guidelines, R7
    - Wet lay up steam generator sample frequency

NRC Discussion Items

NRC Discussion/Items of Interest

- Essential Variable Tolerance
- Time Dependent Leak Rate
- Performance Standards for Tube Integrity
- Review of ETSS Reports
- Channel Head Cladding Degradation
- Information Notice on Tube-to-Tube Contact
- Pre-Service Inspection Requirements in Code
- Industry Guidelines Pertaining to Use of Nitrogen-16 Monitors
- Others?

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