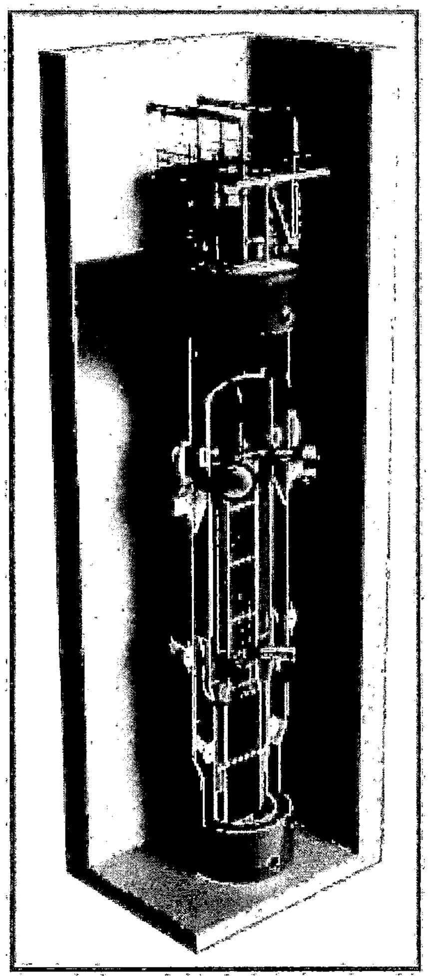

ACRS Subcommittee Presentation

NuScale FSAR

STEAM GENERATOR DESIGN

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Revision: 0

NUSCALE™ Power for all humankind

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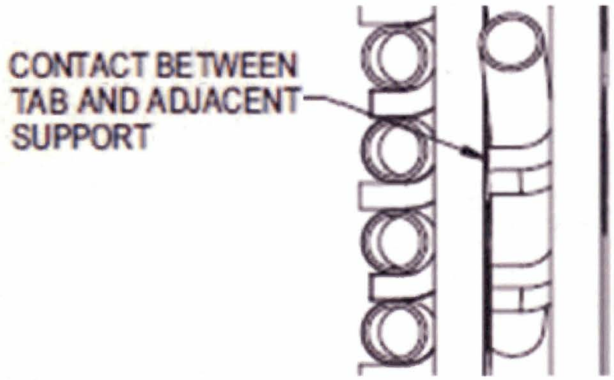
Steam Generator Design - Open Session Agenda

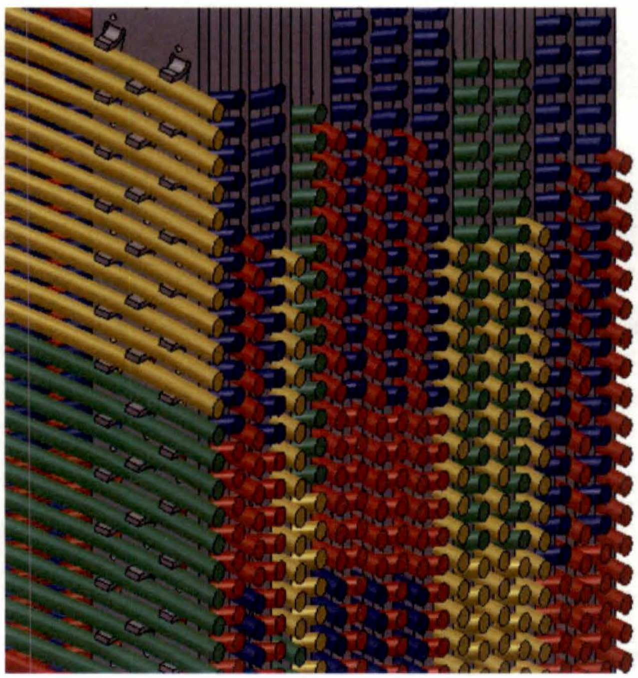
- Steam Generator Design
- Steam Generator Inspection Program
- Density Wave Oscillation Overview
- ITAAC Closure Path for DWO
- Preliminary Scoping Study
- Planned Closure Activities Through ITAAC

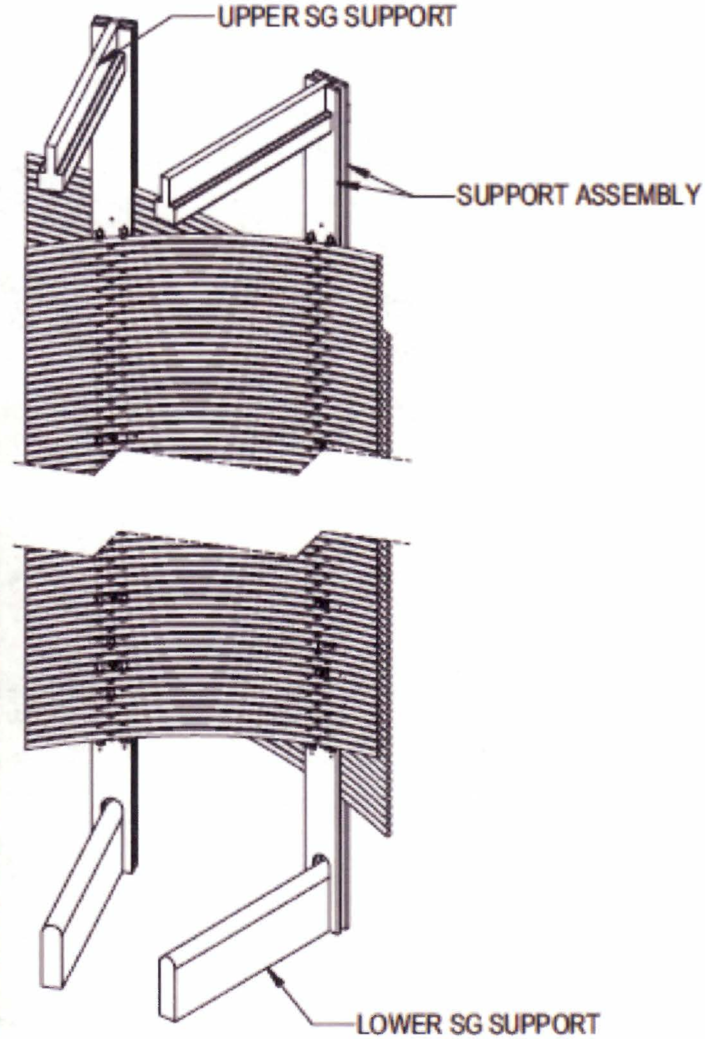
Steam Generator Design

- **Integral Helical Coil SG Design features**
  - Shell side is primary side - Tube side is secondary side
  - Alloy 690 TT (1380 tubes, 77 - 87ft long, 5/8" OD)
  - Low flow in primary (~1ft/sec)
  - Tube wall degradation allowance (0.010" > ASME min wall)
  - Support 100% volumetric inspection
  - Normal access to shell side of tubes from below during refueling
- **Incorporation of Operating Experience**
  - Follow guidance of NEI 97-06 & EPRI (COL Item 5.4-1: Develop and implement a SG Program)
- **Flow restrictor design at SG tube inlet ensures acceptable tube flow fluctuations during operation**

Steam Generator Design (Cont'd)





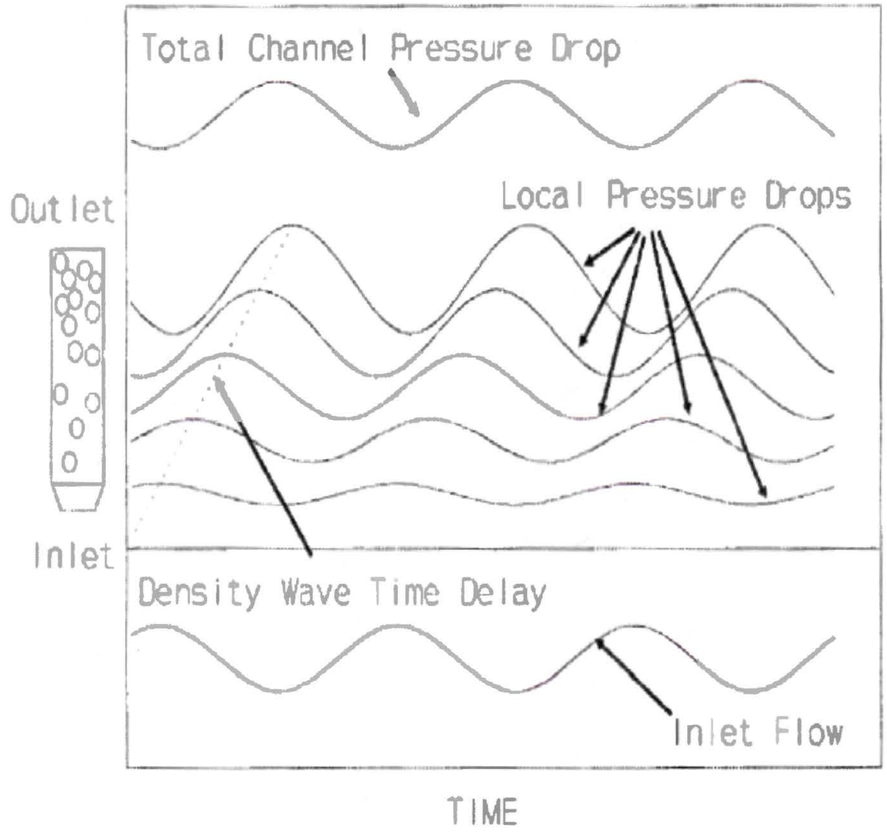


Steam Generator Inspection Program

- Monitors performance and condition of SGs as part of ISI
- Implements applicable portions of B&PV code Section XI and 10 CFR 50.55a(g)
- Appendix B to 10 CFR 50 applies to implementation
- Follows NEI 97-06 and EPRI guidance 1013706 Rev 7 "Steam Generator Management Program, PWR SG Examination Guidelines"
- Includes
  - Degradation assessment (including wear due to fretting)
  - Tube integrity assessment
  - Shell side integrity assessment

Density Wave Oscillation – Overview

- Consider a case for inlet flow reduction
  – sinusoidal flow fluctuation
- Causes increase in void
- Voids move through the channel
- Voids movement also known as Density Wave Motion
- Density wave produces pressure drop fluctuations
- Pressure drop is delayed with respect to the inlet flow fluctuations
- At certain frequency
  – Total pressure drop is completely out of phase with the flow fluctuations
  – Effectively produces the negative pressure drop
  – Causes flow surge
  – Cycle repeats
- DWO can be self sustaining



(March-Leuba, J., "Density Wave Instabilities in BWR", NUREG/CR-6003, Oct. 1992.)

Density Wave Oscillation – Overview (continued)

- DCA Rev. 3 Section 3.9.1 discusses the possibility of secondary flow oscillations during power ascent and descent
- Section 5.4.1.2 addresses Inlet Flow Restrictor (IFR) sizing to limit DWO to acceptable limits
- The NuScale Stability Topical Report TR-0516-49417 concludes that secondary oscillations do not challenge fuel thermal limits
- Additional review of the DCA language is ongoing and adjustments will be made in a final revision as necessary

ITAAC Closure Path for DWO

- ITAAC 02.01.01 requires that an inspection is performed of the NuScale Power Module "ASME Code Class 1, 2, 3, and CS as-built component Design Reports to verify that the requirements of ASME Code Section III are met"
- Tier 1 Table 2.1-2 defines the NuScale Power Module (NPM) ASME Code Class 1, 2, 3, and CS components:

Equipment Name	ASME Code Section III
RCS Integral RPV/SG/Pressurizer	1

- Therefore, ITAAC 02.01.01 requires the inspection of the certified ASME Design Reports for the RPV and the steam generator

ITAAC Closure Path for DWO (continued)

- Subsection NCA of the 2013 Edition of the ASME Code defines requirements of what is to be included in ASME Design Specifications and ASME Design Reports.
  - Design Specifications
    - NCA-2142.2 requires that Design Specifications identify all loadings (e.g. pressure, temperature, mechanical loads, cycles, and/or transients) and the service limits a component will experience
      - » Loading combinations for the RPV (including SG tubes) defined in Table 3.9-3 of DCA
      - » Transient (TH) loads are based on time history of design basis transients, described in DCA Section 3.9.1.

ITAAC Closure Path for DWO (continued)

- Subsection NCA of the 2013 Edition of the ASME Code defines requirements of what is to be included in ASME Design Specifications and ASME Design Reports.
  - Design Reports
    - NCA-3260 requires that the Design Report evaluate the loads and load combinations as defined in the Design Specification to the applicable acceptance criteria are met.
    - NCA-5350(4) requires the Design Report be certified by a Registered Professional Engineer (RPE) competent in the applicable field. The RPE confirms all loads and load combinations specified in the Design Specification have been addressed and satisfied.
    - NCA-8310(a) permits application of the ASME 'N' Certification Mark to the Reactor Pressure Vessel which provides certification by an Authorized Nuclear Inspector that all ASME examinations and testing have been completed.
- Therefore, the resolution of DWO will be achieved through ITAAC 02.01.01 activities related to the RPV and the steam generator

Preliminary Scoping Study

- Steam Generator Tubes
  - The applicable primary side conditions were applied to the exterior of the SG tubes and DWO full flow reversal was considered on the interior (secondary side) for the total length of the tube.
  - The resultant alternating stress due to this oscillation is below the ASME Code endurance limit; therefore, preliminary analyses demonstrate that DWO full flow reversal will not result in any fatigue damage to the steam generator tubes.
- Feedwater Plenum Tube-to-Tubesheet Weld
  - Preliminary analyses using bounding DWO transient definitions, assuming complete tube dry out, and conservative tube to plenum interaction, resulted in alternating stresses above the ASME Code endurance limit.
    - The DWO transient definition in this vicinity is undergoing further evaluation.
    - The preliminary DWO alternating stress in relation to the ASME endurance limit, coupled with the analytical conservatisms applied in this evaluation, enable NuScale to confidently predict the final alternating stress due to DWO in this region will be below the ASME Code endurance limit.
    - ITAAC 02.01.01 requires the inspection of the Design Report in which this evaluation will be documented.

Planned Closure Activities Through ITAAC

- ITAAC 2.01.01 inspection is performed of the NuScale Power Module "ASME Code Class 1, 2, 3, and CS as-built component Design Reports to verify that the requirements of ASME Code Section III are met"
  - NRELAP5 will provide thermal-hydraulic time histories of design transients in support of the fatigue analysis, including fluid temperatures, pressures, nominal flow rates, and quality
  - TF-1 and TF-2 test data will provide a basis for parameters used to calculate film coefficients and resulting stresses during DWO
  - Thermal response of the tube is much faster than the DWO frequency, so a quasi-static analysis can be performed
  - The stresses from all loadings and transients (including those from DWO) will be combined and compared to allowable stress limits
  - The goal of the SG ASME Code calculations is to confirm that the alternating stresses on the SG tubes, the tube-to-tubesheet welds, and the tubesheets due to DWO stresses are below the ASME endurance limit; thereby enabling these components to withstand infinite cycles

NuScale Conclusion

- The successful completion of ITAAC by the licensee constitutes the basis for the NRC determination to allow operation of a facility certified under 10 CFR 52

Acronyms

ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
DCA	Design Certification Application
DHRS	Decay Heat Removal System
DWO	Density Wave Oscillation
EPRI	Electric Power Research Institute
FSAR	Final Safety Analysis Report
FW	Feedwater
IFR	Inlet Flow Restrictor
ISI	Inservice Inspection
ITAAC	Inspection, Test, Analysis and Acceptance Criteria
NEI	Nuclear Energy Institute
NPM	NuScale Power Module
NSSS	Nuclear Steam Supply System
PWR	Pressurized Water Reactor
RCS	Reactor Coolant System
RPV	Reactor Pressure Vessel
SG	Steam Generator
TH Code	Thermal Hydraulic Code

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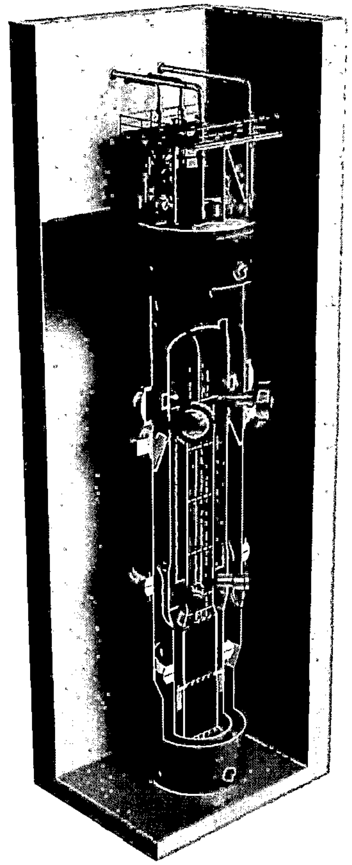

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