



AREVA Experience with Tube Wear and Vibration

Jeffrey Fleck

Manager, NSSS Mechanical Engineering
Engineering and Projects Organization

February 7, 2013



Background



- ▶ **AREVA has designed and manufactured replacement steam generators since 1989**
- ▶ **Experience includes international and domestic plants**



▶ Different designs

- ◆ Function of plant size and type
- ◆ 67 Recirculating Steam Generators (RSGs)
- ◆ 4 Enhanced Once Through Steam Generators (EOTSG)
- ◆ Materials of construction are similar (alloy 690 tubes and SS supports)

▶ **4 US plants have AREVA RSGs,
1 more will install in 2013**

▶ **2 US plants have EOTSG designs**

US Component Experience



- ▶ **All of the in service components have had at least one inspection, with most having two**
- ▶ **Inspection methods ensure wear is identified at low levels of percent throughwall**

US Component Experience



▶ Varying degrees and types of wear have been identified

- ◆ AVB, TSP, peripheral bundle supports, as well as loose parts
- ◆ No tube-tube wear resulting from in-plane fluid elastic instability has been identified in AREVA RSG designs
- ◆ Tube-tube wear has been identified in the EOTSGs
 - Root cause evaluation still in progress
 - Tube instability is not a causal factor
 - NDE results from multiple inspections indicate it is a manageable mechanism

US Component Experience



- ▶ **Significant efforts have been undertaken to quantify and understand causes of unexpected wear mechanisms in our SGs**

Design Considerations



- ▶ **During design phase, a specification imposes requirements on the designer/fabricator**
- ▶ **SGs are designed, fabricated, and tested in accordance with the requirements of the ASME Code and best practices**

Design Considerations



▶ **Minimization of tube vibration and wear is optimized and considers:**

- ◆ **Thermal hydraulic conditions**
- ◆ **Support configuration**
- ◆ **Tube bundle configuration**
- ◆ **Materials selection**
- ◆ **Flow induced vibration response**

Design Considerations



- ▶ **Stability margins, turbulence response and non-linear wear analysis are performed and evaluated against acceptance criteria**
- ▶ **Conservative inputs are used in all design analyses to ensure margin is maintained and the specification is satisfied**

Design Considerations



- ▶ **Analysis codes have been benchmarked with laboratory and mockup testing, as well as other codes**
- ▶ **Changes or adaptation of existing designs are challenged and vetted for acceptability**

Design Considerations



- ▶ **Past lessons learned and experience are evaluated for applicability**
- ▶ **Final design is validated as meeting the specification by professional engineer**
- ▶ **Owner acceptance of the component then occurs**

Inspection/Repair Experience



- ▶ **Extensive experience with assessments of all SG degradation mechanisms**

- ▶ **Industry experience with wear**
 - ◆ **Easily detected using EPRI qualified techniques**
 - ◆ **Sizing uncertainties are well quantified**
 - ◆ **Structural relationships are well established and conservative**
 - ◆ **Detected indications are well below tube integrity performance criteria**

Inspection/Repair Experience



► Industry Framework for SGs

- ◆ Establishes a firm basis for the SG program in testing and qualification of people and techniques
- ◆ Standardizes requirements and methods
- ◆ Provides for Operating Experience (OE) sharing
- ◆ Established conservative Technical Specifications for effective and conservative management of SG degradation

Support of San Onofre



- ▶ **AREVA provided SG inspection, repair and engineering for both San Onofre Units**
- ▶ **Tube-tube wear due to in-plane fluid-elastic instability is a new phenomena**
- ▶ **In Unit 2, the majority of tube repairs were “preventive” in nature**

Support of San Onofre



- ▶ **AREVA's condition monitoring and operational assessments have been completed and submitted for NRC review**
- ▶ **Engineering analysis supports Unit 2 return to operation at 70% power**
 - ◆ Improves thermal hydraulic conditions that affect tube vibration
 - ◆ Provides for margin to the onset of in plane instability
 - ◆ Significantly reduces the probability for tube-tube wear to occur

Summary



- ▶ **Tube wear is a manageable mechanism**
- ▶ **Even in cases of large populations of tubes with wear, plant cycle length and tube integrity margins can be safely maintained**
- ▶ **Inspection/repair strategies for wear mechanisms result in conservative tube integrity projections**

Summary



- ▶ **Current industry practices/programs and Plant Technical Specifications provide a robust and sufficient methodology and requirements for managing all SG tube degradation**