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Steam Generator Management Program

Steam Generator Divider Plate Cracking Engineering Study

Non-Proprietary Version

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Technical Update, December 2009

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PRODUCT DESCRIPTION

Cracking in steam generator (SG) divider plate to stub runner welds has been reported by Electricité de France (EdF) plants. EPRI Report 1014982 describes results of a conservative Phase I analysis of a crack in the divider plate to stub runner weld of a domestic Westinghouse-designed SG. The results of the Phase I analysis show that such a crack could grow in the heat-affected zone and the divider plate welds between the divider plate and the stub runner during normal operating conditions. Therefore, Phase II work began in 2008 to better understand crack initiation and growth in a divider plate to stub runner weld and its impact on plant accident analyses, ASME stress report fatigue limits, alternate repair criteria, and installed plugs and sleeves. EPRI technical update 1016552, published in 2008, provides a detailed analysis of the effect of a cracked divider plate on the behavior of a steam generator during normal and accident operating conditions. This technical update addresses the concern that a cracked divider plate may result in exceeding a design criterion in the SG design documentation for Model F, Model 44F, Model D5, Model 51F, and Model 51 SG. This update also addresses the potential of a degraded divider plate to affect alternate repair criteria and installed plugs and sleeves.

Results and Findings

All of the structures and related components affected by the divider plate were reviewed for the potential effect of a degraded divider plate condition during operations. In this context, a degraded divider plate is considered to be a divider plate with a flaw or crack that extends the full length of the divider plate to tubesheet connection (100% of the length) and fully through the width of the weld (100% through-wall).

- The design and technical justification of the tubesheet, channelhead, divider plate, and lower shell are not affected by the presence of a degraded divider plate.
- The design and technical justification of the significant tubesheet junctions and welds are not affected by a degraded divider plate.
- The repair devices (plugs and sleeves) and alternate repair criteria for the tube portion within the tubesheet are sensitive to a degraded divider plate assumptions, but no changes to the conclusions from those analyses or the level of conservatism in the results are expected in the case of a degraded divider plate condition.

Challenges and Objectives

This report is intended for steam generator analysts and engineers in nuclear power. This report is mainly applicable to nuclear power plants that have Westinghouse-designed steam generators in the existing domestic fleet with Alloy 600 divider plates. This report does not apply to steam generators with center stays or floating divider plates. The purpose of this report is to establish that divider plate cracking is not a safety significant issue for domestic plants. Specifically, the purpose of the analysis is to determine the impact of SG divider plate cracking on:

- ASME Stress Report fatigue limits
- Alternate Repair Criteria
- Installed plugs and sleeves

Applications, Values, and Use

This research was done in response to operating experience at EdF. It is intended, if possible, to provide a technical justification for not inspecting SG divider plates in the domestic fleet. This determination would save utilities on inspections costs and radiation exposure.

EPRI Perspective

This study focuses on Westinghouse-designed steam generators with Alloy 600 divider plates in the domestic fleet. This is the only study on the impact of a degraded divider plate on steam generator operations in the United States.

Approach

The project team reviewed more than 600 reports, calculation notes, drawings, and change notices for this study with a focus on information that relates most closely to concerns about maintaining the safety margin in the lower SG complex in the event that a degraded divider plate condition occurs during operations.

Keywords

Divider plate cracking
Lower steam generator complex
Channel head

CONTENTS

1
INTRODUCTION

The divider plate is a component in the lower SG complex. It is connected to the channel head and tubesheet, but it is not part of the primary pressure boundary for the reactor coolant system [1]. The divider plate influences the deformation and stress distributions in the lower SG complex. Multiple indications of cracking in the divider plate welds have been reported in foreign steam generators [2]. Two EPRI reports [2] and [4] discuss the initial investigation of the impact that such degradation, if found, could have on domestic SGs. The cracks in the divider plate welds in the foreign fleet occur on the welds that connect the stub runner to the divider plate and the stub runner to the tubesheet. Cracks were observed on both the cold leg and hot leg side of the divider plate. The most likely cause of the degradation is a combination of primary water stress corrosion cracking (PWSCC) and fatigue. However, it is also possible that factors such as loose parts impingement on the primary face of the hot leg material and manufacturing artifacts have contributed to the observed divider plate degradation.

Pictures of the as installed divider plate and the interior hot leg chamber of the lower steam generator complex are shown in Figures 1 and 2. Figure 3 provides a schematic of the divider plate and channel head geometry and the site of observed cracking at EdF.

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Figure 1
Divider Plate Welds in an Older Model of Steam Generator, With a Two Piece Stub Runner

Figure 2
Divider Plate Welds in a Recent Replacement Model of Steam Generator, With a Single Piece Stub Runner

Figure 3
Sketch of Divider Plate Geometry

The United States Nuclear Regulatory Commission (US NRC) has also expressed concerns about the foreign divider plate cracking phenomena. Most of the US NRC concerns on record in topically related requests for additional information [5] focus on the application of tube-in-tubesheet alternate repair criteria. However, this project focuses on all the concerns below from both industry and the NRC.

- Is it more limiting to have a cracked or an uncracked divider plate in an operating SG?
- Does a degraded divider plate affect the operation of the SG under any design conditions?
- Does a degraded divider plate invalidate the qualifications of installed plugs or sleeves?
- Does a SG with a cracked divider plate violate the ASME Code structural criteria?
- Is it necessary to inspect the divider plate and the connecting welds between the tubesheet, stub runner and divider plate?

The purpose of this technical update is to address the concern of a cracked divider plate resulting in a violation of an ASME Code design condition or concern in the SG design documentation for Model F, Model 44F, Model D5, Model 51F, and Model 51 SG. It also addresses alternate repair criteria and installed plugs and sleeves.

The conclusions in this report do not apply to any SG design or model that directly takes credit for the divider plate in order to meet ASME Code design requirements, which includes some of the recent replacement steam generator designs in the domestic fleets. It is assumed that recent replacements include improved material that would not be susceptible to PWSCC and other degradation mechanisms in the existing domestic fleet. The conclusions in this report also do not apply to Combustion Engineering (CE) design steam generators with a central stay column in the lower steam generator complex.

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ASME STRESS REPORT UPDATE SUMMARY

The design and analysis of the major components, welds and repair devices in the lower SG complex must satisfy the requirement of the ASME Code [1]. There have been different lower SG complex designs over the last 40 years. However, the requirements and criteria that apply to the design of those structures have not changed with respect to the ASME Code. The following summarizes the role of the divider plate structure in the lower SG complex with respect to the design and operation of a SG. More than 600 reports, calculation notes, drawings, and change notices were reviewed for this study. The information in References [6] through [48] represents the most significant information that directly relates to the concern of the lower SG complex maintaining its safety margin during operations in the event that a degraded divider plate condition occurs.

2.1 Tubesheet, Channelhead, Lower Shell and Divider Plate

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2.2 Tube-to-Tubesheet weld

2.3 Lower SG Thermal Hydraulic Boundary Conditions

3
INSTALLED PLUGS AND SLEEVES

There are several types of Westinghouse SG tube repair sleeve designs. These sleeve designs include: laser welded sleeves, TIG sleeves and leak limiting Alloy 800 sleeves. A tube sleeve design that is intended for the repair of the tube portion within the tubesheet may be affected by the change in tubesheet displacement due to a degraded divider plate because a change in the tubesheet displacement can effect the contact pressure distribution between the tube, sleeve and tubesheet. Some tube sleeve designs do not take credit for tubesheet displacement when considering the forces holding the tube repair sleeve in the tube. The summary contained in this report will address only the Westinghouse tube sleeve designs. It is important to note that there are no tubes currently in operation with Westinghouse tube sleeve repairs.

3.1 TIG and Laser Welded Sleeves

3.2 Leak Limiting Alloy 800 Tube Sleeves

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3.3 Mechanical Tube Plugs

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SG TUBE ALTERNATE REPAIR CRITERIA

Many different alternate repair criteria (ARC) have been employed in SGs over the last 40 years. The discussion below pertains only to the alternate repair criteria that involve the tube portion within the tubesheet. This is because ARC for the tube portion within the tubesheet could be directly affected by tubesheet displacements. Several of the ARC discussed below are no longer used in the domestic fleet (e.g., C*, L*). In those cases, the details of how past ARC may have been affected by a degraded divider plate condition are included for the sake of completeness.

4.1 C* - Alternate Repair Criteria for CE SGs

4.2 F*/L* - Alternate Repair Criteria for Westinghouse SGs

4.2.1 F*, L* and W*- Hard Roll and WEXTEX Expansions

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4.2.2 H* - Hydraulic Expansions

4.2.3 *Interim ARC*

5
CONCLUSIONS

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