Enclosure 4

PWR Primary to Secondary Leak Guidelines:

Draft Revision 3

Non-Proprietary Version

PWR Primary-To-Secondary Leak Guidelines - Revision 3

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PWR Primary-To-Secondary Leak Guidelines - Revision 3

Draft Final Report, June 2004

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REPORT SUMMARY

Primary-to-secondary leakage of steam generator tubes in PWRs can result from mechanisms that propagate slowly or rapidly. This report represents Revision 3 of industry-wide guidelines first proposed in 1995 to address the issue of leakage.

Background

The original recommendations, PWR Primary-to-Secondary Leak Guidelines (TR-104788) dated May 1995, were developed by a committee of industry experts from a variety of disciplines under the auspices of EPRI. The Guidelines were updated by a similar committee in 1997, resulting in the issue of Revision 1 in November 1997. The Guidelines were again revised (Revision 2) in April 2000.

The PWR Primary-to-Secondary Leak Guidelines can be credited with providing defense-in-depth to ensure that operation with primary-to-secondary leakage has a low probability of escalating to a tube rupture.

Objectives

- To present a complete, technically justified program that can be used to develop station-specific operating programs.
- To revise the Guidelines to reflect recent field experience, and to reflect the current status of the NEI 97-06 initiative.
- To ensure that the Guidelines continue to help utility personnel to manage small leaks and to ensure that the likelihood of propagation of flaws to tube rupture is minimized under both normal and faulted conditions.

Approach

A committee of industry experts from a number of disciplines reviewed the operating experience with Revision 2 to the PWR Primary-to-Secondary Leak Guidelines. Industry experience with implementing the guidelines was also extensively reviewed. From this information, the committee developed recommended changes to the program designed to ensure proper monitoring of and responses to leakage. The recommended changes to the guidelines are intended to clarify implementation of the guidelines, and to ensure that the likelihood of

propagation of flaws to tube rupture is minimized under both normal and faulted conditions and should help utilities manage small primary-to-secondary leakage.

Results

The committee generated a revision to the guideline document following the format of Revision 2. Additionally, this revision of the guidelines delineates Mandatory and Shall requirements. These guidelines include six operating conditions with respect to primary-to-secondary leakage. Two of these conditions contain recommended actions that can result in rapid, controlled plant shutdown if primary-to-secondary leakage displays evidence of undesirable propagation.

EPRI Perspective

This document provides a series of industry-wide recommendations for station management of primary-to-secondary leakage, including detailed description of leak characteristics which warrant rapid, controlled plant shutdown to minimize the likelihood of propagation of flaws to tube rupture under both normal and faulted conditions. The Guidelines also provide technical information on standardized approaches for calculation of primary-to-secondary leak rates from various secondary system radiochemical data. They should serve as a pattern for development and review of station-specific programs for primary-to-secondary leakage.

TR-104788-R3

Interest Categories

Steam Generators
Corrosion Control
Plant maintenance assistance

Key Words

PWR
Steam Generators
Leakage
Tubes

ABSTRACT

Primary-to-secondary leakage can result from mechanisms that propagate slowly or rapidly. The willingness of the industry to prescribe and implement operational responses to primary-to-secondary leakage, as described in the PWR Primary-to-Secondary Leak Guidelines, has contributed to the successful minimization of tube ruptures since 1995. The committee reconvened in 1997 and again in 1999 and 2003 to review industry experience and new laboratory data to update the guidelines. As before, these revised guidelines provide an effective station program for monitoring primary-to-secondary leakage to ensure necessary operational actions are taken and to ensure the likelihood of propagation of flaws to tube rupture is minimized under both normal and faulted conditions. These guidelines contain recommended operating actions in response to primary-to-secondary leakage of varying magnitudes, appropriate methods of calculating leak rates from various secondary system sample points, and various methods of monitoring leakage once detected. These guidelines emphasize the need for using continuous on-line radiation monitors to provide for rapid detection and response to leakage, rather than relying on grab samples. These guidelines should serve as a pattern for development and review of station-specific programs for primary-to-secondary leakage.

EPRI FORWARD

Under the auspices of EPRI, the electric power industry has developed operating guidelines for various station activities, including secondary cycle chemistry control and steam generator inspection. Industry-wide guidelines were developed in 1995 to help utilities develop and implement station-specific primary-to-secondary leak monitoring and action plans. The guidelines were updated in 1997 and 2000 to reflect additional industry experience and laboratory results. The guidelines have contributed to the successful industry defense against tube ruptures.

After two years of experience with Revision 2 of the guidelines, EPRI reconvened a committee of multi-disciplinary experts, including several members of the original committee, to address information developed since publication of Revision 2.

GLOSSARY AND ACRONYMS

ABB/CE	ABB Combustion Engineering
Activity	Concentration of radioactivity in liquid (μCi/g or μCi/ml, as appropriate) or gas (μCi/cc)
AE	Air ejector
AL	Action level
ALARA	As low as reasonably achievable
ANO	Arkansas Nuclear One
ASAP	As soon as possible
AVB	Antivibration bar
BAT	Boric acid treatment
B&W	Babcock & Wilcox
CE	Combustion Engineering
CFR	Code of Federal Regulations
CPM	Counts per minute
Faulted Condition	Design basis accident condition such as a steam line break
FOSAR	Foreign object search and recovery
GDC	General design criteria, in Appendix A of 10CFR50
GM	Geiger-Muller
HOH	Hydrogen ion - hydroxyl ion form resin
ICE	Ion exclusion chromatography
IGA	Intergranular attack
IGA/SCC	Intergranular attack/stress corrosion cracking
LLD	Lower limit of detection
MCA	Multiple channel analyzer
MSR	Moisture separator reheater
NDE	Non-destructive examination
ODSCC	Outer diameter stress corrosion cracking
OTSG	Once-through steam generator
P_b	Burst differential pressure
PORV	Pressure operated relief valve
P_{SLB}	Differential pressure for steam line break
PWR	Pressurized water reactor
PWSCC	Primary water stress corrosion cracking
RCPB	Reactor coolant pressure boundary
RCS	Reactor coolant system

RMS	Radiation monitoring system
RPC	Rotating pancake coil
RSG	Recirculating steam generator
SCC	Stress corrosion cracking
SG or S/G	Steam generator
SGBD	Steam generator blowdown
SGTR	Steam generator tube rupture
SLB	Steam line break
TBAOH	Tetrabutylammonium hydroxide
TTS	Top of tube sheet
UFSAR	Updated final safety analysis report
WE	Westinghouse Electric
ΔP_{NO}	Differential pressure under normal operation at 100% power
ΔP_{SLB}	Differential pressure for steam line break

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INTRODUCTION AND MANAGEMENT RESPONSIBILITIES

1.1 Background

Historically, steam generator tubes in pressurized water reactors (PWRs) have experienced various types of degradation from both the primary and secondary sides of the tubes. Corrosion mechanisms of concern include wastage, pitting, secondary side stress corrosion cracking (ODSCC), intergranular attack (IGA) and primary water stress corrosion cracking (PWSCC). Mechanical damage from fretting, fatigue and loose parts has also resulted in tube degradation.

Utility inspection and diagnostic programs are designed to detect incipient conditions before steam generator tube corrosion or mechanical damage lead to through-wall failure. In most cases, tube degradation mechanisms that result in primary-to-secondary leakage propagate slowly and lead to operational difficulties, but do not diminish any safety margins. However, some damage mechanisms can progress rapidly and can result in a tube rupture, resulting in significant secondary system contamination and potential actuation of reactor safety systems.

1.2 Guidelines Objectives

1.3 Primary-to-Secondary Leak Program Considerations

This section discusses the considerations common to most utilities, including the elements of organizations that are needed to effectively carry out the primary-to-secondary leak monitoring program.

1.4 Training

1.5 General Guidelines for Development of a Primary-to-Secondary Leak Administrative Program

1.6 Summary

1.7 References

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TECHNICAL BASES FOR PRIMARY-TO-SECONDARY LEAKAGE LIMITS

2.1 Purpose

This section provides the technical bases for the operating leak rate limits given in Section 3.

2.2 Normal Operation Leak Rate Limit for Any One Steam Generator

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2.3 Rate of Increase in Leak Rate

2.4 References

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OPERATING GUIDELINES FOR PRIMARY-TO-SECONDARY LEAKAGE

3.1 Purpose

The guidance contained in this section is designed so that appropriate actions can be taken early enough to preclude most through-wall tube defects from propagating to rupture. The guidance is presented in a series of defined operating conditions that reflect increasing primary-to-secondary leakage. Accordingly, the plant actions become more stringent as leak rates increase. Immediate power reduction and plant shutdown is mandatory if leakage trends suggest that a tube defect is rapidly propagating.

3.2 Action Level Criteria and Recommendations

3.3 Leak Rate Monitoring During Modes 3 and 4

3.4 Leak Rate Monitoring During Startup in Modes 1 and 2

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CONTINUOUS RADIATION MONITORING

4.1 Monitoring Program and Methods

4.2 Evaluation of Monitoring Methods

When selecting which monitoring method to use or evaluating the best way to use the method, two key elements that should be considered are detection capability and measurement uncertainty.

4.3 Radiation Monitoring Programs

4.4 References

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LEAK RATE CALCULATIONS

5.1 Introduction

The recommended operational responses to primary-to-secondary leakage discussed in Section 3 rely on accurate assessments of the leak rates. This section identifies how to calculate leak rates based on isotopic analyses of various secondary system samples.

5.2 Leak Rate Calculations Via Condenser Off-Gas Analysis

Dissolved radiogases in the RCS pass into the secondary side of a steam generator when a primary-to-secondary leak exists. These radiogases are quickly transported out of the steam generators with the main steam and are removed from the condensing steam by the condenser air removal system. Quantification of the primary-to-secondary leak can be made by comparing the radiogas activity removed through the condenser off-gas system (neglecting the solubility of the radiogases in condensate) to the radiogas in the reactor coolant.

5.3 Leak Rate Calculations Via Blowdown Analysis

Radionuclides from the reactor coolant system enter the steam generator bulk water when a primary-to-secondary leak exists. Due to their low solubility, radiogases are quickly transported out of the steam generator bulk water into the steam. Dissolved solids and very low concentrations of radiogases remain in the steam generator bulk water. These radionuclides can be quantified in the steam generator blowdown and used to estimate primary-to-secondary leak rate and determine which steam generator is leaking.

5.4 Leak Rate Calculations Via Tritium

5.4.1 Introduction

Tritium from the reactor coolant enters the SGs and secondary system when a primary-to-secondary leak exists.

5.5 Leak Rate Evaluation Via Other Methods

There are other qualitative and quantitative methods to detect and determine primary-to-secondary leaks and leak rates. Qualitative methods can be used for a rapid determination of the presence of a leak and identification of the leaking steam generator.

5.6 Leak Rate Calculations in Non-Operating Modes

Section 3.3 discusses the need to monitor leakage in non-operating modes and provides a discussion of the methods used for such monitoring.

5.6 References

A

DATA INTERPRETATION

1.0 Introduction

This appendix provides information for use by plant personnel attempting to categorize a primary-to-secondary leak.

2.0 Background

3.0 Characteristics of Primary-to-Secondary Leakage

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1.0 Condenser Off Gas Transport Decay Effects

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2.0 Leak Rate Monitoring Prior to Power Operation

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EXAMPLE OF COMPUTER CALCULATED PRIMARY-TO-SECONDARY LEAK RATE FROM CONDENSER AIR EJECTOR MONITOR

1.0 Overview

This appendix provides an example method for determining primary-to-secondary leak rate using a computer with continuous input from one or more air ejector (AE) process monitors.

2.0 Assumptions

3.0 Example AE Radiation Monitor Isotopic Efficiency Factors

4.0 Calculation

5.0 Calculation Steps

6.0 Isotopic Considerations

7.0 Conclusion