Materials Reliability Program: Visual Examination for Leakage of PWR Reactor Vessel Upper Head Nozzles

(MRP-60 Rev 5)

3002013268

Technical Update, December 2018

EPRI Project Manager
J. Spanner

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) and Materials Reliability Program (MRP) prepared this report:

Principle Investigator
M. McCallum

The following MRP members provided information for this report:

R. Allen	Entergy
R. Doss	Duke Energy
K. Hacker	Dominion Energy
G. Kammerdeiner	First Energy
H. Smith	Exelon
P. Torsten	Ringhals
C. Wax	Palo Verde

This report describes research sponsored by EPRI.

This report was prepared through a cooperative effort of PWR utilities, the EPRI MRP, and inspection organizations. Critical information on head penetration visual inspection practices, equipment, and interpretation processes was obtained from key individuals who performed the visual inspections at the various plants and was made available through this cooperation.

This publication is a corporate document that should be cited in the literature in the following manner:

Materials Reliability Program: Visual Examination for Leakage of PWR Reactor Vessel Upper Head Nozzles: (MRP-60 Rev 5). EPRI, Palo Alto, CA: 2018. 3002013268.

Intentionally Blank

ABSTRACT

Visual inspection of the top of the reactor pressure vessel head has been a primary method of identifying penetrations that are leaking as a result of cracking in the J-groove attachment weld (partial penetration) or penetration housing. Past experience at U.S. plants shows that small or large amounts of boric acid buildup could be expected to accumulate from such leaks.

At the direction of the Electric Power Research Institute Materials Reliability Program, this report was initially developed to provide guidance for plants preparing their examiners for inspections, by improving their awareness of the appearance of relevant conditions. It has been revised to include some of the most recent head examination results performed from 2014 to 2018. This report also includes information on visual inspection devices that are applicable to top-of-the-head inspections. Included are photographs and inspection results from Duke's Oconee and Entergy's Arkansas Nuclear One Unit 1 plants (inspections performed in 2000 and spring 2001). These two plants experienced leaks that provide relevant and practical information on the characteristics of boric acid deposits resulting from head penetration leaks. Key individuals at these units, as well as personnel from other plants, who performed the examinations were interviewed to determine the most effective inspection approaches, including equipment application, accessibility issues, lessons learned, and methods for determining the source and characteristics of boric acid deposits. In this report, images are provided by member utilities that focus on detecting relevant conditions and distinguishing between reactor vessel upper head penetration leaks and leaks from other sources, such as flanges and refueling activities. Enhancements to the inspection philosophy have been incorporated as a result of these inspections and are described in this report.

Keywords
Bare metal visual (BMV) examination
Control element drive mechanism (CEDM)
Control rod drive mechanism (CRDM)
Primary water stress corrosion cracking (PWSCC)
Reactor vessel upper head penetration (RVUHP)

Intentionally Blank

PRODUCT DESCRIPTION

Primary water stress corrosion cracking (PWSCC) has been reported in Alloy 600 reactor vessel upper head penetrations (RVUHPs) in pressurized water reactor (PWR) plants in Europe and the United States. Visual inspection of the top of the reactor pressure vessel (RPV) head has been the primary method to identify leaking penetrations. Numerous plants have replaced their upper heads using Alloy 690 materials to address this PWSCC issue. This report was originally developed to provide guidance for plants that are preparing their examiners for these inspections by increasing their awareness of the appearance of relevant conditions. In addition, results from the past 15 years of bare metal visual (BMV) inspections from numerous PWR nuclear power plants are included.

Background

Discoveries of cracked and leaking Alloy 600 vessel head penetration nozzles, including RVUHP and thermocouple nozzles, at PWR plants have led to the implementation of in-service inspection methodologies to detect cracks. Discovery in 2001 of cracking and wastage of the vessel head prompted the industry to revisit the inspection and qualification program. The Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) has taken the lead role for the industry in addressing the issue of cracking above the weld and head wall loss resulting from corrosion.

Visual inspection (that is, BMV inspection) of the top of the RPV head continues to be a primary method of detecting leaking penetrations. Early detection of cracking in the control rod drive mechanism and control element drive mechanism penetrations and wall loss of the head surface can allow utilities to make relatively small repairs, which is obviously less expensive than replacing the head.

Objectives

- To support RVUHP and head surface visual examinations in PWR plants
- To provide utilities with information from previous examinations and lessons learned
- To provide visual examiners with information and guidance to increase their awareness as to where to look and what to look for when attempting to detect leakage
- To provide visual examiners with information and guidance to evaluate deposits and determine if they are relevant

Approach

EPRI solicited information from U.S. and international utilities that have been performing their examinations of RVUHPs. The data and photographs were then assembled and incorporated into this report, which can be used as a guideline for developing visual examination procedures and/or performing actual visual examinations of the RVUHPs.

Results

The report presents data, lessons learned, color photographs, and video stills from visual examinations. Section 1 provides an introduction and some background on visual inspection of the RVUHP. Section 2 addresses the scope, purpose, conditions, and equipment for performing visual examinations. Section 3 covers direct and remote examination methods, and Section 4 provides detailed discussion of inspections conducted in the spring and fall outages from 2014 to 2018. Sections 5 and 6 provide detailed discussion of inspections conducted during outages from 2001 to 2013. Appendix A presents images captured from Duke Energy's RVUHP examination of its Oconee Unit 1 in 2000. Appendix B includes a brief history of the examination requirements for RVUHP and Appendix C includes an evaluation process that can be modified and adopted by utilities. Images of remote visual equipment, boron deposits, wastage, and leakage are included.

Applications, Value, and Use

Utilities considering visual examinations require reliable information on nondestructive evaluation capabilities. Reliable flaw detection is needed to ensure that any relevant conditions are detected. This report provides information to assist utilities that are developing and/or validating procedures for performing a visual examination. It provides information related to the characterization of relevant and nonrelevant indications. This report is a revision to EPRI report 3002000711 (MRP-60 Rev 4) [1], which included information from the 2003–2013 inspections.

[REMAINDER OF DOCUMENT REDACTED]