NRC INSPECTION MANUAL

EMCB

Temporary Instruction 2515/150, Revision 2

REACTOR PRESSURE VESSEL HEAD AND VESSEL
HEAD PENETRATION NOZZLES
(NRC ORDER EA-03-009)

CORNERSTONE: BARRIER INTEGRITY
INITIATING EVENTS

APPLICABILITY: This Temporary Instruction (TI) applies to all holders of operating licenses for pressurized-water reactors (PWRs). The scope of this TI is very similar to TI 2515/145. This TI supercedes TI 2515/145.

2515/150-01 OBJECTIVE

The objective of this TI is to support the review of licensees' reactor pressure vessel (RPV) head and vessel head penetration (VHP) nozzle inspection activities that are implemented in accordance with the requirements of Order EA-03-009 (NRC Accession Number ML030410402), issued on February 11, 2003. This TI validates that a plant conforms to its inspection commitments and requirements, during its next and subsequent refueling outages, using procedures, equipment, and personnel that have been demonstrated to be effective in the detection and sizing of primary water stress corrosion cracking (PWSCC) in VHP nozzles and detection of RPV head wastage. As an ancillary benefit, this TI promotes information gathering to help the Nuclear Regulatory Commission (NRC) staff identify and shape possible future regulatory positions, generic communications, and rulemaking.

2515/150-02 BACKGROUND

The discoveries of leaks and nozzle cracking at PWR plants, including the RPV head wastage cavity identified at the Davis-Besse Nuclear Power Station, have made clear the need for more effective inspections of RPV heads and VHP nozzles. The current RPV head inspection requirements as implemented from the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) by 10 CFR 50.55a require

visual examination of the insulated surface or surrounding area for signs of leakage. Such inspections are not sufficient to reliably detect circumferential cracking of RPV head nozzles and corrosion of the RPV head. Circumferential cracking of RPV head nozzles and corrosion of the RPV head pose a safety concern because of the possibility of a nozzle ejection or loss-of-coolant accident if the conditions are not detected and repaired.

The discovery of cracks in PWR control rod drive mechanism (CRDM) nozzles and other VHP nozzles fabricated from Alloy 600 is not a new issue. Axial cracking in the CRDM nozzles has been identified since the late 1980s. In addition, numerous small-bore Alloy 600 nozzles and pressurizer heater sleeves have experienced leaks attributable to PWSCC. The area of interest for potential cracking of RPV head penetrations is the pressure-retaining boundary, which includes the J-groove weld between the nozzle and reactor vessel head and the portion of the nozzle at and above the J-groove weld. Circumferential cracking above the J-groove weld is considered a safety concern because of the possibility of nozzle ejection should the circumferential cracking progress without being detected and corrected.

To address the immediate concerns raised by the increasing discovery of problems with RPV heads at PWRs, the NRC has issued a series of bulletins and other communications. The intent of the first bulletin, Bulletin 2001-01 issued in August 2001, was to ascertain the extent of CRDM cracking in PWRs. One of the intents of the second bulletin, Bulletin 2002-01 issued in March 2002, was to ascertain the extent of material wastage in the RPV heads at other PWRs, as a follow-up to the findings at Davis-Besse. During the review of the responses to the first two bulletins, the staff identified a weakness in the ASME Code requirements applicable to RPV head and VHP nozzle inspections. Specifically, the staff questioned the adequacy of current RPV head and VHP nozzle inspection requirements and programs that rely on visual examinations as the primary inspection method. Visual examinations, as a primary inspection method for the RPV head and VHP nozzles, may need to be supplemented with additional non-visual examinations to demonstrate compliance with applicable regulations. The intent of Bulletin 2002-02, issued in August 2002, was to identify any changes that PWR licensees have made to their RPV head and VHP nozzle inspection programs to account for the identified weakness in the ASME Code requirements. Most licensees responded to Bulletin 2002-02 with descriptions of their near-term inspection plans or with a schedule to submit such descriptions. Many of the responses to the Bulletin did not describe long-term inspection plans. Instead, licensees typically stated that they would follow guidance being developed by the industry-sponsored Materials Reliability Program (MRP).

The long-term resolution of this issue is expected to involve changes to the ASME Code and will involve changes to the NRC regulations in 10 CFR 50.55a, "Codes and standards." The development of the NRC regulations, whether the rule adopts the ASME Code standards or defines separate requirements, will benefit from additional operating experience, continuing assessments, and research being conducted by the NRC and the MRP.

Although licensees' actions to date have provided reasonable assurance of adequate protection of public health and safety for the near-term operating cycles, the NRC deemed it appropriate to establish a clear regulatory framework pending the revision of 10 CFR 50.55a. Therefore the NRC issued Order EA-03-009 (NRC Accession Number ML030410402) on February 11, 2003, to impose enhanced requirements for PWR licensees to inspect RPV heads and VHP nozzles pending the expected revision of 10 CFR 50.55a. The requirements of the Order were immediately effective and are expected to remain in place until superceded by changes to 10 CFR 50.55a. A summary of the inspection requirements is provided in Appendix A.

Additional background on the technical and safety concerns and descriptions of selected plant events can be found in the Discussion and Background Sections of Bulletins 2001-01 (Accession Number ML012080284), 2002-01 (Accession Number ML020770497), and 2002-02 (Accession Number ML022200494).

2515/150-03 INSPECTION REQUIREMENTS

03.01 General

Licensees shall implement inspections of their RPV head and VHP nozzles consistent with Order EA-03-009, issued on February 11, 2003, dependent on the susceptibility ranking of their plant. These inspection requirements are provided in Appendix A. Deviation of these inspections from the requirements of Appendix A should be discussed with the NRC's Office of Nuclear Reactor Regulation (NRR), Division of Engineering (DE), Materials and Chemical Engineering Branch (EMCB), immediately.

The Order requires that licensees perform both visual and non-visual nondestructive examinations (NDE) of the RPV head and VHP nozzles, with the timing of the first inspection and frequency of subsequent inspection dependent on the susceptibility ranking for the plant. The visual examination is a bare metal visual examination of the RPV head that is used to identify degradation of the RPV head and boric acid deposits that may be indicative of leakage from VHP nozzles and may cause degradation of the RPV head. The non-visual NDE is either: 1) a combination of ultrasonic examination of the VHP nozzle base material and an assessment to determine if leakage has occurred into the interference fit zone (actually the annulus between the RPV head and the VHP nozzles), or, 2) surface examination (using either eddy current or dye penetrant testing) of the wetted surface of the VHP nozzle base material and the J-groove weld.

In addition, all plants are required to perform visual examinations to identify potential boric acid leaks from pressure-retaining components above the RPV head at each refueling outage. If boron deposits are identified on the surface of the RPV head or related insulation, licensees are required by the Order to perform inspections of the affected RPV head surface and VHP nozzles appropriate to the conditions found to verify the integrity of the affected area and nozzles. These activities are required to be performed before returning the plant to operation.

03.02 Susceptibility Ranking

| The susceptibility ranking for a plant is based on a calculation of effective degradation years (EDY) that accounts for the plant's RPV head time and temperature operating history. Regardless of the EDY calculated for a plant, the plant is categorized as a high susceptibility plant if any PWSCC has been experienced in a VHP nozzle or J-groove weld in the current RPV head at the plant. The susceptibility calculation should take into account the time-at-temperature for operation until the current outage. For plants replacing their RPV head at their on-going refueling outage, the susceptibility ranking for the plant is 0 EDY and no inservice inspections (ISIs) of the replaced head are required. The replacement head will have preservice inspections required by the ASME Code, but these inspections are not within the scope of this TI.

| A preliminary listing of plant susceptibility rankings is provided in Appendix B. Plants that are expected to replace their head at their next refueling outage are indicated in this listing.

| a. The inspector should review the susceptibility ranking for the plant, including the EDY calculation.

03.03 Volumetric Examination

If volumetric examinations are performed, the inspection will consist of the following activities:

a. ISI specialist inspectors will perform Inspection Procedure (IP) 57080, "Ultrasonic Testing Examination." Inspection requirements and guidance associated with inspection objective 01.01 in IP 57080 will be excluded from the inspection scope. The inspection of the licensee's VHP nozzle examinations may be considered part of the sample required by IP 71111.08, "Inservice Inspection Activities," Sections 02.01 and 02.03. The inspection sample should consist of:

    1. Independently review 10% of VHP nozzle volumetric examinations.

| 2. If an inspection opportunity is available, observe one or two VHP nozzle volumetric examinations.

    3. If applicable, review one or two examinations from the previous outage with recordable indications that have been accepted by the licensee for continued service.

    4. If applicable, review one examination of a repaired nozzle. This review may be included in the 10% sample described in 03.03.a.1.

| 5. If applicable, review one or two repairs.

b. The inspector will independently review the licensee's implementation of the chosen method to detect PWSCC in the VHP nozzles. In particular, verify that the implementation of the chosen method is consistent with the qualification or demonstration of that method.

c. The inspector will report anomalies, deficiencies, and discrepancies identified with the reactor coolant system (RCS) structures or the examination process, when such problems are judged to be significant enough to potentially impede the examination process.

03.04 <u>Surface Examination</u>

If a surface examination (i.e., liquid penetrant or eddy current) is to be performed, the inspection will consist of the following activities:

a. ISI specialist inspectors will follow IP 57060, "Liquid Penetrant Testing Examination," using a sample of VHP nozzles to assess the licensee's qualified liquid penetrant examination. Since there is no IP for eddy current examinations, Article 8 in Section V of the ASME Code provides background on eddy current examinations. The inspection of the licensee's VHP nozzle and/or J-groove weld surface examinations may be considered part of the sample required by IP 71111.08, Sections 02.01 and 02.03. The inspection sample should consist of:

    1. Independently review 5% - 10% of VHP nozzle and/or J-groove weld surface examinations.

    2. If an inspection opportunity is available, observe one or two VHP nozzle and/or J-groove weld surface examinations.

    3. If applicable, review one or two examinations from the previous outage with recordable indications that have been accepted by the licensee for continued service.

    4. If applicable, review one examination of a J-groove weld that was repaired during a previous inspection. This review may be included in the 5% - 10% sample described in 03.04.a.1.

    5. If applicable, review one or two repairs.

b. The inspector will independently review the licensee's implementation of the chosen method to detect relevant surface conditions. In particular verify that the implementation of the chosen method is consistent with the qualification or demonstration of that method.

c. The inspector will report anomalies, deficiencies, and discrepancies identified with the RCS structures or the examination process, when such problems are judged to be significant enough to potentially impede the examination process.

03.05 <u>Bare Metal Visual Examination</u>

The bare metal visual (BMV) examination is implemented to verify the absence of boron crystals, which may be evidence of a leak in the VHP nozzles, and to verify the integrity of the RPV head. If a BMV examination is to be performed, the inspection will consist of the following activities:

a. Inspectors will follow IP 57050, “Visual Testing Examination.” Inspection requirements and guidance associated with inspection objective 01.01 in IP 57050 will be excluded from the inspection scope. The inspection of the licensee’s reactor VHP nozzle examinations may be considered part of the sample required by IP 71111.08, “Inservice Inspection Activities,” Sections 02.01 and 02.03. The inspection sample should consist of:

    1. Independently observe (via videotape if available and if direct observation of the head is not possible) 5% - 10% of RPV head bare metal visual examination.

    2. If an inspection opportunity is available, independently observe (via videotape if available and if direct observation of the head is not possible) three to five VHP nozzle examinations (i.e., 360° around penetration).

b. If an inspection opportunity is available, inspectors will independently review and report the condition of the reactor vessel head, and also report on the licensee’s capability to detect small amounts of boron.

c. Inspectors will report areas of the RPV head or VHP nozzles obscured by boron deposits from preexisting leaks (i.e., masked, masking), debris, insulation or other obstructions.

d. Inspectors will report anomalies, deficiencies, and discrepancies identified with the associated structures or the examination process when such problems are judged to be significant enough to potentially impede the examination process in accordance with the reporting instructions of this TI.

03.06 <u>Assessment of Leakage into the Interference Fit Zone</u>

If the licensee has implemented volumetric examinations of the VHP nozzle base material, then Order EA-03-009 also requires an assessment to determine if leakage has occurred into the interference fit zone of the nozzles. Although the order explicitly addresses the “interference fit zone of the nozzles,” the intent of the order was that this assessment would address the “annulus between the VHP nozzle and the RPV head, including the

interference fit zone." For example, nozzles that do not have an interference fit zone are still required to have this assessment performed. With the ultrasonic examination providing verification that the nozzle base material does not have through-wall cracks causing leakage, this assessment provides verification that the J-groove weld does not have through-wall cracks causing leakage. It is expected that licensees will perform this assessment by reviewing ultrasonic data from the interference fit zone on nozzles to provide assurance that leakage has not occurred into the annulus between the VHP nozzle and the RPV head. If the licensee does not utilize ultrasonic data to make this assessment or the nozzle does not have an interference fit, then it is expected that this assessment will be satisfied through measurements which verify the absence of through-wall cracks in the J-groove weld. This verification can occur through the implementation of surface examinations of the J-groove weld, including either eddy current or liquid penetrant testing.

03.07 Identification of Potential Boric Acid Leaks

All licensees are required to perform visual examinations to identify potential boric acid leaks from pressure-retaining components above the RPV head at each refueling outage. If boron deposits are identified on the surface of the RPV head or related insulation, licensees are required by the Order to perform inspections of the affected RPV head surface and VHP nozzles appropriate to the conditions found to verify the integrity of the affected area and nozzles. These activities are required to be performed before returning the plant to operation. The inspection of these licensee activities will consist of the following:

a. The inspector will review the scope of the licensee's plan to examine the pressure-retaining components above the RPV head to ensure that all possible sources of boric acid leakage are included, that the examination would be effective in identifying boric acid leakage in this area, and that appropriate actions are implemented should boron deposits be identified on the RPV head or related insulation.

b. The inspector will review the results of the licensee's examination to ensure that the licensee has taken appropriate actions in response to identified boron deposits on the RPV head or related insulation.

2515/150-04 GUIDANCE

04.01 General. The inspectors should be cognizant of extenuating circumstances at their respective plant(s), such as the operational history, physical layout and material condition of the reactor vessel head, and any identified VHP nozzle leakage or other Alloy 600 PWSCC indications that would suggest a need for more aggressive licensee inspection practices. In addition, since inspection and repair activities can potentially result in large collective occupational doses, licensees should ensure that all activities related to the inspection of VHP nozzles and the repair of identified degradation are planned and

implemented to keep personnel exposures as low as reasonably achievable (ALARA), consistent with the NRC Part 20, ALARA requirements.

04.02 Susceptibility Ranking. The susceptibility ranking is based on a calculation of effective degradation years (EDY) that accounts for the plant's RPV head time and temperature operating history. Regardless of the EDY calculated for a plant, the plant is categorized as a high susceptibility plant if any PWSCC has been experienced in a VHP nozzle or J-groove weld in the current RPV head at the plant. Other factors that affect crack initiation and growth such as material heat, microstructure, and residual stresses are not included in the susceptibility ranking established by Order EA-03-009, although such factors may be included in future revisions to the susceptibility model.

a. Review the plant's RPV head susceptibility calculation to verify that appropriate plant-specific information was used as input. The time-at-temperature model required by Order EA-03-009 is described in Appendix C.

b. Review the basis for the RPV head operating temperature(s) used by the licensee to determine the RPV head susceptibility ranking.

c. Review previous inspection results to determine if there were any cracks identified and whether that information was used in determining the RPV head susceptibility ranking.

04.03 Volumetric Examination

a. Verify whether the examination procedures and equipment used in the examinations are consistent with those used during the qualification or demonstration. (References 1 through 3 provide information for Framatome inspections; similar information is not available at the present time for any other inspection vendor).

b. Verify whether the essential variables such as type and frequency of transducer used in the examination are consistent with the those used during qualification or demonstration. (References 1 through 3 provide information for Framatome inspections; similar information is not available at the present time for any other inspection vendor).

c. Review the qualifications and certification of the inspection personnel to ascertain the basis used for certification (e.g., successful participation in the qualification or demonstration of the equipment and methods).

d. Review the examination procedure to verify that it requires documentation of work, such that the examination scope, process, criteria, and results are complete and clearly described.

e. Review the examination procedure to verify that it provides inspection standards and acceptance criteria that are clear and on which personnel have been trained.

f. Review the licensee's documentation to verify that it provides flaw evaluation guidelines that are clear and on which personnel have been trained. An example of acceptable flaw evaluation guidelines are provided in Appendix D. [NOTE: The guidelines provided in Appendix D are revisions to the guidelines specifically described in Footnote 1 of Order EA-03-009, and provided for in Footnote 1.]

g. Identify any anomalies, deficiencies, and discrepancies associated with the RCS structures or the examination process including those identified by the licensee and then verify they are placed in the licensee's corrective action process. In accordance with Section IV.E of Order EA-03-009, the licensee will provide information concerning any identified VHP nozzle leakage and for cracking detected in the plant. The inspectors will report lower-level issues concerning data collection and analysis, as well as any issues that are deemed to be significant to the phenomenon described in the Order. The inspector will report whether the demonstrated exam procedures were implemented properly. These items should be reported in accordance with the reporting instructions of this TI.

04.04 <u>Surface Examination</u>

a. Verify whether the examination procedures and equipment used in the examination are consistent with those used during qualification or demonstration.

b. Review the qualifications and certification of the inspection personnel to ascertain the basis used for certification (e.g., successful participation in the qualification or demonstration of the equipment and methods).

c. Review the examination procedure to verify that it requires adequate documentation of work, such that the examination scope, process, criteria, and results are complete and clearly described.

d. Review the examination procedure to verify that it provides inspection standards and acceptance criteria that are clear and on which personnel have been trained.

e. Review the licensee's documentation to verify that it provides flaw evaluation guidelines that are clear and on which personnel have been trained. An example of acceptable flaw evaluation guidelines are provided in Appendix D. [NOTE: The guidelines provided in Appendix D are revisions to the guidelines specifically described in Footnote 1 of Order EA-03-009, and provided for in Footnote 1.]

f. Identify any anomalies, deficiencies, and discrepancies associated with the RCS structures or the examination process including those identified by the licensee and then verify they are placed in the licensee's corrective action process. In accordance with Section IV.E of Order EA-03-009, the licensee will provide

information concerning any identified VHP nozzle leakage and for cracking detected in the plant. The inspectors will report lower-level issues concerning data collection and analysis, as well as any issues that are deemed to be significant to the phenomenon described in the Order. The inspector will report whether the demonstrated exam procedures were implemented properly. These items should be reported in accordance with the reporting instructions of this TI.

04.05 Bare Metal Visual Examination

a. Independently review a sample of the visual examination of the VHP nozzles. The sample should consist of VHP nozzles at different points distributed around the reactor vessel head curvature. The sample should also allow for assessment of the physical difficulties in conducting the examination. Assess the effectiveness of the visual examination and ensure that it can reliably detect and accurately characterize any leakage from cracking in VHP nozzles, and that it is not compromised by the presence of insulation, pre-existing deposits on the reactor vessel head, or other factors that could interfere with the detection of leakage.

1. Review the qualifications and certification of the inspection personnel to ascertain the basis used for certification (e.g., successful participation in the qualification or demonstration of the equipment and methods).

2. Review the examination procedure to determine whether it provides adequate guidance and examination criteria to implement the licensee's examination plan. The procedures should meet the following minimum criteria:

(a) Ensure that a complete reactor vessel head examination (RVH) is planned and successfully implemented. A complete examination means that all penetration nozzles are examined 360^{o} around the circumference of the nozzle and the entire RPV head has been examined. This examination does not require examination inside the RV head stud holes, under the cooling shroud ring, the underside of the head, or inside the RVH lifting lug bolt holes. In addition, those portions of the RPV head that are covered by immovable structures, such as cooling shroud rings or service structure supports, and do not have a meaningful source of boric acid leakage may be inspected uphill and downhill of the structure to demonstrate the absence of boric acid wastage of the RPV head. A VHP nozzle location indexing plan may be established to ensure that the examination accounts for all nozzles. If so, it should be reviewed for completeness.

(b) Require adequate documentation of work, such that the examination scope, process, criteria, and results are complete and clearly described.

(c) Provide inspection standards and acceptance criteria that are clear and on which personnel have been trained.

3. Conduct a performance-based inspection to verify that the licensee properly performed the procedure. Pay particular attention to ensure that the visual clarity of the examination process was adequate; the method used to track identification of the penetrations being inspected is effective; and that prior (pre-existing) boron deposits, debris, and insulation were effectively identified and categorized.

b. If an inspection opportunity is available, inspectors will assess the condition of the reactor vessel head through either direct observations, video inspections, or some other means of independent review. In particular, inspectors should look for and document items on the reactor vessel head, such as debris, insulation, dirt, boron from other sources, physical layout, and viewing obstructions. Additionally, inspectors should assess the licensee's ability to distinguish small boron deposits on the head. If an opportunity to independently review the reactor vessel head does not become available, inspectors will briefly describe the circumstances (i.e., is this a routine outage condition that does not permit viewing the reactor vessel head) and what they could independently review.

c. If boron deposits are attributed to a source other than leakage through the pressure boundary and if supplemental non-visual nondestructive examination (NDE) is not performed of the obscured area (i.e., masked), inspectors will review the criteria used by licensee to assure boron deposit may not be the result of leakage from a through wall or through weld crack in the VHP assembly.

d. Inspectors will identify any anomalies, deficiencies, and discrepancies associated with the RCS structures or the examination process including those identified by the licensee and then verify they are placed in the licensee's corrective action process. In accordance with Section IV.E of Order EA-03-009, the licensee will provide information concerning any identified VHP nozzle leakage and cracking detected. The inspectors will report lower-level issues concerning data collection and analysis, as well as any issues that are deemed to be significant to the phenomenon described in the Order. These items should be reported in accordance with the reporting instructions of this TI.

04.06 <u>Assessment of Leakage into the Interference Fit Zone</u>

a. If the licensee is performing an ultrasonic examination of their VHP nozzles and is using ultrasonic data to provide this assessment of leakage, verify that there are procedures in place for the interpretation of this data to make this assessment.

b. If the licensee is performing an ultrasonic examination of their VHP nozzles and is not using ultrasonic data to provide this assessment of leakage, verify that the licensee has alternative examination procedures to provide this assessment of

leakage. These alternative procedures should involve evaluation of the J-groove welds to provide verification that the welds do not have any cracks that could lead to leakage. Acceptable alternatives include eddy current or liquid penetrant testing of the surfaces of the J-groove welds.

04.07 <u>Identification of Potential Boric Acid Leaks</u>

a. Review the scope of the inspection plan to verify that all possible sources of boric acid leakage located above the RPV head are included.

b. Review the inspection procedure to verify that it provides inspection standards and acceptance criteria that are clear.

c. Review the inspection procedure to verify that it provides specific actions to be implemented should boron deposits be identified on the RPV head or related insulation.

d. Review the results of the licensee's examination to ensure that the licensee has taken appropriate actions in accordance with their corrective action program in response to identified boron deposits on the RPV head or related insulation.

2515/150-05 REPORTING REQUIREMENTS

Document inspection results in a resident inspectors' routine inspection report (i.e., quarterly inspection report), and send a copy of the applicable sections to NRR/DE/EMCB, Attention: Allen Hiser and Eric Reichelt, or e-mail to ALH1@NRC.gov and EGR3@NRC.gov. Dr. Hiser can also be reached by telephone at (301) 415-1034 and Mr. Reichelt can be reached by telephone at (301) 415- 2776. In addition, as soon as it is finalized, a copy of the feeder to the quarterly inspection report should be sent to NRR/DE/EMCB, to the attention of Dr. Hiser and Mr. Reichelt as indicated above. One purpose of this TI is to support NRR/DE/EMCB by inspecting and reporting on the licensees' performance of RPV head and VHP nozzle examinations. Specifically, the inspectors should provide a qualitative description of the effectiveness of the licensees' examinations. At a minimum, the inspectors should be able to briefly answer the following questions (with a description of inspection scope and results) in Section 4OA5, "Other," of the next integrated inspection report.

a. For each of the examination methods used during the outage, was the examination:

   1. Performed by qualified and knowledgeable personnel? (Briefly describe the personnel training/qualification process used by the licensee for this activity.)

   2. Performed in accordance with demonstrated procedures?

3. Able to identify, disposition, and resolve deficiencies?

4. Capable of identifying the PWSCC and/or RPV head corrosion phenomena described in Order EA-03-009?

b. What was the physical condition of the reactor vessel head (e.g., debris, insulation, dirt, boron from other sources, physical layout, viewing obstructions)?

c. Could small boron deposits, as described in the Bulletin 01-01, be identified and characterized?

d. What material deficiencies (i.e., cracks, corrosion, etc.) were identified that required repair?

e. What, if any, impediments to effective examinations, for each of the applied methods, were identified (e.g., centering rings, insulation, thermal sleeves, instrumentation, nozzle distortion)?

f. What was the basis for the temperatures used in the susceptibility ranking calculation, were they plant-specific measurements, generic calculations (e.g., thermal hydraulic modeling, instrument uncertainties), etc.?

g. During non-visual examinations, was the disposition of indications consistent with the guidance provided in Appendix D of this TI? If not, was a more restrictive flaw evaluation guidance used?

h. Did procedures exist to identify potential boric acid leaks from pressure-retaining components above the RPV head?

i. Did the licensee perform appropriate follow-on examinations for indications of boric acid leaks from pressure-retaining components above the RPV head?

Any issues identified during this inspection should be processed and documented in accordance with NRC Inspection Manual Chapter (IMC) 0612, "Power Reactor Inspection Reports." Significance of inspection findings should be evaluated in accordance with applicable appendices of IMC 0609, "Significance Determination Process." Any noncompliance resulting from this inspection should be evaluated and documented in accordance with NRC Enforcement Policy (NUREG -1600) and Section 3.12 of the NRC Enforcement Manual. It should be noted that licensees' failure to comply with the requirements of the Order (EA-03-009, issued on February 11, 2003) must be treated as a violation of the Order unless a relaxation of the requirements have been approved by the NRC. Also, licensees are required to address the findings resulting from these inspections (i.e. perform analyses and repairs) in accordance with existing requirements in the ASME code and 10 CFR 50.55a. Failure to meet these requirements must be identified as violations of these requirements.

2515/150-06 COMPLETION SCHEDULE

This TI should be completed at least twice prior to its expiration date, including prior inspections using Revisions 0 and 1 of this TI and under TI 2515/145 after September 1, 2002. At least one of those inspections must have been of licensee's non-visual NDE of VHP nozzles. If there are insufficient inspection weeks to inspect all units during an outage season, the following priority ranking should be used to determine which units will be inspected at a subsequent outage:

a. Units with the highest susceptibility rankings (i.e., EDY) should be given the highest priority.

b. Units, regardless of susceptibility ranking, that plan to perform non-visual NDE of VHP nozzles should be given the next highest priority.

c. Moderate and low susceptibility plants that plan to perform visual examinations only should be given the lowest priority.

2515/150-07 EXPIRATION

This TI will expire February 11, 2009 (i.e., approximately 6 years from the date of issuance of Order EA-03-009). Before that date, each PWR unit should have performed this TI at least twice, except as noted below.

a. Plants that were inspected under TI 2515/145 after September 1, 2002, and prior to the cancellation date of TI 2515/145 (i.e., January 24, 2003) are not expected to perform TI 2515/150 more than once.

b. Plants that are replacing their RPV head during the outage, are not expected to perform TI 2515/150, unless the licensee' intends to inspect the RPV head prior to removal from service.

2515/150-08 CONTACT

For questions regarding the performance of this TI and emergent issues, contact Allen Hiser at (301) 415-1034. or ALH1@NRC.GOV.

2515/150-09 STATISTICAL DATA REPORTING

All direct inspection effort expended on this TI is to be charged to 2515/150 for reporting by the Regulatory Information Tracking System (RITS) reporting with an IPE code of SI.

2515/150-10 ORIGINATING ORGANIZATION INFORMATION

10.01 Organizational Responsibility

This TI was initiated by the Materials and Chemical Engineering Branch (NRR/DE/EMCB).

10.02 Resource Estimate

The estimated direct inspection effort to perform this TI is estimated to be 20 to 50 hours per PWR unit.

10.03 Training

No formal training is proposed for the performance of this TI. However, if technical support is needed during the inspection of licensees volumetric or surface examinations, contact EMCB through IIPB at least 30 days before the anticipated need for technical support.

10.04 References

Hacker, K. J., “Framatome ANP Nondestructive Examination Procedure: Remote Ultrasonic Examination of Reactor Head Penetrations,” Procedure Number 54-ISI-100-09, Framatome ANP, September 9, 2002. (PROPRIETARY) [ML023180603]

Hacker, K. J. and Hacker, M. G., “Reactor Head Penetration UT Analysis Training,” Framatome ANP, September 9, 2002. (PROPRIETARY) [ML023180603]

Hacker, K. J. and Key, M. W., “Framatome ANP Nondestructive Examination Procedure: Remote Ultrasonic Examination of Reactor Vessel Head Vent Line Penetrations,” Procedure Number 54-ISI-137-00, Framatome ANP, February 15, 2002. (PROPRIETARY) [ML023180603]

END

Attachments

Appendix A: Reactor Pressure Vessel Head Inspection Requirements for Pressurized Water Reactors (Order EA-03-009)

Appendix B: Plants’ RPV Head Susceptibility Rankings

Appendix C: Calculation of Susceptibility Ranking

Appendix D: Flaw Evaluation Guidelines Acceptable to the Staff

Appendix A

Reactor Pressure Vessel Head Inspection Requirements for Pressurized Water Reactors

Source: NRC Order EA-03-009, “Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors,” February 11, 2003.

Table 1: Reactor Pressure Vessel Head Inspection Requirements

Inspections	Frequency/Time (Note 1)		
	Low Susceptibility < 8 EDY	Moderate Susceptibility ≥8 EDY and ≤12 EDY	High Susceptibility > 12 EDY (Note 2)
100% Ultrasonic testing of each RPV head penetration nozzle (i.e., nozzle base material) from two (2) inches above the J-groove weld to the bottom of the nozzle and an assessment to determine if leakage has occurred into the interference fit zone. or Eddy current testing or dye penetrant testing of the wetted surface of each J-Groove weld and RPV head penetration nozzle base material to at least two (2) inches above the J-groove weld.	every four refueling outages or seven years, whichever occurs first (Note 3)	every other refueling outage (Note 4)	every refueling outage
Bare metal visual (BMV) examination of 100% of the RPV head surface (including 360 degrees around each RPV head penetration nozzle).	every three refueling outages or five years, whichever occurs first (Note 5)	every other refueling outage (Note 4)	every refueling outage

Table 1: Reactor Pressure Vessel Head Inspection Requirements (continued)

Visual inspections to identify potential boric acid leaks from pressure-retaining components above the RPV head. and For any plant with boron deposits on the surface of the RPV head or related insulation, discovered either during the inspections required by this Order or otherwise and regardless of the source of the deposit, before returning the plant to operation, perform inspections of the affected RPV head surface and penetrations appropriate to the conditions found to verify the integrity of the affected area and penetrations.	every refueling outage	every refueling outage	every refueling outage

Note 1: Susceptibility to PWSCC is estimated using effective degradation years (EDY), which accounts for the RPV time and temperature operating history.

Note 2: Regardless of EDY, a plant with an RPV head that has experienced cracking in a penetration nozzle or J- groove weld due to PWSCC is classified as a high susceptibility plant.

Note 3: The first non-visual NDE must be completed at least once over the course of five years after the issuance of the Order.

Note 4: During each refueling outage at least a BMV or non-visual NDE has to be completed.

Note 5: If BMV was not performed during the refueling outage immediately preceding the issuance of this Order, the licensee must complete a BMV inspection meeting the requirements of the Order) within the first two refueling outages following issuance of this Order.

Appendix B

Plants' RPV Head Susceptibility Rankings

The susceptibility ranking is based on a calculation of effective degradation years (EDY) that accounts for the RPV head time and temperature operating history. Appendix C provides a description of the procedure used to calculate EDY. Regardless of the EDY calculated for a plant, the plant is categorized as a high susceptibility plant if any PWSCC has been experienced in a VHP nozzle or J-groove weld in the current RPV head at the plant. The susceptibility calculation should take into account the time-at-temperature for operation with the current RPV head until the current outage.

For plants replacing their RPV head at their on-going refueling outage, the susceptibility ranking for the plant is 0 EDY and no inspections of the replaced head are necessary.

The susceptibility rankings provided below (for information purposes only) reflect what the licensees included in their 15-day or 30-day responses to Bulletin 2002-02. If a licensee did not include a value for EDY in their 15-day or 30-day response to Bulletin 2002-02, the ranking for the plant reflects an NRC estimate for the plant. The information provided in this table is considered accurate as of the date of issuance of this TI and does not necessarily reflect plant operation after March 2003.

High Susceptibility includes the sub-population of the following plants that have an EDY greater than 12 or have identified PWSCC in VHP nozzle or J-groove weld in the current RPV head at the plant.

Plant	EDY	Plant	EDY	Plant	EDY
ANO 1	19.5	North Anna 1 *	0	St. Lucie 1	15.8
Beaver Valley 1	14.0	North Anna 2 *	0	St. Lucie 2	14.0
Calvert Cliffs 1	16.3	Oconee 1 *	0	Surry 1 *	0
Calvert Cliffs 2	15.2	Oconee 2 *	0	Surry 2 *	0
Crystal River 3 *	0	Oconee 3 *	0	TMI 1 *	0
D.C. Cook 2	14.6	Point Beach 1	14.5	Turkey Point 4	18.6
Davis-Besse *	0	Point Beach 2	16.6	Turkey Point 3	18.3
Farley 1 *	0	Robinson	19.0	Waterford 3	14.1
Farley 2	15.6	San Onofre 2	15.5		
Ginna *	0	San Onofre 3	15.5		

* RPV head has been or will be replaced at the next refueling outage, at which time the plant will become a low susceptibility plant.

Moderate Susceptibility includes the sub-population of the following plants that have an estimated EDY between 8 to 12.

Plant	EDY	Plant	EDY	Plant	EDY
ANO 2	10.5	Indian Point 3	10.6	Palo Verde 3	11.0
Beaver Valley 2	10.1	Kewaunee	10.8	Prairie Island 1	9.9
D.C. Cook 1	10.3	Millstone 2	10.5	Prairie Island 2	9.9
Diablo Canyon 1	10.2	Palisades	10.0	Salem 1	11.9
Diablo Canyon 2	10.9	Palo Verde 1	11.2	Salem 2	10.3
Fort Calhoun	11.8	Palo Verde 2	10.5		

Low Susceptibility includes the sub-population of plants that have an estimated EDY of less than 8.

Plant	EDY	Plant	EDY	Plant	EDY
Braidwood 1	1.7	Comanche Peak 2	1.8	Shearon Harris 1	2.0
Braidwood 2	1.7	Indian Point 2	7.9	South Texas 1	4.5
Byron 1	2.0	McGuire 1	2.2	South Texas 2	5.2
Byron 2	2.0	McGuire 2	2.2	V.C. Summer	2.3
Callaway	2.5	Millstone 3	1.8	Vogtle 1	2.6
Catawba 1	2.1	Seabrook	1.6	Vogtle 2	2.2
Catawba 2	1.9	Sequoyah 1	3.4	Watts Bar 1	0.7
Comanche Peak 1	2.1	Sequoyah 2	3.4	Wolf Creek	2.2

Appendix C

Calculation of Susceptibility Ranking

Source: PWR Materials Reliability Program Response to NRC Bulletin 2001-01 (MRP-48NP), EPRI, Palo Alto, CA: 2001. 1006284-NP.

PWSCC Rankings

Plants have been ranked for the potential for RPV top head nozzle PWSCC using a time-at-temperature model.

Time-at-Temperature Model

Since stress corrosion cracking (SCC) of Alloy 600 nozzle material and Alloy 182 weld metal is sensitive to operating temperature, the current MRP model adjusts the operating time for each plant using its head temperature history and an activation energy appropriate to SCC initiation. Initiation is a more important factor than crack growth for assessing plants since the time for crack initiation is longer than the time for crack growth.

The ranking for a particular plant is based on a calculation of the plant operating time normalized to a RPV head operating temperature of 600°F. The result for each plant is a value of effective degradation years (EDYs).

Calculation of Effective Degradation Years

Calculation of susceptibility requires information on the RPV head operating temperature(s) and the operating time (i.e., effective full power years, EFPY) at each operating temperature. These data are used to integrate the effects of operating temperature, normalized to 600°F. The standard Arrhenius activation energy dependence on temperature is applied to each time period with a distinct head temperature:

$$EDY = \sum_{j=1}^{n} \left\{ \Delta EFPY_j \exp\left[-\frac{Q_i}{R} \left(\frac{1}{T_{head,j}} - \frac{1}{T_{ref}} \right) \right] \right\}$$

where:

EDY	=	effective degradation years
n	=	the number of distinct operating temperatures used at the plant
Q_i	=	activation energy for crack initiation (50 kcal/mole)
R	=	universal gas constant (1.103×10^{-3} kcal/mol-°R)

$T_{head,j}$ = RPV head operating temperature at 100% power during time period j (°R = °F + 459.67)

$\Delta EFPY_j$ = the effective full power years of operation at temperature $T_{head,j}$

T_{ref} = reference temperature (600°F = 1059.67°R)

An activation energy of 50 kcal/mole is an accepted industry best estimate activation energy for SCC initiation in primary water environments. A sensitivity study included in MRP 2001-050 shows that a change in the activation energy for crack initiation from 50 kcal/mole to a lower bound of 40 kcal/mole has little effect on the relative ranking of plants.

Appendix D

Flaw Evaluation Guidelines Acceptable to the Staff

April 11, 2003

Mr. Alex Marion, Director of Engineering
Nuclear Energy Institute
1776 I Street, N.W., Suite 400
Washington, D.C. 20006-3708

SUBJECT: FLAW EVALUATION GUIDELINES

Dear Mr. Marion:

Enclosure 2 to the letter from Jack Strosnider to you dated November 21, 2001, contained flaw evaluation guidelines for control rod drive mechanism (CRDM) penetrations. These guidelines were developed by the Office of Nuclear Reactor Regulation (NRR) staff and were needed since no guidance or rules existed in the American Society of Mechanical Engineers (ASME) Code, Section XI to evaluate flaws found in the CRDM pressure boundary. While these guidelines have fulfilled a need, subsequent interactions with the industry and further information from multiple sources have rendered these guidelines obsolete. This situation was recognized in Footnote 1 to the February 11, 2003, NRC Order EA-03-009 establishing interim inspection requirements for reactor pressure vessel heads at pressurized water reactors. Footnote 1 states in part, "..The NRC has issued guidance to address flaw evaluations for RPV head penetration nozzles (see letter from J. Strosnider, NRC, to A. Marion, Nuclear Energy Institute) and will, as necessary, issue revised guidance pending the updating of the ASME code and related NRC regulations."

Attached to this letter as Enclosures 1 and 2 [**NOTE: Enclosure 2 is not included with this copy of the letter.]** is revised guidance that is generally consistent with the recently approved action by Section XI at their meeting in San Francisco on February 27, 2003. That action consisted of a Code addition and an enabling Code Case to establish rules for flaw evaluation for PWR reactor vessel upper head penetration nozzles. The NRR staff, through their representation on the cognizant Section XI groups and committees, participated in the development and approval of these new flaw evaluation rules. Publication of the Code addition and Code Case and subsequent formal approval by the NRC will take time. In the interim, the staff intends to reference these guidelines in interactions with licensees during the current and future outage seasons. Note that we have modified the flaw acceptance criteria of Table 1 in Enclosure 1. Any plant specific considerations can be discussed with the staff as appropriate.

As additional information becomes available, further development or changes to these guidelines can be anticipated. The staff contact for flaw evaluation issues is Keith Wichman who can be reached at (301) 415-2785. Your continued cooperation is appreciated.

Sincerely,

/RA/
Richard Barrett, Director
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosures: As stated

ENCLOSURE 1 TO APPENDIX D

FLAW EVALUATION GUIDELINES AND ACCEPTANCE CRITERIA FOR PWR REACTOR VESSEL UPPER HEAD PENETRATION NOZZLES

PWR reactor vessel upper head penetration nozzles containing flaws may be evaluated to determine acceptability for continued service in accordance with the evaluation procedure and acceptance criteria specified herein. Application of the evaluation procedures shall be subject to review and approval by the U.S. Nuclear Regulatory Commission (NRC).

Scope

This evaluation procedure is applicable to upper head penetration nozzles with eight inch (200 mm) nominal outside diameter and less. This procedure shall not be used for J-groove welds.

Evaluation Procedure

- The acceptance standards of IWB-3500 of Section XI of the ASME Code (herein after referred to as Section XI) shall not be used to accept flaws in this region.
- A flaw growth analysis shall be performed on each detected flaw to determine its maximum growth due to fatigue, stress corrosion cracking or both mechanisms, when applicable, during a specified evaluation period. The minimum time interval for the flaw growth evaluation shall be until the next inspection.
- All applicable loadings shall be considered, including weld residual stress, in calculating the crack growth.
- The flaw shall be characterized in accordance with the requirements of IWA-3400 of Section XI including the proximity rules of Fig. IWA-3400-1 for surface flaws.
- The flaw shall be projected into both axial and circumferential orientations, and each orientation shall be evaluated. The axial orientation is the same for each nozzle, but the circumferential orientation will vary depending on the angle of intersection of the penetration nozzle with the head. As illustrated in Fig. 1, any flaws within ±10° of the plane formed by the J-groove weld root shall be considered pure circumferential flaws.
- The location of the flaw, relative to both the top and the bottom of the J-groove attachment weld, shall be determined.
- The flaw shall be evaluated using analytical procedures, such as those described in Appendix A (Enclosure 2) **[NOTE: Enclosure 2 is not included with this copy of the letter.]**, to calculate the following critical flaw parameters:

a_f = the maximum depth to which the detected flaw is calculated to grow at the end of the evaluation period

l_f = the maximum length to which the detected flaw is calculated to grow at the end of the evaluation period.

Acceptance Criteria

The calculated maximum flaw dimensions at the end of the evaluation period shall be compared with the maximum allowable flaw dimensions in Table 1.

Table 1 Reactor Vessel Upper Head Penetration Nozzle Acceptance Criteria(1) (3)

Location	Axial		Circumference	
	a_f	l_f	a_f	l_f
Below Weld (ID)(2)	**t**	**No Limit**	**t**	**0.75 Circ. (4)**
At and Above Weld (ID)	**0.75 t**	**No Limit**	**repair**	**repair**
Below Weld (OD) (2)	**t**	**No Limit**	**t**	**0.75 Circ. (4)**
At and Above Weld (OD)	**repair**	**repair**	**repair**	**repair**

Notes:
(1) Surface flaws of any size in the attachment weld are not acceptable.
(2) Intersecting axial and circumferential flaws in the nozzle are not acceptable.
(3) t = wall thickness of head penetration nozzle
(4) 75 percent of the circumference

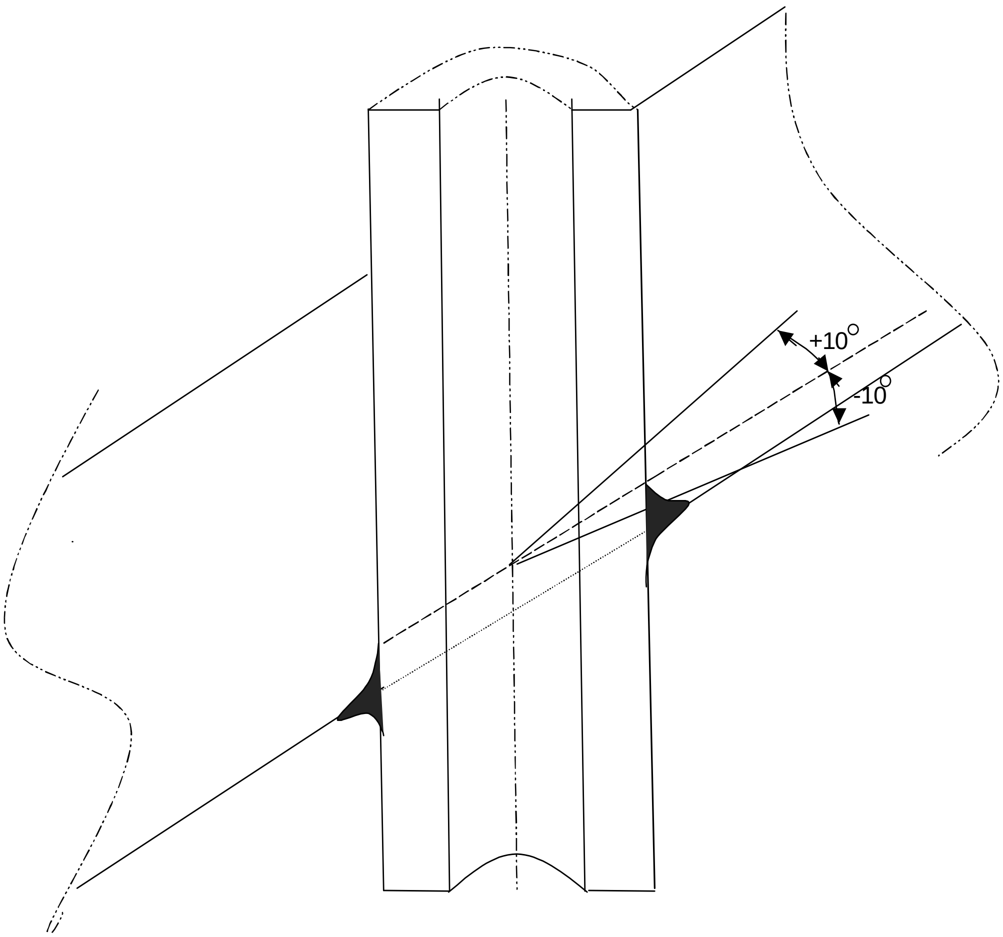

Fig. 1 Definition of Circumferential Orientation for Flaw Characterization

Note: Planar flaws within +/- 10° of the plane formed by the J-groove weld root, shown as the dashed line, shall be considered circumferential flaws.

END