

**OFFICE OF NUCLEAR REACTOR REGULATION**  
**SUMMARY ASSESSMENT OF PRESSURIZED-WATER REACTOR OWNERS GROUP -**  
**15105-NP, REVISION 0, "PA-MSC-1288 PRESSURIZED-WATER REACTOR VESSEL**  
**INTERNALS COLD WORK ASSESSMENT"**

**STAFF ASSESSMENT**

1.0 **BACKGROUND**

Applicant/Licensee Action Item (A/LAI) 1 of U.S. Nuclear Regulatory Commission (NRC) staff Safety Evaluation (SE) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML11308A770) for MRP-227-A, "Materials Reliability Program Report, Pressurized Water Reactor (PWR) Internals Inspection and Evaluation Guidelines," states, in part:

"...Each applicant/licensee shall refer, in particular, to the assumptions regarding plant design and operating history made in the failure modes, effects and criticality analysis (FMECA) and functionality analyses for reactors of their design (i.e., Westinghouse, [Combustion Engineering] CE, or [Babcock and Wilcox] B&W) which support MRP-227. The applicant/licensee shall submit this evaluation for NRC review and approval as part of its application to implement the approved version of MRP-227. This is Applicant/Licensee Action Item (AI) 1."

Part 1 of A/LAI 1 addresses the effect of cold work on Stress Corrosion Cracking (SCC) in Reactor Vessel Internal (RVI) components and Part 2 of A/LAI 1 addresses fuel management issues of the reactor vessel. This assessment focusses on Part 1 of A/LAI 1 only, and is applicable to PWR units designed by Westinghouse and CE. The supporting documents of MRP-227-A do not address the effect of cold work on SCC in RVI components designed by CE and Westinghouse units

The effect of cold work on SCC in Babcock and Wilcox (B&W) RVI components was addressed in MRP-189 Revision 1, "Materials Reliability Program: Screening, Categorization, and Ranking of B&W-Designed PWR Internals," (ADAMS Accession No. ML092250189). MRP-189 Rev 1 was the precursor for the development of Aging Management Program for B&W RVI components, which is addressed in MRP-227-A. Search of manufacturing and fabrication records indicated that, with the exception of two RVI components, all other RVI components in B&W units were not exposed to cold work greater than twenty percent. The two RVI components identified were: (1) crimped lock cups and (2) hot-headed or shot peened Alloy A-286 bolts. Based on this information, the staff, in its SE for MRP-227-A, did not require any response to Part 1 of A/LAI 1 for B&W units.

ENCLOSURE

As a result of the technical discussions with the NRC staff, the basis for a plant to respond to the NRC's RAI to demonstrate compliance with MRP-227-A for originally licensed and uprated conditions was determined to be satisfied, in part, with a plant-specific response to the following question:

Question: Does the plant have non-weld or bolting austenitic stainless steel components with 20 percent cold work or greater, and, if so, do the affected components have operating stresses greater than 30 ksi? If both conditions are true, additional components may need to be screened in for SCC.

By MRP Letter 2013-025 dated October 14, 2013, Electric Power Research Institute provided to licensees "MRP-227-A Applicability Template Guideline," a non-proprietary document (ADAMS Accession No. ML13322A454) containing guidance for responding to this question. As described in the staff's non-proprietary assessment of MRP Letter 2013-025 and WCAP-17780, "Reactor Internals Aging Management MRP-227-A Applicability for Combustion Engineering and Westinghouse Pressurized Water Reactor Designs." (ADAMS Accession No. ML14309A484), the staff concluded that if an applicant or licensee demonstrates that its plant(s) comply with the guidance in MRP Letter 2013-025, there is reasonable assurance that the I&E guidance of MRP-227-A will be applicable to the specific plant(s). Further, the staff's evaluation concluded that the guidance in MRP Letter 2013-025 provides an acceptable basis for licensees to respond to the generic question addressed above.

Operational experience and laboratory experiments suggests that stainless steel components are susceptible to SCC when exposed to cold work greater than twenty percent. Cold working that was introduced during fabrication of the RVI components could enhance the initiation and propagation of SCC in these components. In order to respond to Part 1 of A/LAI 1, the Pressurized-Water Reactor Owners Group (PWROG) developed a generic evaluation report PWROG-15105-NP, Revision 0, "PA-MS-C-1288 PWR Reactor Vessel Internals Cold Work Assessment," which was submitted to the staff (ADAMS ML16222A302) for information only. However, the PWROG requested the staff to assess the report so that each plant can use this assessment as part of its response to A/LA 1 of the staff's SE for MRP-227-A. In this report, PWROG had developed technical bases to support a generic approach to review the amount of cold work that was potentially used during initial fabrication and /or modification of the RVI components. The staff's assessment of PWROG-15105-NP, Revision 0, is addressed in the following paragraphs.

## 2.0 TECHNICAL ASSESSMENT

PWR RVI components contain austenitic stainless steel materials and were screened in for aging management due to their susceptibility to SCC. The screening criteria were addressed in MRP-175 Revision 0, "Materials Reliability Program: PWR Internals Material Aging Degradation Mechanism Screening and Threshold Values," ADAMS Accession No. ML063470637. MRP-175 was used in developing I&E guidelines that are addressed in MRP-227-A. Cold work that was introduced during fabrication of the RVI components could enhance the initiation and propagation of SCC in these components. The effect of cold work on non-fastener RVI components in Westinghouse and CE units were assessed in this report. This technical assessment of PWROG-15105-NP, Revision 0, focuses on the three sections and three Appendices: Section 4, "Approach Description," Section 5, "Results," Section 6, "Conclusions", and Appendices A, B and C. The staff reviewed the remaining Sections and determined that these Sections had no specific technical information, which would affect the review.

Therefore, staff's review of these sections are not included in this report. The Sections are Section 1, "Executive Summary", Section 2, "Introduction," and, Section 3, "Background."

## 2.1 Section 4, "Approach Description"

### 2.1.1 Summary

Cold work on RVI components in Westinghouse and CE units was evaluated by reviewing the following fabrication records: (1) component drawings, (2) material specifications, and (3) fabrication procedures. In particular, review of component drawings provided information to determine if any cold work was induced during component fabrication and on-site assembly of the RVI components. Drawings were reviewed for any additional information on the material call-outs, and in comparison with the prevailing materials specifications at the time of construction, to determine if material with cold work greater than twenty percent could have been introduced in that plant's construction. The PWROG stated that information collected to date on cold work during fabrication and construction assembly has demonstrated that non-fastener RVI components contained no evidence of cold work greater than twenty percent

Furthermore, the PWROG reiterated that cold work was generally avoided during the fabrication process to minimize its effect on the occurrence of SCC in RVI components. Welding fit-up and auxiliary processes could introduce cold work less than the allowable twenty percent. The effect of these processes is minimal and they are localized on the surface only. Conduits used in RVI components which were cold formed to shape could potentially be subject to higher amounts of cold work. The effects of cold work on these components were already evaluated by the PWROG while developing MRP-227-A. Based on its review, the PWROG stated that in limited instances, when bending was applied to fabricate RVI components, the amount of cold work was restricted to less than three percent by the geometry of the allowed bends. Therefore, it was concluded that the only concern with regards to cold work was limited to inherent cold work allowed in the specifications of the procured material. Based on its review of material specifications, drawings and fabrication procedure, the PWROG determined that: (1) the majority of austenitic stainless steel materials that were used in RVI components were solution annealed; (2) some material specifications stipulate limitations on the tensile strength and hardness; and (3) as stated in Section 4.2 of the subject report, materials that were severely cold worked (bending) without subsequent annealing were further evaluated. Based on the evaluation, the components were binned under appropriate category, which is addressed in Section 2.1.2.

Details of the evaluation process are addressed in Appendix A of PWROG-15105-NP, Revision 0. RVI material specifications review and categorization for CE and Westinghouse units are addressed in Appendix B and Appendix C, respectively.

Based on the aforementioned evaluation, PWROG concluded that no cold worked material was used in non-fastener RVI components for units designed by CE and Westinghouse.

### 2.1.2 NRC Staff Assessment

Staff reviewed Section 4.0 of PWROG-15105-NP, Revision 0 and, based on the information provided, the staff observed the following: RVI components were built to the requirements addressed in the applicable component drawings, material specifications, and fabrication procedures. Compliance with the requirements for the RVI components was mandated during the construction period. These documents contained limitations on the amount of cold work that was allowed on RVI components during the construction phase. The limitations stipulate the following requirements for the RVI components: (1) the majority of austenitic stainless steel materials were required to be solution annealed, which eliminated the effect of cold work on SCC in these components; and (2) some material specifications stipulate limitations on the maximum allowed tensile strength and hardness values.

Tensile strength and hardness values in austenitic stainless steel increase with an increase in the amount of cold work. Imposition of limitations on the maximum allowed tensile strength and hardness values of the stainless steel RVI components resulted in components with limited cold work.

The staff reviewed Appendix A of PWROG-15105-NP, Revision 0 and noted that based on the specifications and component drawings, the PWROG identified potential for cold work in the RVI components and binned the components in following five categories: (1) Cast Austenitic Stainless Steel; (2) hot formed austenitic stainless steel; (3) annealed austenitic stainless steel; (4) austenitic steel fasteners; and, (5) cold-formed austenitic stainless steels without subsequent solution annealing.

Materials binned under Categories 1, 2 and 3 contain no greater than twenty percent cold work due to controlled fabrication and compliance with material specifications. Therefore, the RVI components binned under Categories 1, 2 and 3 were considered not susceptible to SCC. Only materials that fall under Categories 4 and 5 were treated as cold worked and were evaluated as such. Materials used for fasteners were binned under Category 4 and were potentially subject to cold work greater than twenty percent. Hence, they were evaluated for their susceptibility to SCC. Materials under Category 5 were cold-formed austenitic stainless steels without subsequent solution annealing. The staff noted that, upon further investigation, PWROG identified that Category 5 components were not subject to cold work greater than twenty percent. The staff also noted that for all cases, material specifications mandated appropriate limitations on the maximum allowable tensile strength and hardness values for these materials. These limitations provide reasonable assurance that cold work greater than twenty percent was not applied to Category 5 materials. Based on this evaluation, the staff concluded that non-fastener RVI components in CE and Westinghouse units are not susceptible to SCC.

Appendices B and C contained a list of RVI components that were used in CE and Westinghouse units. These documents included material specifications and cold work that was introduced to the component during construction. Based on the review, the staff concluded the following: (1) RVI components binned under Categories 1, 2 and 3 were not exposed to cold work greater than twenty percent. Therefore, these components were considered less susceptible to SCC. (2) Categories 4 and 5 were subject to cold work without subsequent solution annealing. (3) Fasteners which were binned under Category 4 were excluded in this report because they were already evaluated for SCC. This evaluation process was used in the development of I&E guidelines of MRP-227-A. (4) Evaluation of Category 5 materials indicated that they were not subject to cold work greater than twenty percent hence, they are less susceptible to SCC.

## 2.2 Section 5 “Results”

### 2.2.1 Summary

Section 5 of PWROG-15105-NP, Revision 0, “Results,” addresses evaluation of CE and Westinghouse design plant configurations. To date, fifty-six percent of Westinghouse and forty-three percent of CE units were evaluated for the presence of cold work on their RVI components. The PWROG reviewed major design features of the assessed units to date and compared them to that of the unassessed units. The comparison provided a basis for the determination of whether the already established conclusions regarding the potential for the use of cold worked materials in non-fastener applications can be applicable to the unassessed units. Based on the comparison of the design features, the PWROG concluded that no cold work will be found in the unassessed units. This is due to the fact that the PWR units maintained similar design and fabrication features during the construction period. The comparison also identified that there is no effect of plant vintage on the inclusion of cold work and this was confirmed by the fact that material specification and design with respect to cold work did not change over the years of construction of PWR fleet. Based on this information, the PWROG concluded it is reasonable to expect that no cold work will be identified in the non-fastener components in the remaining CE and Westinghouse units.

### 2.2.2 NRC Staff Assessment

The staff’s review of Section 5 indicated that no cold worked materials were used in non-fastener applications in Westinghouse and CE units. The staff’s conclusions are:

- (1) Material specifications published during 1970 through 1990 indicates that usage of solution annealed austenitic stainless steel materials for non-fastener RVI components was a standard practice.
- (2) As described in the staff’s conclusion (addressed in Section 2.1.2), all non-fastener RVI components that were binned under various Categories were not exposed to cold work greater than twenty percent. Assessment of cold work that was performed by various CE and Westinghouse units to date indicated that no cold work was identified in these components. The design features, material specifications, and fabrication methods used for these components in CE and Westinghouse fleet did not change over time. Therefore, it can be expected that no cold work would be identified in remaining unassessed operating units.

Based on its review stated above, the staff concludes that cold work is not a concern for non-fastener RVI components in the unassessed CE and Westinghouse units.

## 2.3 Section 6. “Conclusions”

### 2.3.1 Summary

The PWROG performed a review on the effect of SCC in some PWR RVI components and their conclusions were based on the review of regulatory requirements, fabrication practices at the time of RVI construction, and materials specification. The PWROG concluded that non-fastener RVI components in PWR units that were reviewed to date indicate that these components were not subject to cold work greater than twenty percent.

Based on the generic review performed to date on some of the PWR units, the PWROG has stated that no cold work greater than twenty percent is present in the remainder of the PWR fleet.

### 2.3.2 Staff Assessment

The staff reviewed the PWROG evaluation and concluded the following: (1) the fabrication practices at the time of RVI construction, and the materials specifications used for PWR RVI indicate that cold work greater than twenty percent without subsequent solution annealing in non-fastener RVI components was not allowed in PWR units; (2) RVI components that were exposed to cold work greater than twenty percent without subsequent solution annealing were evaluated for their susceptibility to SCC in MRP-227-A. Therefore, the staff determined that the PWROG has adequately addressed the effects of cold work on SCC in RVI components in PWR units. Since non-fastener RVI components were not subjected to cold work greater than twenty percent, these components are less susceptible to SCC.

## 3.0 CONCLUSIONS

The NRC staff has reviewed PWROG-15105-NP, Revision 0. The following summarizes the NRC staff's conclusions.

- The majority of austenitic stainless steel materials were required to be solution annealed, which eliminates the possibility of effects from cold work on the SCC behavior of the materials,
- Some of the material specifications stipulate limitations on the maximum allowed tensile strength and hardness values, which restricts the possible amount of cold work in the component,
- No non-fastener RVI components were subject cold work greater than twenty percent in PWR units, and these components are less susceptible to SCC.
- Material specification and design with respect to the consideration of cold work in CE and Westinghouse non-fastener RVI components did not change over the years of construction of the PWR fleet. Since cold work on these RVI components was adequately controlled during the construction period, it is concluded that non-fastener RVI components from unassessed Westinghouse and CE plants have low cold work and limited susceptibility to SCC.

Based on the conclusions, the staff determined that the applicants/licensees can use the guidelines in the report PWROG-15105-NP, Revision 0, as a part of its response to Part 1 of A/LAI 1 of the staff's SE for MRP-227-A.