Response to Request for Additional Information (Redacted)

By electronic mail dated October 5, 2020, the Nuclear Regulatory Commission (NRC) staff requested additional information to complete its review of Proposed Alternative Request No. IR-056, Revision 3. The responses for the Perry Nuclear Power Plant (PNPP) are provided below. The NRC staff request is presented in bold type, followed by Energy Harbor Nuclear Corp.'s response.

RAI-NVIB-03 (IR-056)

During the review, the staff noted that on page 3 of the January 6, 2020 submittal, the licensee referenced BWRVIP-48, Revision 1, "BWR Vessel and Internals Project: BWR Vessel [Internal Diameter] Attachment Welds Inspection and Flaw Evaluation Guidelines," which is not approved by the staff. However, the staff has approved the BWRVIP-48-A report.

(a) The staff requests that if the licensee intends to use BWRVIP-48, Revision 1, in lieu of BWRVIP-48-A, provide a summary of the revised changes between BWRVIP-48-A and BWRVIP-48, Revision 1.

The technical changes to BWRVIP-48 Revision 1 are listed in Table F-1 (provided as Appendix 1 below.) The principal change in BWRVIP-48 Revision 1 is the revision to the periodic reinspection frequency for Core Spray Bracket to Vessel ID welds and heat affected zones (HAZs) from 100 percent every four refueling cycles to 100 percent every 10 years.

(b) Based on these changes, justify why BWRVIP-48, Revision 1 may be implemented as an acceptable basis for inspection of the applicable RPV interior attachments welds without prior NRC approval of the methods in BWRVIP-48, Revision 1.

Technical justification for changing the reinspection frequency is reported in Appendix E Section E.4 (provided as Appendix 2 below.)

Table F- 1
Revision Details BWRVIP-48, Revision 1

Revision	Source of Revision	Description of Revision Implementation
In Abstract, clarified inspection area of interest to include attachment welds and heat affected zones on the vessel side of the welds.	Need to clarify inspection areas of interest for vessel attachment welds	Added the following to Abstract: "The recommended inspections contained herein apply to the attachment welds and the heat affected zones the vessel side of the welds. The inspection recommendations for the brackets themselves (HAZs on the bracket side) are provided in the I&E guidelines for the component for which they provide support."
Clarify applicable Sections of ASME B-N-2	ASME Section XI	Section 1.2 revised to specify applicable Sections of ASME Code Section XI B-N-2
Add Section 1.3 "Implementation Requirements" to this revision as NEI-03-08 was not published at the time of publication of BWRVIP-48-A.	NEI-03-08, Revision 3	Added new Section 1.3: 1.3 Implementation Requirements In accordance with Nuclear Energy Institute (NEI) 03-08, "Guideline for Management of Materials Issues" the requirements in Section 3 and 4 of this report are considered "needed" and the remaining Sections are "For Information Only". Although a previous version of this report has been reviewed by the NRC, this report revision was evaluated using the NEI 03-08, Appendix C document screening process. Using this process, it was determined that the report may be generically released for implementation without NRC approval. This determination was based a "yes" response to step 2d and a "no" response to step 2e of the screening evaluation. Appendix E provides the details of the screening result and basis.
Change plant name from WNP-2 to Columbia	Editorial	As plant designation has changed, plant name changed from WNP-2 to Columbia in Table 2-2.
Revise Section 3.1 to reflect the current state of knowledge regarding vessel ID attachment weld inspection history.	BWRVIP-301 BWRVIP-251 BWRVIP-266	Added section headings to separate historical OE (associated with inspections performed before initial development of BWRVIP-48) from more recent OE. Added new sub-sections to describe recent inspection trends based on the sources listed and to provide an updated performance summary.

Table F-1
Revision Details BWRVIP-48, Revision 1 (Continued)

Revision	Source of Revision	Description of Revision Implementation
Change "should" to "shall" for all "needed" guidance requirements.	BWRVIP requirement	Changed "should" to "shall" for "needed" guidance in Sections 3.2.1, 3.2.2, 4.1, 4.2, Table 3-2 footnote 1 and Table 4-1 footnote 1.
In Table 3-2, clarified inspection area of interest to include attachment welds and heat affected zones on the vessel side of the welds.	Need to clarify inspection areas of interest for vessel attachment welds	In Table 3-2, the "area of interest" to be inspected during EVT-1 inspections of jet pump riser brace and core spray bracket to vessel ID attachment welds recommended in BWRVIP-48, Revision 1 was clarified to include "the attachment welds and the HAZs on the vessel side of the weld".
Revise Table 3-2 to reflect revised periodic inspection interval for Core Spray bracket to vessel ID welds and HAZs	Qualitative Risk Assessment performed in accordance with NEI-03-08, Revision 3, Appendix C (see Appendix E)	Inserted revised inspection guidance in Table 3-2 as follows: [ ]
Add SI unit conversion	EPRI requirement	Added SI conversion from Kips to KN on page 4-3
Update definition of VT-1 in Section 3.1.2	ASME Section IX	Changed to: "VT-1 is defined using the ASME Section XI criteria for the Edition and Addenda applicable to the Owner's in-service inspection program."
Update definition of EVT-1 in Section 3.1.2	BWRVIP-03 Rev 19	Changed to: "Enhanced VT-1 (EVT-1) is defined in the latest revision to BWRVIP- 03."
Add/update References	Editorial	Updated References 2 and 5 and added new References 10, 11 and 12.
Remove Appendix A "License Renewal Appendix on BWRVIP-48" and replace with explanation of basis for removal.	BWRVIP position on LR appendices implemented in revisions to other I&E guidelines	Removed Appendix A "License Renewal Appendix on BWRVIP-48" and replaced with explanation of basis for removal.
Remove Appendix C "NRC SE on License Renewal Appendix on BWRVIP-48" and replace with explanation of basis for removal.	BWRVIP position on LR appendices implemented in revisions to other I&E guidelines.	Removed Appendix C "NRC SE on License Renewal Appendix on BWRVIP-48" and replaced with explanation of basis for removal.
Add documentation of screening to determine whether BWRVIP-48, Revision 1 can be generically released for implementation without NRC approval.	NEI-03-08, Revision 3, Appendix C	Added new Appendix E: Screening of BWRVIP-48, Revision 1 in Accordance with NEI-03-08, Revision 3, Appendix C "Document Screening".
Add Appendix F Record of Revisions (BWRVIP-48 Revision 1)	BWRVIP Practice	Added new Appendix F Record of Revisions (BWRVIP-48 Revision 1)
End of Revisions		

E.4 Qualitative Risk Assessment for Extension of the Core Spray Piping Bracket Attachment Weld Examination Interval in Rev. 1 to BWRVIP-48

E.4.1 Introduction

The examinations specified for core spray piping bracket to reactor vessel wall welds in BWRVIP-48 [E4] were deemed to be needed primarily because of concerns regarding potential susceptibility of RPV ID attachment welds to stress corrosion cracking (SCC). The scope of inspection in BWRVIP-48 of this weld is confined to the groove weld of the bracket to the weld buildup pad or cladding on the vessel wall and the associated heat affected zone (HAZ) induced by the groove weld in the weld buildup pad or cladding. The following discussion is limited to material in this inspection scope.

At the time BWRVIP-48 was initially issued, SCC of BWR internals was still largely in a discovery phase, with the frequency and ultimate extent of cracking largely unknown. As a result, the inspection program specified by BWRVIP-48 was purposely conservative. About twenty years have elapsed since the initial issue of BWRVIP-48 and it is reasonable to revisit the specified inspection intervals based on the current state of knowledge regarding performance in the field and understanding of the progression of SCC in BWRs. This qualitative change in risk evaluation addresses a change from [

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E.4.2 Historical Performance of Core Spray Piping Attachment Welds and HAZs

BWRVIP-48 [E4] (published in 1998) and BWRVIP-48-A [E2] (published in 2004) required [

] BWRVIP-48-A required examination by EVT-1. In Revision 10 of BWRVIP-03, published in December 2007, the requirements for EVT-1 were updated to require character height resolution requirements and to impose limits on camera travel speed and camera angle. Examinations performed to this standard have been demonstrated capable of detecting very small indications. Based on that implementation date, it is known that all core spray piping bracket attachment welds and HAZs in US BWRs currently remaining in operation have been inspected at least once using this technique. Additionally, at least one, and potentially two, prior exams have been performed for all locations, either by the initial EVT-1 standard (the examination method specified in BWRVIP-48-A) or by MVT-1 (examination technique specified in the original version of BWRVIP-48). There are between 4 and 8 core spray piping brackets per unit and 34 US BWR units with core spray bracket to vessel ID welds that have performed inspections as required by BWRVIP-48. There have been over 450 detailed visual examinations completed to date, with most of these exams using EVT-1. No reportable conditions have been identified in these inspections [E5]. In addition, a general review of examination coverage was performed. EVT-1 inspection coverage for the primary core spray brackets is typically in the range from 80 to 100% and for supplemental core spray brackets from 60-95% (Note: These coverage values are associated with the current, more conservative interpretation of coverage for EVT-1 exams). Given that examination coverage is good and exams have not detected any indications, the performance of these welds to date is considered to be excellent with no SCC found.

E.4.3 SCC Susceptibility Discussion

SCC Factors

As with all SCC-related phenomena, it is necessary to consider the three essential factors for cracking to occur. These are: 1) a conducive environment, 2) material susceptibility, and 3) sufficient tensile stress. The absence or significant reduction of any one of these three factors is sufficient reason to conclude the risk of SCC is very low. The discussion below is specific to the core spray bracket welds based on the materials of construction, weld design and application, and the location of the welds in the reactor vessel:

- *Environment*:
  With respect to environment, the core spray piping brackets are located in the mixing plenum or upper down comer region of reactor vessel at an elevation just below the feed water spargers. In this region of the reactor vessel, the bracket welds are exposed to a blend of feedwater and the drains coming from the steam separators and the steam dryer. The reactor water at this elevation is oxidizing and ECP (electrochemical corrosion potential) reduction is unlikely by any form of hydrogen water chemistry (HWC). It must therefore be concluded that the core spray bracket welds are exposed to an environment conducive to SCC during normal power operation, regardless of HWC technology implementation.
- *Material Susceptibility*:
  The materials of construction and the general configuration of the welds are shown in Figures 2-6 and 2-7 of this document (BWRVIP-48-Rev. 1), along with supplemental bracket welds present in some plants, which are shown in Figure 2-8. For the purposes of this evaluation, the supplemental bracket welds are included within the discussion of the stainless steel bracket welds shown in Figure 2-7. Table 2-2 lists figures in BWRVIP- 15 [E6] that show the specific configuration applicable to each plant. Although there are some differences in weld preparation details, the primary difference between the two configurations is weld material. One group of plants have core spray piping bracket welds fabricated using Nickel Alloy 182, while the other set of plants have the welds fabricated using stainless steel weld metal (Type 308 or 308L). In general, Alloy 182 weld metal deposits have been found to be susceptible to SCC in the field and laboratory studies, while stainless steel weld deposits generally have not. The relative SCC susceptibility of these two weld materials will be discussed separately below.
- *Tensile Stresses*:
  During steady state operation, the only applied load to the bracket welds is the dead weight of the core spray pipe. The stresses associated with dead weight are minimal. The main stress applied to the weld is weld residual stress. An assessment of weld residual stress is provided below.

Weld Metal SCC Susceptibility

Alloy 182 weld metal exposed to the BWR environment has been seen to be susceptible to SCC in both laboratory testing and in operating plants. Field observations of SCC began in 1984 [E7]. Since that time, significant cracking has been reported in nozzle butters, safe end-to-nozzle welds, and shroud support structure welds. Based on this experience, it must be concluded the core spray piping bracket welds fabricated from Alloy 182 weld metal are at least nominally susceptible to SCC. Review of Table 2-2 and supporting document NP-7139-D [E8] show that only reactor vessels constructed by Combustion Engineering have core spray piping bracket welds fabricated from Alloy 182.

Core spray piping bracket welds made with stainless steel filler metal represent a different case from the nickel alloy welds with respect to SCC susceptibility. Materials having a duplex cast stainless steel microstructure have shown significant resistance to SCC in the BWR environment. This has generally been attributed to the presence of ferrite intermixed with the predominately austenitic structure [E9]. The ferrite serves two significant purposes. It breaks up continuous austenite-austenite grain boundary pathways for crack propagation, and the solubility of carbon in ferrite is significantly greater. Therefore, the presence of ferrite limits the amount of carbon available at austenite boundaries to form the chromium carbides that generate chromium depletion. It has been seen that the presence of as little as 3 to 4% ferrite is sufficient to render the weld deposit essentially immune to SCC [E10]. Most, if not all, stainless steel weld metal used to fabricate the core spray piping bracket welds may be expected to contain at least that much ferrite because ferrite is also essential to prevent hot cracking of stainless steel weld deposits. This was recognized by the NRC in Regulatory Guide 1.31 and ASME Section III which both require a minimum of 5% (or 5 FN) ferrite to prevent hot cracking. The presence of at least some ferrite in stainless steel weld deposit as an SCC deterrent is supported by the fact that no spontaneous SCC initiation has been observed in stainless steel welds in BWR piping or internals (excepting rare instances of cracking in weld surfaces heavily cold worked by machining). There is no heavy machining of core spray piping bracket welds. Consequently, it may be concluded that the stainless steel weld metal used to fabricate the core spray bracket welds can be considered not susceptible to SCC. This position is consistent with the BWRVIP position taken for other internals components in NRC approved BWRVIP guidelines. A directly applicable example of this case is BWRVIP-18, Revision 2-A [E3] where the examination requirements specifically state that the inspection requirements for locations where stainless steel welds are used to join fully austenitic stainless steel base materials are applicable only to the HAZs associated with the stainless steel weld base materials (and not the welds themselves). Similarly, within BWRVIP-03, Rev. 19 [E11], the areas of interest defined for thick stainless steels specifically include only the toe of the weld and one-half inch of the adjacent base material on each side of the weld. The stainless steel weld itself is excluded.

HAZ (Vessel side) Material SCC Susceptibility

The bracket attachment weld on the vessel side of the joint is applied to a weld buildup pad on the vessel wall or in some cases to the cladding. For the Combustion Engineering plants, the weld buildup pads are Alloy 182. Therefore, the HAZs on the vessel side of the weld are in

Alloy 182 and have the same SCC susceptibility as the groove welds. For the stainless steel bracket attachment welds, the arrangement is similar with a stainless steel weld buildup pad or cladding applied to the vessel wall. This results in the HAZ on the vessel side of the groove weld being in stainless steel weld deposit. The discussion above on SCC susceptibility of the stainless steel bracket attachment welds is equally applicable to these stainless steel HAZs.

Stress State (Weld and HAZ on Vessel Side)

Since no cracking has been observed to date irrespective of weld filler type or HAZ material on the vessel side [E5] even though the Alloy 182 bracket welds/HAZs must be considered SCC susceptible material and operate in a very aggressive environment, rationalization of a lack of cracking in what, for many plants, is more than 40 years of operation must focus on stress state. As noted above, applied loads on the core spray bracket welds/HAZs are minimal during steady state operation. That leaves weld residual stress as the likely source of any sustained tensile stress in the weld. Weld residual stresses can be substantial for large internal structures such as shrouds or the shroud supports as a result of weld size and restraint imposed by adjacent thick base metal. These residual stresses have been judged to be sufficient to explain the observed SCC in core shroud stainless steel weld heat affected zones and shroud support Alloy 182 welds. While the weld is being made, the weld deposit tries to shrink as it cools down after solidification. However, this natural shrinkage is constrained by the adjacent base metal. This occurs in part because the base metal parts being joined are not free to move, being constrained by configuration and thickness. This results in residual stresses that, in some cases, approach the yield strength of the material. Such stresses are more than sufficient to promote initiation and growth of SCC in Alloy 182 when exposed to an oxidizing reactor water environment.

However, fabrication of the Alloy 182 core spray piping bracket welds present a substantially different case. For the piping bracket design using Alloy 182, the diameter of the bracket is typically only about 1.5 inches (38.1 mm). Also, and very importantly, the bracket is completely unrestrained as the weld is being made. That is, the end of the bracket was free to move as shrinkage of the weld deposit occurred. As can be seen in Figure 2-6 of BWRVIP-48-A [E2] (Figure 2.13.2.23 of BWRVIP-15 [E6]), the weld preparation of the bracket was designed as a two-sided weld to be made from above and below the bracket post. In order to complete the weld with the post level within the specified tolerance, it was necessary for the welder to apply one or two passes from the top side. Weld shrinkage would pull the end of the post upward. At that point the welder would have back gouged the unfused root to sound metal and applied weld passes from the underside to pull the end of the post back level. Welding would have proceeded in this alternating fashion until the weld groove was filled to the specified dimensions and the post was level within the drawing tolerance. Throughout this process, the post was free to move with the weld shrinkage such that the final residual tensile stresses were limited. Based on the results of the repeated inspections over the last 20 years noted above (in many cases accounting for more than 40 years of operation), it is reasonable to conclude the residual tensile stresses in the core spray piping bracket welds are insufficient to promote SCC.

E.4.4 SCC Risk Assessment

As described above, the overall risk of SCC occurring in a given component depends on convergence of the three essential conditions, i.e. susceptible material, conducive environment, and tensile stress. The relative risk in turn is dictated to a large extent by the level or intensity of these three conditions. Over the history of SCC in BWRs, it has been observed that not all components in a given system experience cracking even though they are fabricated from the same material and operate in the same water chemistry environment. Further, it has been determined that the probability of cracking as a function of time is more appropriately described by a Weibull distribution than a normal distribution [E12]. Frequently, the available data indicate the cracking probability distribution is characterized by a rapid peak in occurrences early in service life followed by a decline to low probabilities at longer operating times. This trend continues to be consistent with field observations of SCC in BWR components. Many cracks were identified within the first 10 years of operation (or at the time of initial inspections using high resolution visual or volumetric techniques), followed by a declining trend with additional operating time. For many components, virtually no new observations of cracking are being reported with continued operation. Additionally, most recent new cracking indications can be attributed in some way to improved NDE capabilities or procedures. There is little evidence of any ongoing trend of new SCC initiation. Assuming these trends are also applicable to the core spray piping bracket welds where no cracking has been observed, it is reasonable to conclude that a sudden increase in cracking probability is extremely unlikely.

E.4.5 Qualitative Risk Assessment Summary and Conclusions

Reinspection intervals for the core spray piping bracket welds were established with the initial issue of BWRVIP-48 [E4]. At that time, SCC of reactor internals was in the early stages of detection and evaluation. There were virtually no reliable inspection data for the core spray piping bracket welds to establish a likelihood and frequency of cracking and the welds were judged to be at least moderately susceptible to SCC based on materials of construction, local environment, and likely stress state [E8]. Consequently, a conservative approach was used to set baseline inspection and reinspection requirements. However, since the initial issue of BWRVIP-48, over 450 inspections of core spray bracket welds and HAZs on the vessel side have been performed. Despite the early predictions of moderate risk of SCC, no cracking has been identified to date. The stainless steel bracket welds and SS HAZs on the vessel side are fabricated of a material that has been shown to be highly resistant to SCC irrespective of residual stress and environment. Although the Alloy 182 bracket welds and Alloy 182 HAZs on the vessel side must be acknowledged to be fabricated from a susceptible material, no cracking of these welds has been observed even though the welds/HAZs are exposed to an aggressive local environment. The lack of cracking can most likely be attributed to a lack of sufficient tensile stresses. Relatively low weld residual stresses are related to the size, sequencing, and lack of restraint in these specific welds. Observation of SCC occurrences in other BWR internals and piping continue to demonstrate a declining trend in cracking probability with continued operation.

Regarding CS piping to vessel ID attachments, BWRVIP-06 [E16] states
[

] . However, since each unit has between 4 and 8 CS piping to vessel ID attachments, there is significant redundancy to mitigate a single attachment failure. With the proposed change in the inspection interval, [
] and there have been no reportable indications in 40 years (>1300 years of fleet reactor operation). It is therefore concluded that [ ]

[

] is entirely reasonable and appropriate given the current state of knowledge. This conclusion is applicable to both the stainless steel and Alloy 182 core spray piping bracket attachment welds and stainless steel/Alloy 182 HAZs on the vessel side.

E.5 NEI 03-08 Document Screening Conclusion

Based on the "Yes" response to Question 2d and the "No" response to Question 2e, the revised aging management guidance can be released for implementation by the BWRVIP utilities without NRC approval.

E.6 References

E1 *NEI-03-08 Revision 3, Guideline for the Management of Mateirals Issues, Appendix C, Document Screening, February 2017.*

E2 *BWRVIP-48-A: BWR Vessel and Internals Project, Vessel ID Attachment Weld Inspection and Flaw Evaluation Guidelines.* EPRI, Palo Alto, CA: 2004. 1009948.

E3 *BWRVIP-18, Revision 2-A: BWR Vessel and Internals Project, Core Spray Piping Inspection and Flaw Evaluation Guidelines.* EPRI, Palo Alto, CA: 2016. 3002008089

E4 *BWRVIP-48: BWR Vessel and Internals Project, Vessel ID Attachment Weld Inspection and Flaw Evaluation Guidelines.* EPRI, Palo Alto, CA: 1998. TR-108724.

E5 *BWRVIP-301: BWR Vessel and Internals Project, BWRVIP Inspection Trends, 2016 Update*. EPRI, Palo Alto, CA: 2017. 3002008102.

E6 *BWRVIP-15:BWR Vessel and Internals Project, Configurations of Safety-Related BWR Reactor Internals*. EPRI, Palo Alto, CA: 1996. TR-106368

E7 R.M. Horn, P.L. Andresen, and J. Hickling, "*BWR alloy 182 stress Corrosion Cracking Experience",* Societe Francaise d'Energie Nucleaire - SFEN, 75 - Paris (France); (v.1-2). 1175 p; 2002; p. 55-67; Fontevraud 5 International symposium; Fontevraud – Royal Abbey (France); 23-27 Sep 2002.

E8 *Reactor Pressure Vessel Attachment Welds: Degradation Assessment*. EPRI, Palo Alto, CA: 1991. NP-7139-D.

E9 N. Hughes et. al., *Intergranular Stress-Corrosion Cracking Resistance of Austenitic Stainless Steel Castings*, ASTM STP756 *Stainless Steel Castings*, 1982.

E10 G. Nakayama, K. Yoshida, and M. Akashi, *Effects of Carbon and Delta Ferrite on Stress Corrosion Cracking Susceptibility of Type 309 Weld Metal in Simulated BWR Environment*, NACE Corrosion 93, Paper 171.

E11 *TR-105699-R19* (*BWRVIP-03) Revision 19: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines*. EPRI, Palo Alto, CA: 2016. 3002008095.

E12 *BWRVIP-315: BWR Vessel and Internals Project, Reactor Internals Aging Management for Extended Operations*. EPRI, Palo Alto, CA: 2019.3002012535.

E13 *Generic Aging Lessons Learned (GALL) Report – Final Report.* (NUREG-1801, Revision 2), December 2010

E14 *Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report.* (NUREG 2191), July 2017

E15 *BWRVIP-94NP, Revision 2: BWR Vessel and Internals Project, Program Implementation Guide*. September 2011, EPRI Report 1024452

E16 *BWRVIP-06, Revision 1-A*: *BWR Vessel and Internals Project, Safety Assessment of Reactor Internals*. December 2009. EPRI Report 1019058.

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