SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT

"BWRVIP-06-A: BWR [BOILING WATER REACTOR] VESSEL AND INTERNALS

PROJECT [(BWRVIP)], SAFETY ASSESSMENT OF BWR REACTOR INTERNALS,

REVISED SECTION 4.0: CONSIDERATION OF LOOSE PARTS"

BWRVIP

PROJECT NO. 704

1.0 INTRODUCTION AND BACKGROUND

By letter dated May 11, 2005 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML051370191), the BWRVIP submitted "BWRVIP-06-A: BWR Vessel and Internals Project, Safety Assessment of BWR Reactor Internals, Revised Section 4.0: Consideration of Loose Parts" to the U.S. Nuclear Regulatory Commission (NRC) staff for review. Only Section 4.0 of the previously NRC approved TR (BWRVIP-06-A) was revised in its entirety by the BWRVIP. The revision of Section 4.0 provides a general evaluation of the potential impact of loose parts generated in the reactor vessel due to cracking of reactor vessel internal components (CVIP) and assesses how these loose parts may affect the safe shutdown of the reactor plant and offsite dose. Operating experience of most plants indicates that loose parts have not significantly affected plant operations.

By letter dated December 21, 2006 (ADAMS Accession No. ML070030188), the NRC staff sent a request for additional information (RAI) to the BWRVIP. By letter dated August 9, 2007 (ADAMS Accession No. ML072250216), the BWRVIP stated that the response to the RAI would be sent to the NRC staff by November 30, 2007. By letter dated November 30, 2007 (ADAMS Accession No. ML073410041), the NRC staff received the response to the RAI. The purpose of this NRC staff safety evaluation (SE) is to determine the acceptability of the revised Section 4.0.

The original BWRVIP-06 TR was submitted to the NRC staff for review by letter dated May 24, 2002 (ADAMS Accession No. ML021500624). The purpose of the TR was to exchange information with the NRC staff in support of generic regulatory improvements related to assessing the safety consequences of potential cracking of BWR internals.

Increased occurrence of identified intergranular stress corrosion cracking (IGSCC) in BWR internals prompted the U.S. BWR executives to form the BWRVIP in June 1994, to address integrity issues arising from service-related degradation of these important components. It was apparent to the BWRVIP and to the NRC staff that as inspection techniques improve and as more inspections are performed, additional IGSCC related cracking in welded and bolted locations of reactor internals would be identified. On this basis, the BWRVIP submitted

ENCLOSURE

TR BWRVIP-06 to the NRC staff to exchange information and to support generic regulatory efforts related to assessing the safety consequences of potential cracking of BWR/2-6 reactor internals. In addition, TR BWRVIP-06 supports the determination of the short- and long-term actions required to ensure safe operation with the potential for component cracking. TR BWRVIP-06 generically evaluates postulated failures caused by IGSCC in welded and bolted locations of reactor vessel internals (RVIs) and establishes long-term actions which the BWRVIP stated are appropriate to ensure continued safe operation. The assessment considers RVIs functions during normal, transient, seismic, and design basis accident conditions. The results of TR BWRVIP-06 are intended to provide utilities with a generic reactor internals management plan which can be tailored to meet the needs of individual utilities. Additionally, TR BWRVIP-06 is intended to provide the NRC staff with information needed to evaluate future cracking in BWR internal components.

The NRC staff concluded that no technical changes were necessary or required for the approval of TR BWRVIP-06 and by letter dated September 16, 2003 (ADAMS Accession No. ML032650767), the NRC staff informed the BWRVIP of their acceptance and approval of TR BWRVIP-06.

The revised Section 4.0 of TR BWRVIP-06-A applies only to operating BWR/2-6 plants.

2.0 <u>REGULATORY EVALUATION</u>

Guidance applicable for loose parts can be found in the General Design Criteria (GDC) 1 and 13 of Appendix A of 10 CFR Part 50. GDC 1 requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed and that a quality assurance program be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. GDC 13 requires, in part, that instrumentation be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences (AOOs), and for accident conditions to ensure adequate safety, including those variables and systems that can affect the fission process, the integrity of the core, and the reactor coolant pressure boundary. Additional applicable guidance is provided in NRC Regulatory Guide (RG) 1.133, Revision 1, “Loose-Part Detection Program for the Primary System of Light-Water-Cooled Reactors.”

Revised Section 4.0 of BWRVIP-06-A provides a qualitative rationale for any radiation releases to be within acceptable plant-specific limits as specified in Part 100, “Reactor Site Criteria,” of Title 10 of the *Code of Federal Regulations* (10 CFR). Revised Section 4.0 states that smaller loose parts may pass through a fuel lower tie plate, be trapped on a spacer, and may wear a hole in the fuel cladding. As a result of this fuel fretting, fuel cladding leakage may occur, which would be detected by the off-gas system so that appropriate actions could be taken to maintain the off-gas radiation release within acceptable 10 CFR Part 100 limits. All identified technical specification actions will be complied with as required. There are possible operational concerns that a smaller loose part could cause fuel fretting; however, such concerns do not constitute a safety issue with respect to safe shutdown and offsite dose.

In addition, the revised Section 4.0 describes the impact of loose parts on the recirculation system. Smaller loose parts are expected to pass through the recirculation pump without causing any damage or detectable flow reduction in jet pump drive flow. Large and heavy items in the past have passed through the pump and the jet pump nozzles without causing any damage. If a loose part prevents the recirculation discharge valve from fully closing, the loss of low pressure coolant injection (LPCI) flow will delay the core re-flooding leading to an increase in the peak cladding temperature (PCT). Revised Section 4.0 provides a rationale, based on a bounding evaluation using realistic models and assumptions with no credit for LPCI or discharge valve closure, that one core spray system is sufficient to keep the PCT below the 10 CFR 50.46 limit of 2200^{o} F presenting no significant safety hazard.

The NRC staff reviewed the revised Section 4.0 of TR BWRVIP-06-A, and concluded that the safety assessment of potential impact of loose parts generated in a BWR, as provided, is consistent with the above criteria and guidance.

3.0 <u>TECHNICAL EVALUATION</u>

The NRC staff has reviewed "BWRVIP-06-A: BWR Vessel and Internals Project, Safety Assessment of BWR Reactor Internals, Revised Section 4.0: Consideration of Loose Parts." The revised Section 4.0 presents a general and a qualitative type consideration of loose parts. It addresses safety concerns and operational concerns from postulated loose parts.

The evaluation addresses the potential impact of loose parts generated in the vessel due to cracking of RVIs. Additionally, evaluation is included to assess why loose parts do not negatively affect safe shutdown and offsite dose. This analysis is also valid for loose parts generated outside the reactor vessel, as long as they reach the regions inside the vessel considered as source locations, and their sizes are within the range of sizes considered in this evaluation. Operating experience of most plants indicates that loose parts have not significantly affected plant operation. However, there has been some degradation of certain components and/or systems at times. It is important to ensure that programs are in place to effectively eliminate the introduction of loose parts, promptly identify loose parts that enter the vessel, and implement appropriate corrective action upon identification of loose parts wherever they may be. The evaluation provided in the TR is general in nature and does not assess the effects on the basis of individual part geometries or material properties, as these are resolved on a case-by-case basis. The generation of multiple loose parts that could arrange themselves in a manner that would cause unacceptable conditions was not considered to be credible for the purpose of this evaluation.

Only loose parts that are not detectable and could impact the safe plant operation and shutdown capability are generally considered to be of safety significance. Loose parts that are detectable due to their observable collateral impact on plant operation would indicate that an abnormal plant condition exists and the plant would normally be brought to a safe condition by operator action.

Because several plant-specific features can determine the acceptable loose part size limits for safety and operational concerns, only general criteria were provided.

3.1 Loose Parts and Structural Issues

The safety concerns addressed in this SE are the potential of loose parts to interfere with the main steam isolation valves (MSIV), safety/relief valve (SRV) operation, control rod operation, high pressure coolant injection (HPCI), and reactor core isolation cooling (RCIC), reactor water clean up (RWCU), or residual heat removal (RHR) isolation valves, nuclear instrumentation, and operation of RHR pumps and heat exchangers. Also addressed are the potential for fuel damage due to fuel bundle flow blockage, impact damage on reactor internals, and corrosion or adverse chemical reaction with other reactor materials. The operational concerns evaluated are potential for fuel fretting, interference with operation of RWCU pumps, heat exchangers and filter demineralizers, flow blockage of the reactor vessel bottom head drain, and impairment of recirculation system performance. The NRC staff finds that the TR has adequately addressed the safety and operational concerns due to loose parts from qualitative considerations.

The revised Section 4.0 considers transport of loose parts in the reactor vessel and associated systems from gravity, flow, or combined gravity and flow considerations. The possibility of loose parts being carried over by the flow to locations where they could present a safety concern or affect safe shutdown and offsite dose is evaluated. The evaluation also addresses the source location of loose parts that have been lost in or migrated to the upper plenum, steam separator/dryer, downcomer, and lower plenum regions. From geometric considerations, the loose parts can be in a variety of sizes and shapes classified into three categories, namely large parts greater than 2 inches in size, small parts 1 to 2 inches in size, and debris smaller than 1 inch in size. The NRC staff finds that the evaluation of loose parts from the source location, transport, size, and shape considerations to be acceptable.

The NRC staff sought information about large loose parts resulting from steam dryer failure becoming missiles that could damage other reactor components. For example, large loose parts entering the Reactor Recirculation System (RRS) could cause damage to recirculation pump. The BWRVIP indicated that normal monitoring activities of the recirculation system would ensure that either damage to the pump or recirculation system performance degradation in terms of flow reduction could be noted and appropriate steps taken to mitigate the condition. The NRC staff finds this acceptable.

The NRC staff questioned the BWRVIP on the potential for impact of loose parts on the standby liquid control (SLC) system standpipe. The BWRVIP responded that the differential pressure (DP) line and the liquid control line are supported at the vessel nozzle, the shroud support skirt, and along the shroud as it is routed inside the core. This results in a configuration that is a well supported pipe within a pipe configuration and is unlikely to be damaged from impact by a loose part entering the lower plenum. The injection of sodium pentaborate is not prevented even if the pipe attached to the core shroud, which is for core DP and not SLC, is damaged by a loose part. Also, failure of the pipe in the lower plenum, which results in a change of measured core DP, will be detected in the control room. The NRC staff finds the clarification provided by BWRVIP on the impact of loose parts on SLC standpipe is acceptable.

The NRC staff sought information regarding fuel bundle upper tie plate pass through sizes. The BWRVIP provided a table of maximum pass through sizes for rectangular, cylindrical, and square shaped loose parts for various General Electric (GE) nuclear fuel designs. The NRC staff sought a discussion on whether there is a potential for both MSIVs failing to close due to large loose parts from steam dryer failure. BWRs are designed with a redundant valve for valves in a line that require redundancy. From past experience, it is highly unlikely that two large loose parts from the steam dryer would migrate down a single main steam line and bend or break both of the legs on the vertical center line of both MSIVs. One potential loose part and definitely more than one from a failed steam dryer will be detected by changes in steam quality.

If a large part is lodged in a main steam line, control room indicators will detect the mismatch in steam flow. The above rationale provided by the BWRVIP, regarding the unlikelihood of both MSIVs failing due to large loose parts from steam dryer failure and the detection of the effects indicated by the changes in moisture carryover and the main steam flow imbalance, is acceptable to the NRC staff.

The BWRVIP addressed the NRC staff question on the possibility of loose parts drawn into the SRV standpipe and SRV valve due to vortex shedding and flow excited resonances at the standpipe inlet and interfering with the SRV operation. The responses were as follows:

(a) The SRVs for almost all plants (except a few early plants) are located on the top of the horizontal run of the main steam line piping with the standpipe oriented vertically. In this orientation, the inlet to the side branch located at the bottom of the standpipe prevents the accumulation of condensate in the standpipe. This orientation will also ensure that loose parts cannot collect in the standpipe. The shear layer instability and vortex shedding associated with flow-excited acoustic resonances of the standpipe are local to the entrance region of the standpipe. The vortex acoustic coupling produces an in-out flow with rapid cycling (typically over 100 Hertz for a relief valve), and so the likelihood of drawing a loose part in without it subsequently being driven out into the main steam line flow in the next half cycle is very small. In order for the loose part to be drawn into the standpipe region, the loose part would have to be traveling along the top of the steam line past the standpipe opening, pass by the opening at the right time in the vortex cycle to be subjected to an upward drag force to lift the loose part up and out of the main flow stream. It is unlikely that anything other than the very small pieces could be lifted up and out of the main stream and carried into the standpipe by the vortex. Once inside the standpipe, there is no force that will hold the loose piece in the standpipe where the fluid is stagnant. The cyclical nature of the vortex will tend to return the loose part to the main flow stream. Therefore, the NRC staff finds that it is unlikely that the loose parts will be drawn into the standpipe by vortex shedding associated with flow-excited acoustic resonances in such a way that it can interfere with the SRV operation.

(b) A few of the early plants may have SRVs mounted on a vertical run of the main steam line with the standpipe oriented horizontally. In this configuration, it is possible that a small loose part may come to rest in the horizontal section of the standpipe. Again, in order for the shear layer instability and vortex shedding associated with flow-excited acoustic resonances to affect the trajectory of the loose part, the loose part would have to be traveling along the side of the steam line right next to the standpipe opening, at just the right time in the vortex cycle, and the part would have to be very small in order for the vortex to be able to deflect the part out of the main flow stream. It is unlikely that these conditions will be satisfied and, therefore, it is unlikely that the vortex shedding associated with flow-excited acoustic resonances will draw a loose part into the standpipe where it can interfere with the SRV operation. The BWRVIP stated that the momentary occurrence of a passing loose part coincident with an AOO is incredible. The NRC staff finds the BWRVIP rationale on the unlikely nature of loose parts interfering with the SRV operation to be acceptable.

Based on this evaluation, the NRC staff has determined that, regarding structural issues, the BWRVIP has adequately considered safety and operational aspects in addressing the impact of loose parts.

3.2 Loose Parts and Components Issues

After reviewing the information provided in the revised Section 4.0 of TR BWRVIP-06-A, the NRC staff requested the BWRVIP to submit additional information. The response to the RAI was provided by letter dated November 30, 2007 (ADAMS Accession No. ML073410041).

3.2.1 Standby Liquid Control System Standpipe

In Sub-section 4.1 of the revised Section 4.0 of TR BWRVIP-06-A, the potential impact of loose parts on the SLC system standpipe and the safety consequences were not discussed. Therefore, the NRC staff issued a RAI on the subject. In response, the BWRVIP stated that the DP and the SLC line consist of two sections: the first one is the SLC line section serving as a pressure tap for one end of the core DP instrumentation and the second pressure tap is an instrumentation line running to the top of the core plate. The DP and the SLC line are supported at the vessel nozzle, the shroud support skirt, and along the shroud as it is routed inside the core. The resulting configuration is a pipe within a pipe that is well supported and is unlikely to be damaged from impact by a loose part entering the lower plenum. It was further stated that even if the pipe attached to the core shroud was damaged by a loose part, it would not prevent the injection of sodium pentaborate into the vessel. This pipe is for core DP measurement and not standby SLC. Additionally, failure of the pipe in the lower plenum would result in a change in measured core DP and be detected in the control room. Therefore, it was concluded that there is no safety concern associated with the potential impact on the SLC system standpipepipe due to the presence of potential loose parts, and that the item need not be added in the list of concerns. The NRC staff finds the response acceptable.

3.2.2 Main Steam Isolation Valves

In Section 4.1.1 of the revised Section 4.0 of TR BWRVIP-06-A, potential interference by loose parts with MSIVs was discussed. The BWRVIP indicated that the fixed liner on the vertical centerline could be bent or broken when hit by a large loose part that might prevent the valve from closing. The NRC staff believed that there is a potential for both MSIVs in a single steam line to fail to close, and therefore, requested that the BWRVIP address the possibility for both valves failing to close due to large loose parts generated as a result of the steam dryer failure. In response, it was stated that there is no known case where a redundant MSIV has failed to provide the design backup expected. BWRs are designed with redundancy as a standard for valves in a line that require the redundancy. It is highly unlikely that two large steam dryer loose parts would migrate down to a single main steam line and bend or break both of the legs on the vertical centerline of both valves. Two valves were considered adequate for the original design, with approval being given based on the necessity of a two valve redundant design. One or more large potential loose parts from a failed steam dryer should be detected by change in steam moisture quality. In addition, if a large loose part were to become lodged in a main steam line this would likely be detected as a mismatch in flow by control room indicators. As a result, the probability of failure of both MSIVs to close in the same steam line due to damage caused by loose parts is insignificant. The NRC staff finds the response acceptable.

3.2.3 Safety/Relief Valve Operation

In sub-section 4.1.2 of the revised Section 4.0, the BWRVIP indicated that potential loose parts are not expected to interfere with the SRV operation because of the following reasons:

(1) SRVs are closed during normal plant operation, and as such there is no flow to draw the loose parts into the standpipepipe and the valve, and (2) the failure of system components coinciding with a loss-of-coolant accident is unlikely. Recent industrial experience has suggested that the shear layer, which separates the mean flow in the main pipe from the stagnant fluid in the branch, can be unstable due to the acoustic resonance in the SRV standpipe. The NRC staff requested the BWRVIP to address the possibility that the loose parts may be drawn into the standpipe and the valve due to vortex shedding and flow-excited acoustic resonances at the inlet. The BWRVIP responded by stating that the SRVs for almost all plants are located on the top of the horizontal run of the main steam line piping with the standpipe oriented vertically. This orientation prevents the accumulation of condensate in the standpipe. This orientation will also ensure that loose parts cannot collect in the standpipe. The shear layer instability and vortex shedding associated with flow-excited acoustic resonances of the standpipe are local to the entrance region of the standpipe. The vortex acoustic coupling produces an in-out flow with rapid cycling (typically, over 100 Hertz for a relief valve), and so the likelihood of drawing a loose part in without it subsequently being driven out into the main steam line flow in the next half-cycle is very small. In order for the loose part to be drawn into the standpipe region, the loose part would have to be traveling along the top of the steam line past the standpipe opening, pass by the opening at the right time in the vortex cycle to be subjected to an upward drag force, and the vortex would have to be strong enough to lift the loose part up and out of the main flow stream. Given the flow velocities in the main steam line, it is unlikely that anything other than the very smallest pieces could be lifted up and out of the main stream and carried into the standpipe by the vortex. Once inside the standpipe, there is no force that will hold the loose piece in the standpipe where the fluid is stagnant; the cyclical nature of the vortex itself will tend to return the loose part to the main flow stream. Therefore, it is unlikely that the loose parts may be drawn into the standpipe by vortex shedding associated with flow-excited acoustic resonances in such a way that it can interfere with the SRV operation.

The response further stated that a few of the early plants may have SRVs mounted on a vertical run of the main steam line with the standpipe oriented horizontally. In this configuration, it is possible that a small loose part may come to rest in the horizontal section of the standpipe. However, in order for the shear layer instability and vortex shedding associated with flow-excited acoustic resonances to affect the trajectory of the loose part, the loose part would have to be traveling along the side of the steam line right next to the standpipe opening, at just the right time in the vortex cycle, and the part would have to be very small in order for the vortex to be able to deflect the part out of the main flow stream. It is unlikely that these conditions will be satisfied and, therefore, it is unlikely that the vortex shedding associated with flow-excited acoustic resonances will draw a loose part into the standpipe where it can interfere with the SRV operation. The NRC staff finds the response acceptable.

3.2.4 High Pressure Coolant Injection and Reactor Core Isolation Cooling

Sub-section 4.1.7 of the revised Section 4.0 discusses the potential for interference with the HPCI and RCIC operation, indicating that during normal operation, both systems are idle and stagnant, and no flow will draw loose parts into the system piping. Similar to the previous RAI, the NRC staff requested that the BWRVIP address whether loose parts could be drawn into the system piping when the shear layer at the opening to the HPCI and RCIC systems become unstable due to a higher flow of the main steam line because of acoustic resonance. The BWRVIP responded by stating that in order for the shear layer instability and vortex shedding associated with flow-excited acoustic resonances to affect the trajectory of the loose part, the loose part would have to travel along the side of the steam line right next to the HPCI or RCIC opening, at just the right time in the vortex cycle, and the part would have to be very small in order for the vortex to be able to deflect the part out of the main flow stream. It is unlikely that these conditions will be satisfied and, therefore, it is unlikely that the vortex shedding associated with flow-excited acoustic resonances will draw a loose part into the HPCI or RCIC where it can interfere with the HPCI or RCIC operation. The NRC staff finds the response acceptable.

3.2.5 Upper and Lower Tie Geometry

Sub-section 4.1 of the revised Section 4.0 stated that, "The geometry of certain parts and their components may be such that they would not be able to pass through the fuel bundle upper tie plate openings." Furthermore, while discussing potential for interference with control rod operation, sub-section 4.1.4 of the TR stated that, “The debris filter on the lower tie plates could stop even the smallest parts.” The NRC staff requested that the information regarding the fuel bundle upper tie plate openings and the mesh size for the debris filter on the lower tie plate be provided. In response, the BWRVIP provided upper tie plate pass through sizes for potential loose parts with rectangular, cylindrical, and square shapes for various GE Nuclear Fuel BWR fuel designs and other fuel designs (Westinghouse and AREVA) currently in use in BWRs. In addition, debris filter mesh opening sizes for GE fuel and other fuel designs (Westinghouse and AREVA) currently in use in BWRs were provided.

Based on the information provided, the NRC staff believes that installing debris filters will limit the size of the loose parts to pass through. However, the NRC staff agrees with BWRVIP that there is still a safety concern associated with the potential of a control rod to scram due to the presence of potential smaller loose parts. In the worst-case scenario, the accident analysis covers the condition of loose parts causing a single failure to scram a control rod. Therefore, this condition is unlikely to negatively affect safe shutdown and offsite dose.

3.2.6 Loose Parts History

The NRC staff noted that some licensees keep a list of loose parts from the beginning of operation of the plant. The NRC staff, therefore, recommended that the BWRVIP add a section in the TR to indicate that keeping an inventory and history of the loose parts (indicating the number, size, date the part was lost, and the date it was recovered) is a good practice to keep a track of the loose parts, per RAI 06-A-13. The BWRVIP agreed to modify revised Section 4.0 of BWRVIP-06-A to include statements to reflect that it is a good practice to keep an inventory and history of the loose parts including the number, the size, the date the part was lost, and the date it was recovered.

3.2.7 Regulatory Guide 1.133

The NRC staff requested the BWRVIP to reference RG 1.133, Revision 1, "Loose Parts Detection Program for the Primary Systems of Light Water Cooled Reactors," 1981, in the revised Section 4.0 of the BWRVIP-06-A TR. RG 1.133 describes a method acceptable to the NRC staff with respect to detecting a potentially safety-related loose part in light-water-cooled reactors during normal operation by installing a Loose Parts Monitoring System (LPMS). In response, the BWRVIP indicated that referencing RG 1.133 in the revised Section 4.0 of the BWRVIP-06-A TR would lead to confusion because a review of the operating history of the LPMS does not indicate significant differences in the impact or consequence of loose parts in the reactor coolant pressure boundary between plants with a LPMS, and those without. In an NRC letter dated January 25, 2001 (ADAMS Accession No. ML051110043), from S.A. Richards to J.M. Kenny (BWROG), “BWR Owners Group - Topical Report NEDC-32975(P), Regulatory Relaxation For BWR Loose Parts Monitoring Systems,” the NRC approved the regulatory relaxation of LPMS that were requested by the BWROG, TR NEDC-32975P, "Regulatory Relaxation for BWR Loose Parts Monitoring Systems," dated July 31, 2000 (ADAMS Accession No. ML003754771), and subsequent removal of the LPMS from other operating plants. The NRC staff approval and the associated design evaluation that defines the basis for NRC acceptance of regulatory relaxation of LPMS is available in ADAMS as Accession No. ML051110043. The NRC staff concluded that the safety benefits of the LPMS do not appear to be commensurate with the cost of maintenance and the associated radiation exposure for the plant personnel. The NRC staff agrees with BWRVIP and accepts that referencing RG 1.133, Revision 1, in TR BWRVIP-06-A is not necessary.

3.3 Radiation Release Limits

Sub-section 4.1.1.1 of the revised Section 4.0 specified 10 CFR Part 100 limits for off-gas radiation release. The NRC staff believed that the main concern that should have been addressed is as low as reasonably achievable (ALARA), and hence 10 CFR Part 20, "Standards for Protection Against Radiation," is applicable. The NRC staff requested that the BWRVIP address the application of 10 CFR Part 20 with regards to ALARA considerations. In response, the BWRVIP stated that the subject statement concerns the ability of the off-gas system to monitor and maintain off-site releases below plant-specific licensing limits to comply with 10 CFR Part 100 requirements. This is because one of the evaluation bases of the BWRVIP-06-A TR was "The capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposures comparable to the 10CFR100 guidelines." As a result, 10 CFR Part 100 was addressed in the TR.

The response further stated that all facilities are required to follow 10 CFR Part 20, "Standards for Protection Against Radiation," and are required to have an approved ALARA program for work at the facility, and it is expected that all work at the facility follows a procedure requiring that a necessary radiation survey to be completed prior to the start of any work in a radiation environment. With a completed radiation survey, the worker is expected to keep the work radiation exposure absorbed ALARA. In an ALARA program, the following four major ways are relied upon to reduce radiation exposure from any radioactive loose part to workers or to the population:

- Shielding: Use proper barriers to block or reduce ionizing radiation,
- Time: Spend less time in radiation fields,
- Distance: Increase distance between radioactive sources and workers or population, and
- Amount: Reduce the quantity of radioactive material for a practice.

Because plants are required to have an approved ALARA program, and are required to follow the program to minimize radiation exposure, the NRC staff finds the above response acceptable.

3.4 Loose Parts and Corrosion Issues

Section 4.1.6 of the revised Section 4.0 of TR BWRVIP-06-A addresses potential corrosion that could be caused in the RVIs by the presence of loose parts. The NRC staff agrees with the BWRVIP's contention that corrosion of RVI components due to loose parts is not a concern because the materials used for the RVI components are the same as the materials in loose parts. Consequently, general corrosion should not take place in RVIs. However, localized crevice corrosion can occur as a result of a potential crevice condition caused by a loose part lodged on top of any RVI. By letter dated December 21, 2006 (ADAMS Accession No. ML070030188), the NRC staff requested that the BWRVIP address possible crevice corrosion due to the presence of a crevice created between a lodged loose part and the RVI. Crevice corrosion can be more pronounced in RVIs where effective protection due to hydrogen water chemistry and/or noble metal chemical addition is not available and when the reactor water flow is stagnant. By letter dated November 30, 2007 (ADAMS Accession No. ML073410041), the BWRVIP stated that the tight deep crevices with susceptible microstructures are more prone to crevice corrosion when they are subject to applied stresses during normal operating conditions. The BWRVIP reiterated that plant experience indicates that there are many examples where one of these factors is present and yet no crevice corrosion has been observed. For example, a bolted structure does have a crevice at the thread root location. However, in the absence of any susceptible microstructure (sensitized) such as the one that is typically present in the heat affected zone of a weld joint, thus far, no crevice corrosion was observed. A postulated loose part may not be susceptible to crevice corrosion mainly due to the absence of stress or susceptible microstructure or cold work. Additionally, an existing loose part may not have a tight crevice because it is not mechanically attached to a RVI. Based on the above, the BWRVIP concluded that there is no concern regarding the onset of crevice corrosion in RVI components as a result of a loose part.

The NRC staff reviewed the BWRVIP response and concludes that the BWRVIP response is acceptable because: (1) plant experience does substantiate the claim that, thus far, no failures due to crevice corrosion has occurred in non-welded areas (i.e., bolts); (2) absence of any tight crevice between the loose part and the RVI minimizes the chances of crevice corrosion; (3) no susceptible microstructure exists in a loose part as it does not contain any weld and consequently, no sensitized heat affected zone exists and, (4) lack of crevice corrosion in non-welded RVIs (i.e., bolts) suggest that effect of cold work may not play a major role in crevice corrosion.

Based on the above evaluation, the NRC staff concludes that it is less likely that crevice corrosion will occur in RVI components as a result of loose parts. Therefore, the NRC staff considers that its concern is resolved when the BWRVIP includes its RAI response related to the corrosion issue in the "A" version of the revised Section 4.0 of TR BWRVIP-06-A.

4.0 LIMITATIONS AND CONDITIONS

When referencing the revised Section 4.0 of TR BWRVIP-06-A in licensing applications, the following limitations and conditions shall apply:

1. The conclusions of the safety assessment documented in the revised Section 4.0 of BWRVIP-06-A report shall apply only to BWR/2-6 plants.

2. Because the evaluation provided in TR BWRVIP-06-A is general in nature and does not assess the effects on the basis of individual geometries or material properties, as these are resolved on a case-by-case basis, and because several plant-specific features can determine the acceptable loose part size limits for safety and operational concerns, TR BWRVIP-06-A and the SE for revised Section 4.0 provide only general criteria for acceptability of loose parts in operating BWR/2-6 plants. Plant-specific safety assessment is, therefore, required to be performed by a licensee in the event loose parts are detected in its plant.

3. The NRC staff considers that its concern related to corrosion is resolved when the BWRVIP includes its RAI response related to the corrosion issue discussed in Section 3.4 of this SE in the "A" version of the revised Section 4.0 of TR BWRVIP-06-A.

4. The BWRVIP agreed to modify revised Section 4.0 of BWRVIP-06-A to include statements to reflect that it is a good practice to keep an inventory and history of the loose parts including the number, the size, the date the part was lost, and the date it was recovered in the "A" version of the TR.

5.0 CONCLUSION

The BWRVIP evaluation as described in revised Section 4.0 of TR BWRVIP-06-A shows that safe reactor operation and safe shutdown capability are not compromised for most categories of postulated loose part sizes. Based on the operating experience of BWRs, larger and heavier parts like pieces of a jet pump beam or plate from a steam dryer have not negatively affected safe shutdown or offsite dose. While it is possible for loose parts, with particular size and shape, to compromise fuel performance, it is extremely unlikely that such loose parts would result from the failure of RVIs. If it were to occur, damage would likely be limited to a single fuel bundle, which would be detected by routine monitoring of the off-gas monitors or LPRMs. As a result, there is no significant safety concern from potential loose parts on fuel. In addition, there is no safety concern for interference with MSIVs, control rod operation, damage to reactor internals, corrosion or chemical reaction with other reactor materials, interference with HPCI or RCIC operation, RWCU or RHR isolation valves, nuclear instrumentation, and RHR pumps and heat exchangers. There could be some possible operating concerns from the potential loose part(s) with regard to fuel fretting, bottom head drain plugging, and recirculation system performance, but none of these are expected to negatively affect safe shutdown or increase in off-site dose.

The NRC staff concludes that the generic safety assessment provided in revised Section 4.0 of BWRVIP-06-A is applicable only for BWR/2-6 reactor internals. The evaluation provided in the TR is general in nature and does not assess the effects on the basis of individual part geometries or material properties, as these are resolved on a case-by-case basis. In addition, several plant-specific features can determine the acceptable loose part size limits for safety and operational concerns. As a result, the NRC staff also concludes that this SE provides only general criteria for acceptability of loose parts in operating BWR/2-6 plants, and that a plant-specific safety assessment is required to be performed by the licensee in the event of loose parts being detected.

The NRC staff, therefore, finds the revised Section 4.0 of the BWRVIP-06-A TR acceptable for referencing, subject to the limitations and conditions identified in this SE.

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