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LTR-NRC-21-33

October 13, 2021

Subject: NSAL-20-1 Revision 1, "Reactor Vessel Head Control Rod Drive Mechanism Penetration Thermal Sleeve Cross-Sectional Failure"

Westinghouse Letter LTR-NRC-20-12 (ML20063J583), dated March 2, 2020, transmitted Nuclear Safety Advisory Letter (NSAL) NSAL-20-1, Revision 0, "Reactor Vessel Head Control Rod Drive Mechanism Penetration Thermal Sleeve Cross-Sectional Failure". Based on additional work performed by the Pressurized Water Reactor Owners Group (PWROG), NSAL-20-1 was revised and distributed to our utility customers in late September and is attached for your information.

Camille T. Zozula, Manager
Regulatory Compliance and Corporate Licensing

Attachment: NSAL-20-1, Revision 1

cc: Allen Hiser (NRC)
Kate Lenning (NRC)
Leslie Fields (NRC)
Jim Medoff (NRC)
David Rudland (NRC)
Rob Tregoning (NRC)

Westinghouse

Nuclear Safety Advisory Letter

This is a notification of a recently identified potential safety issue pertaining to basic components supplied by Westinghouse.
This information is being provided so that you can conduct a review of this issue to determine if any action is required.

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Subject: **Reactor Vessel Head Control Rod Drive Mechanism Penetration Thermal Sleeve Cross-Sectional Failure**	Number: **NSAL-20-1 Revision 1**
Basic Component: Thermal Sleeve in CRDM Reactor Head Penetration	Date: September 23, 2021
Substantial Safety Hazard or Failure to Comply Pursuant to 10 CFR 21.21(a)	Yes ☐ No ☒ N/A ☐
Transfer of Information Pursuant to 10 CFR 21.21(b)	Yes ☐
Advisory Information Pursuant to 10 CFR 21.21(d)(2)	Yes ☐

SUMMARY

Operating experience (OE) in 2019 showed that Westinghouse nuclear steam supply system (NSSS) plants that operate in a T-cold configuration and have control rod drive mechanism (CRDM) penetration thermal sleeves with a collar below the flange (Figure 2), are susceptible to cracking and separation of the flange from the sleeve. This separated condition, when combined with the type of flange wear discussed in NSAL-18-1 [1], was conservatively assumed to be capable of impeding control rod movement and Rod Cluster Control Assembly (RCCA) insertability. In accordance with 10 CFR Part 21, Westinghouse identified this to be a potential defect and reported it to the U.S. NRC [2] on December 12, 2019.

Revision 1 of this NSAL revises this position that CRDM penetration thermal sleeve flange separation due to cross-sectional fracture at the flange collar is a reportable defect. This revision summarizes the latest technical evaluation given in PWROG-21010-P [6], removes the inspection recommendations, and clarifies that CRDM thermal sleeve cross-sectional failures at the flange collar cannot create a substantial safety hazard.

Additional information, if required, may be obtained from Bryan Wilson, (412) 374-3281

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*Electronically approved records are authenticated in the electronic document management system

ISSUE DESCRIPTION

During a planned 2019 refueling outage at a Westinghouse NSSS plant, a thermal sleeve (Figure 1) was observed to be fractured and resting upon an upper internals upper guide tube (UGT). The OE showed that a mechanical failure of the thermal sleeve had occurred across its cross-section. The failure mechanism was different from the thermal sleeve flange wear discussed in NSAL-18-1 and TB-07-2, Revision 3 [3]. The fracture occurred beneath the “collar” (illustrated in Figure 2) which is present on a subset of thermal sleeves supplied by Westinghouse (The affected plant was operating with its original reactor vessel closure head [RVCH] and CRDM thermal sleeves.)

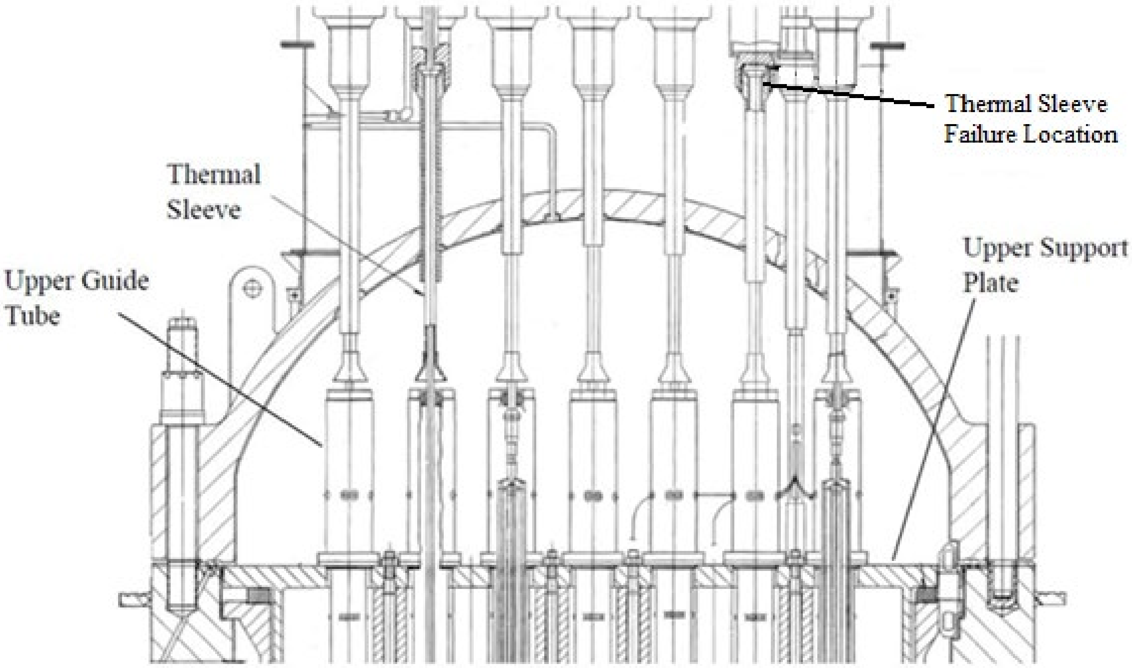

Figure 1 Thermal Sleeve Location in the RVCH

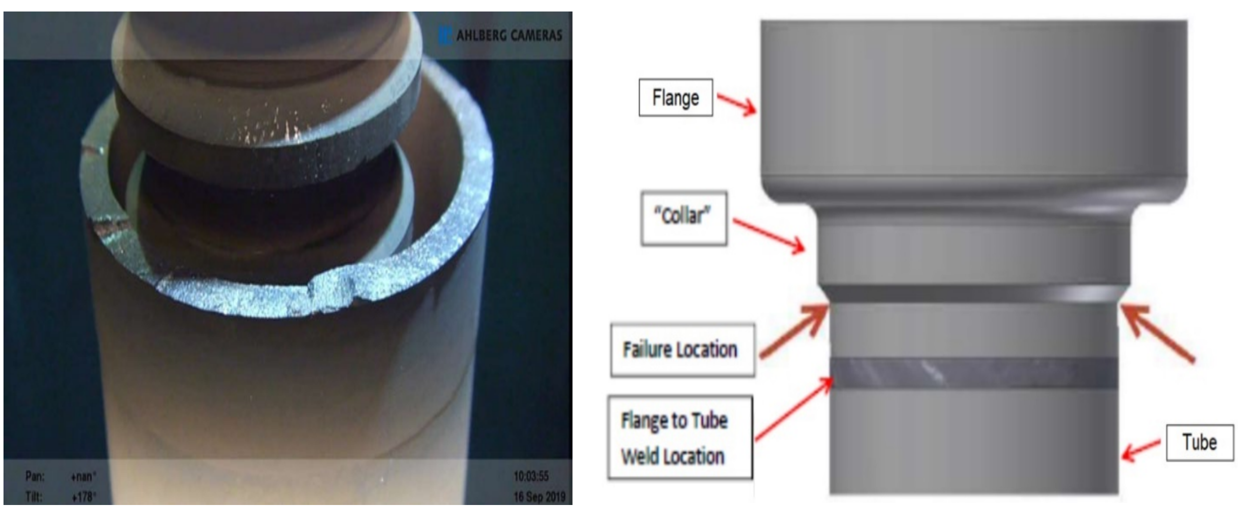

Figure 2 Thermal Sleeve Flange Failure Location

The utility performed extent of condition inspections on the remaining thermal sleeves at the affected plant as well as on a second plant at the same site. Both plants have the same thermal sleeve design. The inspections were performed via visual examination of the inner surface of the thermal sleeve. A total of thirteen thermal sleeve locations (twelve at the first unit and one at the second) had visible crack-like indications, as shown in Figure 3. No additional locations had failed. The locations of the affected sleeves were distributed throughout the RVCH, with a higher concentration of cracked sleeves toward the center of the head. Crack-like indications of varying lengths were identified with no correlation to the amount of flange wear experienced. The affected utility did not identify any issues associated with drive rod movement during operation prior to identifying the failure.

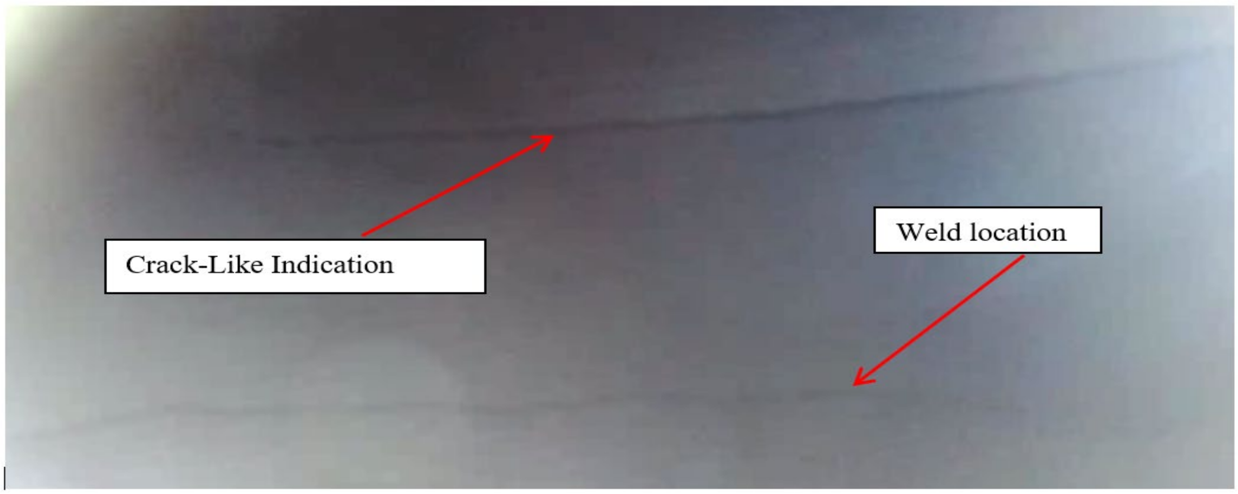

Figure 3 Crack-Like Indication Identified by Visual Inspection

TECHNICAL EVALUATION

2019 Operating Experience

In response to this OE, the affected utility performed a causal analysis with support from Westinghouse. Based on metallurgical examination of the separated sleeve, the analysis concluded that the most likely cause of failure was fatigue crack propagation. The analysis identified the transition between the collar and the tubular section on the outer diameter of the thermal sleeve to be a potential contributor, due to the stress concentration resulting from the tube wall thickness transition and potentially sharp transition radius in this location; however, this was not substantiated through the identification of a crack initiation site. These results were later corroborated through an industry-backed examination of the fractured part. This examination identified multiple initiation locations without a clear initiation mechanism.

Thermal sleeve designs without the collar have a large, controlled transition radius between the tubular section and the flange. This transition results in a much lower stress concentration, which is less susceptible to this failure mechanism. Therefore, plants operating with thermal sleeve designs without a collar below the flange are not included in Table 1.

The causal analysis also identified the loading, more specifically flow-induced vibration (FIV), as a potential contributor to the cracking and failure. Plants with higher head bypass flow, referred to as "T-cold" head plants, tend to produce more significant FIV loads on the thermal sleeves as compared to plants with lower head bypass flow, referred to as "T-hot" head plants. This is evidenced by T-cold head plants consistently experiencing a greater amount of thermal sleeve wear [3]. As such, it is anticipated that T-cold head plants will have much greater susceptibility to this issue than T-hot head plants.

In certain conditions in which the CRDM housing is worn (as discussed in NSAL-18-1) and the thermal sleeve flange is separated from the sleeve, the flange remnant can move from its normal position and become misoriented at the top of the CRDM housing. Evaluations of this misorientation were conducted in support of Revision 0 of this NSAL and included a simplifying assumption that the drive rod could radially deflect far enough within the thermal sleeve and penetration housing assembly to permit the separated flange remnant to orient itself such that wedging could occur, as depicted in Figure 4.

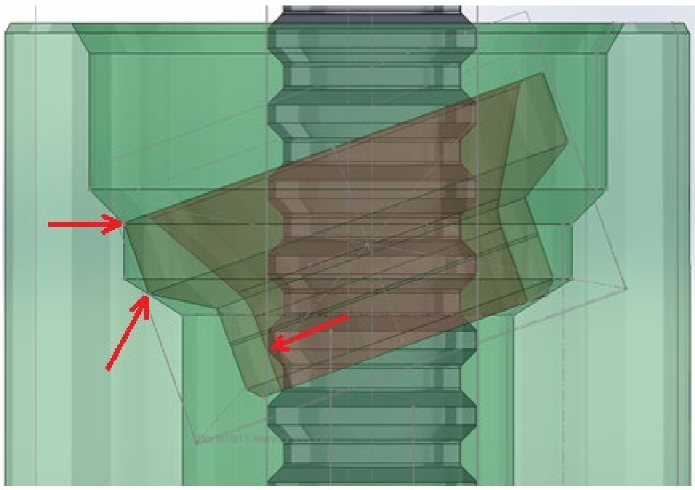

Figure 4 Potential Flange Wedging Scenario

Additional Technical Evaluation

The simplifying assumption and other geometric constraints were evaluated in PWROG-21010-P to determine the feasibility of this potential wedging scenario. It was determined that applicable forces and geometric constraints would not permit the drive rod to deflect far enough in the radial direction to allow wedging to occur. Moreover, the flange wear lowering criterion (i.e., the 0.80 inch lowering criterion) discussed in Revision 0 of this NSAL is no longer applicable as wedging cannot occur associated with a thermal sleeve that has fractured and separated at the collar, regardless of the amount of flange wear.

While thermal sleeve flange cross-sectional fractures at the collar are no longer determined to be a credible interference mechanism that could impact control rod movement and RCCA insertability, thermal sleeve wear and flange wear, cracking, and separation can still occur. The evaluation from PWROG-21010-P determined thermal sleeve fracture and separation at the collar does not adversely impact the primary design functions of thermal sleeves, however it does present an asset management consideration for utilities.

SAFETY SIGNIFICANCE

The evaluation documented in PWROG-21010-P concluded that CRDM thermal sleeve separation at the flange collar, as discussed herein, cannot impede control rod movement or RCCA insertability. Therefore, this failure scenario cannot create a substantial safety hazard.

Inactive CRDM locations and unrodded thermal sleeve locations do not contain drive rods which can be impeded by separation of the thermal sleeve. A fractured and separated thermal sleeve at one of these locations does not create a condition that impacts adjacent or nearby rodded locations. Therefore, thermal sleeve separation at one of these locations does not have the potential to result in a substantial safety hazard.

Furthermore, this issue does not result in a loose part in the RCS. The thermal sleeve flange remnant would be captured by the geometry of the drive rod, the penetration housing, and the fallen lower portion of the thermal sleeve (which is captured by the drive rod, penetration housing, and the control rod guide tube housing plate).

CRDM thermal sleeve flange wear, as identified in NSAL-18-1, continues to have the potential to create a substantial safety hazard and was reported in LTR-NRC-18-34 [4]. Thermal sleeve flange wear is discussed in PWROG-16003-P [5] which contains the associated NEI 03-08 guidance.

AFFECTED PLANTS

The potentially affected Westinghouse NSSS plants listed in Table 1 are those that:

- Operate with higher upper head bypass flow conditions, known as T-cold head plants.
- Operate with thermal sleeves containing a collar just below the flange (see Figure 2).

Table 1: T-cold Plants Susceptible to Thermal Sleeve Cracking and Flange Wear

Asco 2	Comanche Peak 1 & 2	Seabrook
Braidwood 1 & 2	Doel 4*†	Sizewell B*
Byron 1 & 2	Hanbit 1 & 2	Tihange 3*†
Callaway*	Kori 3 & 4	Vogtle 1 & 2
Catawba 1 & 2	Maanshan 1 & 2	Wolf Creek

(*) Replacement RVCH is not designed by Westinghouse. The thermal sleeves supplied with the original RVCH featured the collar design. If a like-for-like replacement of the thermal sleeves was performed, it is possible that the issue described in this NSAL could apply. It is recommended that these plants contact their replacement head supplier to evaluate applicability.

(†) T-hot head but T-cold capable. These plants are a hybrid of T-hot and T-cold due to some head spray cooling nozzles being plugged and some being open. In this configuration it is uncertain whether the local flow conditions are similar to those of a T-cold head; therefore, these plants are conservatively assumed to have a higher susceptibility to this issue than a standard T-hot plant.

NRC AWARENESS

The issue was determined to be a potential substantial safety hazard and was reported to the NRC by Westinghouse [2] in 2019. As a result of work performed in PWROG-21010-P, Westinghouse no longer considers CRDM thermal sleeve separation at the flange collar to be a reportable defect. CRDM thermal sleeve flange wear continues to have the potential to create a substantial safety hazard, as identified in NSAL-18-1.

RECOMMENDED ACTIONS

The recommendations from Revision 0 of this NSAL were focused on minimizing the risk to nuclear safety. Based on new information documented in PWROG-21010-P, the NSAL recommendations have been re-focused. The recommendation is that affected plants address CRDM thermal sleeve separation at the flange collar as an asset management issue.

REFERENCES

1. Westinghouse Nuclear Safety Advisory Letter NSAL-18-1, "Thermal Sleeve Flange Wear Leads to Stuck Control Rod," July 9, 2018.
2. Westinghouse Letter LTR-NRC-19-79, "Notification of the Potential Existence of Defect Pursuant to 10 CFR Part 21," December 12, 2019 [NRC Accession Number ML19346H873].
3. Westinghouse Technical Bulletin TB-07-2, Rev. 3, "Reactor Vessel Head Adapter Thermal Sleeve Wear," December 7, 2015.
4. Westinghouse Letter LTR-NRC-18-34, "Notification of the Potential Existence of Defects Pursuant to 10 CFR Part 21," May 23, 2018 [NRC Accession Number ML18143B678].
5. Pressurized Water Reactor Owners Group Report PWROG-16003-P, Rev. 2, "Evaluation of Potential Thermal Sleeve Flange Wear," May 2019.
6. Westinghouse Pressurized Water Reactor Owners Group Report, PWROG-21010-P, Rev. 0, "Evaluation of Fractured Thermal Sleeve Remnant Wedging Scenario," July 31, 2021.

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