Issue 109: Reactor Vessel Closure Failure

DESCRIPTION

Historical Background

Potential stress corrosion cracking (SCC) of reactor vessel (RV) closure studs was raised as a GSI in December

1984.[1] Concerns were expressed that two contributors to SCC had not been subject to careful research and evaluation: (1) inappropriate stud tensions; and (2) improper cleaning of dye penetrant following NDT.

It is generally acknowledged that three contributors are necessary to produce SCC in materials: (1) the materials must be susceptible to SCC; (2) the materials must be under stress of sufficient magnitude (threshold) to sustain SCC; and (3) the environment must be conducive to SCC. Where the three conditions exist simultaneously, SCC will occur. Conversely, if one of the above three contributors is eliminated, then SCC is also eliminated.

The RV closure head is a flanged hemispherical component bolted to the vessel by as many as sixty large threaded studs having diameters ranging up to ten inches. The number of head closure studs and their diameter are plant-specific. The head flange is sealed to the vessel flange by two concentric, self-energizing, metallic

O-Rings positioned inboard of the bolt circle. Seal leakage can be detected by leakoff connections between the O-Rings. The RV head leakoff system is instrumented and will alarm in the control room. Plant TS require monitoring of the reactor head flange leakoff system at least once every 24 hours. If any pressure boundary leakage is detected, a plant is required to be in hot standby within 6 hours and in cold shutdown within the following 30 hours. The preload developed in the studs must hold the vessel sealed at operating temperatures and pressures.

The preload tool used to tension the studs is a hydraulic device which typically tensions two to eight studs simultaneously. However, it is possible to buy tools that tension greater numbers of studs. The tensioning is performed using a two- or three-pass procedure. During the basic pass, the tensioner hydraulic pressure is set, each stud is pulled, and the nut run down. Usually, no elongation measurements are made during a basic pass. Some procedures reduce the hydraulic pressure as the pass progresses around the head. After the

required number of basic passes, the stud elongation is measured and studs found outside of specifications are corrected. The preload is thus controlled by the elongation in the studs.

The stud-tensioning (preload) procedures are developed and written by the equipment manufacturers. However, each licensee usually makes minor, plantspecific changes to fine-tune the manufacturer's procedures to suit

its plant. A plant survey[2] conducted by EPRI showed that improved tension devices were considered by licensees to reduce the tensioning time. One manufacturer visited during the 1981 survey reported that over 30 new installations of quick-disconnect tensioners had been made.

The RV closure studs are subject to more rigorous design and materials selection requirements than any other fasteners in nuclear power plants. In addition, the plant TS on leakage control provide defense-in-depth in assuring sufficient preload to minimize leakage that may contribute to environmental conditions

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[1] Memorandum for W. Minners from F. Rowsome, "A Candidate Generic Issue," December 11, 1984. [8501080138]

[2] EPRI NP-2174, "A Study of Bolting Problems, Tools, and Practices in the Nuclear Industry," Electric Power Research Institute, December 1981.

that lead to boron corrosion (wastage) or SCC.

The existing regulations in 10 CFR 50 that relate to the RV head closure studs are:

Section 50.55a addresses quality standards for design, determination, and monitoring of fracture toughness;

GDC 1 and 30 address quality standards for design, fabrication, erection, and testing of structures, systems, and components;

GDC 4 addresses compatibility of components with environmental conditions;

GDC 14 addresses prevention of rapidly propagating fractures of the reactor coolant pressure boundary; GDC 31 addresses material fracture toughness;

GDC 32 addresses the requirements for a materials surveillance program; Appendix B addresses onsite material cleaning control.

Additional guidance on interpretation of the regulations and methods by which the staff reviews the acceptability

of RV materials (including reactor vessel fasteners) are provided in SRP[3] Section 5.3.1, "Reactor Vessel Materials."

To further assure that the RV closure studs provide safe bolting between the RV head and the RV body,

Regulatory Guide 1.65[4] provides guidance that is specific to these components. The regulatory position is that the RV closure studs must meet the requirements of the ASME III Code and additional requirements, as specified in the guide. These additional requirements pertain to specific selection of materials that are highly resistant to SCC, use of lubricants that are stable and compatible with the materials and surrounding

environment, inspection requirements, and guidance on protection against corrosion and contamination during venting and filling the RV while the head is removed.

There are currently no specific regulatory requirements on the preloading methods or procedures to be used in plant bolting applications or fastening the head to the RV other than adherence to the ASME Code requirements

and guidelines. Studies[5,6] have shown that there are problems in the various methods used to preload bolts and studs and that the current ASME guidance is not adequate. However, when compared to other bolting applications, the RV closure studs have received considerable interest and their associated tools and

procedures are generally the most advanced at any plant.[7]

Studies and test results reported in EPRI RP 2520-7[8] showed that the methods used for preloading the RV closure studs (hydraulic tensioning and stretch elongation measurements) were the most precise of the

various methods evaluated. Three of the four methods tested and evaluated fell within a 95% confidence level of providing the desired preload. However, the stretch measurement method had a coefficient of variation of approximately one-third that of the other two methods that met the 95% confidence level.

Safety Significance

Common cause failure of the RV closure studs could constitute a LOCA beyond the capability of the ECCS makeup capacity. The sudden release of energy that could be experienced if all the RV closure studs fail simultaneously may also threaten containment integrity. In such a scenario, the RV head could be propelled upward as a missile, impact with the containment dome, and breach the containment barrier. The resulting core- melt and radioactive release would then yield a high consequence accident and pose

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[3] NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, (1st Ed.) November 1975, (2nd Ed.) March 1980, (3rd Ed.) July 1981.

[4] Regulatory Guide 1.65, "Materials and Inspections for Reactor Vessel Closure Studs," U.S. Atomic Energy Commission, October 1973. [7907100246]

[5] EPRI RP 2520-7, "Degradation and Failure of Bolting in Nuclear Power Plants," Electric Power Research Institute, June 1987.

[6] EPRI NP-2174, "A Study of Bolting Problems, Tools, and Practices in the Nuclear Industry," Electric Power Research Institute, December 1981.

[7] EPRI NP-2174, "A Study of Bolting Problems, Tools, and Practices in the Nuclear Industry," Electric Power Research Institute, December 1981.

[8] EPRI RP 2520-7, "Degradation and Failure of Bolting in Nuclear Power Plants," Electric Power Research Institute, June 1987.

a significant risk to the public.

Possible Solution

In response to the industry concerns on bolting failures in other applications and Issue 29, "Bolting Degradation or Failure in Nuclear Power Plants," industry bolting practices were developed by the Atomic Industrial Forum/ Materials Properties Council (AIF/MPC) Task Group on Bolting and the Generic Bolt Joint Integrity research project. These practices may provide additional guidance that could be applicable to RV studs. This additional guidance deals with strength limits, lubricants, NDE, fracture mechanics analysis of threaded cylinders, and training films and classes on preload applications.

CONCLUSION

Studies on bolting tools and practices[9,10] have revealed that the preload methods and procedures for bolting in general are not adequately treated in the ASME Codes cited in the regulations in 10 CFR 50.

However, the methods used to preload the RV closure studs have received considerably more attention at plants than other bolting applications. Nevertheless, studies have concluded that all bolting applications could be significantly improved with refined procedures and better training.

The absence of any identified SCC in RV closure studs in conformance with existing requirements and guidelines, over approximately 1000 RY of operations, appears to indicate that the current regulations have been highly effective in assuring good design principles and materials selection for the RV closure studs. (See

References [11, 12, and 13].) Therefore, this issue was DROPPED from further consideration.

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[9] EPRI RP 2520-7, "Degradation and Failure of Bolting in Nuclear Power Plants," Electric Power Research Institute, June 1987.
[10] EPRI NP-2174, "A Study of Bolting Problems, Tools, and Practices in the Nuclear Industry," Electric Power Research Institute, December 1981.
[11] NUREG-0943, "Threaded-Fastener Experience in Nuclear Power Plants," U.S. Nuclear Regulatory Commission, January 1983.
[12] EPRI NP-3784, "A Survey of the Literature on Low- Alloy Steel Fastener Corrosion in PWR Power Plants," Electric Power Research Institute, December 1984.
[13] EPRI RP 2520-7, "Degradation and Failure of Bolting in Nuclear Power Plants," Electric Power Research Institute, June 1987.