

Delivering the Nuclear Promise Top Innovative Practice



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First Ever Clevis Insert Bolt Ultrasonic Testing Inspection 2023 Top Innovative Practice Winner¹

Summary

Dominion Energy developed and implemented ultrasonic testing (UT) inspections of the Surry Unit 1 clevis insert bolts during the November 2022 outage. This addresses a widespread aging issue across the fleet. Dominion was the first to take this step in the U.S. fleet, before it became an industry requirement on July 1, 2023. Dominion Energy contracted Framatome to develop the inspection tooling and UT technique that were successfully deployed. Presentations have been made at industry working events to enable other utilities to benefit from Dominion Energy's commitment to safe, cost-effective component management. Other utilities are now following the lead of Dominion Energy and choosing to inspect clevis insert bolts rather than replace them.

Innovation

This first-of-a-kind (FOAK) tooling and technique were developed to perform remote UT examination of the clevis insert bolts under 70 feet of water. Other bolting UT inspections have been performed in the industry but not on the clevis insert configuration in its challenging location.

Background

This TIP Award details the successful FOAK process for inspecting clevis insert bolts, avoiding replacement cost, minimizing radiation exposure, and ensuring safe reactor operation. Clevis insert bolt UT examinations are an option for implementing an industry requirement per NEI 03-08.² Many utilities had planned to replace their clevis insert bolts due to the difficult bolt inspection configuration and challenging bolt locations. In the interest of cost, person-hour, and dose savings, Dominion Energy decided to explore the possibility of performing a UT examination of the clevis insert bolts instead of replacement.

Each lower radial support includes a keyed component attached to the lower end of the lower internals assembly and a mating clevis component mounted to a pair of lugs on the reactor vessel. The clevis component on the vessel side of the lower radial support consists of one insert attached to the lugs. See Figure 1 for an image of the lower radial support, clevis insert and insert bolting. The keyed component engages the mating insert/lug assembly during lower internals installation. Utilities perform inspections of the internals as specified in Section XI of the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME) Code. The EPRI Materials Reliability Program (MRP) evaluated the damage mechanisms that could possibly occur over time

¹ Winning entries of from NEI's Top Innovative Practices (TIP) awards are republished as DNP Efficiency Opportunities to ensure the broadest possible dissemination of these operating plant innovations.

²² NEI 03-08, Guideline for Management of Materials Issues.

and identified appropriate reactor internals examinations required to manage aging degradation effects as defined in EPRI report MRP-227.³

Examinations required by MRP-227 are intended to identify any potential failure mechanisms. Gathering, documenting, quantifying, and validating the inspection data in a timely fashion while ensuring strict adherence to nuclear and industrial safety standards are critical to support business plan goals for any operating unit. Based on recent operating experience and guidance issued by the PWR Owners Group, it became a priority for utilities to plan for clevis insert bolt inspections. The PWR Owners Group put the PWR Lower Radial Support Clevis Insert (X-750) Bolt into an NEI 03-08 "Needed" guidance status per letter OG-21-160, dated September 1, 2021. Utilities are required to take action during their "next scheduled core barrel pull after July 1, 2023, or prior to 55 calendar years of plant operation - whichever comes first." This guidance provides three options:

1. Proactive replacement of clevis insert bolts
2. UT examination with contingency for bolt replacement
3. UT examination with contingency operability assessment

As a result, Dominion Energy asked Framatome to develop a comprehensive tooling package for future clevis insert bolt examinations. Framatome adapted the UT probe and probe holder to the unique locking bar and attachment welds which made seating of the UT probe difficult. See Figure 2 for a typical clevis insert bolt, locking bar and attachment welds.

The UT probe is delivered to the clevis insert bolt head via a modified stable tool delivery system. Key features include:

- Rapid pole deployment / movement of the mast
- Remotely operated from outside containment
- High radiation-tolerant cameras with built-in lights for UT and/or visual testing (VT) examinations
- Encoded-motorized, multi-axis end effector to position the UT transducer accurately on the bolt head

The clevis insert bolt qualification process consists of the following:

- A Technical Justification is prepared in accordance with bolting UT qualification requirements of MRP-228⁴
- A set of bolt mockups that include a range of flaw depths, orientations, and positions along the bolt length are fabricated to support the procedure and personnel qualifications. See Figure 3 for an illustration of the bolting mockup flaw orientations and locations
- Blind procedure qualification is performed to confirm that flaws of $\geq 20\%$ cross-sectional area are reliably detected and characterized from the head-to-shank through the lower threaded region of the bolt
- Full mockup procedure and personnel demonstrations/training are performed at the Framatome Technical Training Center

³ See Electric Power Research Institute report MRP-227, Revision 1-A, "Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines", for example.

⁴ Electric Power Research Institute report MRP-228, Revision 4, "Materials Reliability Program: Inspection Standard for Pressurized Water Reactor Internals—2020 Update", available at <https://www.nrc.gov/docs/ML2101/ML21019A003.pdf>.

Safety

The examinations were developed to ensure that the aging clevis insert bolts could continue to perform their intended nuclear safety function. The team developed remotely operated tooling to ensure that personnel could perform the examinations from outside containment for radiological and industrial safety. No safety issues, personnel contaminations events, or human performance errors were experienced in completing the FOAK clevis bolt examination. The team concentrated on several key design requirements to safely perform the inspection:

- Robust tool design/components
- Easy installation and removal
- Remotely controlled with minimal reactor building support

The examination tooling was installed and control was turned over to the personnel outside containment. Minimal personnel were required to be in the reactor building during these exams. With the older examination techniques, examination tooling had to be manually delivered off poles and ropes by multiple people standing on bridges over these high dose components. These evolutions are typically time-consuming and dose-intensive to inspection personnel. In addition, tool features such as fully remote, encoded, and on-board cameras supported the safe delivery and operation of the tool.

The safe execution of the clevis insert bolt inspection tooling was a direct result of Dominion Energy's and Framatome's commitment to safety and operational excellence. The team properly developed the product to meet the anticipated MRP requirements, but just as important, the team focused on proper delivery. Both Dominion Energy and Framatome supported extensive planning, testing, training, and design reviews and demonstrations. A mockup was designed and fabricated that replicated the exact configuration of the clevis insert and bolts that was used to qualify the tooling and train personnel for safe installation and operation.

Cost Savings

The total cost savings to Dominion Energy for the Surry Units 1 and 2 inspections using the new clevis insert bolt inspection tooling was approximately \$13 million versus having to perform clevis insert bolt replacement. The per unit cost savings were a result of the following:

- Bolt inspection versus replacement cost - \$3.3M saved per outage
- At least four days of critical path time saved, equating to \$3.2 million saved per outage⁵

Productivity/Efficiency

Approximately 13.6 person-weeks of time savings were realized by reducing the number of people required to address the clevis insert bolt potential degradation issue by performing examination instead of repair. The new Framatome inspection tooling and techniques were successfully deployed to complete the clevis insert bolt examination in a little over one shift versus a critical path impact of 6 days or more for repair. The total exam time for 32 bolts was 13.5 hours compared to the anticipated schedule of 24 hours:

- For replacement (12 people x 24 hrs x 10 days = 2880 person-hours, 120 person-days, or 17 person-weeks.
- For inspection (6 people x 24 hrs x 4 days = 576 person-hours, 24 person-days, or 3.4 person-weeks.

⁵ Based on average replacement power costs of \$800k per day.

- Total man-week savings realized: $17 - 3.4 = 13.6$ person-weeks.

Transferability

This technology is transferable to all Westinghouse and CE model PWR nuclear power plants in the United States and other parts of the world. The probe delivery platform has proven very adaptable and further developments using this innovative bolt inspection technique are expected. Framatome continues to explore the possibilities of this innovative bolt inspection tooling and technique and continues to increase the versatility of this trend setting tooling.

Team Members

- Kevin J. Hacker, Principal NDE Specialist
- Timothy Hanna, Consulting Engineer
- Michael Eustice, Sr. NDE Specialist
- Chris Enroughty, Project Manager
- Brad Thigpen, Framatome Level III

Additional Information

Figure 1 - Lower Radial Support Clevis and Insert



Figure 2 – Typical External Hex Clevis Insert Bolt with Locking Bar and Excessive Weld Material



Figure 3 – Typical Clevis Insert Bolt Qualification Mockup

