INSPECTION AND REPLACEMENT OF BAFFLE FORMER BOLTS IN VVER-440 REACTOR TYPE

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ABSTRACT

Reactor vessel internals are structures located within the reactor vessel that support and orient the reactor fuel assemblies and direct coolant flow through the core. The core basket is part of the internals structure which consists of vertical plates that surround the outer faces of the hexagonal peripheral fuel assemblies. The vertical plates are bolted to the edges of horizontal former plates that are bolted to the inside surface of the core basket. There are typically four levels of former plates located at various elevations within the core basket of a VVER-440 reactor. The bolts that secure the baffle plates to the former plates are referred to as "baffle former bolts."

Nuclear power plants identified the cracking of baffle former bolts as early as 1988 and this problem continues to occur. Although this cracking is not fully understood, testing of cracked bolts suggests an age-related intergranular stress-corrosion cracking process influenced by bolt material fluence, stress, and temperature.

Inspection and replacement of baffle former bolts have been carried out successfully at the Loviisa NPP Unit 2 in early September 2003. In particular, this is the first time that bolts replacement is performed in a VVER-440 reactor type. Ultrasonic testing was used to assess the integrity of the baffle former bolts. Subsequently some defective bolts were replaced with a remotely controlled underwater manipulator system as a preventive maintenance measure. This work is a further step in the application of a complex Western PWR technology to VVER reactors type.

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INTRODUCTION

In several inspections performed in the 1980s cracks were discovered in the baffle bolts of PWRs. Some baffle bolts were extracted for metallurgical examinations and the phenomenon was attributed to irradiation assisted stress corrosion cracking (IASCC) [2]. For example, in France [3 4] cracked baffle bolts were found in the CP0 type units. Between 2000 and 2003 complete functional repairs were carried out on three CP0 units with the replacement of 1/3 of the bolts.

In addition to the irradiation dose level there are other factors that might have some influence in the performance of the bolts such as down-flow or up-flow design differences in the cooling of the bolts and differences in geometry and torque. This cracking is a concern and made necessary the development of methods for the non-destructive examination of the bolts and for replacing them in case of failure.

CORE BAFFLE FORMER BOLTS AT LOVIISA NPP

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VISUAL AND ULTRASONIC INSPECTION

A total of 32 baffle bolts have been inspected by Tecnatom at the core basket of the Loviisa NPP Unit 2. They are distributed in 4 rows (A, B, C and D) and 78 columns.

The SUPREEM robotic tool shown in Figure 2 was used for the simultaneously visual (TV) and ultrasonic (UT) inspections of the baffle bolts. The visual inspection is related to the fixing screw washers of the baffle bolts. With...
the SUPREEM all the bolts can be reached from a single position. In this way there is no need to reposition the robotic arm once it is installed. After the visual and UT inspection of the baffle bolts several areas and welds of the core basket interior surface were also TV inspected with the SUPREEM equipment. For the visual inspection high radiation-resistant under-water cameras (Diakont) were provided by Loviisa Nuclear Power Plant.

Utilization of the SUPREEM tool for both UT and TV inspection required the following preparatory activities:

- Modification of the SUPREEM manipulator to fit the geometry and dimensions of the Loviisa core basket.
- Design and manufacture of a fixing system for the Loviisa-supplied Diakont cameras and lights.
- Modeling of the core basket baffle plate and robot programming.
- Qualification of the UT inspection procedure using a baffle bolts’ mock-up provided by Loviisa NPP.

The MIDAS system was used as ultrasonic data acquisition and evaluation equipment. The probe used was the MT-4 (manufactured by Krautkramer) with nominal angle of 0° diameter 2.5 mm and 5 MHz of Frequency. Calibrations were performed each 2 hours according to the inspection procedure. Indications were found in four baffle bolts. The indications were located near the bolt heads. Two indications correspond to high flaw penetration.

Figure 2: SUPREEM equipment (Tecnatom)

BOLTS REPLACEMENT

The Westinghouse system for the replacement of defective core baffle former bolts is a remotely controlled manipulator. The manipulator is designed to operate under water inside the core barrel basket. During bolt replacement activities at Loviisa 2 NPP the basket was located outside the reactor on the storage position Well Nº.

The manipulator was placed in vertical position inside the core basket as shown in Figure 3 and supported by the base plate on the bottom and a support plate on top of the basket. Those two supports are necessary for an accurate and stable position during operation and to ensure the high precision of all machining steps.

The manipulator consists of a m long slim beam and the tool carriage with drive units for all necessary tools. The beam is made of segments with different lengths assembled to the necessary length. The tool carriage with all tool drive units is able to reach every vertical bolts position by moving along the beam. The horizontal adjustments are made by tool drive and by repositioning of the manipulator inside the basket across the base plate.

The polar crane was necessary for the erection of the equipment and for all repositioning activities of the manipulator. Optionally it was possible to install an additional platform with one auxiliary lifting device. Using this additional lifting device the bolts replacement process would be more independent from all other reactor floor activities taking place in parallel.
All functions of the manipulator and their supply units are controlled by a programmable control unit. The entire process was monitored and operated from a workstation which is linked to the control unit through a high speed ARC net link.

According to the inspection results, the four defective baffle bolts found in Loviisa Unit 2 were removed and replaced for new ones. The locking technique of the new bolts was based on the deformation of the structure of the material around the bolt head. This technique is independent of the position of the bolt head in circumferential direction and it was qualified in a preproduction test.

Figure 3: Westinghouse manipulator for bolt replacement

CONCLUSIONS

In addition to the periodic inspections of the reactor internals at Loviisa 2 NPP, an ultrasonic inspection of the reactor core baffle former bolts was performed in order to ensure that they are undamaged. Defective bolts found in the inspection were replaced along with their washers. This was the first replacement for the VVER-440 type reactor.

The planned duration for the baffle bolts replacement was approximately 45 days including the ultrasonic inspection of the bolts and the replacement of damaged bolts as well as the installation and disassembly of the equipment and manipulators. The work was a success and duration was in accordance with the planned schedule. Corresponding inspections and repairs will be carried out for Loviisa during refueling outage of 2008.

Inspection and replacement of defective baffle bolts is an adequate maintenance strategy facing long term operation of the plant. Determination of the factors influencing the extent of the cracking should be part of an extensive R&D programme.

REFERENCES


