In-Service Inspection Approaches of KALIMER-600 Reactor System

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1. Introduction

KALIMER-600 is a pool type sodium-cooled fast reactor (SFR), as shown in Fig. 1. Sodium is opaque, chemically active with water and must be maintained in the liquid state. The in-service inspection (ISI) is necessary to confirm the integrity of the structures and components of KALIMER-600. Periodic in-service inspections for the reactor system are restricted because of the hot sodium hostile environment. In this study, the ISI approaches of the KALIMER-600 reactor system are proposed to permit a structural integrity throughout the life of the plant according to the guidelines of the ASME code [1].

2. ISI Guideline of SFR

ASME Section XI Division 3 provides rules and guidelines for an in-service inspection and testing of the components of SFR [1]. ASME XI specifies the general type and extent of the ISI required for Class 1, 2 and 3 nuclear power plant systems or components. The intent of the ASME ISI requirements is to maintain the nuclear power plant and to return the plant to service in a safe and expeditious manner during plant outages. The rules represent a required mandatory program of examinations, testing, and inspections to evidence an adequate safety. Systems and components that require inspection in accordance with the requirements of ASME XI are designed with an adequate physical access and visibility to allow for the required inspection. The ASME code describes a number of available ISI techniques as follows:

- Visual inspections
- Surface examinations
- Volumetric examinations
- Continuous monitoring
- Alternative examinations

Sodium cooled reactors are fabricated from austenitic stainless steels. Stainless steel exhibits a good ductility and toughness at typical operating conditions justifying a leak-before-break strategy for the piping and vessels. ISI program is aimed at determining the general condition and operability of the reactor system and detecting problems before a significant failure [2,3].

3. ISI Approaches of Reactor System

3.1 Reactor vessel

In-service inspection of the reactor vessel is mainly accomplished by visual examination (VTM-2) and by continuous monitoring for sodium and cover gas leakage. ASME XI does not specify volumetric inspection of SFR reactor vessel except the dissimilar metal welds and the integrally welded attachment. However the volumetric inspection of the reactor vessel weld is provided for the reactor structural integrity with a remote controlled robot crawler through ISI ports in reactor head. The reactor vessel, head, and containment vessel will be designed to facilitate volumetric inspection. To minimize weld length, the vessels and head will be manufactured by forging.

3.2 Containment vessel

The ASME XI Code specifies visual examination for containment vessel welds. VTM-3 inspection will examine the loss of integrity at welded connections. The VTM-3 inspection by remote CCTV camera will be performed in the annulus between reactor vessel and containment vessel.

3.3 Reactor internals

The reactor internals include the reactor core, components (intermediate heat exchanger (IHX), decay heat exchanger (DHX), in-vessel transfer machine (IVTM), and pump) and reactivity control structures (core support structure, core restraint and upper internal structure (UIS)). For the ISI of reactor internals, the ASME Code specifies visual examinations or alternative examinations such as a continuous monitoring and dimensional gauging. In-service inspection of above the sodium level will be done by a direct visual examination using a remote CCTV camera. As the liquid sodium is opaque to the light, ISI of under the sodium level will be done by an under-sodium viewing technique. The under-sodium scanning device will be accessed through the ISI ports on the reactor head.

In hard-to-access areas of the reactor internal structures, a continuous monitoring will give the reliable information about the structural integrity of the internal structures and components. Continuous monitoring of pressures, temperatures, flows, displacements, stains and vibrations will determine the operation condition of the components such as the IHX, DHX and pumps.

3.4 Reactor head

The ASME Code specifies continuous monitoring for the reactor head. Radiation monitoring will be performed in the head access area for the leakage integrity of the reactor head and the reactor cover gas system. If there is a leakage indication, the leak should be located by the helium detector probe technique.

3.5 Auxiliary heat exchanger (AHX)

The AHX will be continuously monitored by measuring air inlet and outlet temperature, air flow rate, and sodium leak. Periodic remote visual inspection of the AHX flow passages will be performed to inspect the integrity of air flow passages with the remote crawler device equipped with a CCTV camera.

3.6 Intermediate heat transfer system (IHTS)

ISI of IHTS piping and components will consist of continuous monitoring of sodium leakage, VTM-2 visual inspection, and surface and volumetric examination of some selected weld. Sodium leaks in the IHTS piping will be detected by placing electric contact wires on the sodium piping. The visual inspection will be performed for the sodium leakage detection of piping. In-service inspection of dissimilar welds between SG and piping will be done by sodium leakage monitoring and volumetric examination. IHTS pipe supports and restraint will be done by visual examination without insulation removal.

3.8 Steam generator (SG)

Steam generator shell welds and support structures will be inspected by remote visual examination using a remote CCTV camera. Sodium ionization detectors and sparkplug sensors will also be located in the cooling annulus. Steam generator tube leakage will be monitored using the hydrogen detectors and the acoustic leak detectors. Steam generator tubes will be done by volumetric inspection such as remote field ECT or ultrasonic test to detect the flaws and measure the tube wall thickness. Surface and volumetric examination of the welds of SG shell will be also performed.

4. Conclusion

In the system design of KALIMER-600, the in-service inspection should be considered to ensure the structural integrity and operability of the plants. The general strategy and approaches of in-service inspection for the reactor system are proposed and described for considering the design characteristics of KALIMER-600 and the intents of the ASME XI Division 3. The visual inspection and continuous monitoring are adopted for the major inspection techniques in the ISI of KALIMER-600 reactor system.

ACKNOWLEDGEMENT

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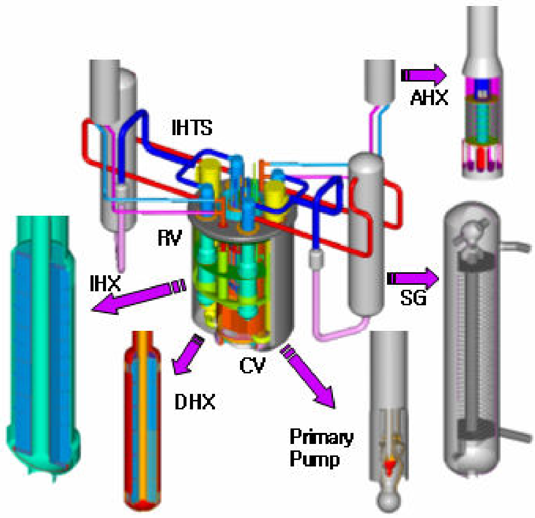

Figure 1. Reactor system and components of KALIMER-600.