

In-Service Inspection and Monitoring for Reactor Internals of KALIMER-600

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1. Introduction

KALIMER-600 is a pool type fast reactor which is operated with a sodium coolant as opposed to water for LWR. Sodium is opaque, chemically active with water and must be maintained in the liquid state. Because the sodium must be kept with a high temperature and in an inert atmosphere, all access must be via penetrations in the reactor head to prevent the ingress of air into the reactor vessel. The reactor internals of liquid metal fast breeder reactor (LMFBR) are enclosed within the reactor vessel by the reactor head covers and submerged in a liquid sodium pool. The in-service inspection (ISI) is necessary to examine the integrity of the safety related internal structures of KALIMER-600. Periodic in-service inspections for inside the reactor vessel are restricted because of the hot sodium hostile environment and the complicated close-up arrangement of internal components and structures. In this study, the ISI strategy for the internal structures of KALIMER-600 is proposed to permit a structural integrity throughout the life of the plant according to the guidelines of the ASME code.

2. ISI Guideline of LMFBR

ASME Section XI Division 3 provides rules and guidelines for an in-service inspection and testing of the components of liquid metal cooled plants [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

Liquid metal 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. These properties of austenitic stainless steel indicate that measurable deflections or dislocations will occur before a structural failure. Thus, it is not necessary to examine all the areas of each component or system. Rather, the ISI program is aimed at determining the general condition and operability of the reactor system and detecting problems before a significant failure [2,3]. The visual inspection and continuous monitoring are adopted for the major inspection techniques in ISI of LMFBR. Visual examinations can be direct, remote, or can use less conventional equipment such as a dimensional gauging and under sodium scanning. In hard-to-access areas of the reactor pool, continuous monitoring may give the most reliable and accurate information about the structural integrity.

3. ISI and Monitoring of Reactor Internals

For the pool type KALIMER-600 reactor, the reactor internals include the reactor core, components (IHX, DHX and IVTM), reactivity control structures (core support structure, core restraint and upper internal structure), as shown in Fig. 1. 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, the conventional visual inspection can not be used for observing the internal structures under the sodium. In-service inspection of under the sodium level will be done by an under-sodium viewing technique. 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. Sensors will be placed in specific locations inside the reactor to provide information about particular internal components. The monitoring sensors are

supported in drywell tubes and installed on the shells of the internal structures. Dimensional gauging will be used to check the dimensional stability of the internal structures by tracking the relative indexing positions before a refueling operation. If a significant change is indicated by a continuous monitoring or dimensional gauging, an under-sodium viewing (USV) will be used to further investigate the condition. The position of the core structures and components can be determined directly through the under-sodium ultrasonic telemetry. Immersion sensors and waveguide sensors have been applied to the USV inspection. Immersion sensors for an under sodium operation have been developed for viewing purposes. The immersion sensors are limited in this lifetime in the hostile sodium environment because of its thermal and radiation damage. The waveguide sensor could be a useful alternative to immersion sensors for some USV applications. Tasks involving the dimensional gauging and the detection of the obstacles are suitable in waveguide applications. The under-sodium scanning device will be accessed through the ISI ports on the reactor head as shown in Fig. 2. The ISI ports improve the inspection and repair capability of KALIMER-600. In-service inspection of the core support structure is difficult and time-consuming because of a space and access restriction. The core support structure is designed with a sufficient redundancy and fault tolerance to obviate the need for a volumetric inspection. In-service inspection of the pump consists of a continuous monitoring of a sodium leakage and a monitoring of the flow rate and pressures. Visual inspection of the sodium retaining welds and pump supports will be performed.

4. Conclusion

In the system design of KALIMER-600, the in-service inspection strategy should be considered to ensure the structural integrity and operability of the plants. The general strategy and approach of an in-service inspection and monitoring for the reactor internals are proposed and described for considering the design characteristics of KALIMER-600 and the intents of the ASME XI Division 3. The general monitoring and inspection requirements of the structural safety concerns of the reactor internals are the measurement of the location and alignment of the structures and a detection of any mechanical damage in the structures. The under-sodium viewing inspection and a continuous monitoring are adopted for the major inspection techniques in the ISI of the reactor internals.

ACKNOWLEDGEMENT

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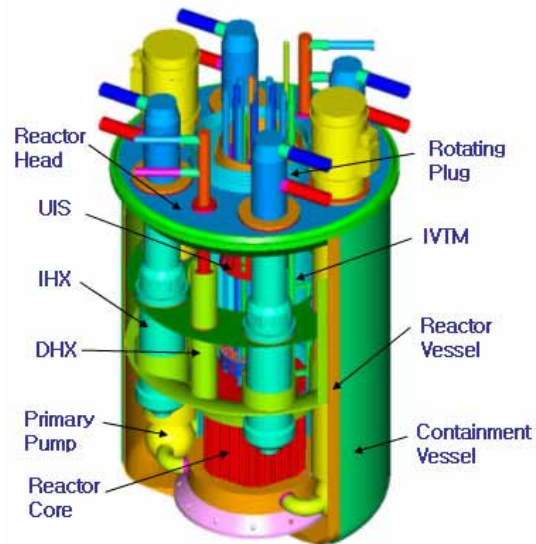


Figure 1. Reactor internal components and structures of KALIMER-600.

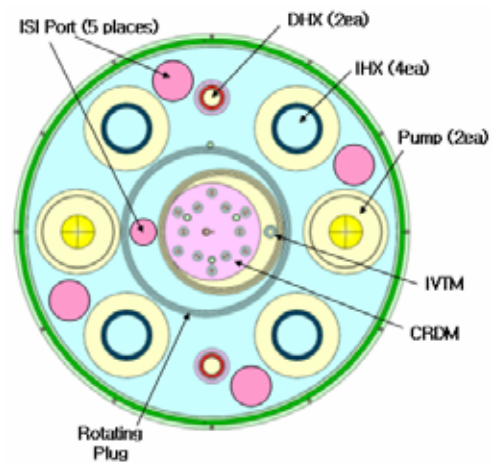


Figure 2. Reactor head of KALIMER-600 and ISI access ports.