Development of Integrated Regulatory Aging Management System related to Reactor Vessel Internals

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1. Introduction

The primary function of the reactor vessel internals (RVIs) is to support the core, the control rod assemblies, the core support structure and the reactor pressure vessel (RPV) surveillance capsules. The RVIs have the additional function to direct the flow of the reactor coolant and provide shielding for the RPV. Ageing mechanisms are specific processes that gradually change characteristics of a component with time and use. According to the Generic Aging Lessons Learned (GALL) report, aging mechanisms, such as fatigue, embrittlement, corrosion, wear, radiation induced creep, relaxation and swelling, is related to RVIs. Establishing that effects of aging degradation in RVIs are adequately managed is vital for assuring continued functionality of RVIs. To achieve this goal, it is necessary to develop the regulatory standard as well as generic inspection and evaluation guideline for RVIs. In this paper, the Integrated Regulatory Aging Management System (IR-Aging), which efficiently manages key data necessary to the development of regulatory standards and assists effective evaluation of RVIs, is proposed. By using the proposed system, experts in different fields can co-operate to resolve safety issues and all users can share information and create valuable knowledge-base.

2. Description and Aging Mechanisms of RVIs

2.1 Description of RVIs

Fig. 1 shows the structural assemble grouping of a PWR RVI[1]. The core barrel provides a boundary for the reactor coolant. The primary coolant enters the reactor vessel via the inlet nozzles, impinges on the side of the core barrel and is directed downward through the annulus formed by the gap between the outside diameter of the core barrel and the inside diameter of the reactor pressure vessel. The primary coolant flow then enters the lower plenum area between the bottom of the lower support plate and the reactor pressure vessel bottom head and is redirected upward through the core. After passing through the core, the coolant enters the upper core support region and then proceeds radially outward through the reactor pressure vessel outlet nozzles.

The RVIs consist of two structural assemble groupings, the upper and the lower internals assemblies. The upper internals assembly consists of all the internals components above the core. The lower internals assembly consists of all the remaining internals components. The fuel assemblies rest on the lower support structure of the lower internals assembly which transmits the resulting loads to the core barrel and, hence to the core barrel flange, which rests on the reactor pressure vessel flange. The upper internals assembly is attached under the reactor pressure vessel head flange.

2.2 Aging Mechanisms of RVIs

Ageing mechanisms are specific processes that gradually change characteristics of a component with time and use. Embrittlement is a loss of ductility of a material, making it brittle. In case of RVIs, embrittlement is occurred by two causes, such as irradiation and heat. Irradiation embrittlement, which may affect core region internals, caused neutrons to displace large number of atoms from crystal lattice positions by atomic collisions. Thermal ageing embrittlement, which may affect the cast stainless steel parts, caused thermally activated movement of lattice atoms over a long time period, which is a time and temperature dependent degradation mechanism. Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading.

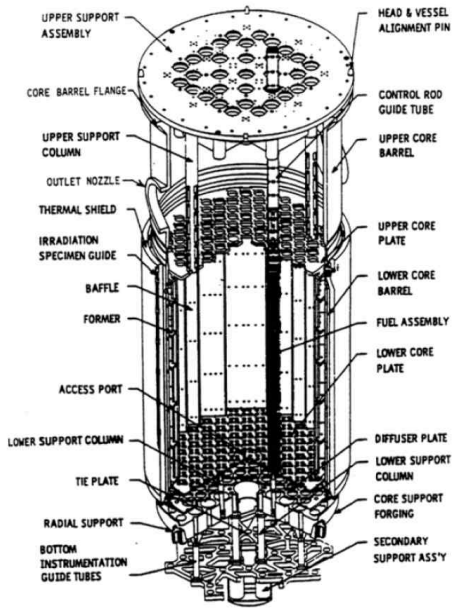

Fig. 1. Structural assembly of PWR RVIs

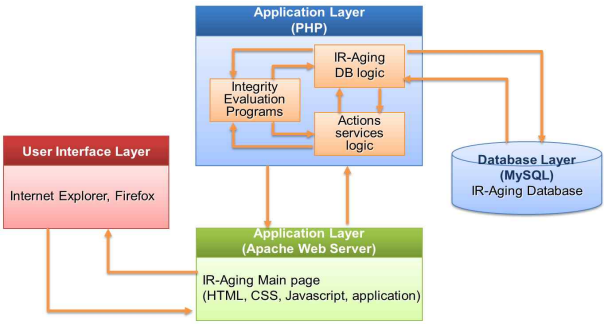

Fig. 2. A 3-tier architecture adopted in web-based IR-Aging

Fig. 3. The initial screen of the IR-Aging

Stress corrosion cracking (SCC) occurs when the following three conditions are present : tensile stress (both applied and/or residual stresses), corrosive environment and susceptible material. Irradiation-assisted stress corrosion cracking (IASCC) is a degradation mechanism where materials exposed to neutron radiation become more susceptible to SCC with increasing fluence. Creep is a function of stress level, temperature and time. Fast neutron exposure enhances austenitic stainless steels to creep. Creep / relaxation of baffle bolts has been observed during testing and replacement of baffle bolts. Locally, if temperature increases, swelling can occur and create local straining. Major possible swelling concern is related to geometrical changes that could occur. This could have potential negative impact on control rod movement or coolant flow. Mechanical wear is defined as the removal of material surface layers due to relative motion between two surfaces or under the influence of hard.

3. Architecture of the web-based IR-Aging

As shown in Figure 2, IR-Aging has been designed as a 3-tier architecture which is widely accepted in the current web-based information systems. The system consists of three layers; the user interface layer, the application layer and the database layer. The user interface layer running on an internet environment such as Internet Explorer or Firefox has been developed by adopting HTML (Hypertext Markup Language), FLASH, CSS (Cascading Style Sheets) and javascripts. This layer transfers the user's action to the application layer and displays the data from the application layer on the screen. The application layer uses the apache web server, PHP (PHP: Hypertext Preprocessor) and JAVA. This layer plays a bridge-like role between the user interface layer and the database layer. The apache web server works as a gate which exchanges requests and results. All users connect the apache web server through the internet and obtain information by submitting queries. Actions services logic and IR-Aging DB logic are programmed based on PHP. PHP is a widely-used general-purpose scripting language that is especially suited to web development and can be embedded into HTML. Integrity evaluation programs are composed by JAVA to perform prompt calculations. Actions services logic analyzes the user's request from the apache web server and the results are provided to the IR-AGING DB logic and integrity evaluation programs according to the requests. Then, the IR-AGING DB logic returns the necessary data to the Action services logic and the integrity evaluation programs. The database layer has been built on a MySQL which is a relational database management system (RDBMS).

4. Architecture of the web-based IR-Aging

The web-based IR-Aging is composed of four sub-modules: Regulatory Requirement, Aging Database, AMP/TLAA, Integrity Evaluation Program modules. Figure 3 shows the initial screen of the web-based IR-Aging. The Regulatory Requirement module provides documents, such as Nuclear Safety Act, Standard Review Plan or GALL report, related to the regulation. And, the Aging Database module supplies licensee's documents submitted to a regulatory body, research documents and design drawings of RVIs. The AMP/TLAA module contains documents on the generic aging management programs to manage aging effects for RVIs. And, the Integrity Evaluation Program module provides is developed to cover the following types of damage mechanisms: cracking, embrittlement, fatigue, Primary Water Stress Corrosion Cracking (PWSCC).

5. Conclusions

In this paper, the Integrated Regulatory Aging Management System (IR-Aging) is proposed in order to manage data necessary to the development of regulatory standards and assists effective evaluation of RVIs. The proposed system provides various documents, such as US NRC and domestic regulatory documents, licensee's documents submitted to a regulatory body, and research documents. By using the proposed system, experts in different fields can co-operate to resolve safety issues and all users can share information and create valuable knowledge-base.

REFERENCES

[1] M. Brumovsky, M., Yu.G. Dragunov, et. al., Assessment and management of ageing of major nuclear power plant components important to safety: PWR vessel internal, IAEA-TECDOC-1119, 1999.