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A review on the OECD Halden reactor project for an irradiation assisted stress corrosion cracking

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1. Introduction

Irradiation assisted stress corrosion cracking (IASCC) involves a premature cracking and a failure of materials in aggressive environments which is induced or accelerated by an ionizing radiation. A number of extensive reviews of IASCC have been written [l-3] and contain a wealth of detailed information upon which the current overview is based. The majority of the information on IASCC has been developed with the experience base from light water reactor (LWR) operations worldwide. The first example of IASCC was identified in the 1960s for high stress stainless steel components, such as fuel elements, in boiling water reactors (BWRs). Subsequent observations were expanded to the field where IASCC was of concern to other LWR types and a variety of lower stress components and austenitic alloys. An international cooperative group on an irradiation-assisted stress corrosion cracking was formed by LWR manufacturers, electric utilities, and national energy agencies to develop a mechanistic understanding and prediction capability for IASCC.

The current understanding of IASCC is reviewed by using references of the OECD Halden reactor project [4] and the Japan Atomic Energy Agency (JAEA).

2. Experimental

2.1 OECD Halden Reactor Project

The OECD Halden reactor project is an international network dedicated to an enhanced safety and reliability of nuclear power plants. The project's strong international profile and solid technical basis represent an asset for the nuclear community at a time in which maintaining centers of expertise at an accessible cost has become increasingly important. The Halden project is a joint undertaking of national organizations from 21 countries sponsoring a jointly financed program under the auspices of the OECD nuclear energy agency. The program is to generate key information for safety and licensing assessments, and aims at providing:

• Basic data on how the fuel performs in commercial reactors, both at normal operation and transient conditions, with emphasis on extended fuel utilization.

• Knowledge of plant materials behavior under the combined deteriorating effects of water chemistry and nuclear environment.

• Advances in computerized surveillance systems, human factors and man-machine interaction in support of upgraded control rooms.

In addition to the joint program work as shown in Fig.1, a number of organizations in the participating countries execute their own development work in collaboration with the project. These bilateral arrangements constitute an important complement to the joint program and normally address issues of commercial interest to a participant organization or group of organizations.

Fig. 1. The Halden reactor project is an international network with 21 member countries. The participants represent a complete cross section of the nuclear community, including regulatory bodies, vendors, utilities and R&D centers.

The proposed program focuses on the following main issues.

2.2 Aims of the program for the time period between year 1997 and 1999

The purpose was IASCC researches of sensitized and pre-irradiated stainless steel materials in a normal BWR water chemistry and in a hydrogen water chemistry. The crack growth is monitored by means of in-reactor potential drop measurements. Pre-irradiated material is retrieved from commercial reactors, and then machined and instrumented at Halden. Two test rigs have been used in the ongoing program periods, a third rig is under preparation.

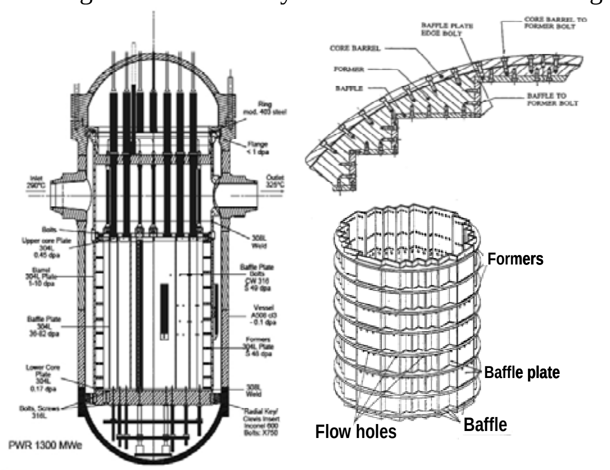
Initiation of IASCC in sensitized stainless steel, aiming at a determining of the onset of IASCC as function of a stress and fast neutron fluence. One rig is being used for this investigation.

Effect of an alloy composition and fast neutron fluence on the susceptibility to IASCC. This test is carried out in collaboration with the USNRC/ANL and involves one irradiation rig. The specimens have been fabricated and are PIE-tested at ANL.

2.3 Aims of the program for the time period between year 2000 and 2002

The aim was generating validated data on a stress corrosion cracking of reactor materials at representative stress conditions and a radiation/water chemistry environment. The work of previous program periods on IASCC was extended to include highly irradiated materials in this period. The program was intended to clarify the extent to which remedies introduced to alleviate the stress corrosion of in-reactor components remain applicable to components that have been in service for a long time. One focus was on representative BWR materials which have been retrieved from commercial reactors and on the use of these materials for in-core measurements of crack growth rates at given stress intensities. A second focus was on stress corrosion studies under PWR conditions, as it is anticipated that a cracking of in-reactor materials in a PWR may also become an issue of concern.

Examination of these cracking incidents in a fuel cladding and more recently a PWR control rod cladding had given rise to the proposition of a threshold fast neutron dose for the occurrence of IASCC; ~5 X 10^{20} n/cm^2 (E > 1 MeV) or ~1.0 displacement per atom (dpa) for BWR and a larger dose ~1 to 2 X 10^{20} n/cm^2 (E > 1 MeV) for PWR. Fig. 2. shows the PWR structure and the PWR internal components at risk from IASCC.



Component	Design Life Fluence (n/cm^2)
Core Baffle	1.6 x 10^{23}
Core Barrel	1.8 x 10^{22}
Upper Core Plate	4.3 x 10^{20}
Lower Core Plate	6.2 x 10^{21}
Lower Core Support	8.3 x 10^{17}

Fig. 2. PWR internal components at risk from IASCC.

2.4. Status of IASCC researches at Japan Atomic Energy Agency (JAEA).

A fund for IASCC research was set up and a SSRT machine was installed in a hot cell of the JMRT hot laboratory of JAEA in 1989.

- Following activities were carried out after the initial step, Type 304/316 SS specimens irradiated at JMTR, JRR-3, ORR, JOYO had been examined in BWR simulated water.
- In 2000, IASCC national project conducted by JNES was initiated to be completed in FY2008.
- In-pile IASCC test program by JAERI/JAPC were initiated and completed in 2006 after successful experiments at JMTR.
- Since 2001, JAERI/JAEA has inspected the failed materials from components of a NPP, e.g. BWR core shroud, PLR piping.
- In 2007, NISA and JNES funded new IASCC related research projects.
- IASCC has been regarded as a critical ageing issue for LWR and next generation reactors.

3. Conclusions

We reviewed the IASCC test activities at the Halden reactor project and JAEA for future researches in KAERI. The paper also contains a brief overview of the results from the programs carried out in the time period from 1997–2002. KAERI will conduct IASCC experiments at the high temperature/high pressure primary condition of a PWR.

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[4] OECD Halden Reactor Project