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Overview of the M5™ Alloy Behavior under RIA and LOCA Conditions

J.P.Mardon[1], L.Heins[2], B.Dunn[3]

1-AREVA NP SAS 10, Rue Juliette Récamier 69456 Lyon Cedex 06 France
2-AREVA NP GmbH Germany, 91058 Erlangen, Freyeslebenstr. 1
3-AREVA NP Inc.3315 Old Forest Road Lynchburg, Virginia, U.S.A.

Tel: + (33) 4 72 74 81 50, Fax: + (33) 4 72 74 81 45,
Email:jeanpaul.mardon@areva.com

Abstract:

Experience from irradiation in PWRs has confirmed that M5™ possesses all the properties required for upgraded operation including new fuel management approaches and high duty reactor operation. In this paper accident behavior is demonstrated through a comparison of M5™ and Zircaloy-4 cladding behavior under RIA and LOCA conditions. AREVA NP supports a significant experimental program of analytical and full-scale tests along with comprehensive analyses on both M5™ and SRA low-tin Zircaloy-4. A key presumption in the conduct of such tests is that, for all Zirconium alloys, the primary effects of high burn-up on cladding thermal-mechanical properties arise from the accumulation of hydrogen within the cladding during operation. This hypothesis is supported through a summarization of the results of the main RIA and LOCA tests performed on virgin, pre-hydrided, and irradiated M5™ and SRA low-tin Zircaloy-4 cladding.

The first part of the paper presents the results of recent room temperature (RT) and high temperature high pressure (HTHP) integral RIA tests, mainly from the NSRR and CABRI programs, and separate effects mechanical properties tests on high burn-up M5™ and Zircaloy-4 irradiated claddings [1].
In the second part of this paper, studies of cladding performance under LOCA conditions are presented [2, 3]. The discussion includes high temperature oxidation kinetics, quench behaviour and post-quenched mechanical behaviour of virgin, pre-hydrided and irradiated M5™ and Zircaloy-4 cladding tubes after oxidation at LOCA temperatures and various quenching scenarios. The hydrogen concentrations studied are alloy dependent. Included are mechanical tests and in-depth metallurgical investigations developed to understand the failure mechanisms with the differing alloys and hydrogen concentrations. The result is a conformation that the effect of hydrogen uptake dominates on the RIA and LOCA response of Zirconium based cladding alloys.

Key words: Nuclear fuel, M5, LOCA, RIA.

[1]-J.P.Mardon et al. "Recent data on M5™ alloy under RIA and LOCA conditions." ANS, Orlando, September, 2004
[2]-J.P.Mardon et al. "Latest results on M5™ alloy under LOCA and RIA representative conditions", ENC, Versailles, France, December 11-14, 2005
[3]-J.P.Mardon et al. "Impact of cooling rate on cladding residual ductility-Recent CEA LOCA test results", FSRM, Kyoto, Japan, October-7, 2005

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