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Major findings of E110 studies under LOCA conditions

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ABSTRACT

The research program to study the embrittlement behavior of zirconium-niobium alloys (E110 and others) under LOCA-relevant conditions was performed by the Nuclear Safety Institute of Russian Research Center "Kurchatov Institute" in the cooperation with the Russian State Research Center "Institute of Atomic Reactors" and with the support of the Joint Stock Company "TVEL" (Russian Federation), the U.S. Nuclear Regulatory Commission (USA) and the Institute for Radiological Protection and Nuclear Safety (France) [1, 2].

The experimental part of the program consists of oxidation and mechanical tests of cladding samples. The first stage of the program allowed to reveal the following:

- the oxide formed on the E110 cladding surface demonstrated the tendency to the spallation at the ECR (Equivalent Cladding Reacted) more than 6 % (breakaway effect);
- this process was accompanied with the hydrogen absorption into the cladding;
- the high hydrogen concentration in the cladding material was with the reason of the cladding embrittlement (zero ductility threshold) at the 8.3 % as-measured ECR (11.3 % as calculated ECR using the conservative E110 oxidation kinetic).

Multiparametric sensitive studies performed at the variation of such factors as: heating and cooling rates, oxidation temperature, oxidation type shown that any combinations of these parameters (at the temperature oxidation more than 800 C) do not allow to eliminate the break away effect completely. Additional tests performed with the variation of alloying composition (oxygen, iron, tin) in the zirconium-niobium alloy had led to the same conclusion.

The second stage of the program was developed on the basis of the following assumption: zirconium-niobium claddings have the significant sensitivity to the initial microchemical composition of the alloy (composition of impurities) under high temperature oxidation conditions. To verify this statement the comparative data base was obtained using E110 claddings manufactured in accordance with two different methods of the alloy fabrication:

- the electrolytic method (traditional method of the E110 fabrication);
- the method based on the preparation of the sponge zirconium (modified method of the E110 fabrication).

Results of appropriate tests allowed to conclude the following:

- the black protective oxide was formed on E110 claddings manufactured on the basis of sponge zirconium;
- the hydrogen concentration in the oxidized modified claddings was very low;
- the significant margin of residual ductility in the E10 oxidized claddings was fixed to the 17 % as-measured ECR.

[1] V. Asmolov, L. Yegorova, K. Lioutov, V. Smirnov, A. Goryachev, V. Chesanov "Understanding LOCA-Related Ductility in E110 Cladding", *Proceedings of the 2002 Nuclear Safety Research Conference*, NUREG/CP-0180, March 2003.
[2] L. Yegorova, K. Lioutov, V. Smirnov, A. Goryachev, V. Chesanov "LOCA Behavior of E110 Alloy", *Proceedings of the 2003 Nuclear Safety Research Conference*, October 2003 (to be published).