Critical analysis of fuel fragmentation and dispersal during the Loss Of Coolant Accident experiments IFA-650

INTRODUCTION

The move to high burnup fuel designs and introduction of new cladding materials have generated a need to re-examine and verify the validity of the safety criteria for Loss of Coolant Accidents (LOCA). The Halden LOCA tests series IFA-650 are integral in-pile single rod tests, and the test conditions were selected to meet the two following primary objectives:

1) to maximize the ballooning size to promote fuel relocation and to evaluate its possible effect on the cladding temperature and oxidation;
2) to investigate the extent (if any) of "secondary transient hydriding" on the inner side of the cladding around the burst region.

The tests have been performed with different fuel rod designs (PWR,BWR and VVER), at different burnups, and the target Peak Cladding Temperatures (PCTs) have been set between 800 °C and 1100 °C.

FUEL FRAGMENTATION AND DISPERSAL

The Halden IFA-650 LOCA test series has shown different degrees of fuel fragmentation, fuel relocation within the rod and fuel dispersal outside the rod.

In the next Figures these different degrees of fuel fragmentation can be observed.

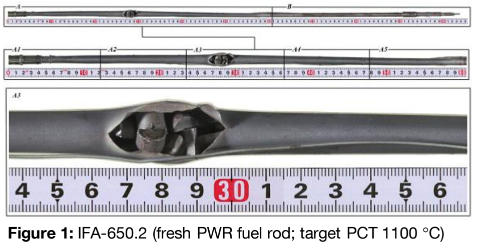

Figure 1: IFA-650.2 (fresh PWR fuel rod; target PCT 1100 °C)

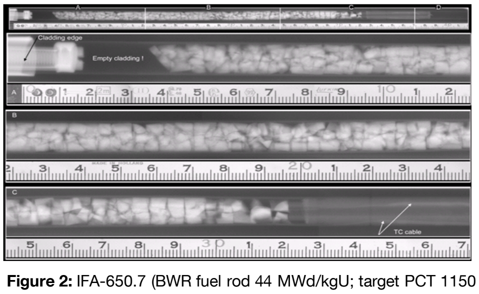

Figure 2: IFA-650.7 (BWR fuel rod 44 MWd/kgU; target PCT 1150 °C)

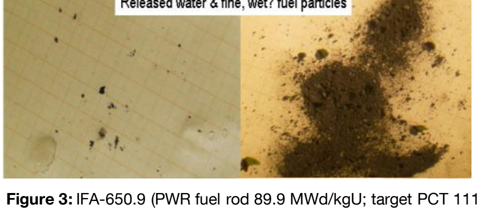

Figure 3: IFA-650.9 (PWR fuel rod 89.9 MWd/kgU; target PCT 1110 °C)

FUEL DISPERSAL

The LOCA experiments IFA-650.4 and IFA-650.9, characterized by very high burnup (92 MWd/kgU and 89.9 MWd/kgU), resulted in a large cladding rupture opening and extensive dispersal of fuel fragments (Figure 4).

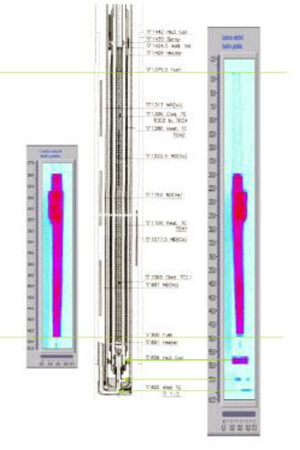

Figure 4: Fuel dispersal for IFA-650.4 (12-13 cm of the original pellet stack was missing at the upper part of the rod)

OBJECTIVES OF THE INVESTIGATIONS

The possibility that fuel particles can escape from a fuel rod and enter the reactor coolant system has never been systematically analyzed. The postulated consequences include:

- Fuel coolant interaction;
- Radiological effects;
- Flow blockage;
- Potential effects on the Emergency Core Cooling System (ECCS) performances.

To investigate the phenomena described above, all the mechanisms and parameters involved in determining fuel fragmentation and dispersal outside the fuel rods need to be understood, and new models and methods need to be developed and validated against the recent experiments so that these phenomena can be integrally and thoroughly described.

The state of the art simulation tools selected for the investigations are the ATHLET (Analysis of THermal-hydraulics of LEaks and Transients) developed by GRS to obtain the thermal-hydraulic boundary conditions of the experiments and TRANSURANUS developed by ITU to study the fuel performance.

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