LOCA Testing at Halden

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The safety criteria for loss-of-coolant accidents are defined to ensure that the core will remain coolable. Since the time of LOCA experiments in the '70s, which were largely conducted with fresh fuel, changes in fuel design, the introduction of new cladding materials and in particular the move to high burn-up have generated a need to re-examine these criteria and to verify their continued validity. Hot cell programmes concentrating on embrittlement and mechanical properties of high burn-up cladding have been initiated in some countries. One of the points to be addressed is for instance how the 15-17% oxidation limit has to be applied to fuel rods that may already be considerably oxidised ahead of the transient.

The Halden reactor is suited for integral in-pile tests on fuel behaviour under LOCA conditions. It is intended to utilise fuel rods irradiated in commercial reactors to burn-up levels >50 MWd/kg with a thorough characterisation regarding the state of the cladding and the bonding with the fuel. The Halden experiments will focus on effects that are different from those studied in out-of-reactor tests. They are single pin tests.

Participating organisations have offered both PWR and BWR fuel with desired characteristics. Preparations for transportation of the segments to the Kjeller hot laboratory are on-going. It has also been proposed to include medium burn-up (40 - 45 MWd/kg) fuel in the test series in order to assess the difference between medium burn-up and very high burn-up fuel (>60 MWd/kg. In workshops it has been emphasised that a prototypical bounding LOCA transient does not exist, and it was recommended that the test conditions be selected to meet the following primary objectives:

- to maximise the balloon size to promote fuel relocation, and to evaluate its possible effect on cladding temperature and oxidation
- to investigate the extent (if any) of - "secondary transient hydriding" - on the inner side of the cladding around the burst region

Target peak clad temperatures (PCT) for the pre-irradiated rods have been set at 800^{o}C and 1100^{o}C for high and medium burn-ups.

The first LOCA trial runs were carried out in the Halden reactor in May, using a fresh, tight-gap and unpressurised PWR rod with Zr-4 cladding. The main objective was practise, to determine how to run the later experiments with pre-irradiated segments. Target PCTs of 800^{o}C and 1100^{o}C for the initial six transients were successfully achieved.

The rig with the fuel rod was located in a high pressure flask connected to an ex-reactor high-pressure loop incorporating a blow down system. The cladding temperature transients can be controlled by rod power and an annular heater surrounding the rod. A spray system at the top of the rig is used to supply steam for the oxidation and hydring processes (and water for rod quenching). The rig/rod instrumentation is extensive and enables power calibration and neutron flux monitoring, and includes a fuel centre thermocouple (first rod only) three cladding thermocouples, rod pressure sensor, cladding extensometer, heater thermocouples etc. The geometry of the test section is shown in Figure 1.

A total of six trial runs were carried out. Cladding temperature histories for these runs are depicted in Fig. 2. The test sequences consisted of a blow-down phase, heat-up, hold at PCTs and quench by the spray system. Runs made under identical conditions (same rod

and heater powers) resulted in very similar temperature transients. The accumulated time above 900°C was >10 min and the fuel did not fail (first pin was unpressurised).

In preparation of the initial tests several code calculations were performed by outside laboratories as well as by the Project. The codes tended to overpredict PCTs, but produced in general fairly good simulations of observed fuel and cladding temperatures in the six transients and will be employed in the data evaluation and planning of further tests.

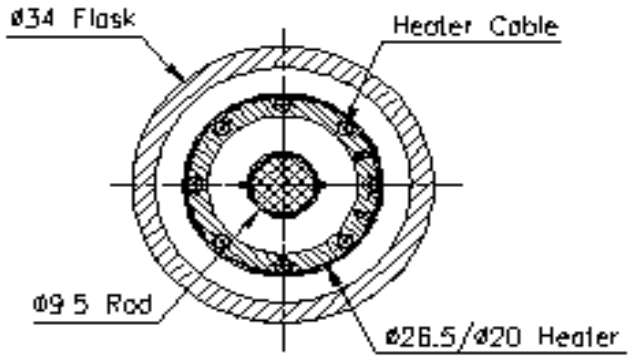

Fig. 1. The geometry of the test section

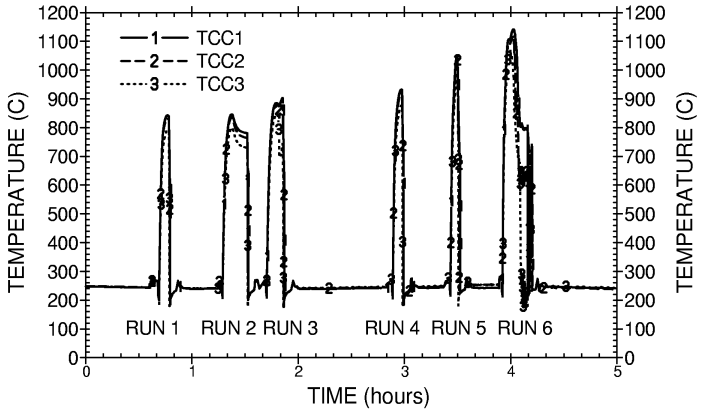

Fig. 2. Cladding temperature history for the six trial runs