FIRST RESULTS OF THE QUENCH-11 EXPERIMENT

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Second Annual SARNET-WP9 Review Meeting (Network of Excellence on Severe Accidents Research), Paul Scherrer Institut, 30.02.06

Abstract

The experiment QUENCH-11 on boil-off and subsequent quenching was successfully conducted at the Forschungszentrum Karlsruhe on 8 December 2005 and was the second of two experiments to be performed in the frame of the EC-supported LACOMERA programme. It was proposed by INRNE Sofia and supported by PSI (Switzerland). The test conditions simulated a depressurised plant sequence in which the core would be essentially dried-out and with a limited steam flow due to boiling of residual water in contact with the hot structures in the lower plenum. The reflood situations with a rather low mass flow rate may occur if pumps cease and/or if low make-up systems are activated in the course of accident management.

In contrast to all the previous QUENCH experiments, the bundle was initially filled with water and slowly evaporated. Among other facility changes, an auxiliary heater was installed in the lower plenum to maintain the evaporation rate at low water level without jeopardizing the bundle heating. To investigate the behaviour of the test section under such conditions, several pre-experiments were performed, simulating the early part of the experiment. In the last one, QUENCH-11v3, the bundle was heated-up to 1080 °C and flooded with the same reflood rate as foreseen in QUENCH-11.

The determination of the test protocol was based on numerous calculations with SCDAP/RELAP5, SCDAPSIM, MELCOR, and ASTEC; the last calculations were also based on the pre-experiments. They were prepared by FZK and performed in collaboration between INRNE, PSI, and FZK. To improve the test conduct further, calculated temperatures and hydrogen production rates were compared with the experimental data during the test.

The experiment started with an application of electrical bundle power of ca. 7 kW. This was initiation of a steady boil-off and a consequent top-down uncovery of the test bundle. To assure that water evaporated in the lower plenum the auxiliary heater was turned on and its power was increased step-wise to a maximum of 3 kW as the uncovery progressed and continued during reflood. In order to maintain a sufficient water level to keep the auxiliary heater covered and thus continue the steaming rate, water was injected into the lower plenum at a rate of ca. 1 g/s when the water level had fallen to 70 mm below the heated section of the bundle.

As in previous experiments, one of the corner rods was removed for inspection before reflood was to be initiated. The later metallographic measurement showed the maximum oxide layer thickness of 170 µm at elevation of 950 mm. As foreseen, the quench flow of 17 g/s water at 20 °C was initiated, when hydrogen generation reached 50 mg/s. The maximum observed temperature in the bundle at this time was 1770 °C.

The bundle power was reduced to 3.9 kW, approximating effective decay heat levels, at about 70 s after quench initiation and later terminated at about 200 s after quench initiation. In contrast to lower elevations, the temperature escalation started above 800 mm, leading to enhanced hydrogen production and temperatures beyond 2100 °C, before final temperature decrease as in the lower part of the bundle. Locations above the heated section also showed an increase, apparently due to reverse heat transfer from the flow of very hot steam-gas mixture. Thermocouples at elevation 850 mm also showed local quenching, but delayed until ca. 300 s after quench initiation and only after the initial escalation.

The total generation of hydrogen was in the region of **140 g**, of which more than **90%** was produced *during the reflood phase* (Fig. 1). It is possible that the modest level of pre-

oxidation, combined with the rather low reflood rate, led to conditions favourable for an enhanced oxidation during reflood.

The first post-test observations of the bundle show the melt formation and his relocation at elevations above 800 mm (Fig. 2). The analysis of the temperature history shows that the majority of hydrogen was produced during the period, corresponding to the melting of metallic Zircaloy.

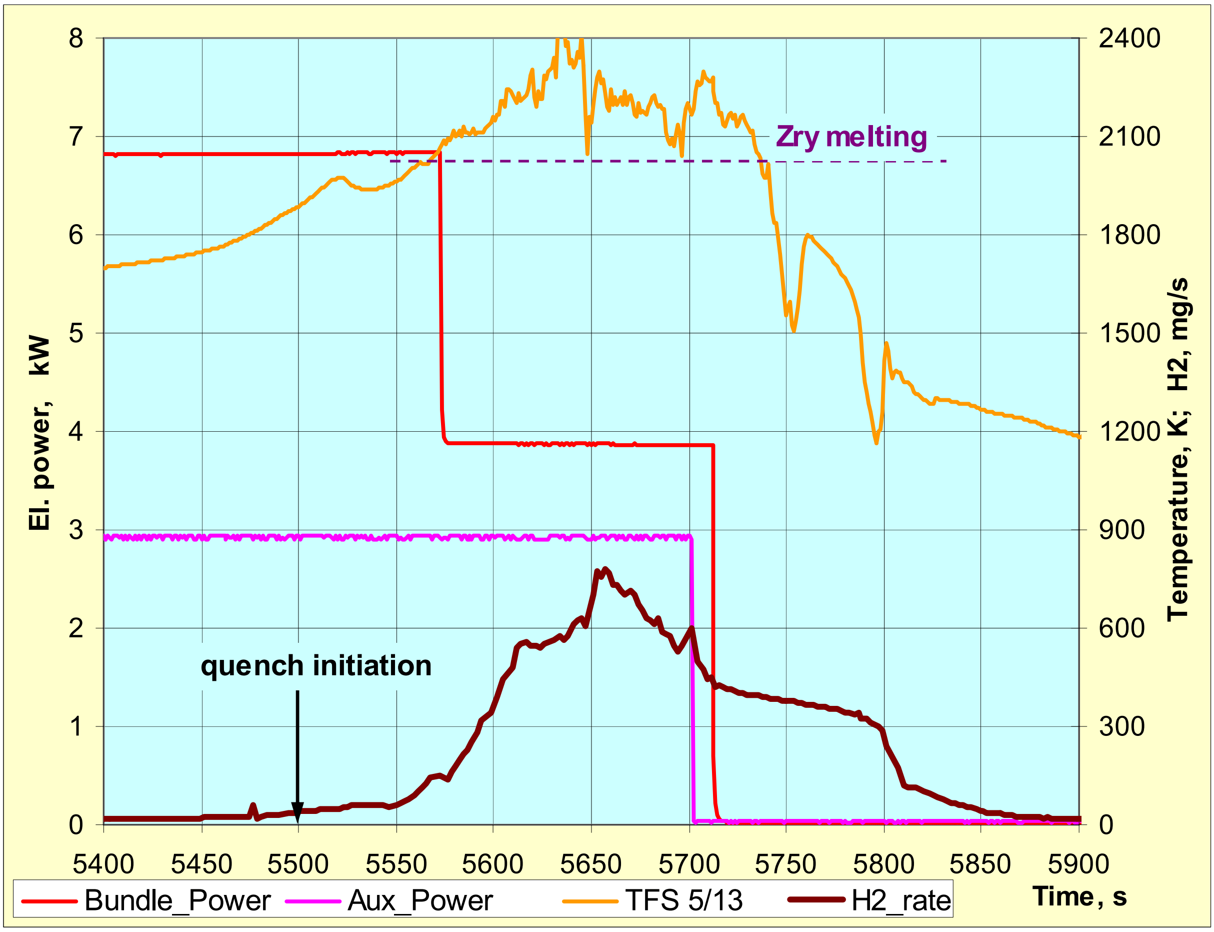

Fig. 1 Draft event diagram including power, temperature and hydrogen

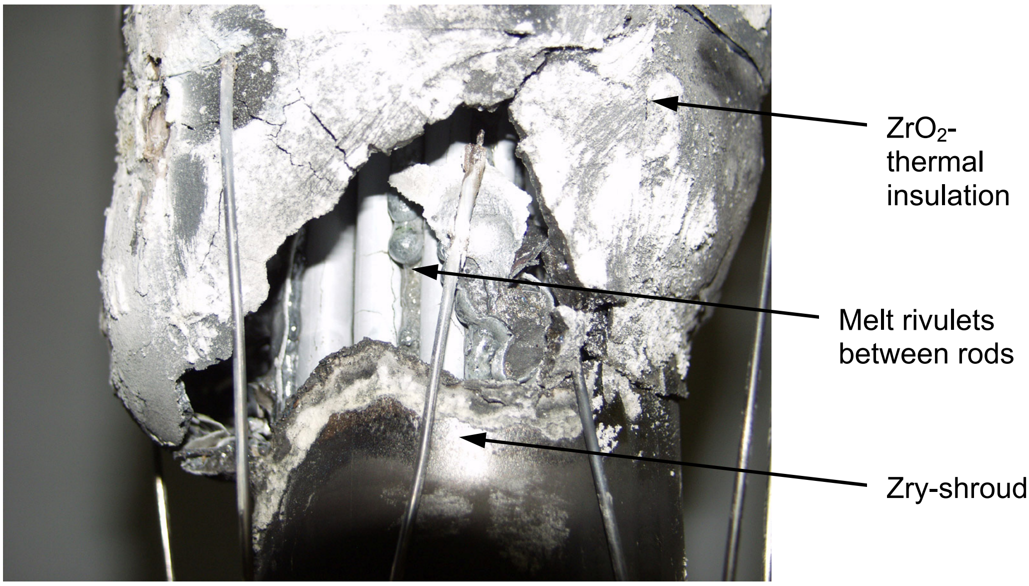

Fig. 2. Melt formation above elevation of 800 mm