Status of the QUENCH-11 test preparation

J. Stuckert, W. Hering, C. Homann, J. Moch, G. Schanz, L. Sepold, U. Stegmaier, M. Steinbrück

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Abstract

The QUENCH-11 experiment is intended to simulate a plant scenario of a small break LOCA or a station-blackout. This also includes a late primary side depressurization that leads to a certain core heat-up prior to core reflood by accumulator injection. In the QUENCH facility the free water surface at the lower end of the bundle leads to a better simulation of reactor conditions and is prerequisite for low reflood rates.

In previous QUENCH tests the lower plenum was empty; the heat losses were compensated by the overheated fluid composed of Ar and superheated steam. As a consequence, the environment was heated up during the pre-test phases, so that at test time zero nearly steady-state conditions were achieved. In the present scenario, the lower plenum will be filled completely with water at saturation. Heat transfer coefficients are much larger and the heat released by the electric bundle heating is rather low. To compensate heat losses and provide well known boundary conditions, the outer surface of the lower plenum structures is heated by an external auxiliary heater, which is temperature controlled.

The QUENCH-11 test will be performed at system pressure of 0.2 MPa. At that low pressure flashing has to be expected if the power density exceeds a given value, which is dependent on the surface and fluid conditions in the vicinity of the auxiliary heater. It can be assessed from dimensionless numbers, but it should be checked in an experiment.

The QUENCH-11 pre-tests comprise three non-destructive stages: Q-11v1 … Q-11v3. The first two pre-tests are used to get familiar with the dynamic behavior of the water-filled bundle, auxiliary heater, and the associated heat-losses to the containment.

Objectives of the *pre-test Q-11v1:* Calibration of the heat balance, compensation of lateral losses in the lower plenum and entry pipes. Testing of the cooling temperature control of the off-gas pipe, the upper plenum, and the upper electrode zone. Become familiar with accuracy under low evaporation.
Results of the Q-11v1 test are the following:

- No essential problems with tested components were observed.
- External heating power of ~200 W at bundle foot outer surface is sufficient to keep outer surface temperature rather constant.
- No fluid flashing was observed with a power of the inner auxiliary heater of up to 3.2 kW.
- Stable steam production rate of 1 g/s ± 10 % (boil-off velocity ~0.3 mm/s) could be achieved.
- Power control of the auxiliary heater was reliable and benign.
- Water level measurement with sensor L 501 had some drift.
- Inlet temperature of the water dosage system could be maintained at 95 °C.

Objectives of the *pre-test Q-11v2:* Slowly raise power of the auxiliary heater to check power level at which flashing can be detected.
Results of the Q-11v2 test are as follows:

- Calibration of water level and TC signals at various levels by slow fill-up of bundle with water (50 °C, 2 g/s) showed good correspondence between water level sensor (L 501) and TC reactions for water below saturation.
- The water temperature in the bundle was raised to nearly saturation (2 bar, 120 °C) with aux. heater (2.2 kW) and DC generator (2 kW).
- Boil-off conditions were started with ~5.5 kW DC generator and 1 kW aux. heater and lasted ~800 s.
- An important observation was made during the decrease of the boiling water level. Significant delay of the TC reactions on the decreasing water front was observed. For example, the TC at the elevation 850 mm detected superheated steam, when the sinking water level already crossed the elevation of 500 mm. Possible explanation could be the existence of the two-phase region above water surface.
- Boil-off rate of 1 g/s was stabilised with 2 kW (DC generator) and a stepwise increase of aux. power to 2.9 kW during the following ~2200 s.
- The evaporated water was compensated with the auxiliary water injection of 1 g/s (95 °C). Therewith the water level was stabilised at about -150 mm during following ~700 s.
- After reaching the maximum bundle temperature of 330 °C (~3800 s after the test begin) reflood with 19 g/s water was initiated.
- The mass-spectrometer data were in good agreement with other bundle instruments.

Pre-test Q-11v3 (to be performed immediate after the Workshop) is intended to perform QUENCH-11 boil-off and heat-up phase up to 1350 K, to check system behavior, bundle response, and controllability. Approximate values for time of water injection and start of auxiliary heater are taken from pre-test calculations. After this pre-test the Zry corner rod will be removed to get information on the achieved axial oxide layer profile. Based on calculations, oxide layers of app. 50 µm have to be expected in the upper third of the bundle at the end of Q-11v3. During pre-test Q-11v3, no fast reflood is foreseen, to avoid fuel rod damages before the QUENCH-11 reflood phase.

The results of the pre-tests and their evaluation are prerequisite to improve the quality of the pre-test calculations.