Overview of the QUENCH Program. Hydrogen generation during core reflooding.

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The QUENCH experimental program at the Karlsruhe Research Center is to investigate the hydrogen source term that results from quenching an uncovered core of a Light-Water Reactor, to examine the physico-chemical behavior of overheated fuel elements under different flooding conditions, and to create a data base for model development and code improvement. The physical and chemical phenomena of the hydrogen release are not sufficiently well understood. In particular, an increased hydrogen production during quenching cannot be determined on the basis of the available Zircaloy/steam oxidation correlations. Presently it is assumed that the following phenomena lead to an enhanced oxidation and hydrogen generation: melt oxidation, steam starvation conditions, crack surfaces oxidation. In most of the code systems describing severe fuel damage, these phenomena are either not considered or only modeled in a simplified empirical manner. One of the main parameters of the test program is the quench medium, i.e. water or cold (saturated) steam, both injected from the bottom. Up to now, ten QUENCH experiments have been performed, eight without and two with B_4C absorber (tests QUENCH-07 and QUENCH-09).

The test bundle consists of 21 rods, 20 of which are electrically heated over a length of 1024 mm. The Zircaloy-4 rod cladding and the grid spacers are identical to those used in Western-type LWRs whereas the fuel was represented by ZrO_2 pellets. The time scheme includes generally the following phases: facility stabilization, transient, pre-oxidation by superheated steam (to achieve the desired oxide layer thickness), second transient (accomplished with exothermal steam-Zircaloy interaction) and quench with water or saturated steam. The test bundle is good instrumented, amongst others with about 30 high-temperature W/Re thermocouples. The mass spectrometer measures the gas composition at the bundle outlet.

In QUENCH-07 and -09 experiments the central rod was made of an absorber rod with B_4C pellets and stainless steel cladding, and of a Zircaloy-4 guide tube. The presence of the B_4C absorber material in the central rod triggers the formation of eutectic melts, i.e. melts that are formed far below the melting point of metallic Zircaloy (~2030 K), and the oxidation of boron/carbon/zirconium-containing melt can lead to increased amounts of hydrogen, compared to a bundle without control rod.

The total amount of hydrogen released during the flooding phase was very different: from 2 g for QUENCH-04 (test on cool-down behaviour of slightly pre-oxidized cladding by cold steam injection) up to 400 g for QUENCH-09 (test on impact of impact of B4C absorber rod; steam-starved conditions prior to cooldown; intensive melt formation).