ЕНЕРГИЕН ФОРУМ 2010

СРАВНИТЕЛЕН АНАЛИЗ НА РЕЗУЛТАТИ ПОЛУЧЕНИ С КОМПЮТЪРНИ КОДОВЕ ASTECV1.3.2 И ASTECV2 НА ЕКСПЕРИМЕНТ QUENCH 12

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COMPARISON OF ASTECV1.3.2 AND ASTECV2 RESULTS FOR QUENCH 12 TEST

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Introduction

This paper presents an comparison of QUENCH 12 test calculated results with ASTECv1.3R2 and ASTECv2 computer codes. The test was performed to investigate the behavior of VVER fuel assemblies.

This investigation is a part of the 6th and 7th framework programs of the EC supported ISTC program. The test facility is located at Forschungszentrum in Karlsruhe. The structure of the test facility allows experimental studies under transient and accident conditions.

The ASTEC1.3R2 and ASTECv2 computer codes have been used to simulate the investigated test. The base line input model for ASTEC was provided from Forschungszentrum, Karlsruhe. During the preparation of QUENCH - 12 experiment, the input deck was adapted to new initial and boundary conditions.

The comparison show good agreement between measured data and ASTEC calculated results.

Description of QUENCH facility

The scheme of the QUENCH facility is presented on Figure 1[1]. The test section includes 31 fuel rods, approximately 2.5 m long, and an unheated rod in the center. The bundle geometry and clad material correspond to Soviet VVER-type. In radial direction the QUENCH fuel rod bundle is composed of an unheated rod at center position, an ring of 6 heated rods connected to an electric power supply, an middle ring with 13 unheated rods an outer ring of 12 heated rods connected to another electric power supply system, and a set of 6 corner rods at the vacant rod positions.

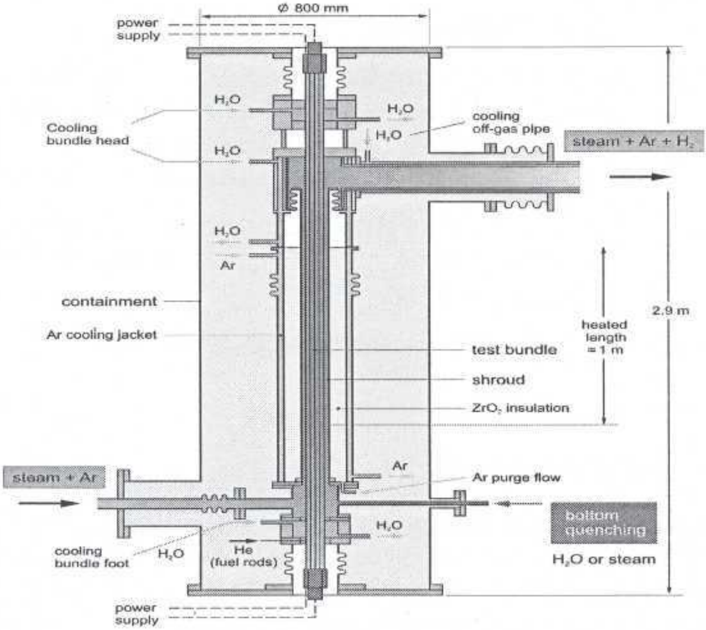

Fig.1 Scheme of Quench test facility

The fuel rod simulators are held in position by seven grid spacers all made of Zr1%Nb with 20 mm length.

Heated and unheated test rods, including the central one, are filled with Ar5%Kr and He, respectively, at a pressure of approx. 0.22MPa.

The bundle is enclosed in a shroud of Zr2.5%Nb, with a 37mm thick ZrO2 fiber insulation extending from the bottom to the upper end of the heated zone and a double-walled cooling jacket of stainless steel over the entire length. The annulus between shroud and cooling jacket is filled (after several cycles of evacuation) with stagnant argon of 0.22 MPa. The 6.7 mm annulus of the cooling jacket is cooled by an argon flow. Both the absence of a ZrO2 insulation above the heated region and the water cooling of the bundle head are to avoid overheating in that bundle region. The main contribution of the radial heat losses is due to radiation.

Scenario

The QUENCH -12 test phases can be summarized as follows.

Stabilization the initial temperature at 873 K.

Phase I **Pre-oxidation** started with an application of electrical bundle power of ca. 3.5 kW, ramped step-wise to 9.9 kW over approx. 2300 s to achieve the bundle pre-oxidation temperature of 1473 K to of 6000 s with 3.3 g/s flow of steam and Ar.

Phase II During the **transient phase** the bundle power was ramped at a rate of 5.1 W/s to reach increasing of maximum bundle temperature of 2073 K.

Phase III **Quenching** of the bundle by a water flow of 48 g/s*)

Description of ASTEC QUENCH facility input model

The input deck originates from an ICARE2 V3mod1 input deck prepared by S. Melis in 2001 for QUENCH - 06. During the preparation of QUENCH - 12 experiment, the input deck was adapted to new initial and boundary conditions as well as modified to new ASTECv2 version. The base module DIVA was changed with ICARE. Geometry of VVER bundle and grid spacer was corrected. Extensions of the online-visualization allowed a faster optimization of experimental parameters. In the radial direction, the whole test section including shroud up to the inner cooling channel is modeled. In axial direction the nodalization starts at -0,47 m and end at 1,5 m elevation, as given in Figure 2. Only the lateral connection to the off-gas pipe could not be simulated adequately. The central rod, the two rings of rods heated independently, the ring with unheated rods between heated rings, the six Zircaloy corner rods, and the shroud up to the inner cooling jacket wall are represented. The three corner rods are modeled as tube structures, the other three are modeled as solid structure. The ZrO_2 fiber insulation is modeled from the bottom of lower plenum to the end of heated zone at 1,024 m. The pipes that connect with the test section are not modeled.

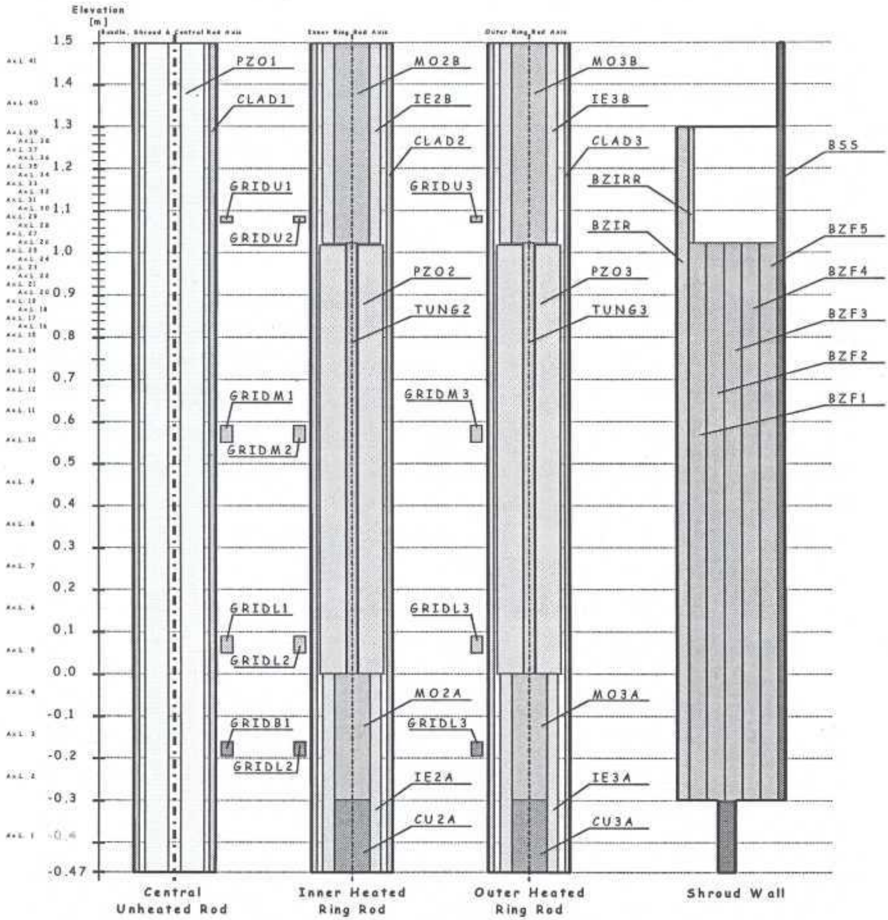

Fig. 2: Nodalization scheme of ASTEC Quench facility

The boundary conditions are given in structure connecty. The materials are different compare to the previous experiments. The bundle heated section is divided into 9 levels each one 0,10 m and two cells with 0,062 m long

A list of modified and used parameters, which deviating in ASTEC default value is given in Table 1.

Table 1. List of ASTEC modified parameters

Zr oxidation correlations	Leistikow:T<1800K transient region: interpolation Prater/Courtwright: T<1900 K
Clad failure	2300 K

Analysis of the Results

The comparison of main calculated results by new and old version of ASTEC with measured data during the test is presented in this section. The main purpose of this comparison was to evaluate the ASTEC improvements in new ASTEC version v2. The main differences is using of different modules to represent the bundle. In new version of ASTEC it has been used ICARE module instead of DIVA module used in ASTEC v1.3.2. As a whole the predicted results by both ASTEC versions are almost the same excuse some deviations. The new ASTEC version predicted a higher hydrogen production compare to the old ASTEC v1.3.2 version.

The comparison of maximum bundle temperature is presented in Figure 5. As it is seen the both ASTEC versions predicted almost the same results with small deviations.

The maximum bundle temperature corresponds to 950 mm elevation. The peak of maximum bundle temperature is observed at approximately 7290 s. The calculated maximum bundle temperatures vary within a range of 100 K during the different phases in the test. At the beginning the test started with bundle temperature stabilization at 873 K. After stabilization it was observed heat-up of the bundle to 2600 s. The comparison show good agreement between calculated results by both ASTEC versions and measured data. There is approximately 100 K deviation between calculated and measured data.

The next phase is the pre-oxidation phase, which continues to 6000 s. During this phase the behavior of both calculated results of maximal bundle temperatures have it a similar trend. The comparison of with measured data with calculated results show negligible discrepancy.

During the "quench phase" the reached ASTEC maximal temperatures is 2560 K, while the maxima! temperature during the experiment is 2020 K which is significantly lower. The observed discrepancy could be explained with radiation bundle heat transfer distribution at this elevation as well as due to behavior of cooling fluid. After quench phase (after stopping the quench water flow), it was observed large discrepancy between predicted temperature and experimental data. The observed discrepancy could be explained with the behavior of collapsed water level.

Comparison of maximal bundle temperature

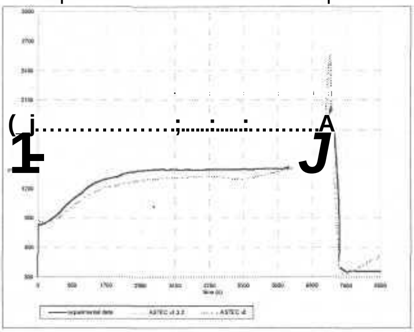

Fig. 1

Comparison of Hydrogen generation mass

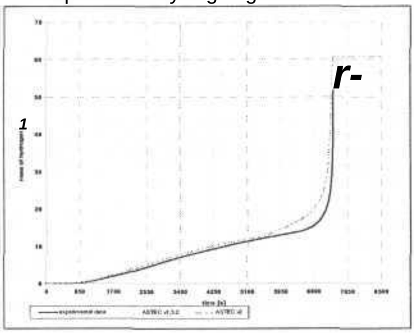

Fig. 2

The comparison of the total hydrogen generation is shown in Figure 6. As it is seen from the figure the reached maximal hydrogen production during the experiment is 58 g.

The start of hydrogen generation during the experiment was observed after 800 s. The comparison of the results with measured data shows that the ASTEC computer codes predicted the same start of hydrogen production. Generally the comparison show good agreement during the whole test. The cladding oxidation was detected in the experiment at approximately 700 s, when the maximal bundle temperature was approximately 1100 K.

The main portion of generated hydrogen is produced between 850 s to 7200 s. The ASTEC v2 predicted higher value of total mass of hydrogen 61 g , while the ASTEC v1.3.2 predicted 56 g total mass of hydrogen, which is below the experimental data. The observed discrepancy could by explained by using of different modeling of bundle.

The comparison of main parameters is presented in Table 2.

Table 2. Comparison of calculated and experimental results

Events	Experimental value	ASTEC v1.3.2 results	ASTEC v2 results
		DIVA module	ICARE module
Beginning of the oxidation, s	-	6963	6963
Total generated hydrogen mass, g	58	56	61
Reached maximum temperature of the fuel, K	2 020	2 560	2 560

Conclusions

The aim of the QUENCH program at Forschungszentrum Karlsruhe concerns integral tests about quenching or cooling an overheated reactor bundle by steam.

As whole, the ASTEC computer code predicted good results for behavior of main parameters shown above. The predicted maximum temperatures by ASTEC is close to the experimental value. The predicted hydrogen show very good agreement with measured data. In ASTEC computer code it is used default correlation for the simulation of QUENCH-12 experiment.

Acknowledgments

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Literature

[1] L. Seport at all., VVER Bundle Test Quench12 Quick Look Report, FZK, Nuclear 3410, December, 2006, Germany;

[2] Stefanova and Groudev, Evaluation of QUENCH12 experiment with ASTEC v1.3.2 computer code, SARNET1, Contract: №.FI6O-CT-2004-509065, September, 2008.

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