# Brief Results of the OECD-SERENA Project

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## 1. Introduction

The objective of the OECD/NEA SERENA project, which has been in progress since 1st Oct. 2007, is to resolve the uncertainties on coolant void and material effect by performing a limited number of well-designed tests with advanced instrumentation reflecting a large spectrum of ex-vessel melt compositions and conditions, and the required analytical work to bring the code capabilities to a sufficient level for use in reactor case analyses. Experiment and analysis programs are running to get the objective.

## 2. Brief Results of the OECD/NEA SERENA Project

### *2.1. Preliminary Experimental results*

Table 1 and 2 show the preliminary test results which have been observed in TROI and KROTOS tests. In TS tests which were conducted in KAERI, a triggered steam explosion was observed at five tests of the six tests. In the fifth test, where no steam explosion was observed, a steam spike appeared before triggering. In the second and third tests which are repeatable tests, the results of many measured data are very similar. The material effect of the binary mixture between TS-3(70 %UO2, 30% ZrO2) and TS-4(80% UO2, 20% ZrO2) is not clear because a trigger time is different, which may influence other parameters such as void fraction and mixture distribution. In the tests, TS-4 test shows larger explosion load than TS-3. Before SERENA project, in past TROI experiments, the material for eutectic composition (70% UO2, 30% ZrO2) showed more explosive than non eutectic materials [J.H. Kim et al., 2009]. The material effect between binary oxides (TS-4) and multiple oxides (TS-6) which is case that the difference between liquidus and solidus temperature is larger than 1,000K is also not so big in the point of explosion load. The more detail observation for the material effect will be explained in the SERENA final integration report. In the KS tests which were conducted in CEA, a triggered explosion was also observed in all tests except the fifth test.

Even though the TS and KS tests were performed at different scale, the results are comparable and fairly consistent, considering that the steam explosion phenomenon is very stochastic. Before the SERENA project, it seemed that it is difficult to judge whether corium is an explosive material or not because some of the experiments had not shown consistent results. From the SERENA project, it is confirmed that a corium shows the low explosivity with comparison of the alumina which was used for the integral FCI test. Furthermore, the energy conversion ratios were compared with the same test series of both test facilities. It was found that the energy conversion ratios obtained in the SERENA project with prototypic corium material are much smaller than with simulant alumina.

Table 1: TROI preliminary results

| | | TS Plan (Actual) | Features |
|---|---|---|---|
| 1 | Challenging conditions | 0.4 MPa, 301K,<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ (73.4:26.6 )<br>Trigger : -0.85 s | S/E<br>Max. C MPa |
| 2 | Geometry effect<br>Effect of geometry by comparison between KROTOS and TROI | 0.2 MPa, 334K<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ ( 68:32)<br>Trigger : -0.85 sec | S/E<br>Max. D2 Mpa |
| 3 | Reproducibility tests | 0.2 MPa, 331K<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ ( 71:29), Trigger : -0.85 sec | S/E<br>Max. D1 MPa |
| 4 | Material effect<br>Oxidic composition | 0.2 MPa, 333K<br>Mat 2: 80%$UO_2$-20%ZrO ( 81:19 ), Trigger:-1.05 s | S/E<br>Max. B Mpa |
| 5 | Material effect<br>Oxidation/composition | 0.2 MPa, 337K<br>Mat 3: 70%$UO_2$-15%$ZrO_2$ + 15%Zr<br>( 75.9 :18.32:0.73:4.99 ; UO2/ZrO2/U/Zr)<br>Trigger :-1.05 s | Steam<br>Spike |
| 6 | Material effect<br>Large solidus/liquidus ΔT | 0.2 MPa, 338K, Mat 4: 70%$UO_2$-30%$ZrO_2$ +FP+iron oxide; 73. : 20.4 : 4.1 : 1.3 0.3 :0.8 :0.2 8.5 (UO2 : ZrO2 : Fe2O3 : Cr2O3: BaO:La2O3:SrO) 73.32: 18.45 : 4.885 : 1.74 : 0.385 : 0.975 : 0.24 ; Trigger : -1.05s | S/E<br>Max A MPa |

Table 2: KROTOS Preliminary Results

| | | KROTOS (Actual) | Features |
|---|---|---|---|
| 0 | KF-C<br>Calibration test | 0.4 MPa, 302K, Tmelt=2930K, free fall: 0.570m<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ | S/E |
| 1 | KS-1<br>Challenging conditions | 0.4 MPa, 302K, Tmelt=2970K, free fall: 0.570m<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ | S/E |
| 2 | KS-2<br>Geometry effect | 0.2 MPa, 334K, Tmelt=3010K, free fall: 0.630m<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ | S/E |
| 3 | KS-3<br>Reproducibility tests | 0.2 MPa, 331K, Tmelt=3013K, free fall: 0.492m<br>Mat 1: 70%$UO_2$-30%$ZrO_2$ | Failure<br>-No S/E |
| 4 | KS-4<br>Material effect<br>Oxidic composition | 0.2 MPa, 333K, Tmelt=2970K, free fall: 0.492m<br>Mat 2: 80%$UO_2$-20%$ZrO_2$ | S/E<br>Max. value for SE |
| 5 | KS-5<br>Material effect<br>Oxidation/composition | 0.2 MPa, 337K, Tmelt=2970K, free fall: 0.492m<br>Mat 3: 70%$UO_2$-15%$ZrO_2$ + 15%Zr | "Explosion" |

### *2.2 Analytical work*

The main tasks of the Analytical Working Group (AWG) are 1) performing pre- and post-test calculations in support of test specification and analysis, 2) improving analytical models and understanding of those key phenomena that are believed to have a major influence on the FCI process, 3) addressing the scaling effect and application to the reactor case, and 4) demonstrating the progress made in SERENA Phase-2 as compared with Phase-1 (in particular on reducing the scatter of the predictions) by repeating the "ex-vessel reactor exercise".

The AWG has performed pre- and post-test calculations for the TS and KS tests. With the support of pre-test calculations the exact test conditions were specified. Post-test calculations and sensitivity studies were performed for code validation, modelling improvements and as a support for the experimental results interpretation. For illustration, in Figure 1 the predicted premixing conditions for KS-2 with TEXAS-V and the calculated pressure for test TS-2 with JASMINE are presented.

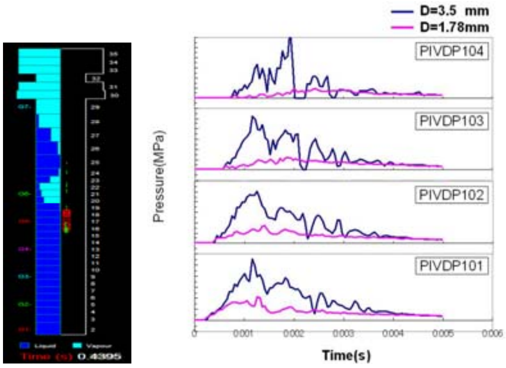


Figure 1 Premixing conditions in KS-2 calculated with TEXAS-V (left) and calculated pressure with JASMINE for TS-2 (right).

To verify the progress made in understanding and modelling FCI key phenomena for reactor applications a reactor exercise has been performed. The objective of the exercise is to demonstrate a reduction of the scatter of the code predictions for ex-vessel FCIs observed in SERENA phase 1 in such a way that the loads on the reactor structures can be predictable. The exercise comprises three cases: BWR axial melt release, PWR axial release and PWR side release. They are based on most relevant conditions for both reactor designs, which were significantly simplified for the purpose of the exercise.

Nothing was imposed to the exercise participants concerning the way they do the calculations, except they should use the codes in a fair and responsive manner, consistently with the way they would use them for safety analysis in their own organizations. The quantities to be provided by each participating organization were defined in detail to enable a straightforward comparison of calculation results. Among others, the following most important quantities had to be provided: axial distributions of radially averaged component fractions at trigger time, histories of total and liquid melt droplets masses in mixture and in region with void less than 60%, history of vapour mass, history of energy release to steam and water, history of fragmented melt mass during explosion, history of kinetic energy, history of pressure and impulse at various locations, etc. For illustration, in Figure 2 the premixing conditions for the BWR case calculated with JEMI and the PWR side release case calculated with MC3D are shown.

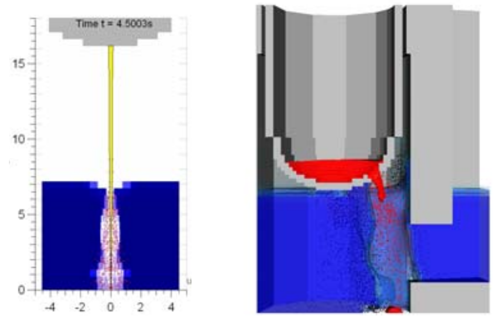


Figure 2: Premixing conditions for BWR axial release and PWR side release calculated with JEMI and MC3D

The calculation results provided by participating organizations using various codes are being compared and the differences discussed. A synthesis report is being prepared showing the progress made in SERENA phase 2.

### 3. Conclusions and Recommendations

The test results confirmed the low explosivity of corium in comparison to simulant alumina, although triggered steam explosions were observed. The analytical objective of SERENA-2 is to bring the scattering of the predictions for ex-vessel steam explosion to acceptable levels for risk evaluation of containment failure by improving the modelling and code performance on the basis of the new data. It seems that the performed reactor exercise will demonstrate a reduction of the discrepancies of code calculations in comparison to SERENA phase 1, but there are further plans to improve the codes to increase the reliability of the predictions in reactor conditions.

### ACKNOWLEGEMENTS

This work was supported by Nuclear Research & Development Program of the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korean government (MEST).

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