Triggered Steam Explosions with Zirconia and Eutectic Corium in the TROI Facility

Jong-Hwan Kim [a*], B. T. Min [a], I. K. Park [a], K. S. Ha [a], S. W. Hong [a]
[a]*Thermal Hydraulics Safety Research Division, Korea Atomic Energy Research Institute,*
150 Dukjin-dong,Yuseong-gu, Taejon, 305-353
[*]*Corresponding author: kimjh@kaeri.re.kr*

1. Introduction

Two triggered steam explosion experiments (TROI-57 & 58) were performed in the TROI facility with zirconia and eutectic corium (UO_2 : ZrO_2 = 70 : 30). The melt interacted with a water pool of 1.0 m in depth and 0.6 m in diameter at an atmospheric pressure and at room temperature. Although many tests were previously performed with these materials in TROI [1,2], the melt delivery was not well-defined. These tests were carried out by changing the melt delivery method to prepare for the tests for the OECD/NEA SERENA program.

Consequently, both tests resulted in triggered steam explosions. Analyses of the dynamic pressure, load, debris size distribution and conversion ratio are to be described.

2. Experimental Results

The experimental facility for TROI-57 & 58 is shown in Fig. 1. The instruments of concern are pyrometers (IRCON 3R-35C15-0-0-0-1), dynamic pressure sensors (KISTLER 6005) and a load sensor (KISTLER 9081A).

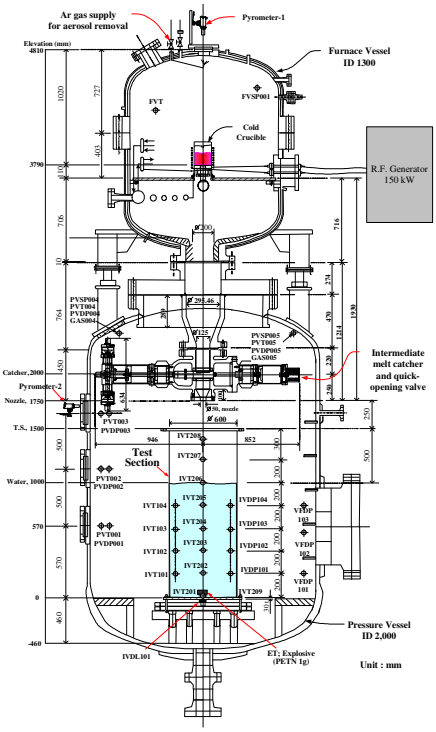

Fig. 1. Schematic diagram of TROI-57 & 58.

The pressure sensors were flush-mounted on the wall of the interaction vessel in a stepwise manner of 0.2 m from the bottom and the load sensor was installed on the bottom of the vessel.

A quick-opening valve with an intermediate melt catcher was newly mounted to deliver the melt with a well-defined jet with an initial diameter of 50 mm.

In the TROI-57 test, a total of 12.930 kg of zirconia was charged into the cold crucible and melted by using an induction heating. The melt was released into the intermediate melt catcher and it was then delivered into the water-filled interaction vessel after the melt was fully collected in the catcher. The melt delivery from the melt catcher is shown in Fig. 2 and it presents a well-defined melt jet.

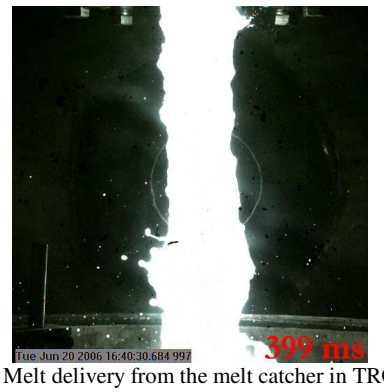

Fig. 2. Melt delivery from the melt catcher in TROI-57.

Fig. 3 shows the melt temperature during a melt delivery. The melt temperature reached 2970 K and the delivery duration was ~ 1 second.

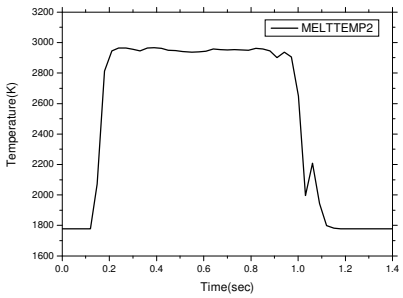

Fig. 3. Melt temperature during a delivery in TROI-57.

Fig. 4 shows the dynamic pressures in the water measured by dynamic pressure sensors. The external triggering occurred at 1.025 s and it induced a triggered steam explosion at 1.026 s. The maximum peak pressure was 22 MPa with a duration of ~ 2 ms.

Fig. 5 shows the dynamic load on the bottom of the interaction vessel. It reached 490 kN with a duration of 11 ms.

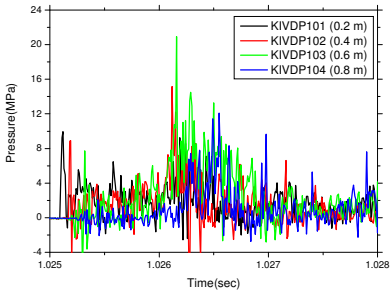

Fig. 4. Dynamic pressures in TROI-57.

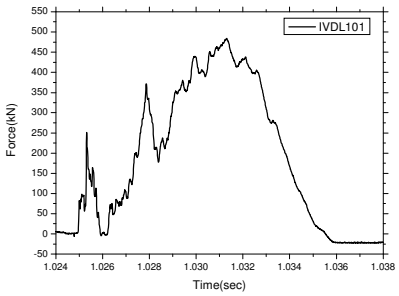

Fig. 5. Dynamic load in TROI-57.

In the TROI-58 test, total 18.000 kg of eutectic corium was charged into the cold crucible. After the same procedure as TROI-57, the melt was delivered into the interaction vessel. The melt temperature during the delivery into water reached 2800 K.

Fig. 6 shows the dynamic pressures in water. The external triggering occurred at 0.975 s and it induced a triggered steam explosion at 0.977 s. The maximum peak pressure was 12 MPa with a duration of ~ 3 ms.

Fig. 7 shows the dynamic load. It reached 280 kN with a duration of 15 ms.

The amounts of the debris smaller than 0.425 mm in TROI-57 & 58 are 22.1 % of 9.437 kg of total delivered melt and 26.8 % of 12.506 kg, respectively. These amounts of fine debris confirm that both tests induced steam explosions.

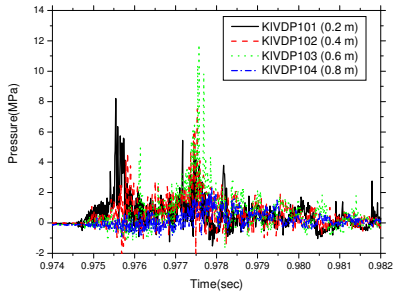

Fig. 6. Dynamic pressures in TROI-58.

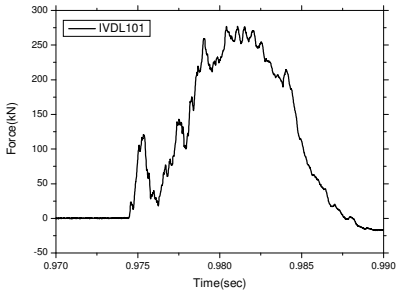

Fig. 7. Dynamic load in TROI-58.

Impulse (I/A) and energy conversion ratio (η) were also calculated from the dynamic load and presented in Table:I. The impulses in TROI 57 & 58 were calculated to be 9.191 and 6.818 kPa·s, respectively. The energy conversion ratios were 0.051 and 0.025 %, respectively.

Table I: Impulse and Conversion Ratio in TROI-57 & 58

	M_{melt} (kg)	I (kN·s)	I/A (kPa·s)	η (%)
TROI-57	9.437	2.601	9.191	0.051
TROI-58	12.506	1.929	6.818	0.026

From these tests, zirconia and eutectic corium confirm their explosivity. The explosivity of zirconia appears to be bigger than that of eutectic corium.

3. Conclusions

Two TROI steam explosion tests have been performed successfully with zirconia and eutectic corium by changing the melt delivery method to achieve a well-defined melt jet. The preparations for the tests for the OECD/NEA SERENA program are satisfactory. Both tests led to triggered steam explosions with a conversion ratio of 0.051 and 0.026 %, respectively. For the estimation of a more credible conversion ratio, more tests need to be performed with various reactor materials.

ACKNOWLEDGEMENTS

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REFERENCES

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[2] J. H. Kim, B. T. Min, I. K. Park, H. D. Kim, S. W. Hong, Triggered Steam Explosions with Corium Melts of Various Compositions in a Narrow Interaction Vessel in the TROI Facility, ICAPP-08, Anaheim, CA USA, June 8-12, 2008.