A TROI Steam Explosion Test with a Zirconia Melt in a Narrow Interaction Vessel

Jong-Hwan Kim [a*], B. T. Min [a], I. K. Park [a], H. D. Kim [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

A steam explosion experiment (TROI-55) was performed in the TROI facility with a narrow (0.3 m in diameter) interaction vessel. TROI-55 was performed with a pure zirconia melt at an atmospheric pressure and at room temperature. Although many tests have been conducted in the TROI test series, this test is the first test performed with a zirconia melt in a narrow interaction vessel of 0.3 m in diameter. Previously, the zirconia melt led to steam explosions in a wide interaction vessel of 0.6 m in diameter [1] and various compositions of corium (UO_2 : ZrO_2 = 70 : 30 and 80 : 20 at weight percent) hardly led to steam explosions in a narrow interaction vessel of 0.3 m in diameter [2]. Therefore, it is of interest whether a steam explosion could occur with a zirconia melt in a narrow interaction vessel or not.

Consequently, this test resulted in multiple spontaneous steam explosions. Analyses of the dynamic pressure, load and debris size distribution are to be described in relation to this result.

2. Experimental Results

The experimental facility for TROI-55 is shown in Fig. 1 and the instrumentations are described in Ref. 2. Two similar pyrometers were used to measure the melt temperatures during a melting and a melt delivery. However, the melt temperature during a melting was succeeded to measure.

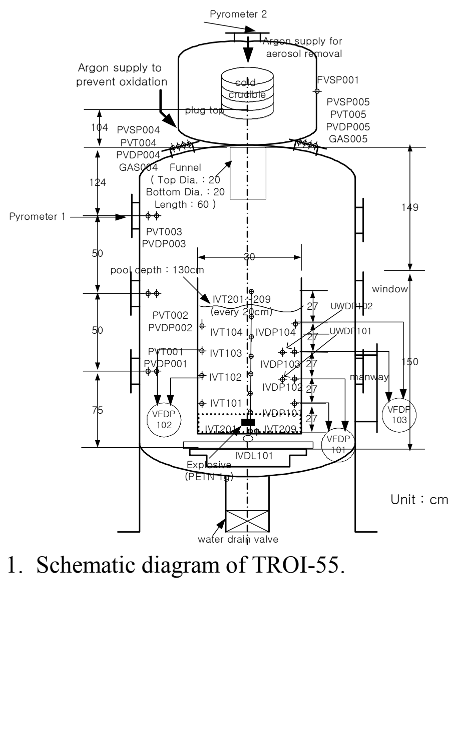

Fig. 1. Schematic diagram of TROI-55.

This test was carried out to observe the occurrence of a steam explosion with a pure zirconia melt in a water pool of 1.3 m in depth at room temperature in a narrow 0.3 m diameter interaction vessel with an external triggering.

The lumps and powder of ZrO_2 were charged into the crucible. The charged weight was 11.265 kg. The charged ZrO_2 was melted and then the molten zirconia of 7.940 kg was delivered into the interaction vessel. Fig. 2 shows the melt temperature during a melting which reached 2960 K.

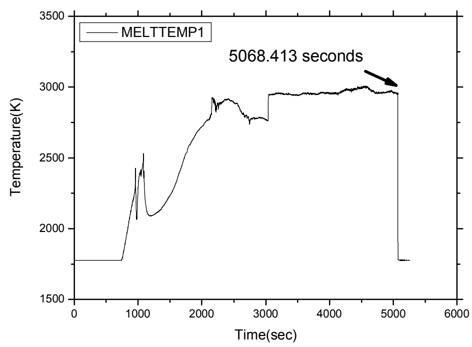

Fig. 2. Melt temperature during a melting in TROI-55.

Fig. 3 shows the dynamic pressures in the water measured by the wall-mounted dynamic pressure sensors. IVDP101 ~ 104 were installed at 27, 54, 81 and 108 cm from the bottom. The external triggering time was set at 2.30 seconds from the dynamic data acquisition. They show several pressure peaks at 0.99, 1.03, 1.15, 1.68 and 2.33 seconds, so multiple spontaneous steam explosions are believed to have occurred before the external triggering shown at 2.33 seconds. The pressure peaks from the external trigger at 2.33 seconds are very small. This is caused by an attenuation of the pressure peaks by the vapor bubbles formed due to the preceding multiple spontaneous steam explosions.

Fig. 4 shows the dynamic load on the bottom of the interaction vessel. It also shows multiple explosions at the load peaks. The load caused by the external trigger was quite small at 150 kN. This value is lower than those (higher than 200 kN) from other tests [2], as is the pressure peak. This can be explained by the fact that the water-starved or void-rich interaction vessel after the spontaneous steam explosions attenuated a pressure wave propagation and it lessened the mechanical constraint of the water so as to produce a small dynamic load.

From the dynamic pressure and load, it is confirmed that the ZrO_2 melt easily leads to spontaneous steam explosions.

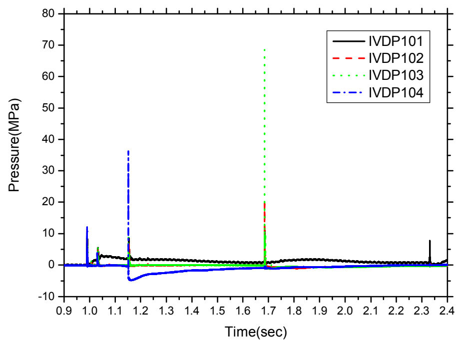

Fig. 3. Dynamic pressures from the wall-mounted sensors in TROI-55.

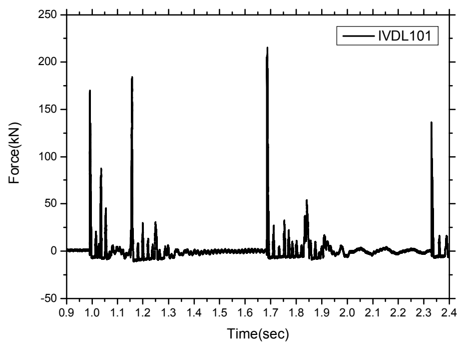

Fig. 4. Dynamic load in TROI-55.

Figs. 5 and 6 show the debris size distribution. These figures show that the mass fraction of the fine particles smaller than 0.425 mm is quite large at 41.1 %. This size distribution means that there would be a strong steam explosion in this test. This is consistent with the dynamic pressure and load. Furthermore, the mass mean diameter of the debris was as small as 0.55mm. It is evident that steam explosions occurred in this test.

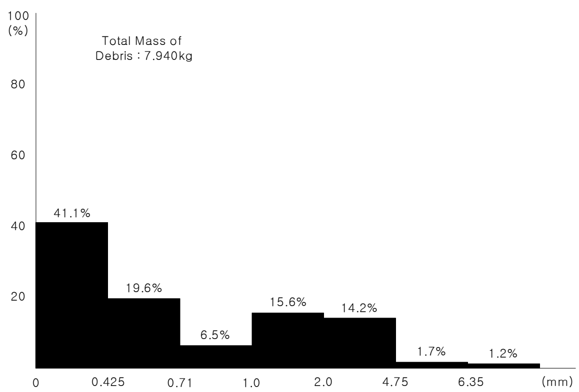

Fig. 5. Debris size distribution in TROI-55.

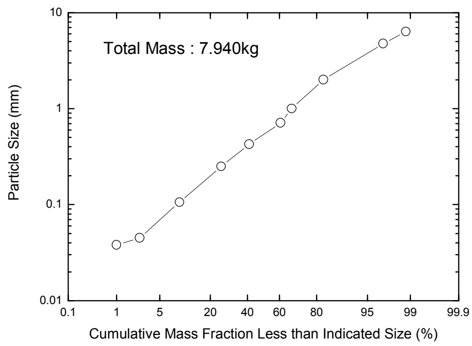

Fig. 6. Cumulative debris size distribution in TROI-55.

3. Conclusions

A TROI steam explosion test has been performed with a pure zirconia melt delivered into a water-filled narrow interaction vessel of 0.3 m in diameter. This test led to multiple spontaneous steam explosions before an external triggering. In this test, the explosivity of the pure zirconia was confirmed, even in a narrow interaction vessel which could suppress a steam explosion due to a high void fraction in it. More steam explosion tests with a prototypic corium in a narrow interaction vessel need to be performed to properly estimate the conversion ratio of the corium.

ACKNOWLEDGEMENTS

This study has been carried out under the nuclear R&D program by the Korean Ministry of Science and Technology.

REFERENCES

[1] J. H. Song, I. K. Park, Y. J. Chang, Y. S. Shin, J. H. Kim, B. T. Min, S. W. Hong, and H. D. Kim, Experiments on the Interactions of Molten ZrO_2 with Water Using TROI Facility, Nuclear Engineering and Design, Vol.213, pp.97-110 (2002).
[2] J. H. Kim, I. K. Park, B. T. Min, S. W. Hong, S. H. Hong, J. H. Song, and H. D. Kim,, Results of the Triggered TROI Steam Explosion Experiments with a Narrow Interaction Vessel, ICAPP-06, Reno, NV USA, June 4-8, 2006.