An Experimental Study on Triggered Steam Explosions in the TROI Facility

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1. Introduction

Although many studies have been performed worldwide on a steam explosion [1,2], there are only a few tests using real reactor material. So the TROI steam explosion experiments have been carried out at the KAERI to evaluate the explosivity of corium[3,4]. In the previous TROI tests, the effects of the water depth and corium composition on the occurrence of a steam explosion were studied[5,6]. In this paper, the results of two TROI tests using two different corium compositions by applying an external trigger are presented.

2. Instrumentations

The instrumentations of the TROI-36 experiment are shown in Fig.1. The IVT series measures the water temperatures in the interaction vessel. The PVT series measures the atmospheric temperatures in the pressure vessel. The IVDP series measures the dynamic pressures in the interaction vessel. The IVDL101 measures the dynamic load on the bottom. The PVSP series measures the static pressures in the pressure vessel. An explosive (PETN 1g) was used as an external trigger.

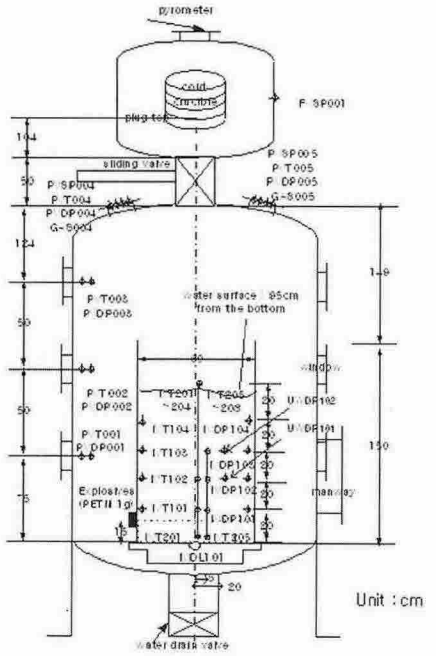

Figure 1. Instrumentations of the TROI-36 experiment.

3. Test Results

The TROI-36 and TROI-37 tests using corium have been performed by applying an external trigger. The initial conditions and test results are presented in Table 1.

Table 1. Initial conditions and test results

	TROI test number	Unit	36	37
Melt	Initial Composition UO2 / ZrO2 /Zr	[w/o]	69/30/1	79/20/1
	Temperature	[K]	3510	3380
	Charged mass	[kg]	17.000	20.000
	Initiator mass	[kg]	0.15	0.15
	Released mass	[kg]	5.260	8.130
	Plug/puncher diameter	[cm]	8.0/6.5	8.0/6.5
	Initial jet diameter	[cm]	8.0	8.0
	Free fall in gas	[m]	3.55	3.55
Test Section	Water mass	[kg]	269	269
	Initial height	[cm]	95	95
	Final height	[cm]	43	47
	Cross section	[m2]	0.283	0.283
	Initial temperature	[K]	305	313
	Sub-cooling	[K]	68	60
Pressure Vessel	Initial pressure(air)	[MPa]	0.110	0.104
	Initial temperature	[K]	297	294
	Free volume	[m3]	8.023	8.023
Results	Maximum PV pressurization	[MPa]	0.028	0.034
	Time to reach peak	[sec]	1.5	3.0
	Maximum PV heat-up	[K]	30	44
	Time to stabilize	[sec]	5	5
	Maximum water heat-up	[K]	13	17
	Time to stabilize	[sec]	5	5
	Steam explosion		SE	SE
	Dynamic pressure peak	[MPa]	17.0	7.7
	Duration	msec	0.2	0.3
	Impulse	kN	360	200
	Duration	msec	5	6

3.1 TROI-36 Test

In the TROI-36 test, 17.0kg of 70 : 30 corium (UO_2 : ZrO_2) was charged into the crucible and melted. Then 5.260kg of the molten corium was delivered into a 95cm deep water pool. The external trigger led to a steam explosion. The dynamic pressure histories are shown in Fig.2. A pressure pulse of 7.5MPa in magnitude produced by the external trigger appeared at 1.1811 seconds after the melt delivery and soon a triggered steam explosion occurred with a magnitude of 17.0MPa at 1.1817 seconds. Fig.3 shows the dynamic load and it reached 360kN with the duration of 5ms.

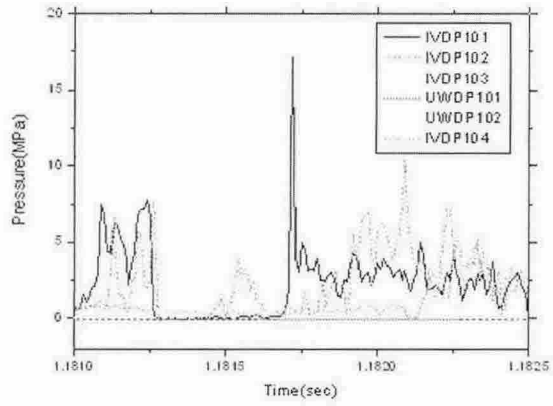

Fig.2. Dynamic pressures in the TROI-36 test

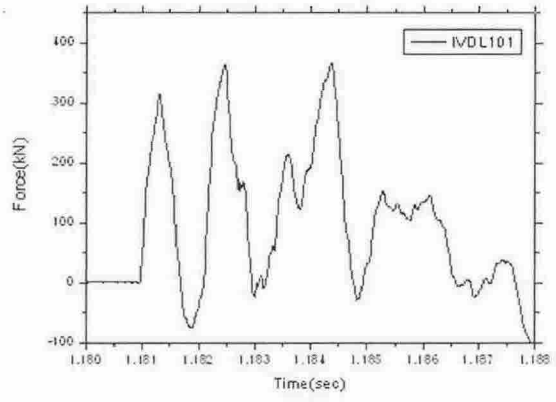

Fig.3. Dynamic load in the TROI-36 test

3.2 TROI-37 Test

In the TROI-37 test, 20.0kg of 80 : 20 corium was charged into the crucible and melted. Then 8.130kg of the molten corium was delivered into a 95cm deep water pool.

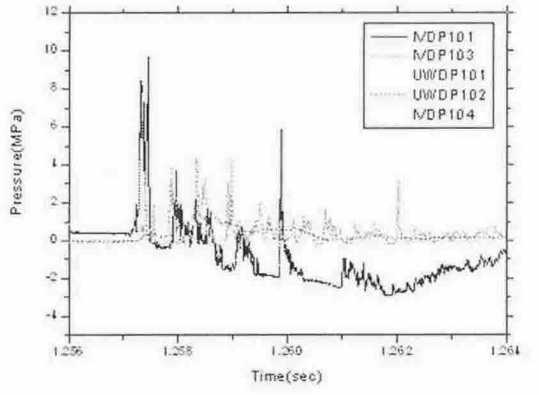

Fig.4. Dynamic pressures in the TROI-37 test

The external trigger led to a steam explosion while a spontaneous steam explosion had not occurred previously with this composition of corium. The dynamic pressure histories are shown in Fig.4. A pressure pulse of 10.0MPa in magnitude produced by the external trigger appeared at 1.2573 seconds after the melt delivery and then a triggered steam explosion occurred with a magnitude of 7.7MPa at 1.2580 seconds. This magnitude is smaller than that with 70 : 30 corium.

4. Conclusion

Two triggered steam explosion experiments with two different compositions of corium have been performed. A triggered steam explosion can occur with 80 : 20 corium which did not lead to a spontaneous steam explosion. The strength of the triggered steam explosion with 80 : 20 corium is smaller than that with 70 : 30 corium which often led to a spontaneous steam explosion. More triggered steam explosion experiments need to be carried out to evaluate the strength of the steam explosions.

ACKNOWLEDGMENTS

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REFERENCES

[1] I. Huhtiniemi and D. Magallon, Insight into Steam Explosions with Corium Melts in KROTOS, Nuclear Engineering and Design, Vol.**204**, p.391, 2001.

[2] D. H. Cho, D. R. Armstrong and W. H. Gunther, Experiments on interactions between Zirconium-containing melt and water, NUREG/CR-5372, 1998.

[3] 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 ZrO2 with Water Using TROI Facility, Nuclear Engineering and Design, Vol.**213**, p.97, 2002.

[4] J. H. Song, I. K. Park, Y. S. Sin, J. H. Kim, S. W. Hong, B. T. Min and H. D. Kim, Spontaneous Steam Explosions Observed in the Fuel Coolant Interaction Experiments Using Reactor Materials, Journal of Korean Nuclear Society, Vol.**33**, No. 4, p.344, 2002.

[5] J. H. Kim, I. K. Park, B. T. Min, S. W. Hong, Y. S. Shin, J. H. Song and H. D. Kim, An Experimental Study on Intermediate Scale Steam Explosions with Molten Zirconia and Corium in the TROI Facilities, NURETH-10, Oct. 5-9, 2003, Seoul, Korea.

[6] J. H. Kim, I. K. Park, B. T. Min, S. W. Hong, Y. S. Shin, J. H. Song and H. D. Kim, The Influence of Variations in the Water Depth and Melt Composition on a Spontaneous Steam Explosion in the TROI Experiments, ICAPP'04, June 13-17, 2004, Pittsburgh, PA USA.