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An Influence of Corium Composition Variations on a Spontaneous Steam Explosion in Severe Accidents in a Nuclear Reactor

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Key Words : Steam Explosion(), TROI Experiment(TROI), Corium(), Eutectic Point(), Mushy Zone(), Explosivity()

Abstract

Recently series of steam explosion experiments have been performed in the TROI facility to identify the influence of corium compositions on the occurrence of a spontaneous steam explosion varying corium melt composition. The compositions of the corium were 0 : 100, 50 : 50, 70 : 30, 80 : 20 and 87 : 13 at weight percent of UO₂ to ZrO₂, and the mass of the corium was about 10kg. Corium melt at 0 : 100 weight percent (pure zirconia) caused a strong spontaneous steam explosion, and melt at 70 : 30 weight percent(eutectic corium) led to a weak steam spike, while melts at other compositions did not result in spontaneous steam explosions, when they came into contact with 67cm deep water pool at room temperature. It seems that the explosivity of pure zirconia is stronger than that of corium at other compositions and a steam explosion is not likely to occur with corium melts at non-eutectic compositions which are included in mushy zone region.

1.

[1], [2, 3, 4],

1.1

[5, 6, 7],

가

[8, 9, 10]

1.2 TROI

가

[11].

ANL ZREX [4] JRC-Ispra
FARO/KROTOS [5, 6, 7] zirconia

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TROI

zirconia

*

가 [12, 13, 14, 15, 16].

TROI

가

2. TROI

2.1 TROI

TROI

1

212°C 20

(>3000K)

가 가

water jacket

가

150kW,

가

50kHz

가

가

가

가

2

(IRCON 1500~3500°C)

(grey-body condition)

가

2.2

가

(zirconia)

가

가
Zr

Zr

가

zirconia 가

가

가

가

가

가

가

plug

plug

puncher

triggering

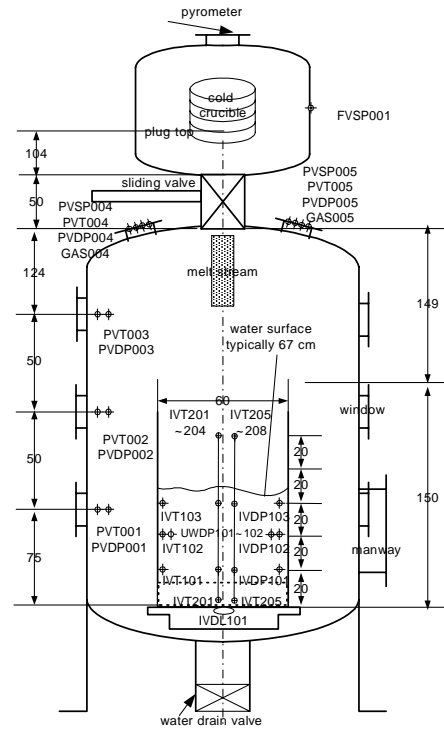


Fig. 1 Schematic diagram of the TROI facility

3. TROI

3.1

zirconia

TROI-28

TROI-32

5

TROI-28

80 : 20 (UO₂ : ZrO₂)

10kg

67cm

TROI-29

50 : 50

TROI-30

가 0 : 100

zirconia

TROI-31

70 : 30

가

TROI-32

UO₂

TROI

가 87 : 13

TROI-28

TROI-32

1

3.2 TROI-28

TROI-28

17.0kg

80 : 20

(UO₂ :

Table 1 Initial conditions and results of the TROI tests (TROI-28 ~ TROI-32)

	TROI test number	Unit	28	29	30	31	32
Melt	Initial Charge Composition	[w/o]	79/20/1	49.5/49.5/1	0/99/1	69/30/1	86/13/1
	Temperature	[K]	3500	3450	3600	3450	3530
	Charged mass	[kg]	17.0	14.3	12.165	17.0	19.950
	Initiator mass	[kg]	0.15	0.15	0.15	0.15	0.15
	Released mass	[kg]	12.105	11.510	2.980	12.000	14.560
	Plug/puncher diameter	[cm]	8.0/6.5	8.0/6.5	8.0/6.5	8.0/6.5	8.0/6.5
	Initial jet diameter	[cm]	4.5	5.0	3.0	8.0	8.0
	Free fall in gas	[m]	3.8	3.8	3.8	3.8	3.8
	Test Section	Water mass	[kg]	241	241	241	189
Initial height		[cm]	67	67	67	67	67
Final height		[cm]	64	63	-	46	66
Cross section		[m ²]	0.36	0.36	0.36	0.283	0.283
Initial temperature		[K]	284	287	284	287	290
Sub-cooling		[K]	89	86	89	86	83
Pressure Vessel	Initial pressure(air)	[MPa]	0.105	0.110	0.114	0.111	0.113
	Initial temperature	[K]	289	289	286	287	293
	Free volume	[m ³]	8.023	8.023	8.023	8.023	8.023
Results	Maximum PV pressurization	[MPa]	0.040	0.030	0.026	0.026	0.038
	Time to reach peak	[sec]	5	4	5	4	6
	Maximum PV heat-up	[K]	185	80	40	100	210
	Time to stabilize	[sec]	15	15	13	17	12
	Maximum water heat-up	[K]	-	21	40	35	27
	Time to stabilize	[sec]	-	25	10	20	25
	Steam explosion		NO	NO	SE	SS	NO
	Dynamic pressure peak	[MPa]	-	-	5.5	0.25	-
	Duration	msec	-	-	5	10	-
	Impulse	kN	-	-	-	80	-
Duration	msec	-	-	-	15.0	-	
Debris	Total	[kg]	12.105	11.510	2.980	12.000	14.560
	>6.35mm	[kg]	1.355	0.910	0.345	1.875	1.890
	4.75mm ~ 6.35mm	[kg]	1.260	1.190	0.270	1.365	1.670
	2.0mm ~ 4.75mm	[kg]	4.620	4.375	0.875	3.680	6.590
	1.0mm ~ 2.0mm	[kg]	2.355	2.245	0.620	2.395	1.955
	0.71mm ~ 1.0mm	[kg]	0.790	0.770	0.210	0.780	0.745
	0.425mm ~ 0.71mm	[kg]	0.960	1.020	0.260	0.940	0.935
	<0.425mm	[kg]	0.765	1.000	0.400	0.965	0.775
H ₂ gas	Before/After the interaction	[ppm]	943/2450	<10/619	<10/<10	186/71	89/1010
	Mass	[g]	1.609	0.407	<0.007	0.047	0.663

ZrO₂) 12.1kg 가
 , 4 가
 67cm 가
 185K 가
 2
 3500K
 3.3 TROI-29
 TROI-29 50 : 50
 가 TROI-28
 가 break-up() 14.3kg 11.5kg

5
80K

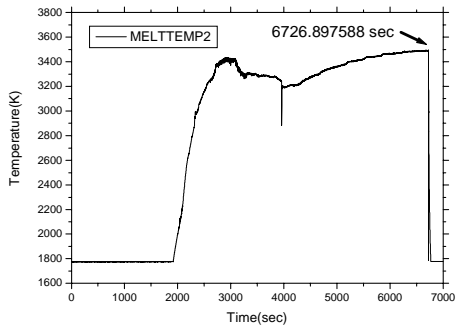


Fig. 2 Melt temperature in the TROI-28 test

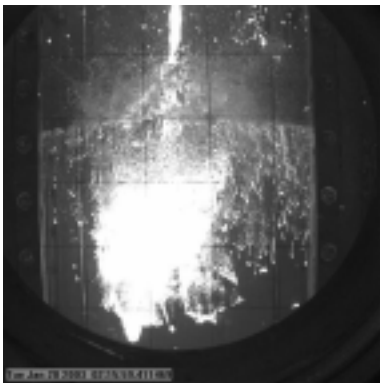


Fig. 3 Melt injection in the TROI-28 test

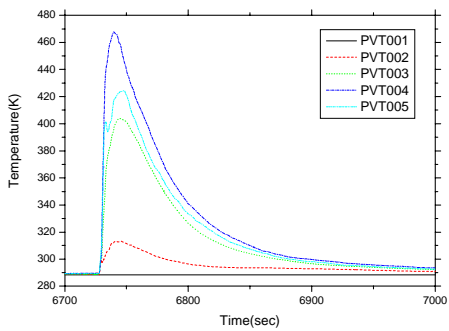


Fig. 4 Ambient temperatures in the TROI-28 test

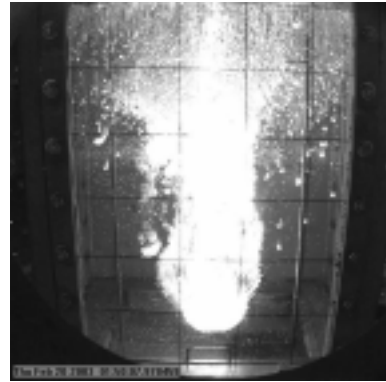


Fig. 5 Melt injection in the TROI-29 test

3.4 TROI-30
12.2kg zirconia
3.0kg

6
5.5MPa
7
zirconia
40K (8)

3.5 TROI-31
TROI-31 15.0kg 70 : 30
12.0kg

steam
spike 가

9 10
0.25MPa, 80kN

3.6 TROI-32
TROI-32 19.95kg 87 : 13
14.56kg

UO₂
가 210K

가

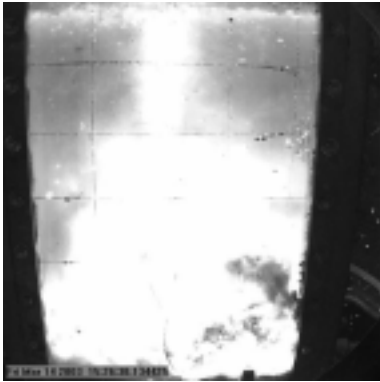


Fig. 6 Melt injection in the TROI-30 test

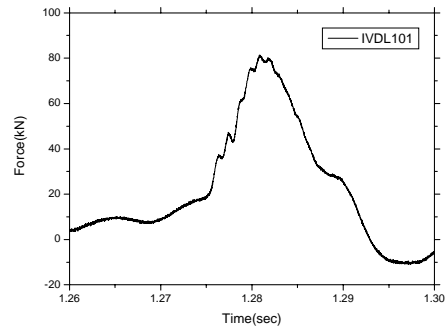


Fig. 10 Dynamic load in the TROI-31 test

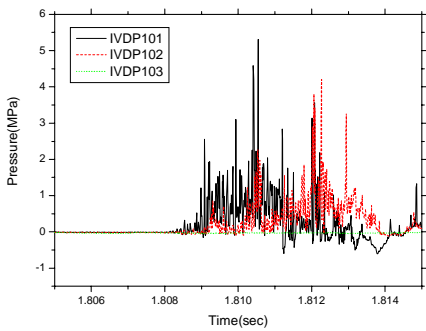


Fig. 7 Dynamic pressures in the TROI-30 test

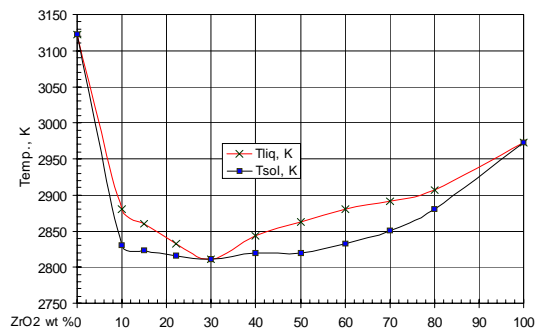


Fig. 11 Phase diagram of corium

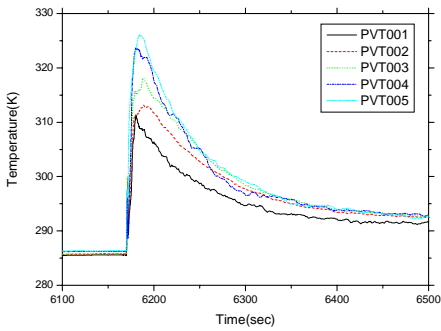


Fig. 8 Ambient temperatures in the TROI-30 test

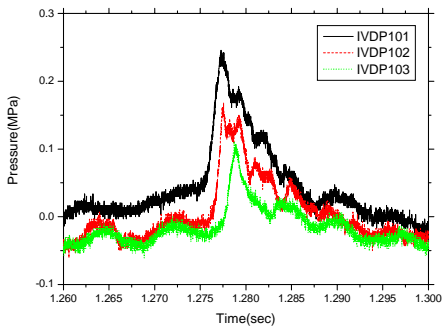


Fig. 9 Dynamic pressures in the TROI-31 test

4.

TROI-28

TROI-32

- zirconia(UO₂ : ZrO₂ = 0 : 100)

- 11

70 : 30

steam spike 가

- mushy zone

zirconia

, mushy zone

70 : 30

(conversion ratio)

가

가

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