Why Abrasion of Concrete was Terminated in Fukushima ?

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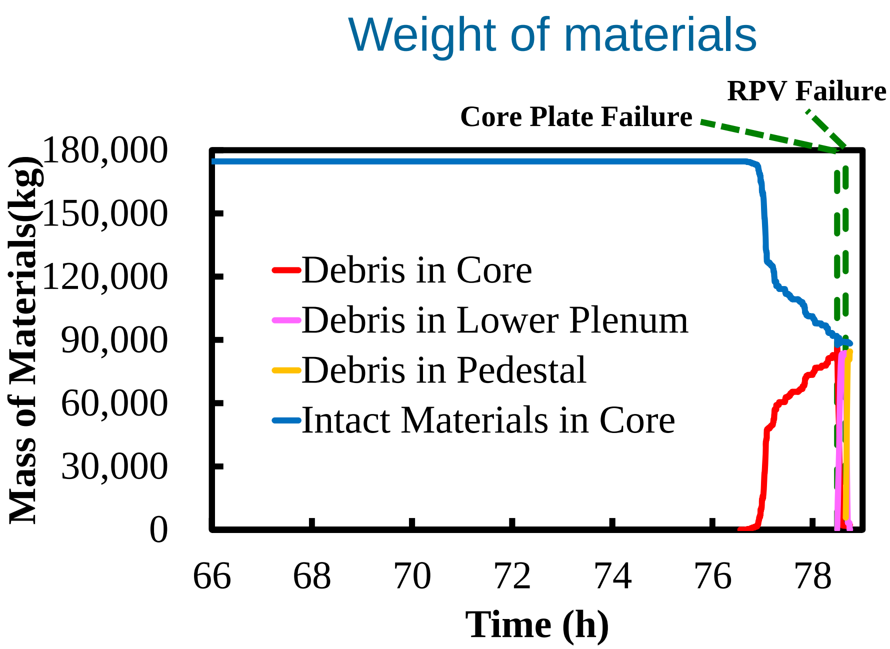
Introduction

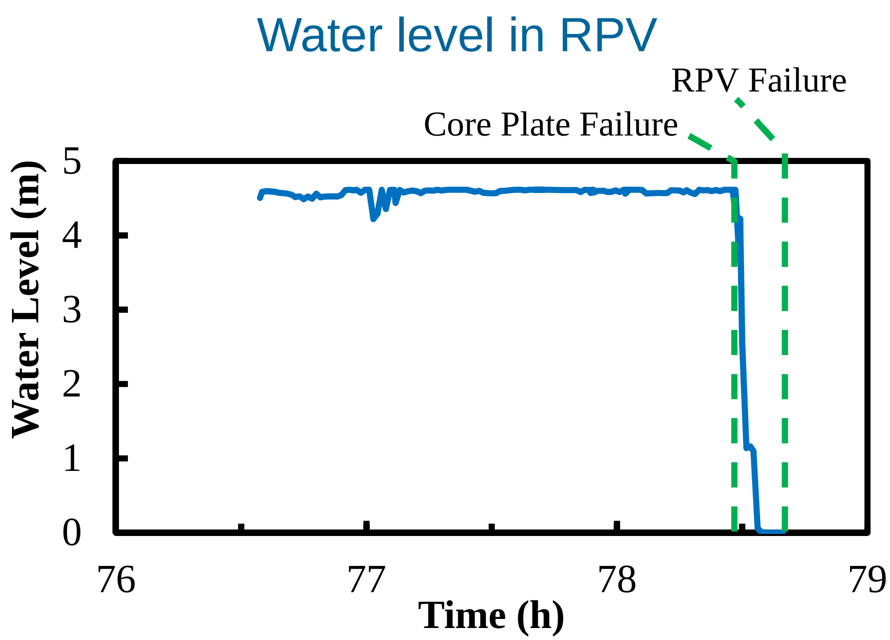
- Debris discharged from RPV onto pedestal at Unit 1-3, according to simulation results
- Debris with amount of ~ 40 t at Unit 1, 80 t at Unit 2 being discharged with or without water
- Debris on pedestal, flooded or non-flooded, continuing to abrade concrete at contacting area
- According to existing experimental results, ex., MCCI, COTELS, WETCOR, MACE/ACE, termination of concrete abrasion achieved only in case of injection of debris and water simultaneously on pedestal
- Why abrasion of concrete terminated at Fukushima

Introduction (Cont'd)

- Unlikely of debris relocating through base mat concrete of PCV at Unit 1-3, considering measured contamination levels in underground water
- Requirements to identify reason why debris was cooled on pedestal

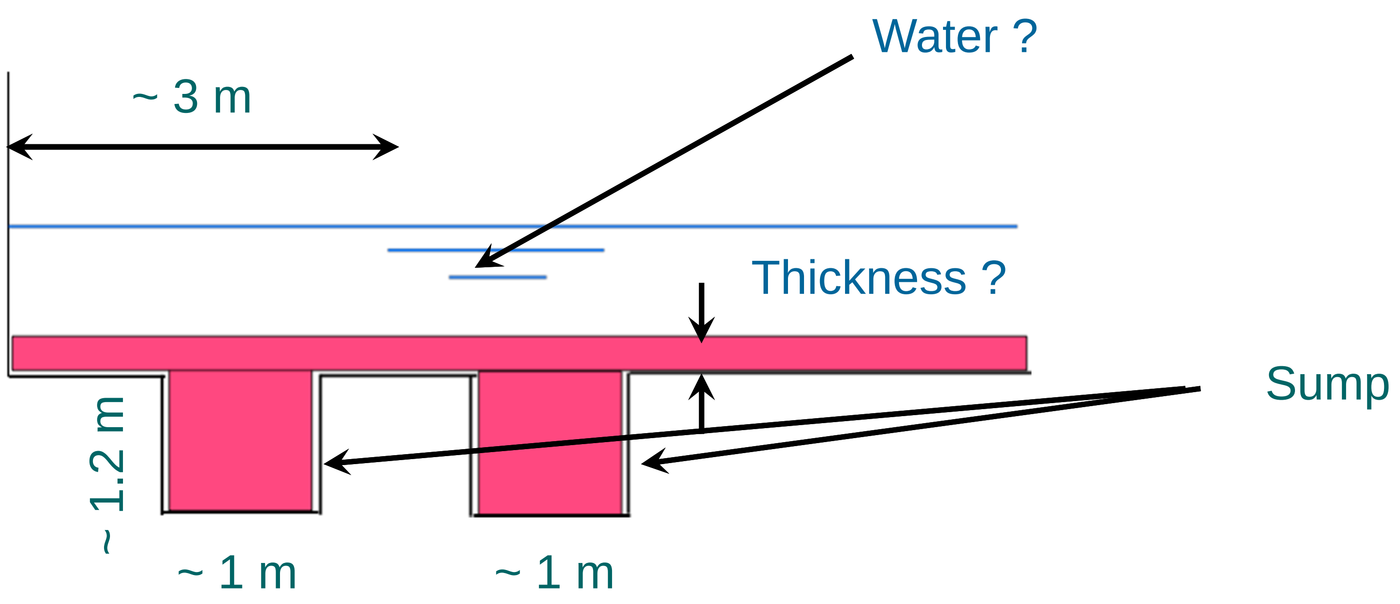
Mass of debris transient at Unit 2





- Reduction of water level in RPV to BAF at 75.5 h (8.8 h), followed by degradation of core
- Debris with an amount of ~ 80 t out of 174.7 t relocated onto core plate at 78.5 h (10.8 h), just before failure of core plate
- Debris with an amount of ~ 80 t dropping onto pedestal due to failure of RPV at 78.7h (12.0 h)
- No water remaining in lower plenum at RPV failure

Schematic figure of debris relocated onto pedestal



- Debris with an amount of ~ 40 t (~ 4 m^3) at Unit, 1 ~ 80 t (~ 8 m^3) at Unit 2 dropping onto pedestal due to failure of RPV at 78.7h (12.0 h)
- No water remaining in lower plenum at RPV failure at Unit 2
- According to existing experimental results, ex., MCCI, COTELS, WETCOR, MACE/ACE, termination of concrete abrasion achieving only in case of injection of debris and water simultaneously on pedestal

What actions should be taken as a next step?

- Experiments to address coolability of debris with internal heat source by flooding of water
- Utilization of existing facilities with modifications if necessary, for instance, MCCI at ANL, in which order of 1 t of real corium can be treated

Summary

- Debris with an amount of ~ 40 t out of ~100 t at Unit 1, ~ 80 t out of 174. 7 t at Unit 2 relocated onto pedestal
- At Unit 2, debris dropped onto pedestal with no water
- Why debris on pedestal cooled and abrasion of concrete terminated ?
- To address those issues, necessity of new experiments

Rupture model for cladding

Rupture of cladding when stress > critical stress evaluated as follows:

$$\sigma_{\theta B} = 1.36 K_A \quad (T<750K)$$
$$\sigma_{\theta B} = 46.861429 K_A \exp(-1.9901087 \times 10^6 / T^2) \quad (750<T<1050K)$$
$$\sigma_{\theta B} = 7.7 K_A \quad (T>1050K)$$

where

$\sigma_{\theta B}$: Critical Stress（Pa）
K_A: Strength Factor（Pa）
T: Temperature（K）

Rupture model for core plant and RPV

Rupture criteria for core plate

- Temperature of core plate > Melting temperature of SS (1670 K)

Rupture criteria for RPV

- Creep rupture
  - $D_c \geqq 1.0$

$$D_c = \sum \frac{\Delta t}{t_{rp}}$$

$$LMP = T\left(C1 + C2 \log_{10} t_{rp}\right)$$ *LMP: Larson-Miller parameter*

$$\log_{10} \sigma = m \times LMP + b$$

$$\sigma = (P_{IO} + P_{DB}) r / 2\Delta r$$

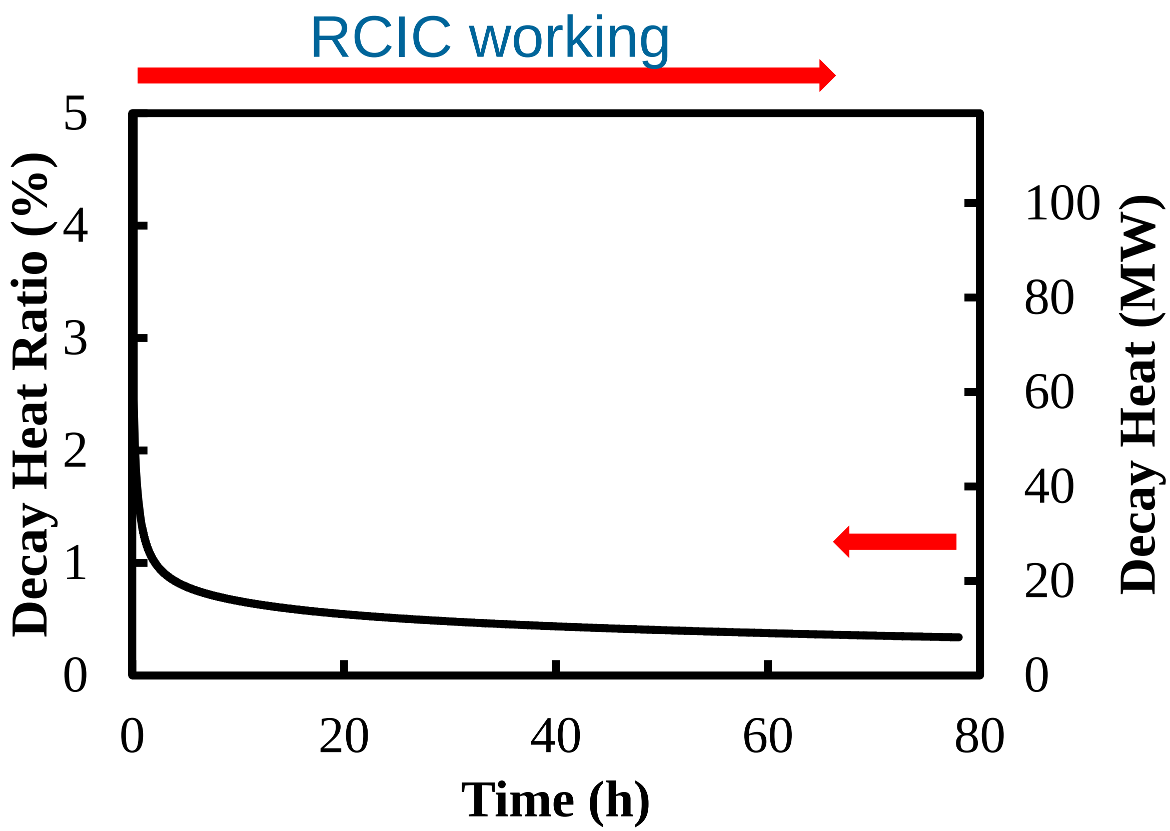
- Melting rupture
  - Temperature at RPV wall > 1700 K

- Rupture area
  - 5.0×10^{-2} m^2

Composition of core and debris

	Initial Weight (t)	Weight of Debris dropped onto Pedestal (t)
UO_2	112.6	40.3
U_3O_8	0	4.00
Fe	19.1	11.3
FeO	0	1.77
Zr	42.1	12.9
ZrO_2	0	12.7
B_4C	0.91	0.49

Decay heat transient



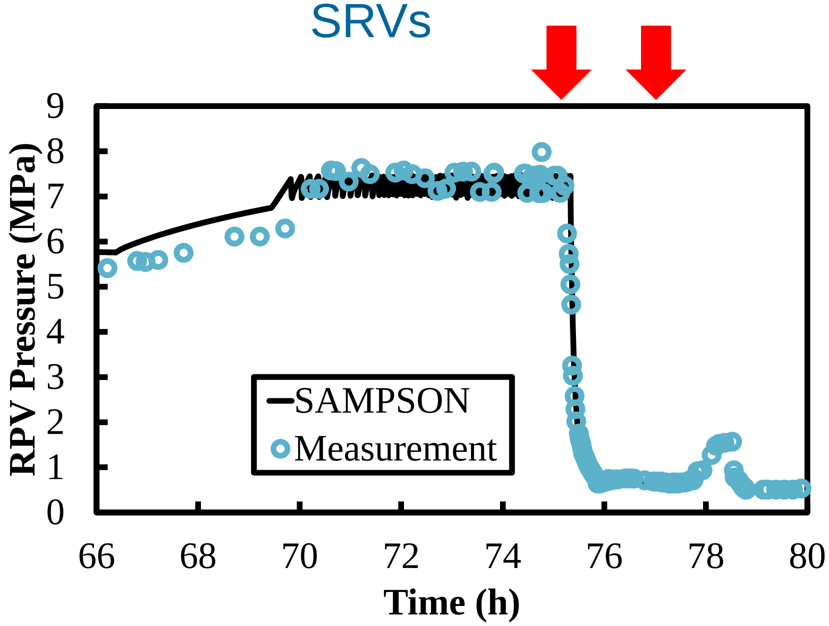
- Malfunction of RCIC at 66.7 h
- Heat to be removed ~ 10 MWt
- Additional heat due to Zr-steam reaction

Pressure and temperature transient in RPV

Pressure in RPV

Manual opening of SRVs

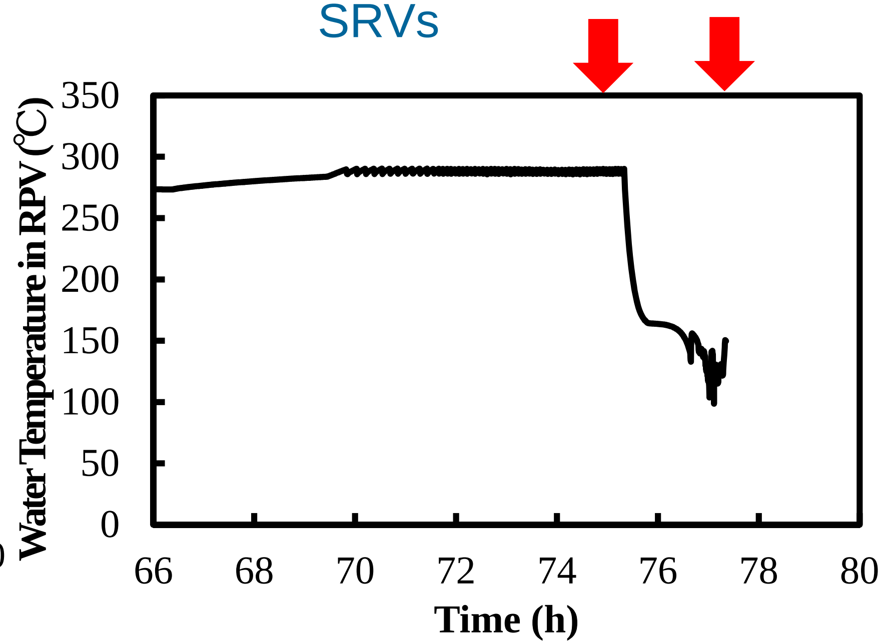
Sea water injection



Water temperature in RPV

Manual opening of SRVs

Sea water injection



- Manual opening of two SRVs at 75.4 h (8.7h)
- Reduction of water level in RPV to BAF at 75.5 h (8.8 h)
- Activation of sea water injection at 77.1 h with a flow rate of 4.86 kg/s (10.4 h)