NUBIKI NUCLEAR SAFETY RESEARCH INSTITUTE

MELCOR 1.8.6
Volatile iodine release challenges in case of external reactor vessel cooling combined with filtered vent - Effect of pH

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  - LLOCA d2x500mm accident terminated
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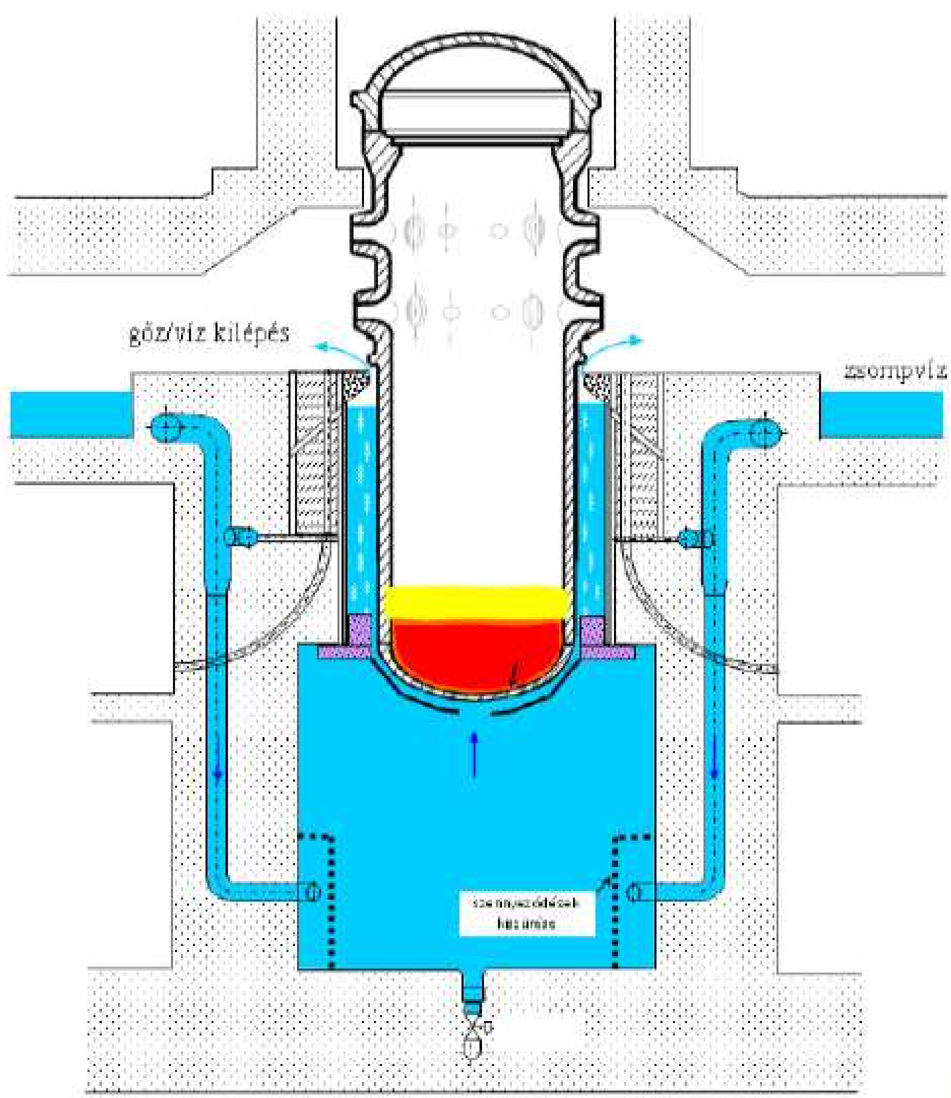
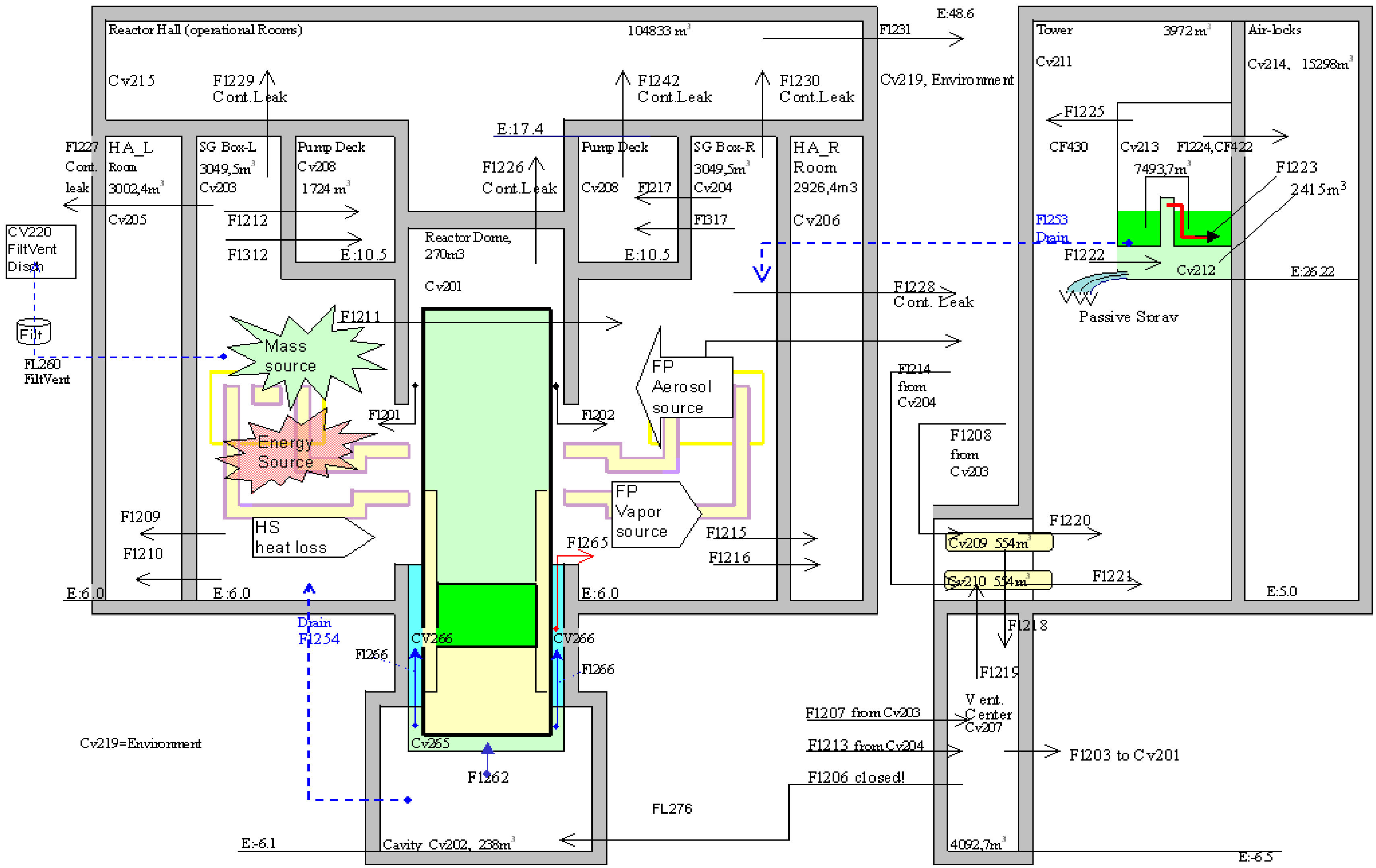
Accident conditions for dominating PSA-2 case: PDS-05C

Initiating event	SBLOCA d=11mm
ECCS	No
Cont. Init. State	Intact
Spray	No
Sec. Side depressurisation	Yes
Sec. Side FW	No
Prim. Side depressurisation	Yes
Early cont failure	No
Ex-vessel cooling	Yes
Filtered vent	Yes
Late phase cont. Failure	No

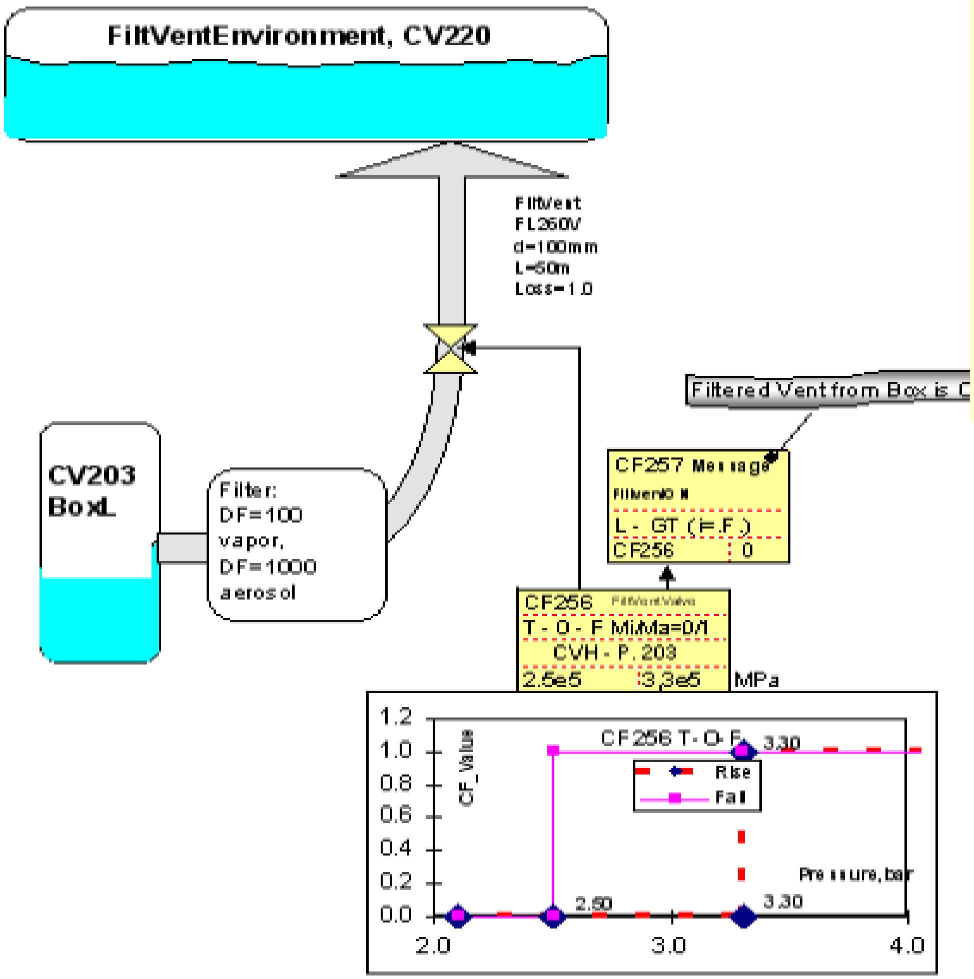
Plant solution: External Vessel Cooling



VVER-440 Simplified Stand Alone Containment:
Sources: Primary circ + Ex-vessel cooling + BC drain+Fvent



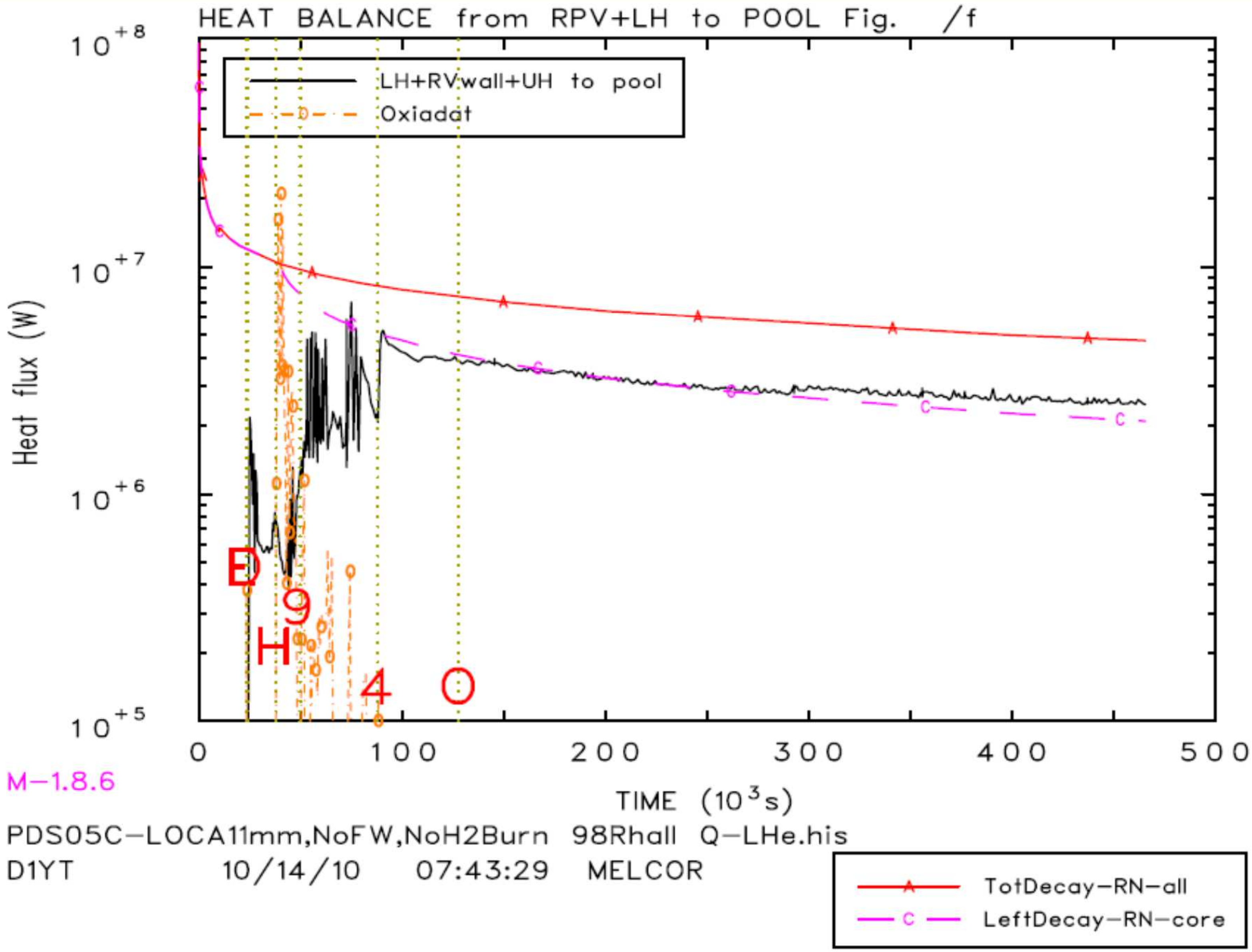
Filtered vent model for VVER-440/213 Stand Alone Containment



Filtered vent from SG box:

- starts: P=3.3 bar
- stops: P=2.5 bar

External reactor vessel cooling: Heat balance - Gross



External Reactor Vessel Cooling: Heat balance - Conclusions

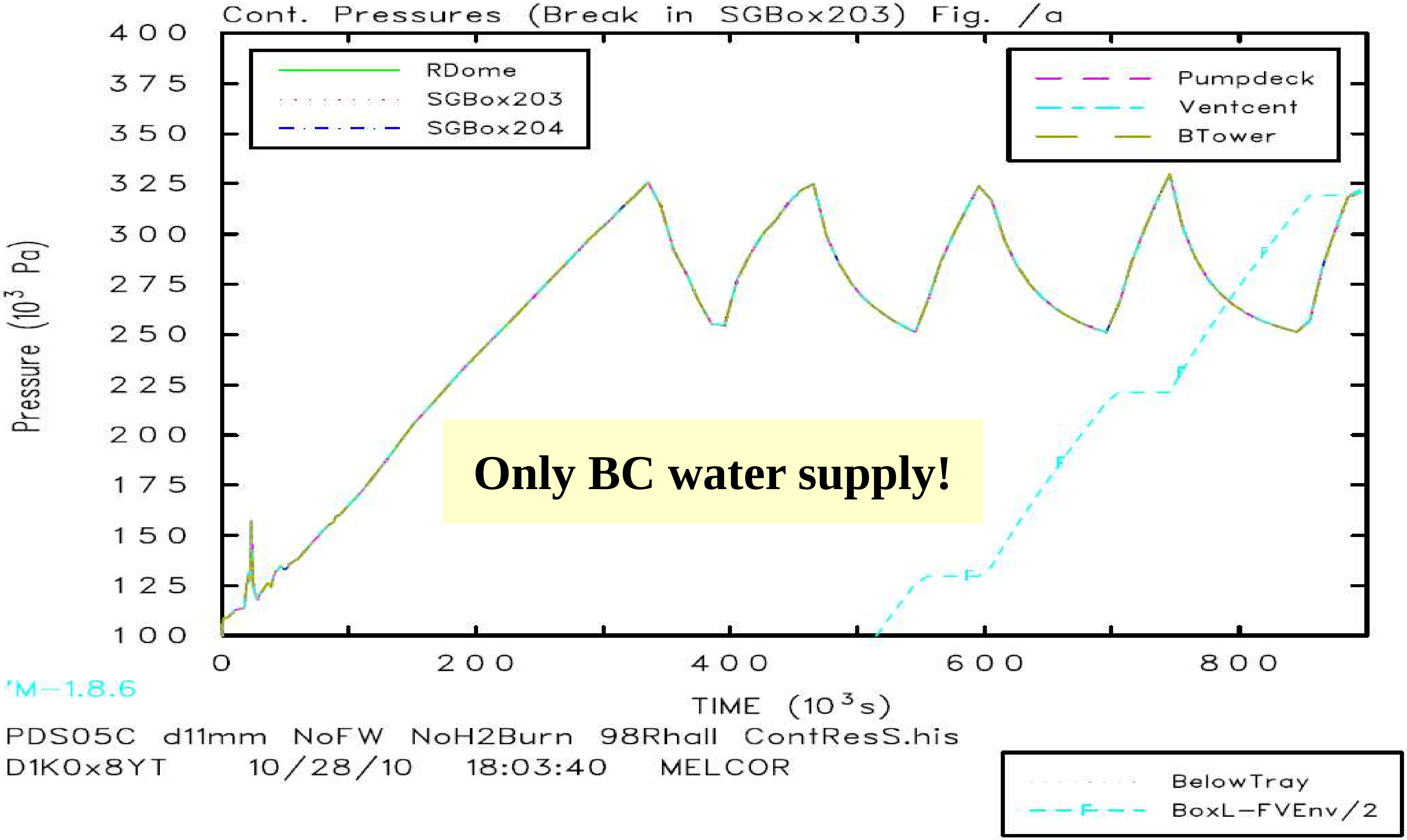
Heat removed from RPV:

- early stages: Vessel wall dominates
- late stages: Lower Head dominates
- Very late stages: Vessel wall and LH are similar

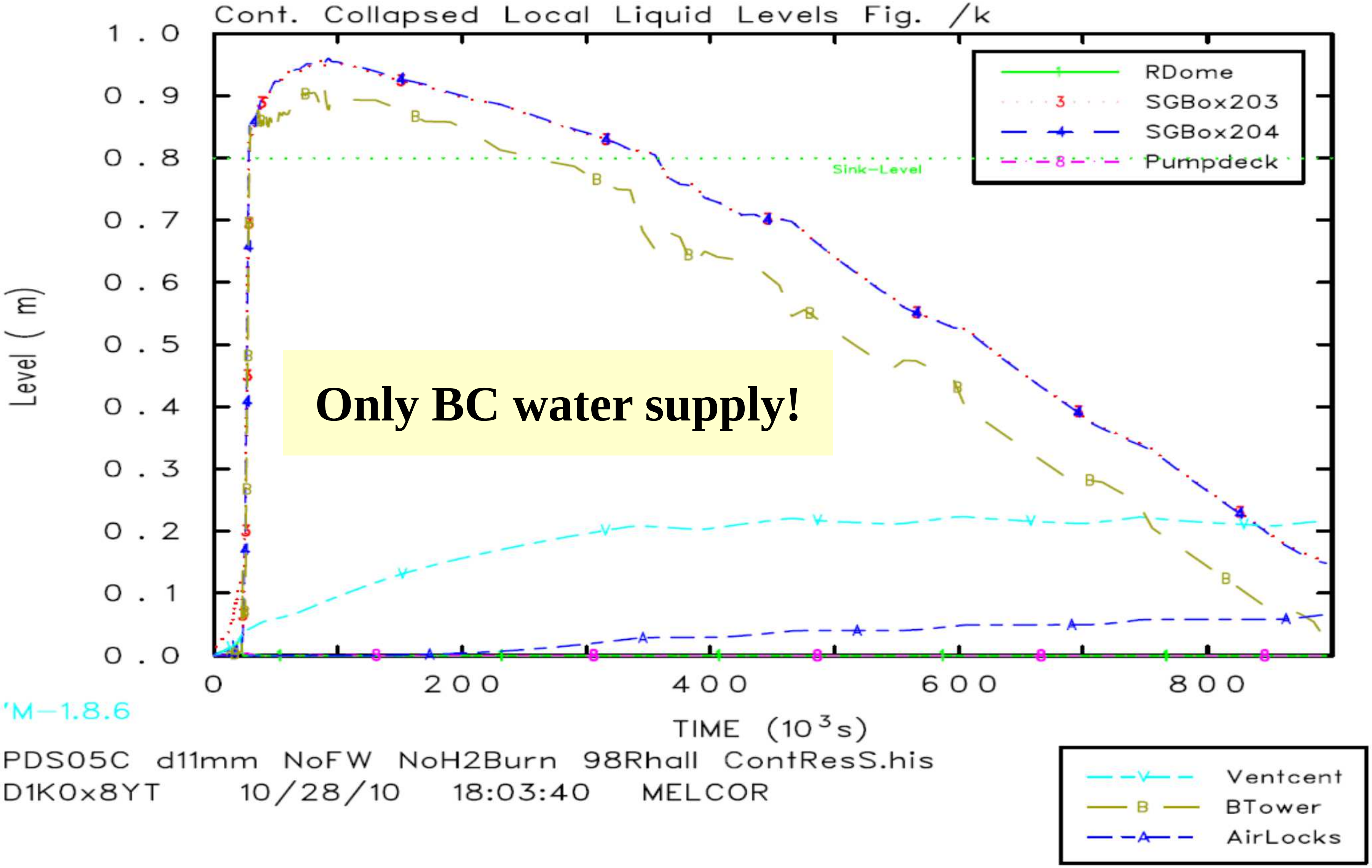
Unresolved:

- Presence of FOCUSING EFFECT of molten metallic layer on RPV wall
- Effect of crust separating the molten metallic layer from the RPV wall

Mid term Containment TH with Ext. Vessel cooling and FVent in Stand Alone Containment – Small LLOCA d=11mm : Pressures

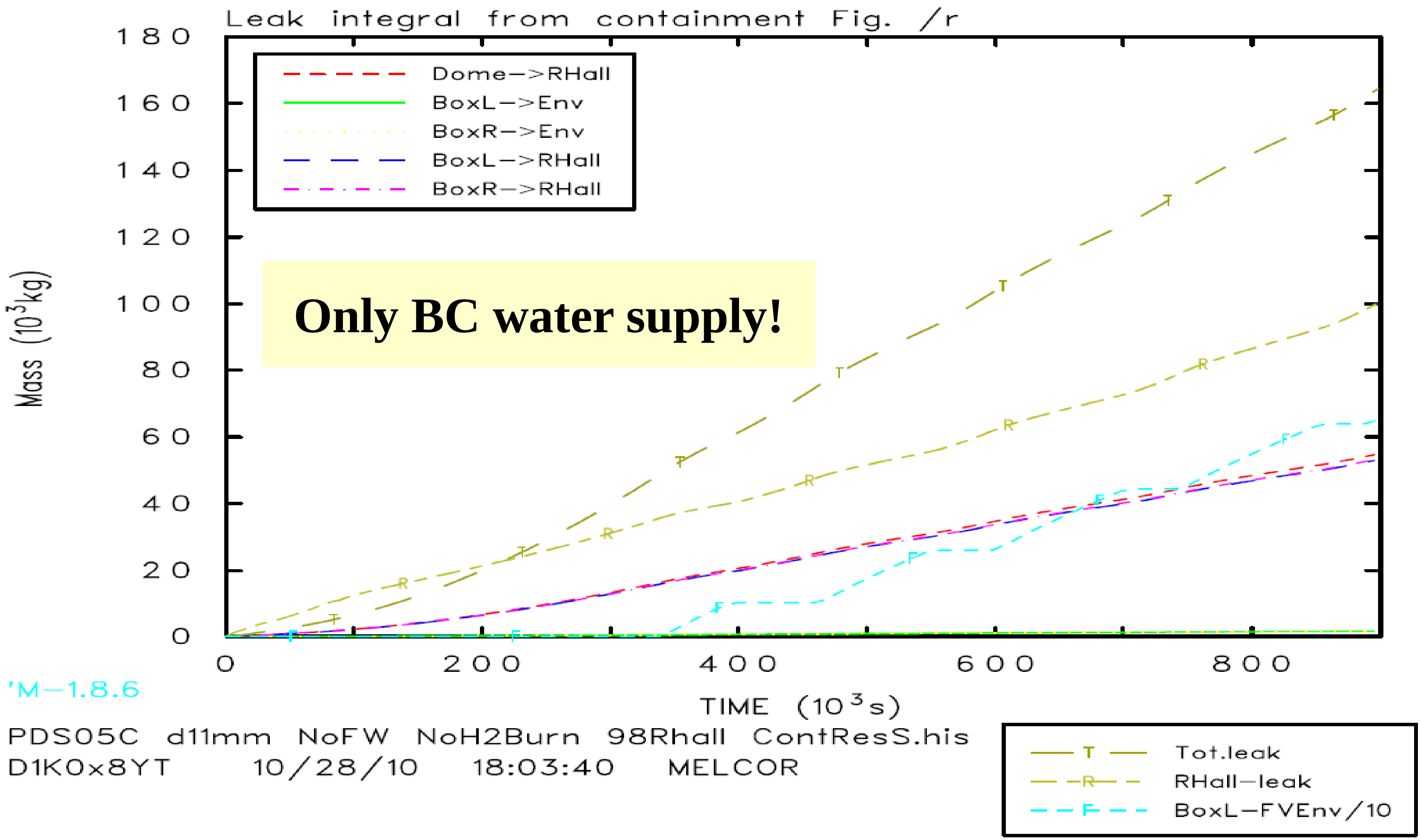


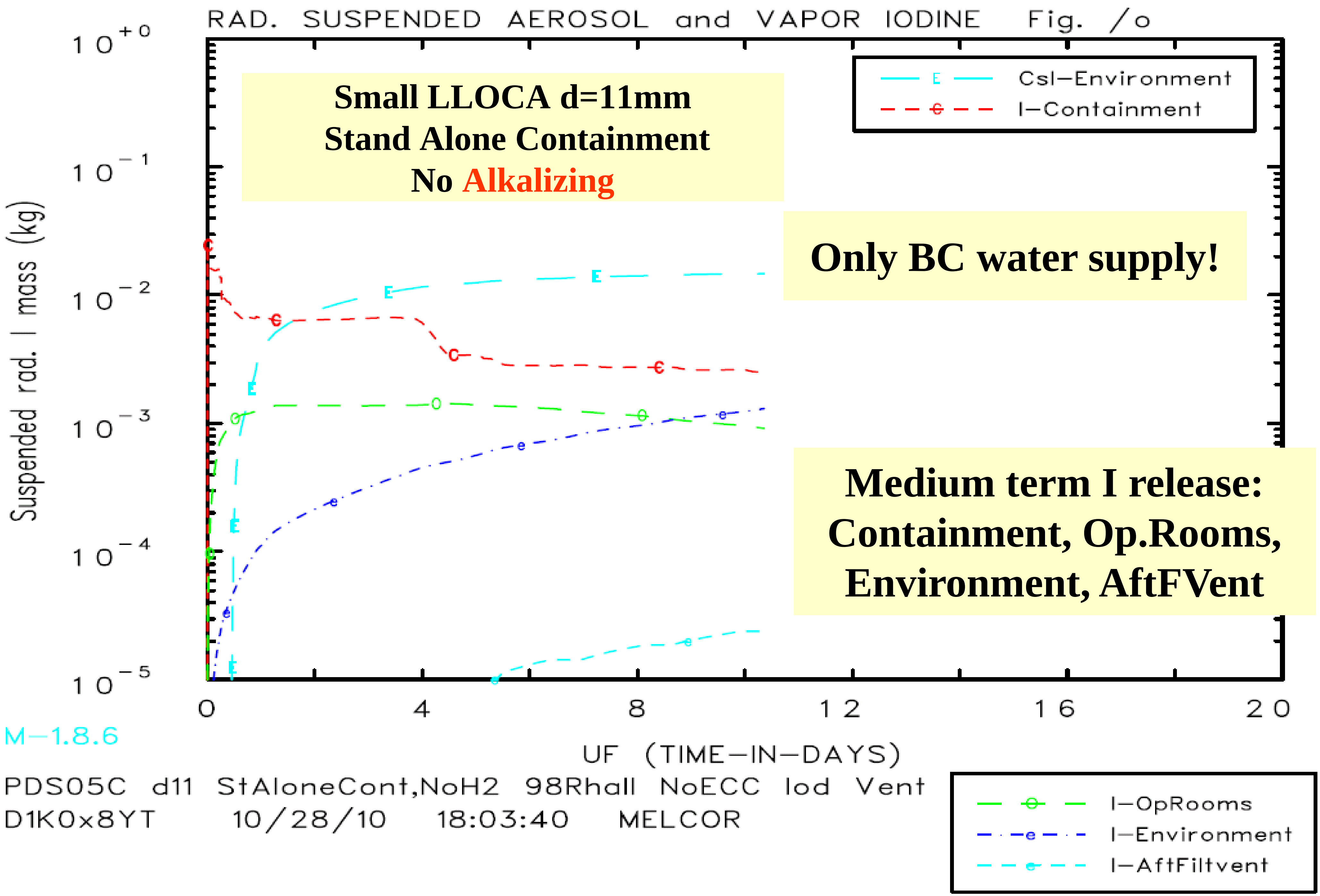
Mid term Containment TH with Ext. Vessel cooling and FVent
Stand Alone Containment – Small LLOCA d=11mm : SGBox Local levels



Only BC water supply!

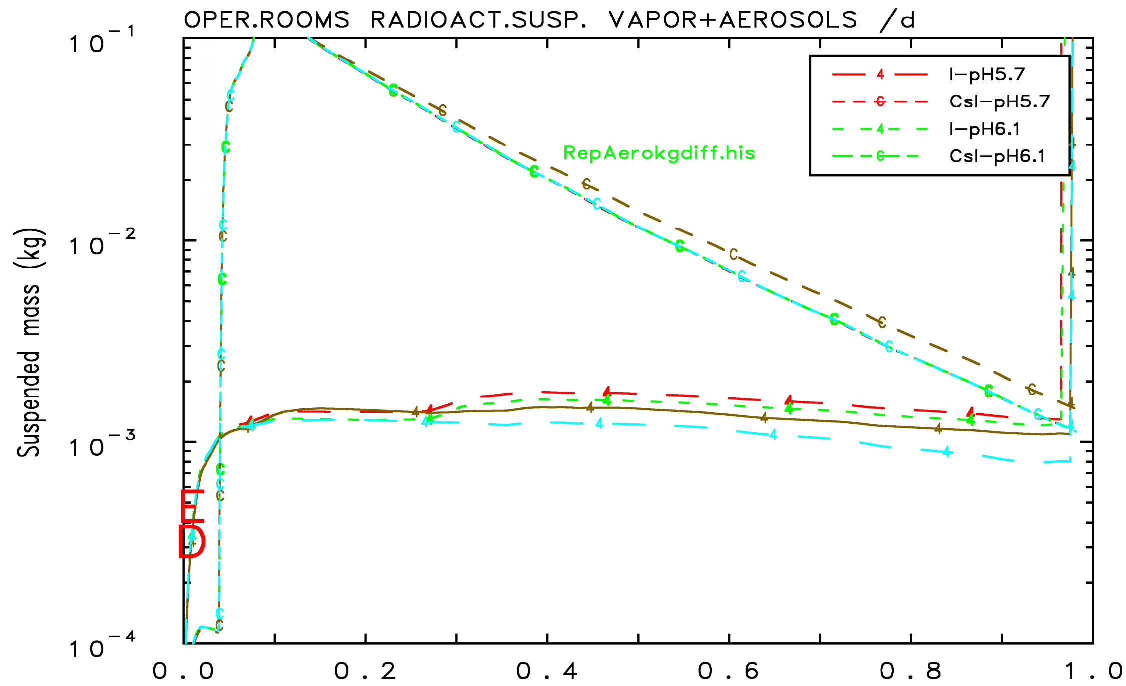
Mid term Containment TH with Ext. Vessel cooling and FVent in Stand Alone Containment – Small LLOCA d=11mm : Leak rates

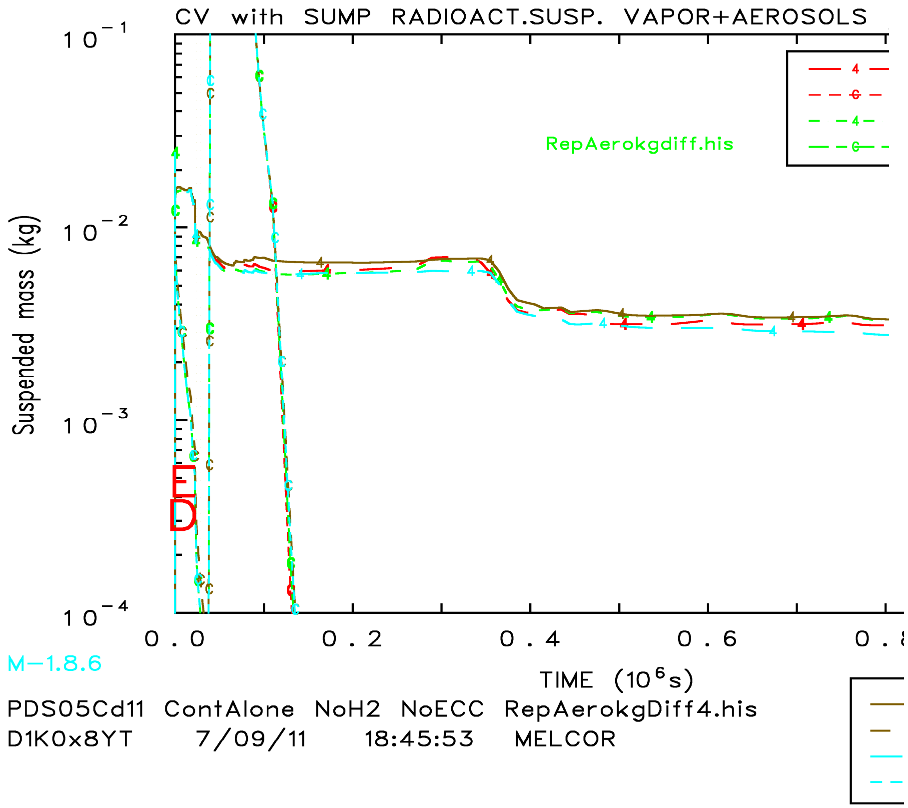


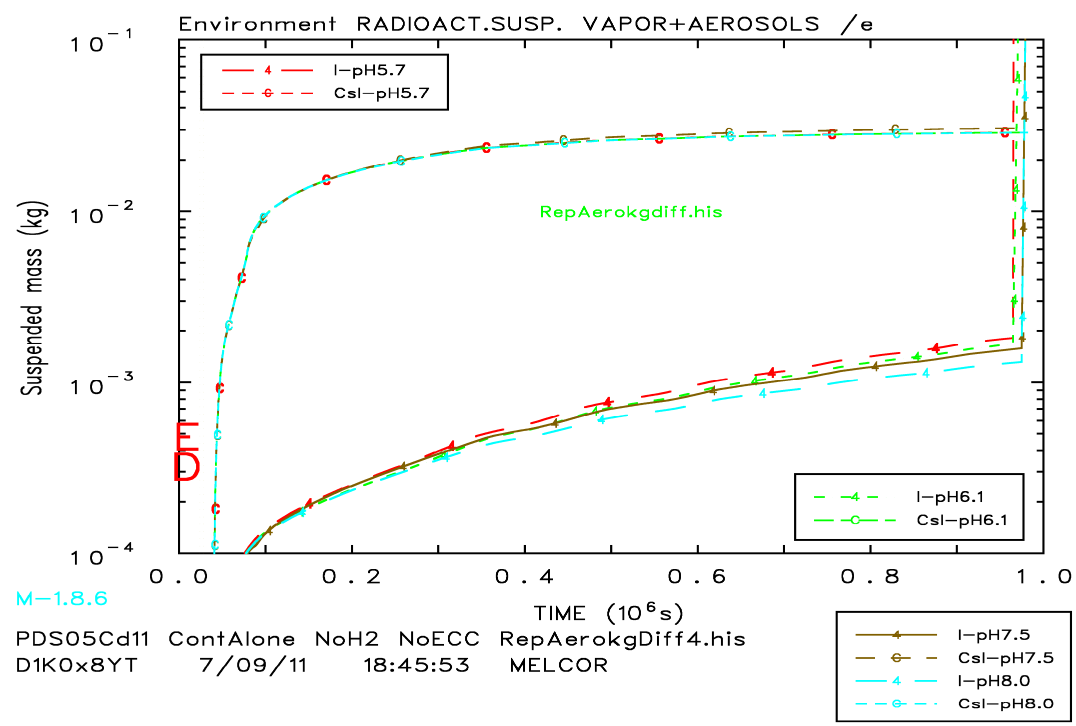

RAD. SUSPENDED AEROSOL and VAPOR IODINE Fig. /o
Small LLOCA d=11mm
Stand Alone Containment
No Alkalizing
Only BC water supply!
Medium term I release:
Containment, Op.Rooms,
Environment, AftFVent
CsI−Environment
I−Containment
I−OpRooms
I−Environment
I−AftFiltvent
Suspended rad. I mass (kg)
10+0
10−1
10−2
10−3
10−4
10−5
0
4
8
12
16
20
UF (TIME−IN−DAYS)
M−1.8.6
PDS05C d11 StAloneCont,NoH2 98Rhall NoECC Iod Vent
D1K0x8YT 10/28/10 18:03:40 MELCOR

Containment with
Ext. RPV Cooling and FVent
Small LLOCA d=11mm

Effect of pH=5.7 – 6.1 – 7.5







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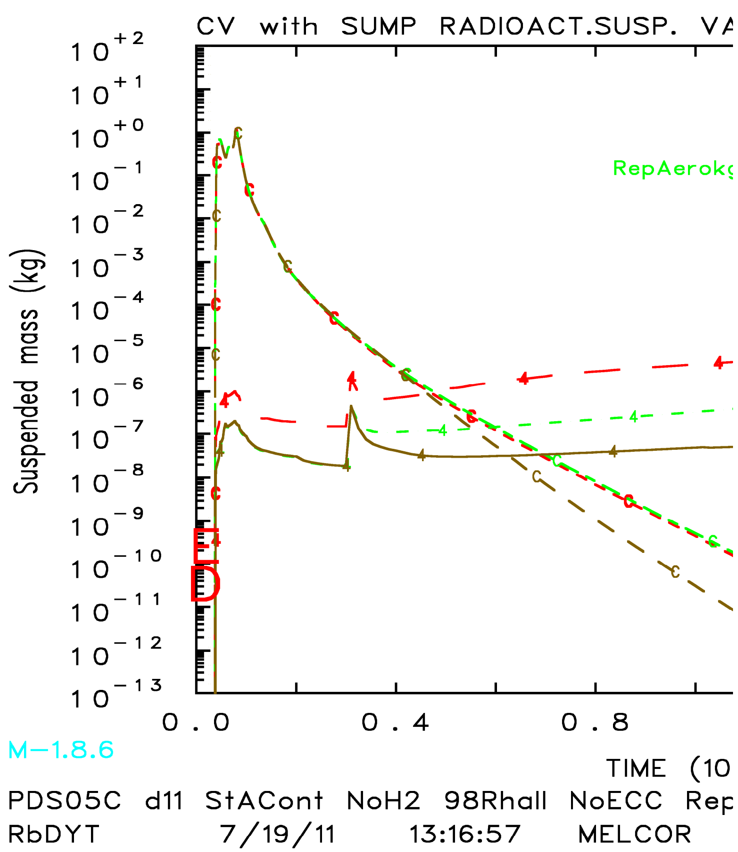
Containment without

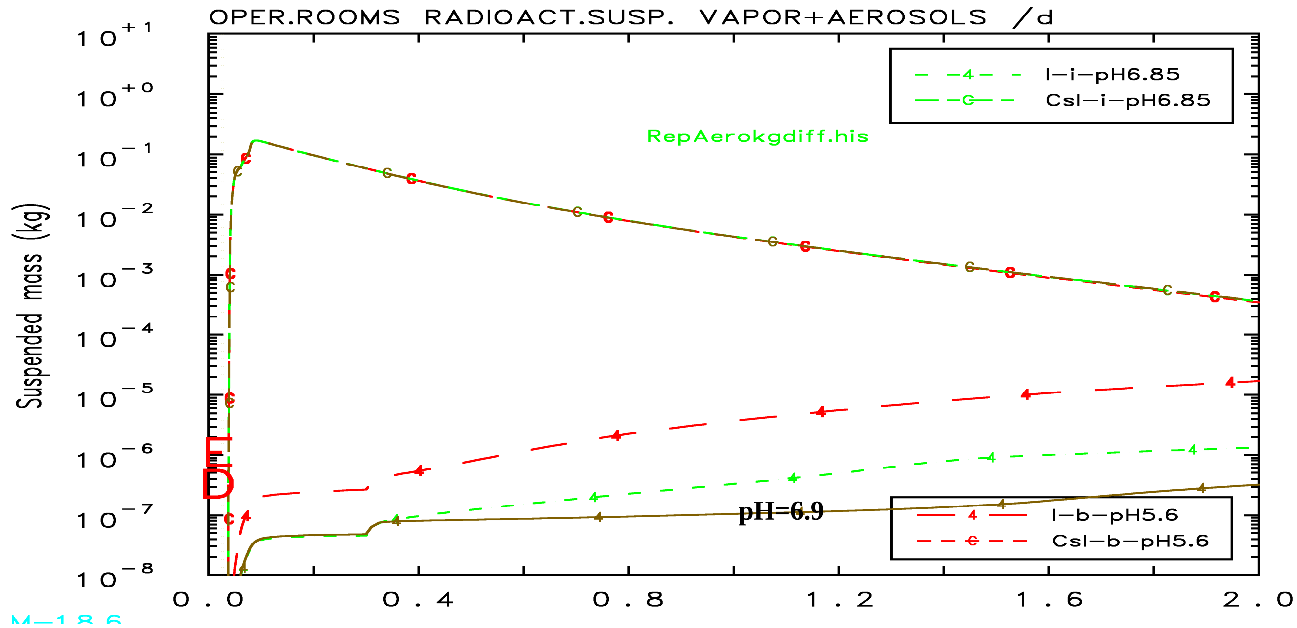
Ext. RPV Cooling and FVent

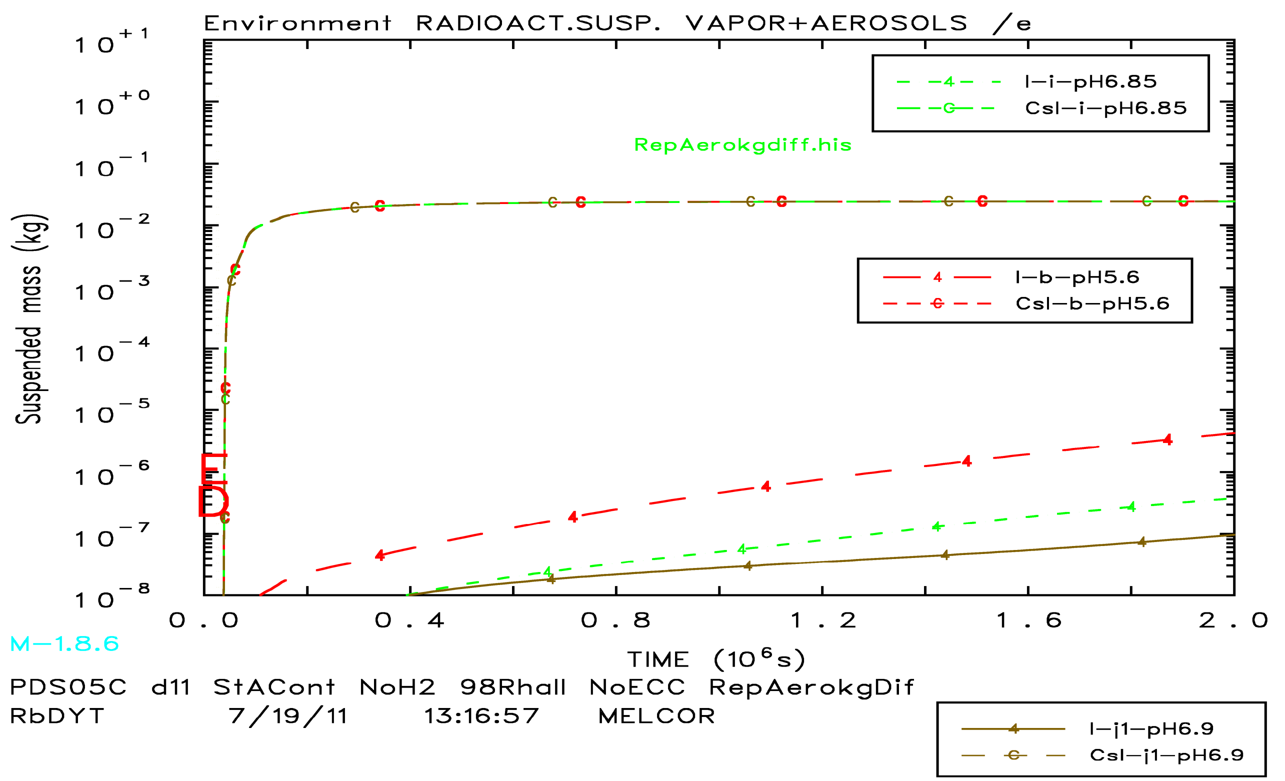
Small LLOCA d=11mm

Cooling revovery

Effect of pH=5.7 – 6.85 – 6.9







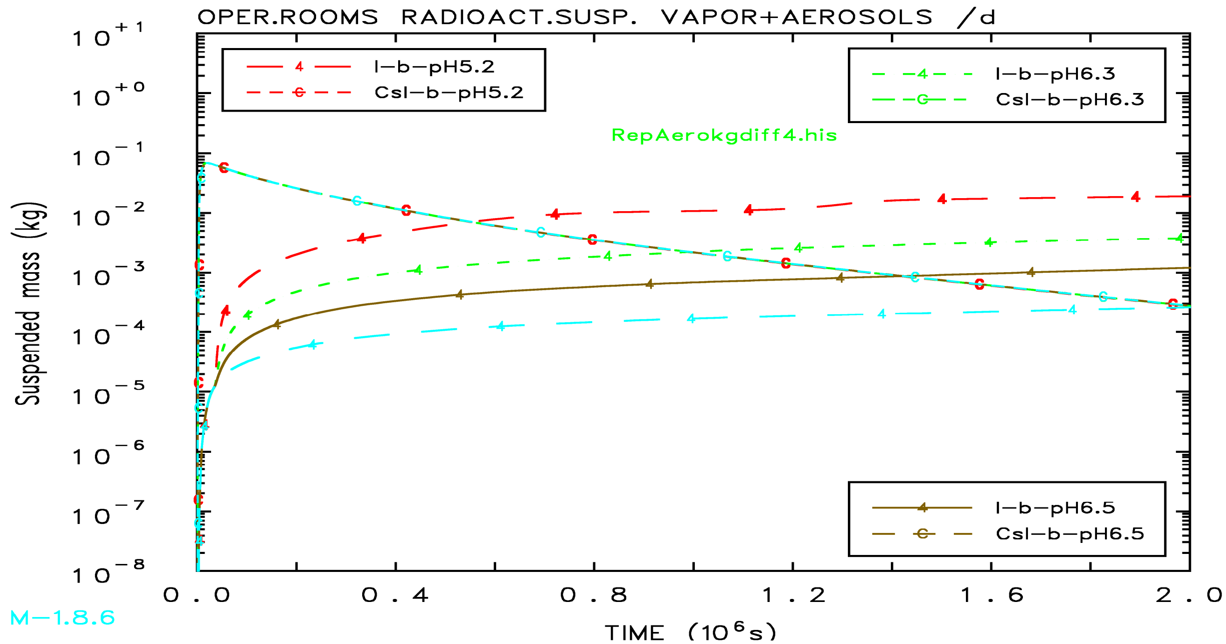
Containment without

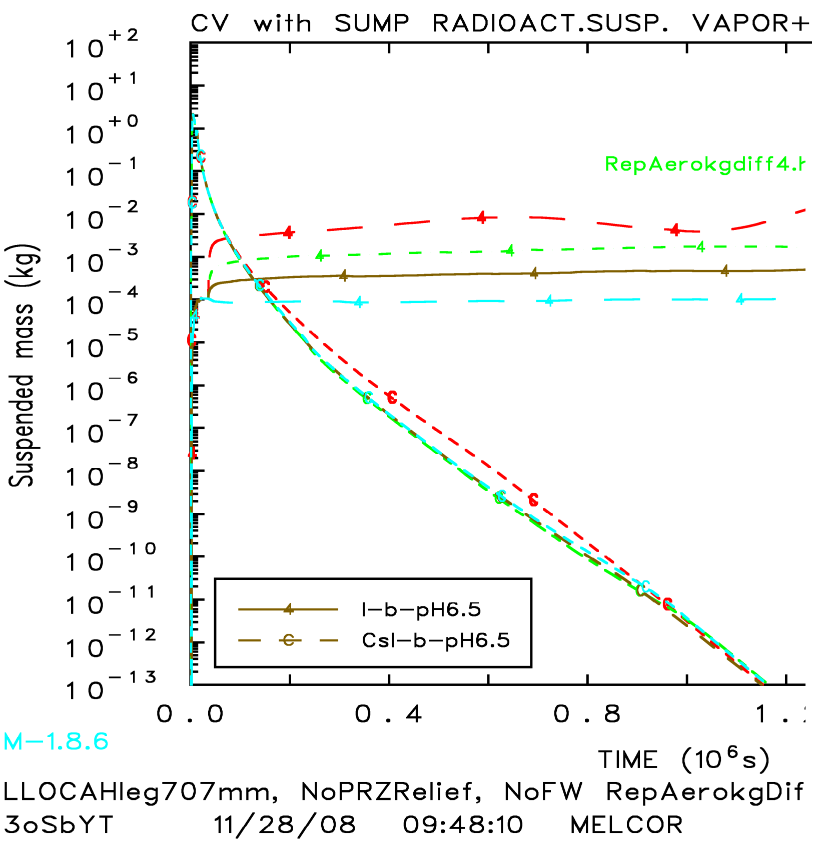
Ext. RPV Cooling and FVent

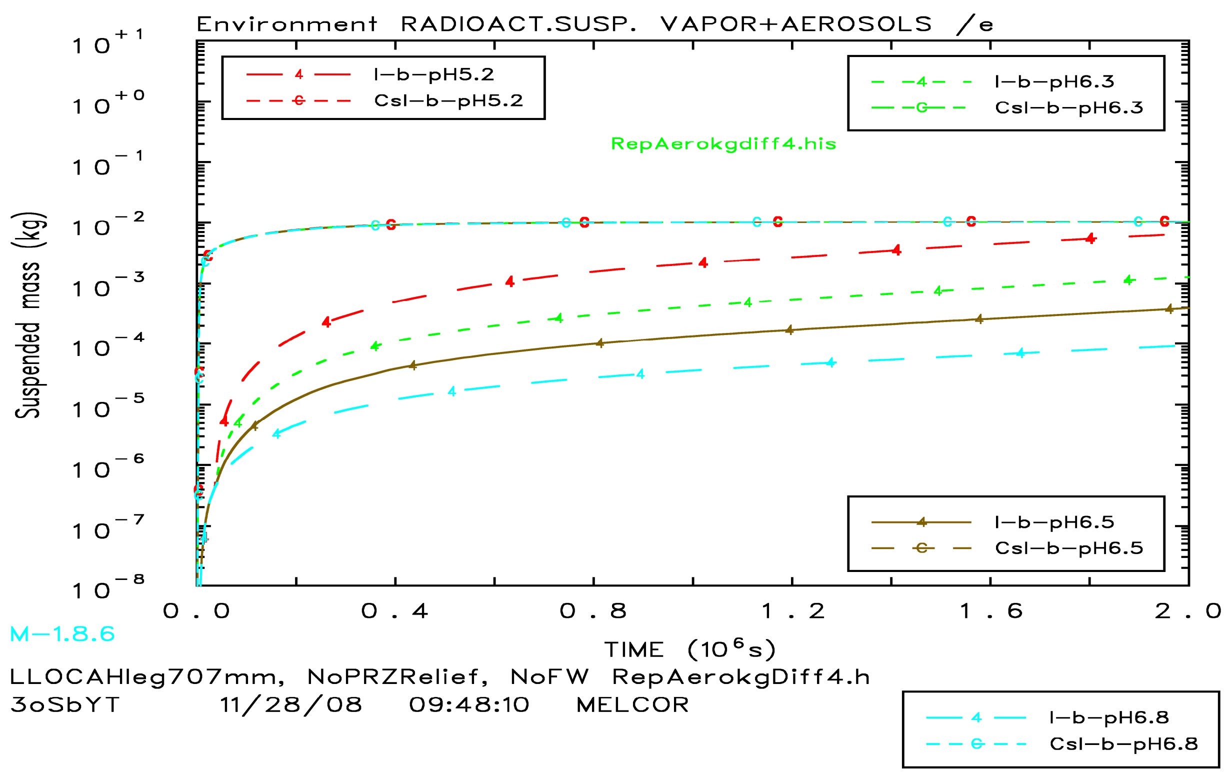
LLOCA d=2x500mm

Cooling revovery

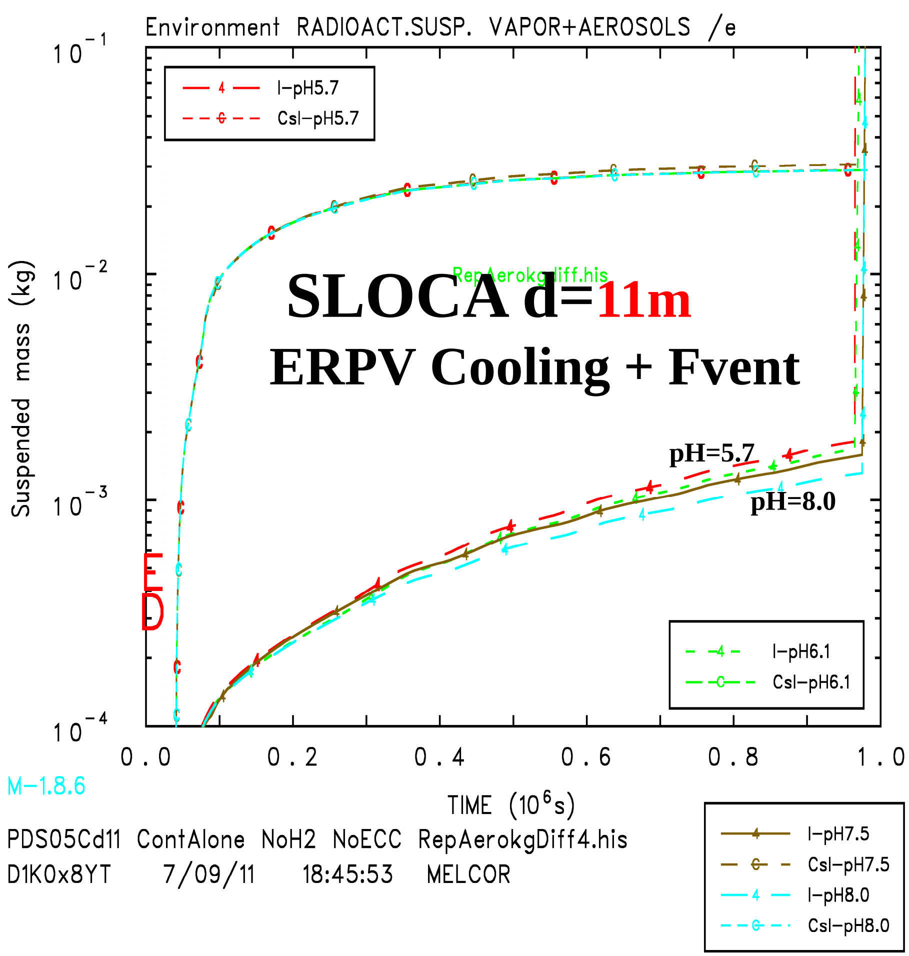
Effect of pH=5.2 – 6.3 – 6.5 -6.8

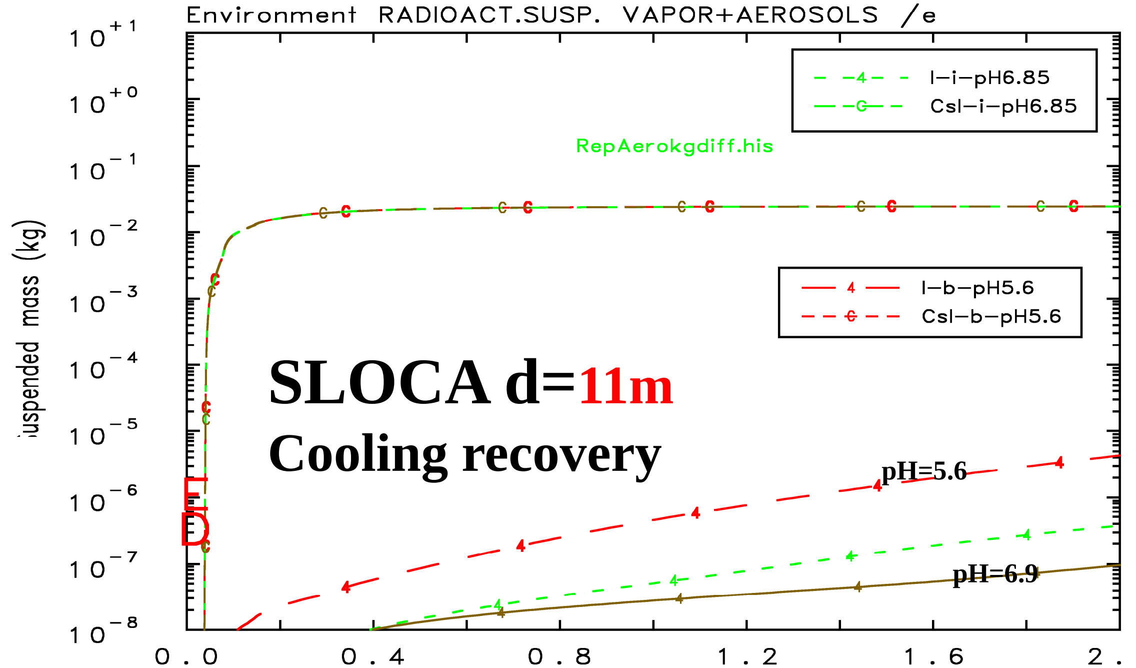


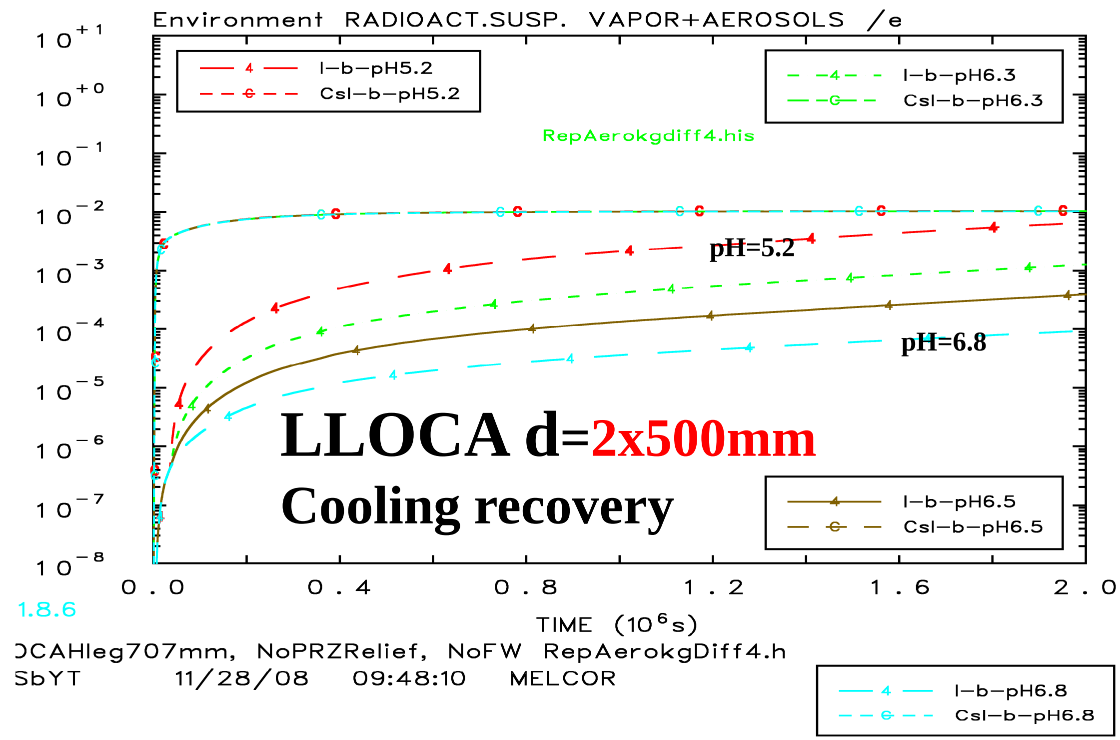




Effect of pH on Iodine in Environment







Volatile Iodine Release to Environment in Stand Alone Containment – Small LLOCA d=11mm and LLOCA 2x500mm:

Summary

Environment after 23 days (Aerosol release ceases after 3 days)

		CsI aerosol,kg	Volatile I,kg	Decrease factor
SLOCA d11mm + Ext.RPV cooling+ Fvent	*pH=5.7*	*3E-3*	*2E-3*	
	pH=8.0	*same*	*0.3E-3*	*6*
SLOCA d11mm + primary circ.cooling recovery	*pH=5.6*	*2.5E-3*	*4E-6 (high humidity)*	
	pH=6.9	*same*	*1E-7 (high humidity)*	*40*
SLOCA d=11mm + Ext.RPV cooling+ Fvent	*pH=5.2*	*1E-2*	*8E-3*	
	pH=6.8	*same*	*1E-4*	*80*

Possible explanation of small effect of pH in case d=11mm LOCA + Ext. RPV cooling + Filt Vent

d=11mm LOCA + Ext. RPV cooling + Filt Vent

Constant evaporation of volatile I from pool at certain pH
Evaporated I interferes with
Huge mass sink from atmosphere provided by FVent

Sink keeps the atmospheric volatile iodine concentration low
No equilibrium between atmoshere and pool forms

As a result

- *Sink effect dominates over pH effect*
- *Long term driving force of volatile I from pool to atmosphere*

Possible explanation of Large effect of pH in case LOCAs WITHOUT Ext. RPV cooling and without Filt Vent

d=11mm LOCA and LLOCA d=2x500mm

Constant evaporation of volatile I from pool at certain pH

Evaporated I accumulates in the atmosphere

Larger atmospheric volatile iodine concentration results in larger back current of I to the pool

Equilibrium between atmosphere and pool forms according to Partition Coefficient

As a result

– *pH effect dominates the release*

MELCOR 1.8.6 In-Vessel Retention and IPM model: Problems

- *Max 2 control volumes with IPM can be activated*
- *Mass balance error is between 8-100% (depends on sequence)*
- *Class assignment is confusing*
- It is not clear if organic iodine is calculated or NOT
- (The framework for the organic reactions is in place, but the equations have not been entered, due to a lack of data to compare results. When data becomes available, the organic reactions can be activated by entering the equations into the EQINIT routine)
- *I2 release from pool is very poorly described*
- *Reference to POOL SPECIATION MODEL – POWERS is NOT available*

Number	Reaction	Rate Constant*

Footnotes to table:

*INSPECT selects a rate constant based on the equilibrium constant and the rate constant for the back reaction.

**See Powers [47].

$$\frac{d[I_2(aq)]}{dt} = -\frac{1}{2}\frac{d[I^-]}{dt} = -\frac{1}{2}\frac{d[H^+]}{dt} = -2\frac{d[O_2(aq)]}{dt} = 34[I^-]^2[H^+][O_2(aq)] + \frac{7.14\times10^4[I^-][B(OH)_3][H^+][O_2(aq)]}{(1+1.47\times10^8[H^+])}$$

***See Powers [47].

$$\frac{d[IO_3^-]}{dt} = -\frac{d[I^-]}{dt} = -\frac{2}{3}\frac{d[O_2(aq)]}{dt} = 3.2\times10^{-5}[I^-][O_2(aq)]$$

MELCOR 1.8.6 In Vessel Retention and IPM model: Problems

IPM

– *NRC questions the validity of the IPM model*

However

– *IPM reproduced the Phebus FPT-1 test well*

– *The plant calculated results seems to be reasonable*

– *Tendencies – sometimes confusing – but according to accepted Kanon*

– *Larger pH resulted in smaller Iodine release to environment*

Major message

– ***External RPVessel Cooling + Filtered Vent NEEDS Volatile Iodine Filter***

Thank You For Your Attention