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MELCOR 1.8.6 Thermal Hydraulic and Iodine Release Calculations for a Small LOCA Initiated Severe Accident with Accident Mitigation Measures

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Contents

- Full circuit model for VVER-440/213 with external vessel cooling and filtered vent
- Full circuit model TH results
- Stand alone VVER-440/213 containment model
- Stand alone containment model iodine results
- Conclusions
- Problems in MELCOR 1.8.6 IPM

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
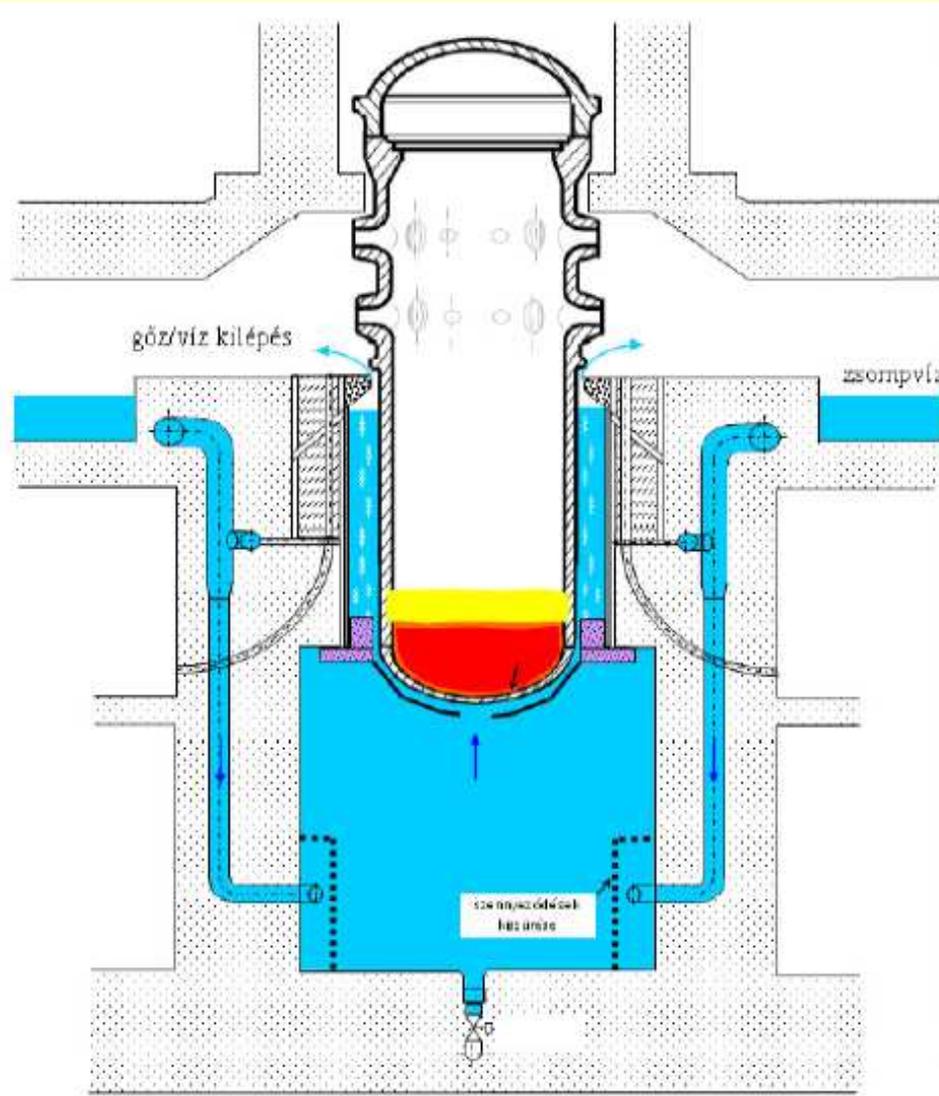
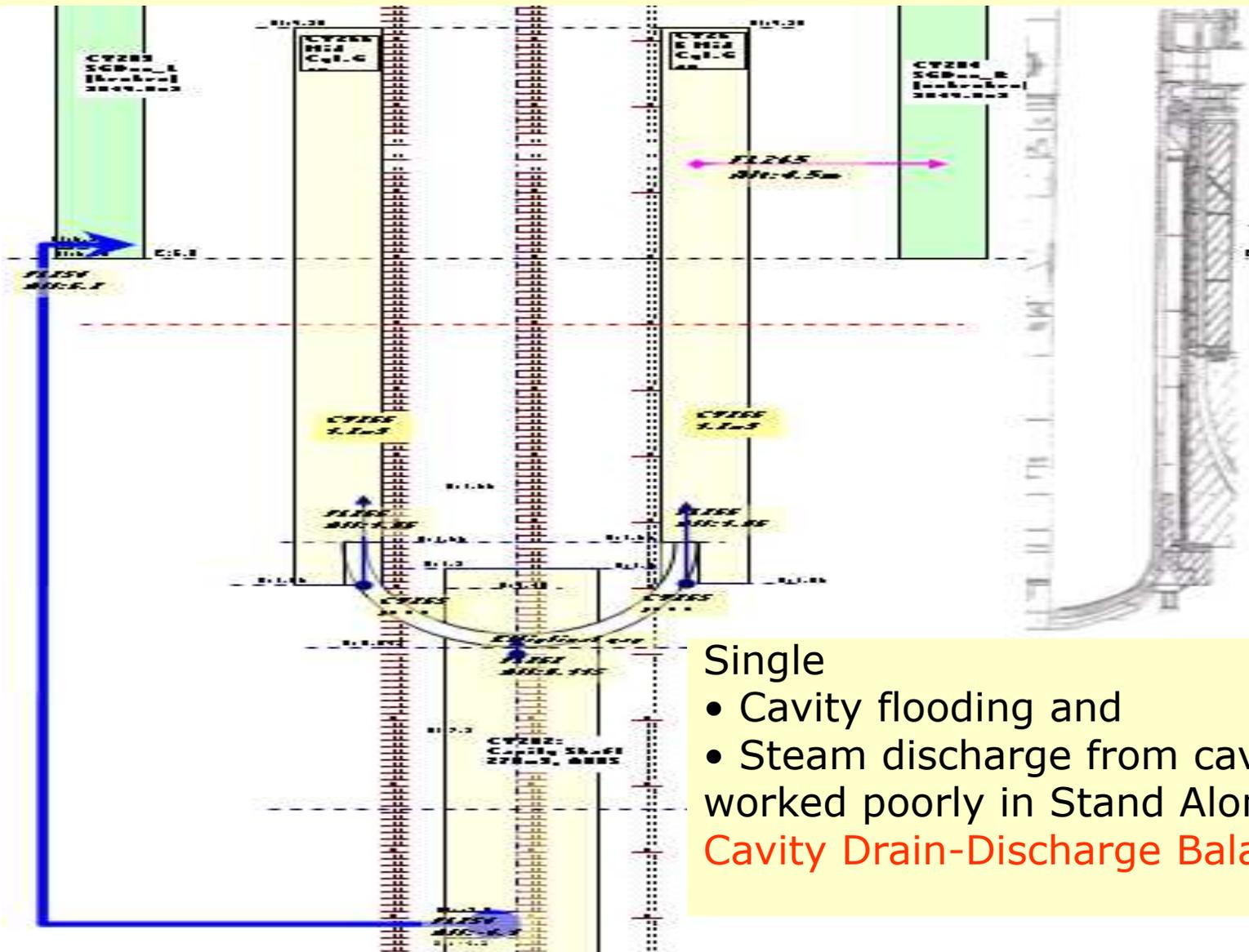# Detailed Full Circuit model: External Vessel Cooling
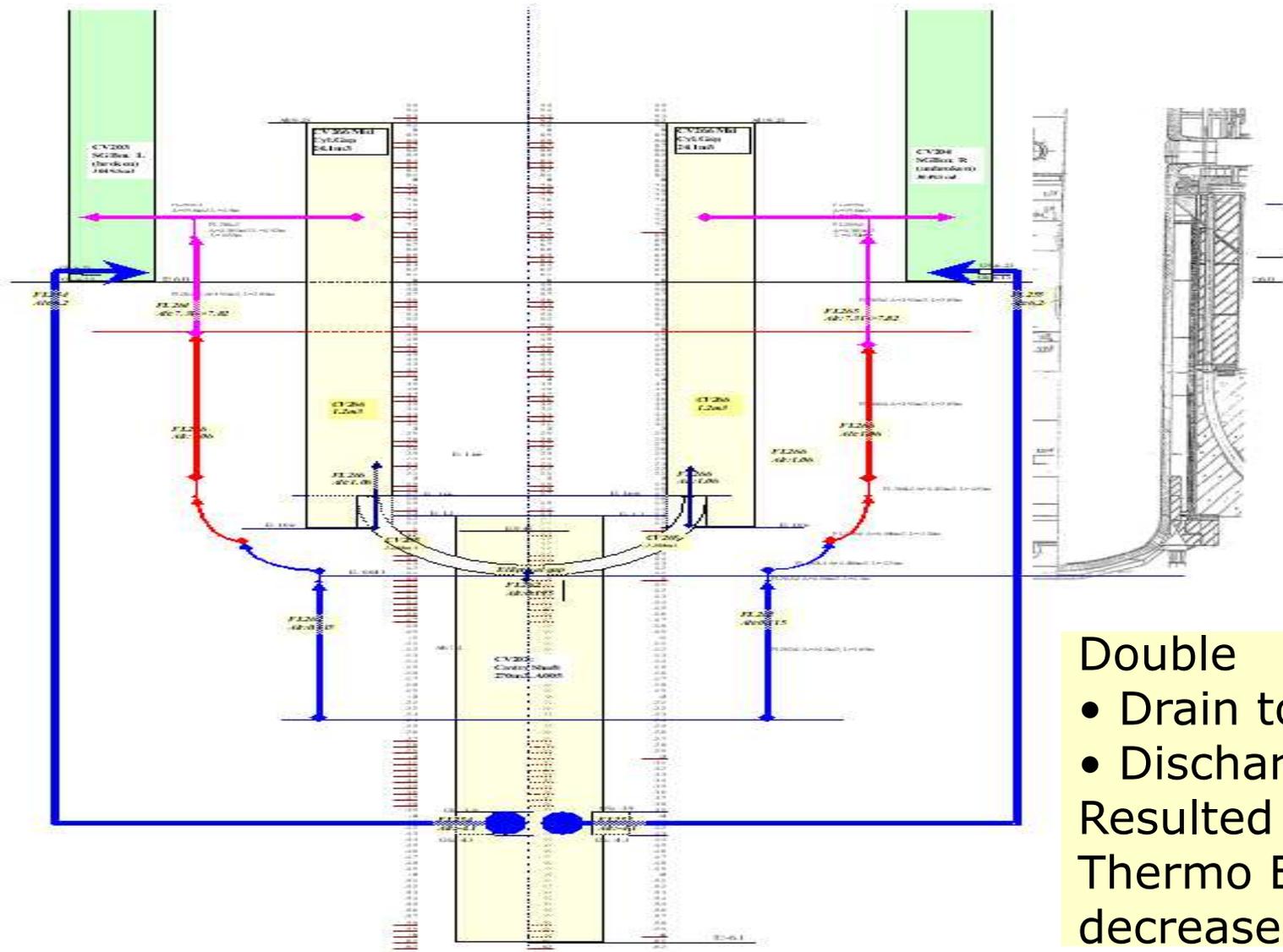
Double
- Drain to cavity and
- Discharge from cavity
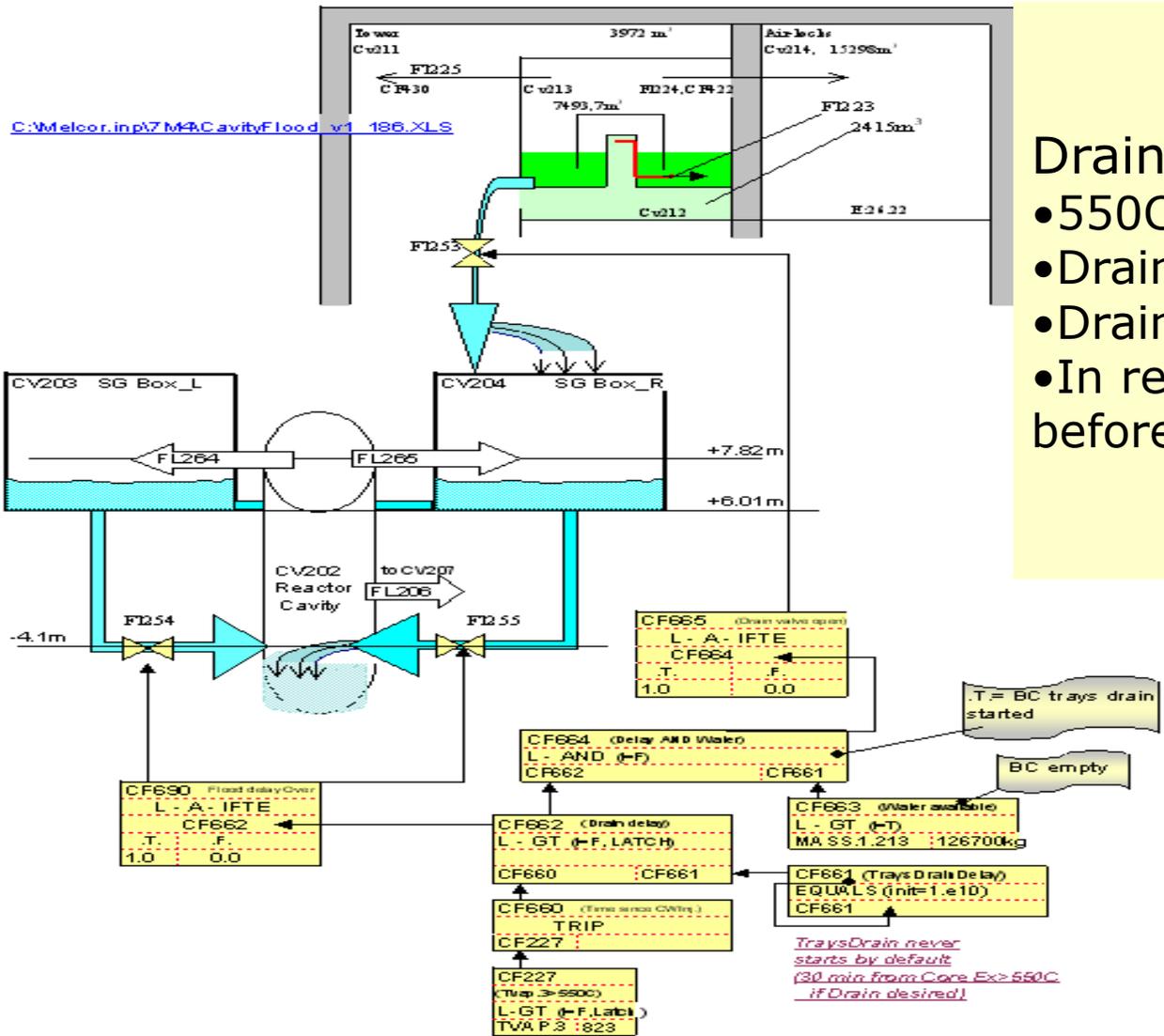Resulted in
Thermo ERROR and DT decrease below limit

Single
- Cavity flooding and
- Steam discharge from cavity worked poorly in Stand Alone Cont.

Cavity Drain-Discharge Balance was OK

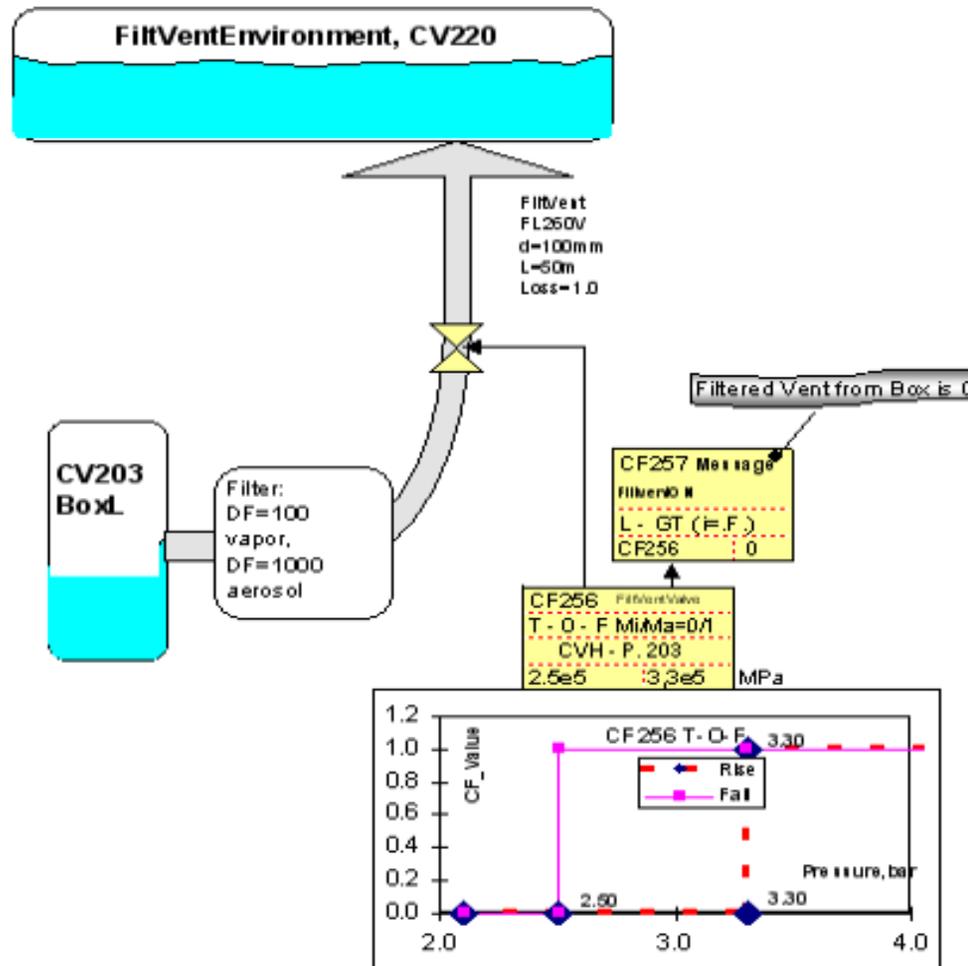# Cavity flooding: Draining the pressure suppression pool water

Drainage starts at:
- 550C core exit temp+30 min
- Drain duration 80 min
- Drain to cavity starts immediately
- In reality cirtain level should form before drain to cavity

VVER-440 Simplified Stand Alone Containment:
Sources: Primary circ + Ex-vessel cooling + BC drain+Fvent
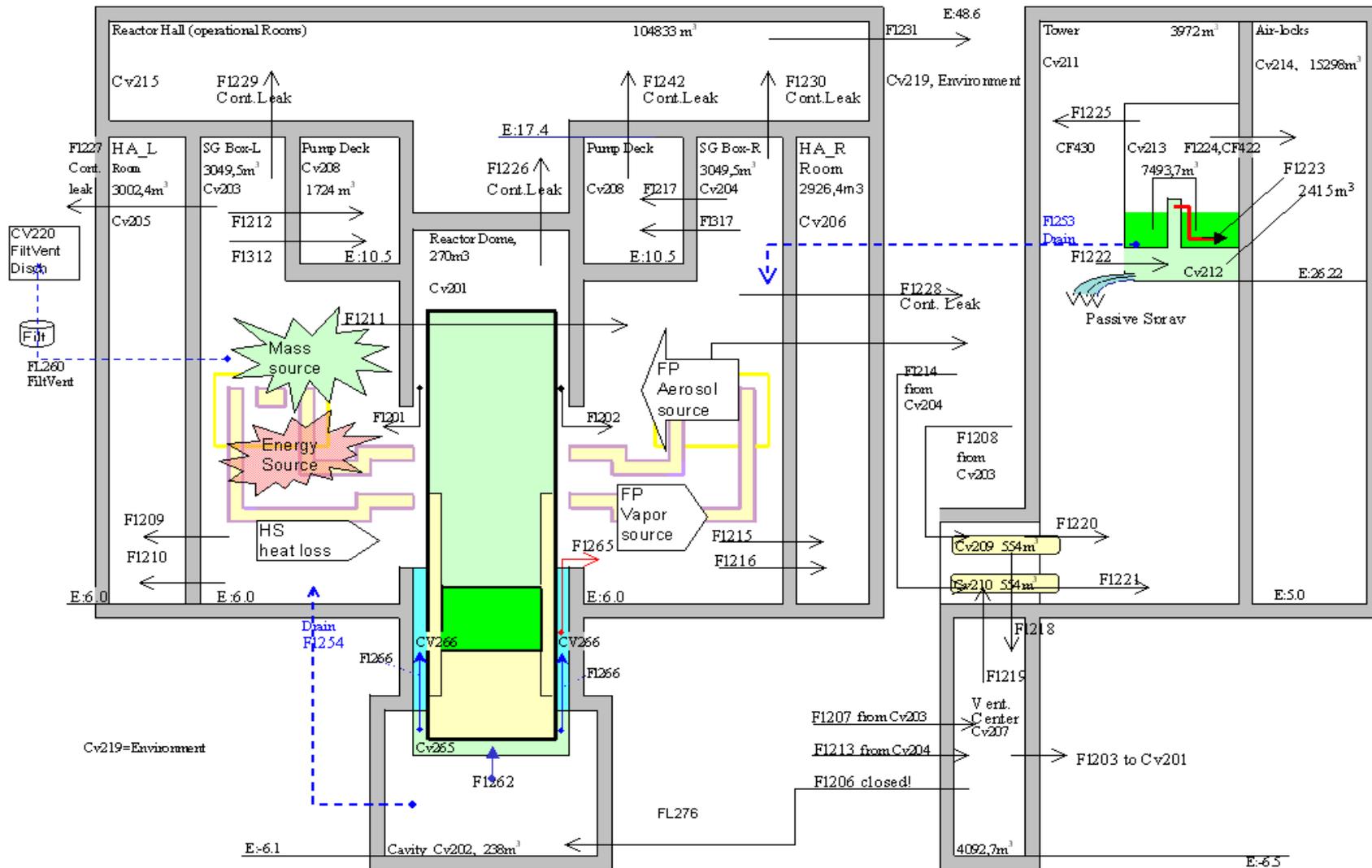
Filtered vent model for VVER-440/213 Stand Alone Containment

FiltVentEnvironment, CV220

FiltVent
FL260V
d=100mm
L=50m
Loss=1.0

Filtered vent from SG box:
- starts: P=3.3 bar
- stops: P=2.5 bar

Filtered Vent from Box is C

CV203
BoxL

Filter:
DF=100
vapor,
DF=1000
aerosol

CF257 Message
FilVentO N
L - GT (= .F.)
CF256   0

CF256   FiltVentValve
T - O - F Mi/Ma=0/1
CVH - P. 203
2.5e5   3.3e5   MPa

External reactor vessel cooling: Heat balance details

HEAT BALANCE from RPV+LH to POOL Fig. /e

C — LeftDecay−RN−core

Heat flux (MW)
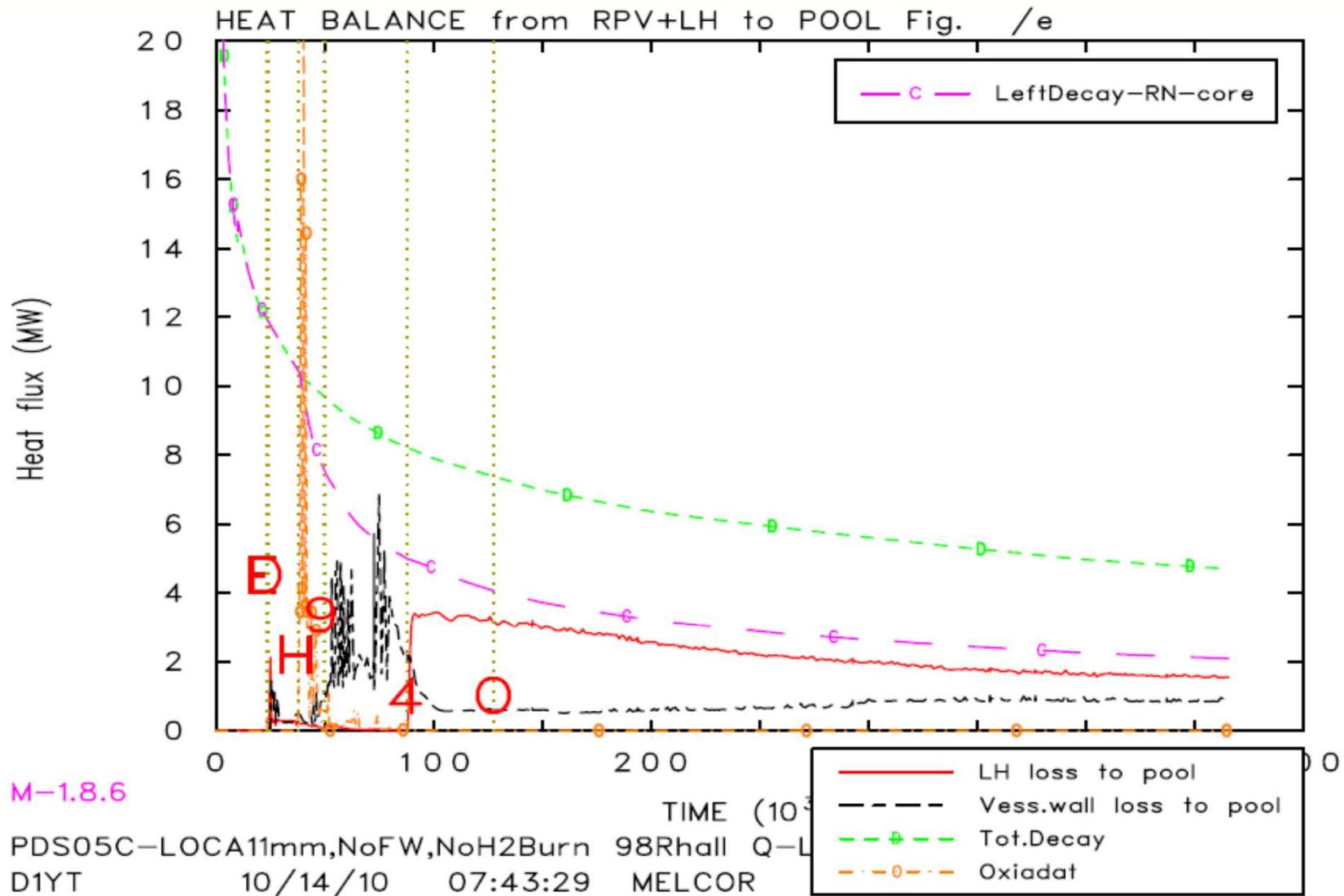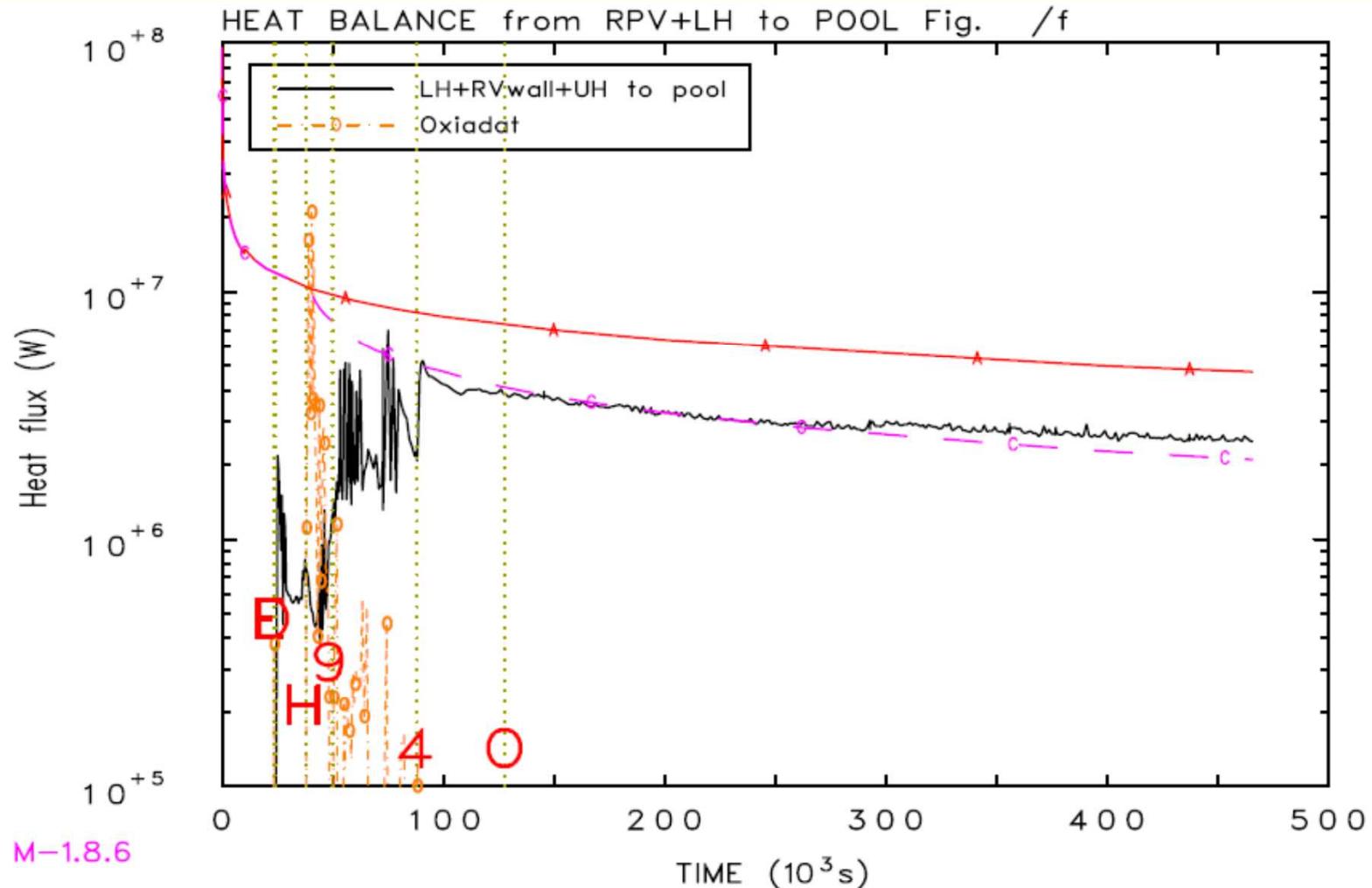
M−1.8.6

PDS05C−LOCA11mm,NoFW,NoH2Burn 98Rhall Q−L
D1YT   10/14/10   07:43:29   MELCOR

TIME (10

LH loss to pool
Vess.wall loss to pool
Tot.Decay
Oxiadat

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

Limiting case:
- No Alkalising agent added to Sump water
- Water limited to Bubbler Condenser (BC) amount

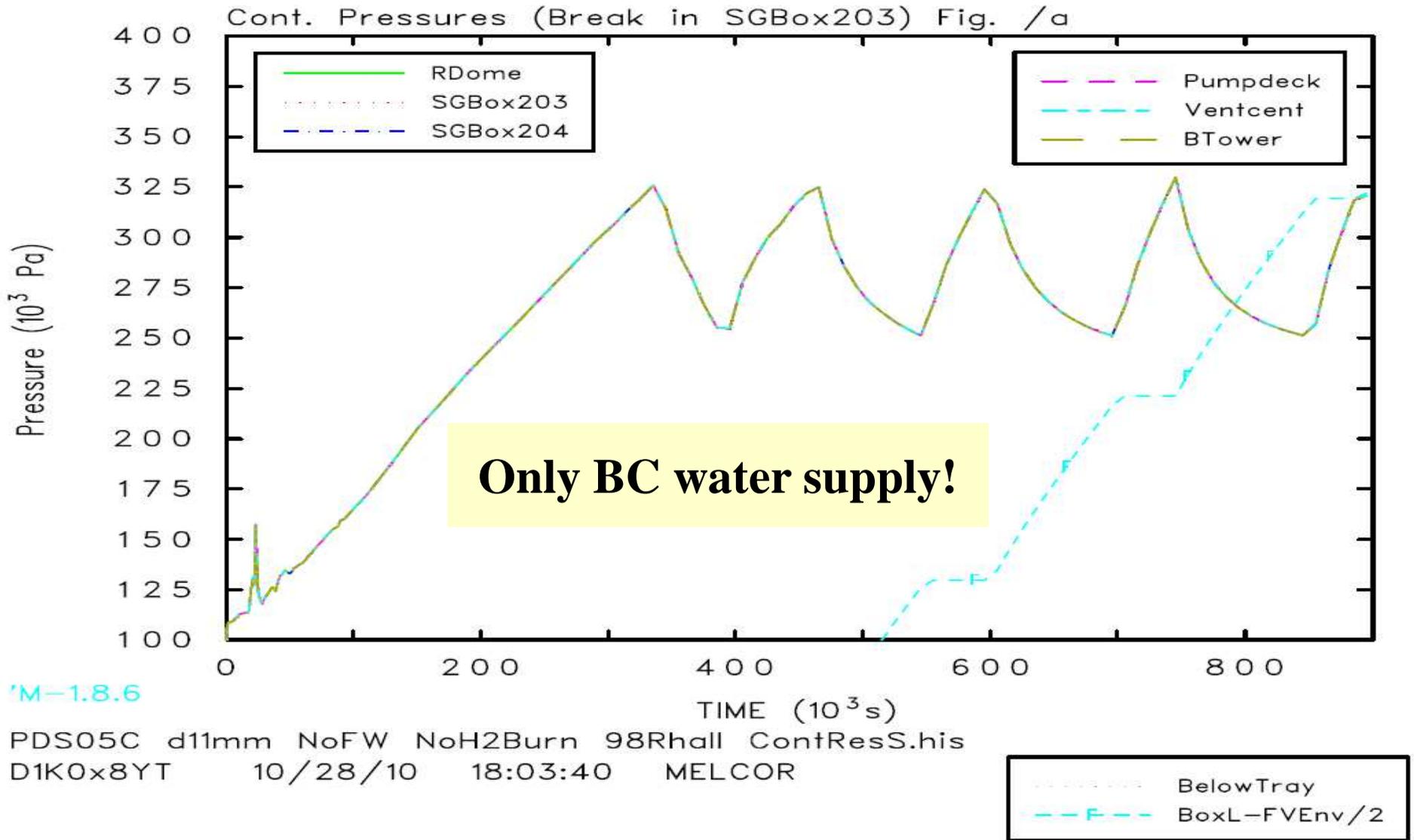*Thermal hydraulic sources from Full Circuit Model:*
- *Pipebreak blowdown d=11mm*
- *PRV relief valve discharge*
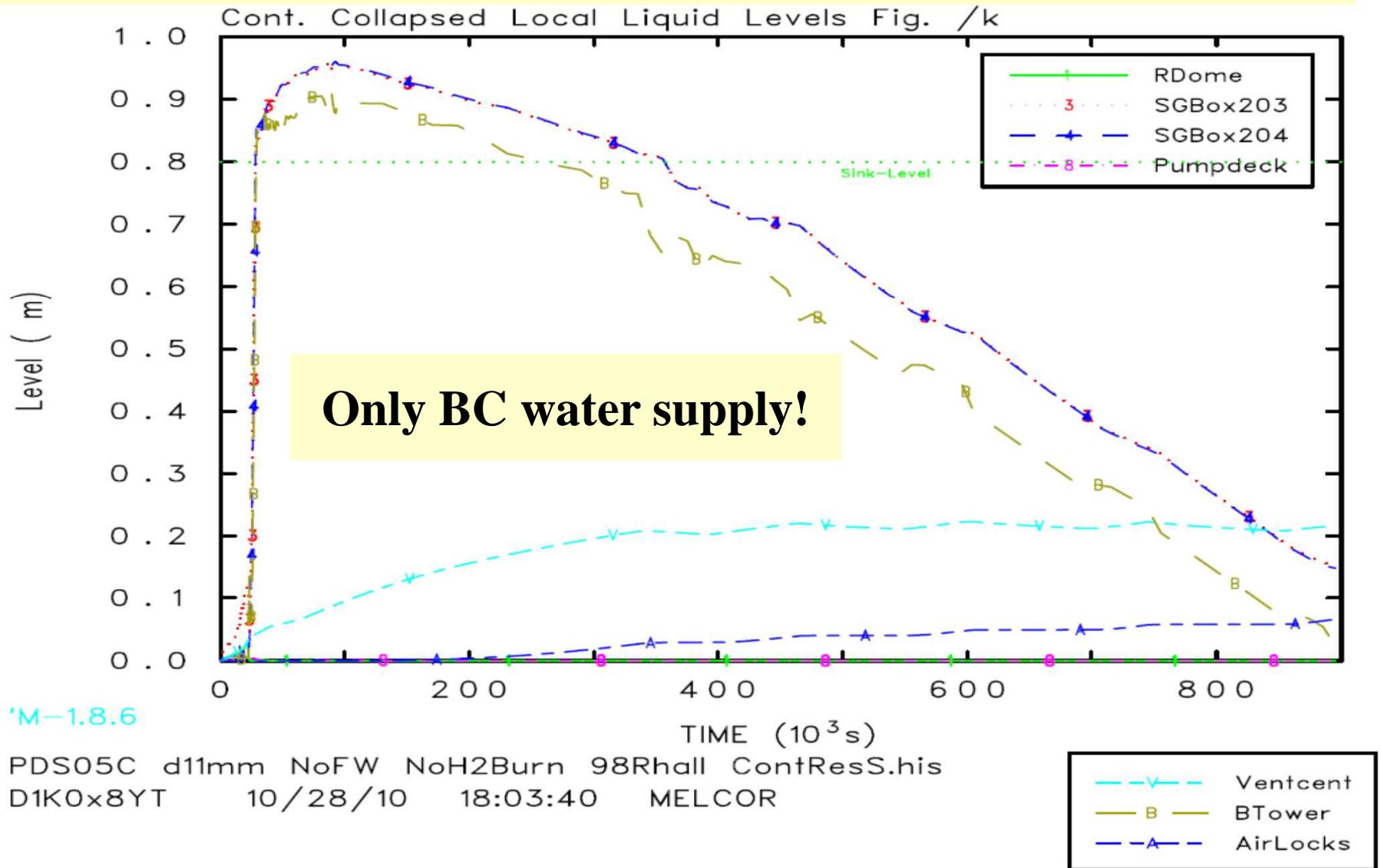- *SGbox-Cavity balance aft. Cavity flooding*

Model verification:

Full circuit and Stand Alone Containment Model Calculated Pressures and Temperatures were very similar

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

Cont. Pressures (Break in SGBox203) Fig. /a

Legend:
- RDome
- SGBox203
- SGBox204
- Pumpdeck
- Ventcent
- BTower
- BelowTray
- BoxL−FVEnv/2

Only BC water supply!

Pressure (10^3 Pa) vs TIME (10^3 s)

'M−1.8.6

PDS05C d11mm NoFW NoH2Burn 98Rhall ContResS.his
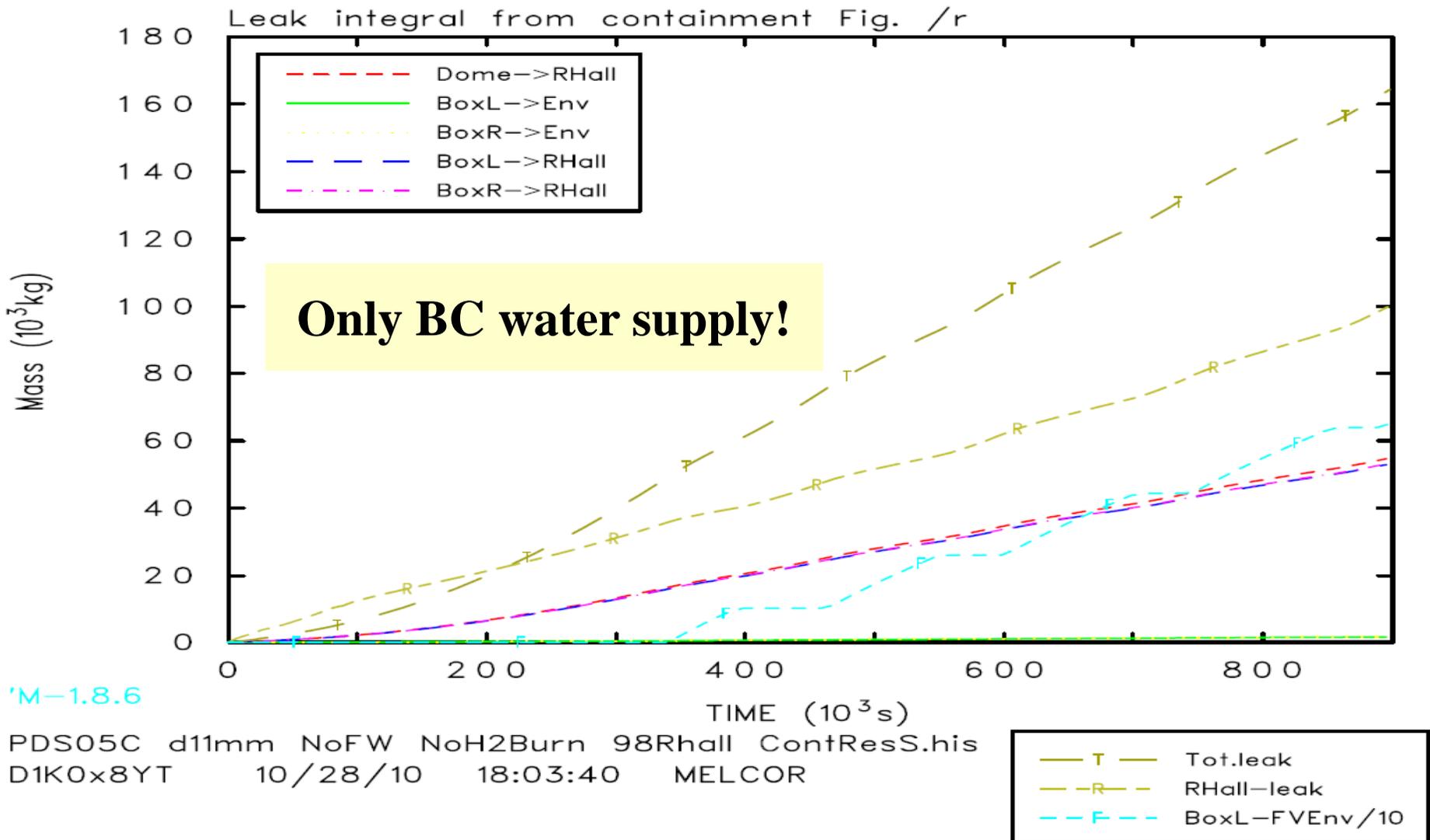D1K0x8YT   10/28/10   18:03:40   MELCOR

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

Cont. Collapsed Local Liquid Levels Fig. /k

Only BC water supply!

Legend:
- RDome
- 3 · · · SGBox203
- SGBox204
- 8 Pumpdeck
- Sink-Level
- V Ventcent
- B BTower
- A AirLocks

Level (m)

TIME (10³s)

'M−1.8.6

PDS05C d11mm NoFW NoH2Burn 98Rhall ContResS.his
D1K0x8YT 10/28/10 18:03:40 MELCOR

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Mid term Containment TH with Ext. Vessel cooling and FVent
in Stand Alone Containment – Small LLOCA d=11mm : H2, O2, Steam
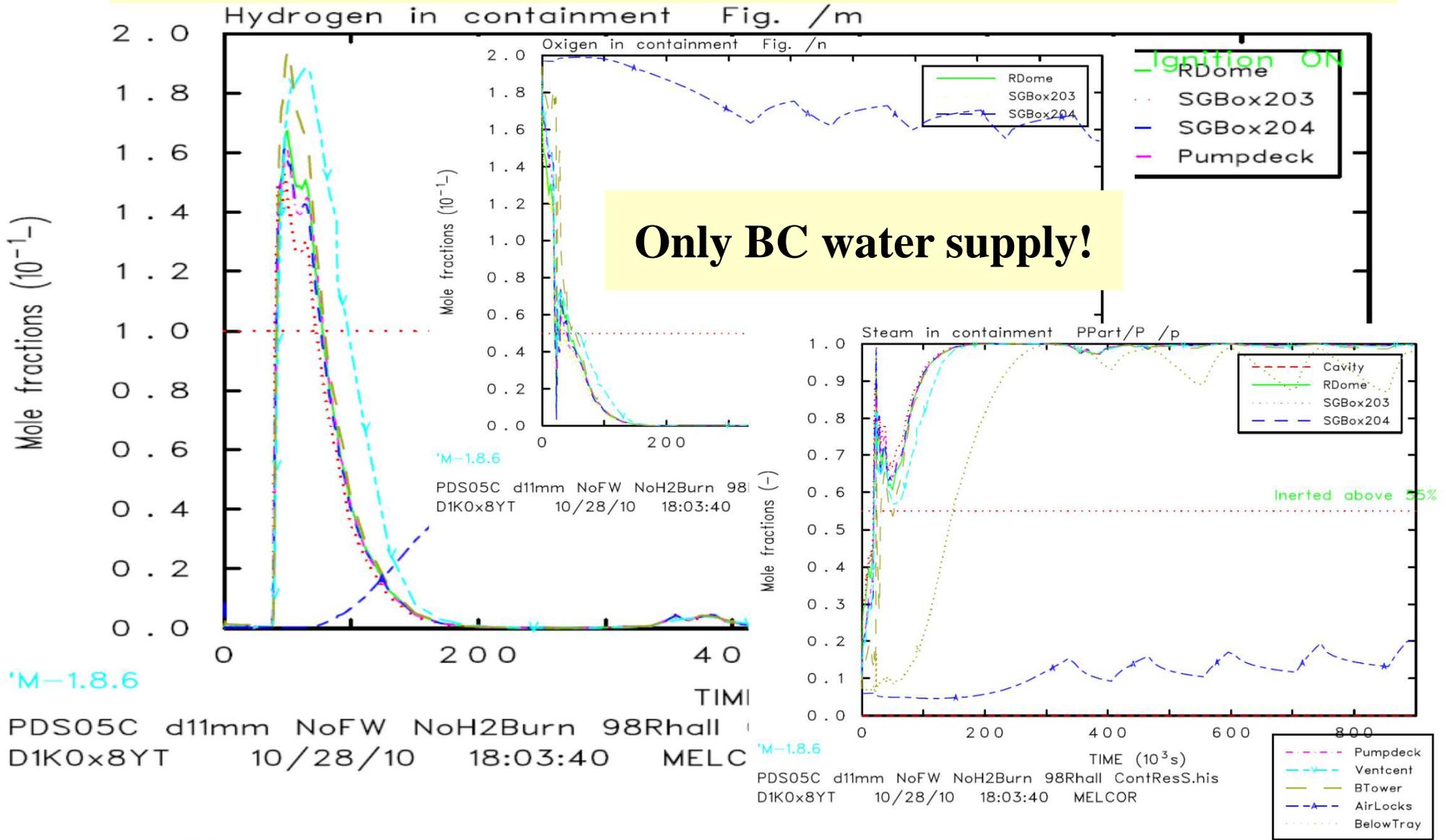
Only BC water supply!

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
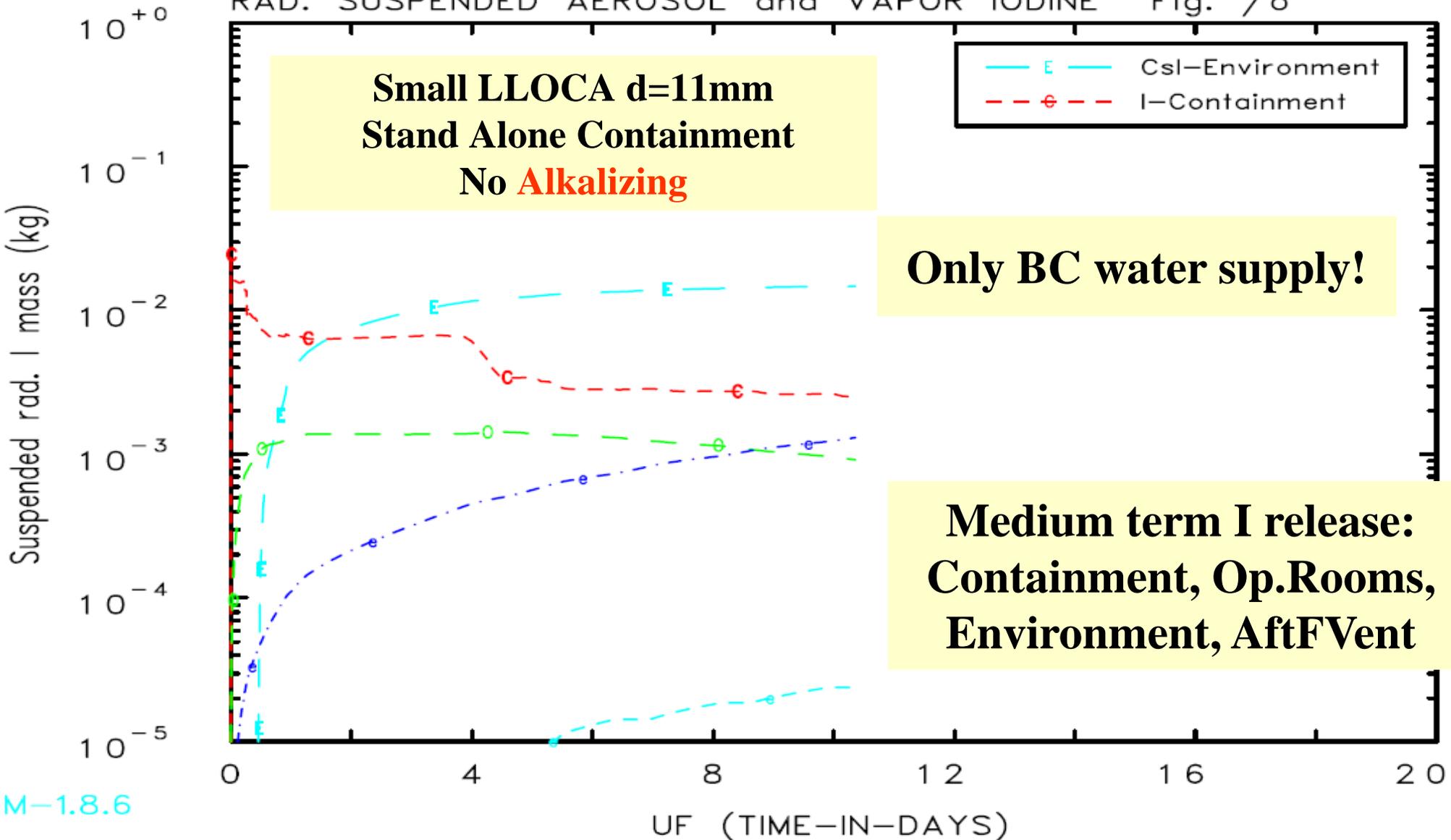
Small LLOCA d=11mm
Stand Alone Containment
No Alkalizing

Only BC water supply!

Medium term I release:
Containment, Op.Rooms,
Environment, AftFVent

Suspended rad. I mass (kg)

UF (TIME-IN-DAYS)

M-1.8.6

CsI-Environment
I-Containment

I-OpRooms
I-Environment
I-AftFiltvent

PDS05C d11 StAloneCont,NoH2 98Rhall NoECC Iod Vent
D1K0x8YT   10/28/10   18:03:40   MELCOR
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Mid term Containment I-131 Release with External Vessel cooling and FVent in Stand Alone Containment – Small LLOCA d=11mm

- **Corrected I-131 distribution:**
  Decay=10days
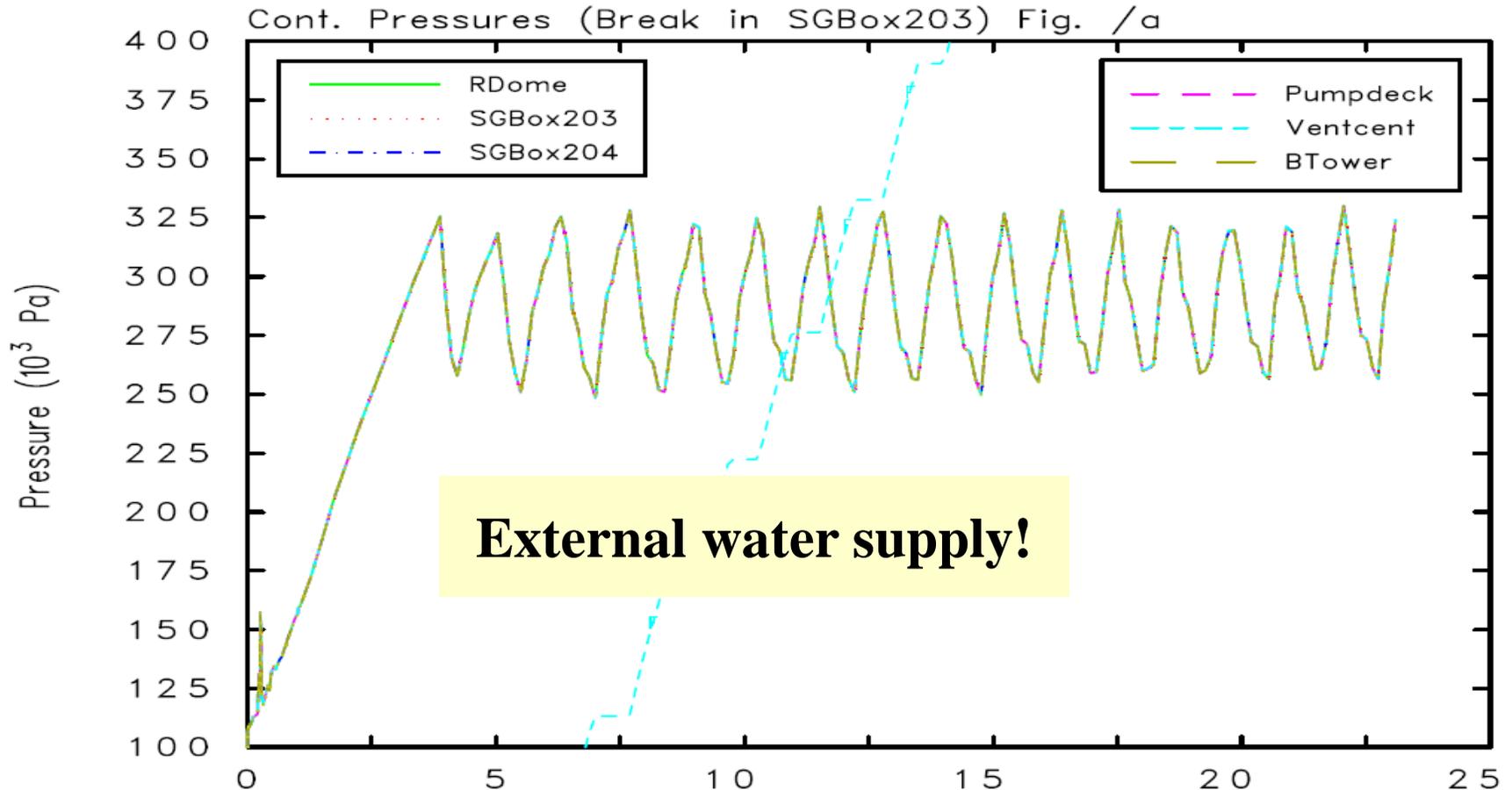 **MELCOR: 2 CVs only calculated = 2.8-times**
  MELCOR mass balance errors: 8% (only!)

Volatile I-131

Room	I-131 TBq	Phase
Oper.Rooms	172	Vapor in Gas
Environment	216	Vapor in Gas
Rest of containment	3530	Bound

Aerosol I-131 (in CsI)

Room	I-131 TBq	Phase
Oper.Rooms	4301	Deposited
Environment	909	Vapor in Gas
Rest of containment	56342	Liquid

Only BC water supply!

Deposited in the pool I-131 (in CsI)

Room	I-131 TBq	Phase
Sump	472431	MI (Bound)

Cont. Pressures (Break in SGBox203) Fig. /a

External water supply!

Legend:
- RDome
- SGBox203
- SGBox204
- Pumpdeck
- Ventcent
- BTower
- BelowTray
- BoxL-FVEnv/2

'M-1.8.6

PDS05C d11 NoFW NoH2 98Rhall ContResSd.his
D1K0y1YT   11/03/10   17:53:42   MELCOR

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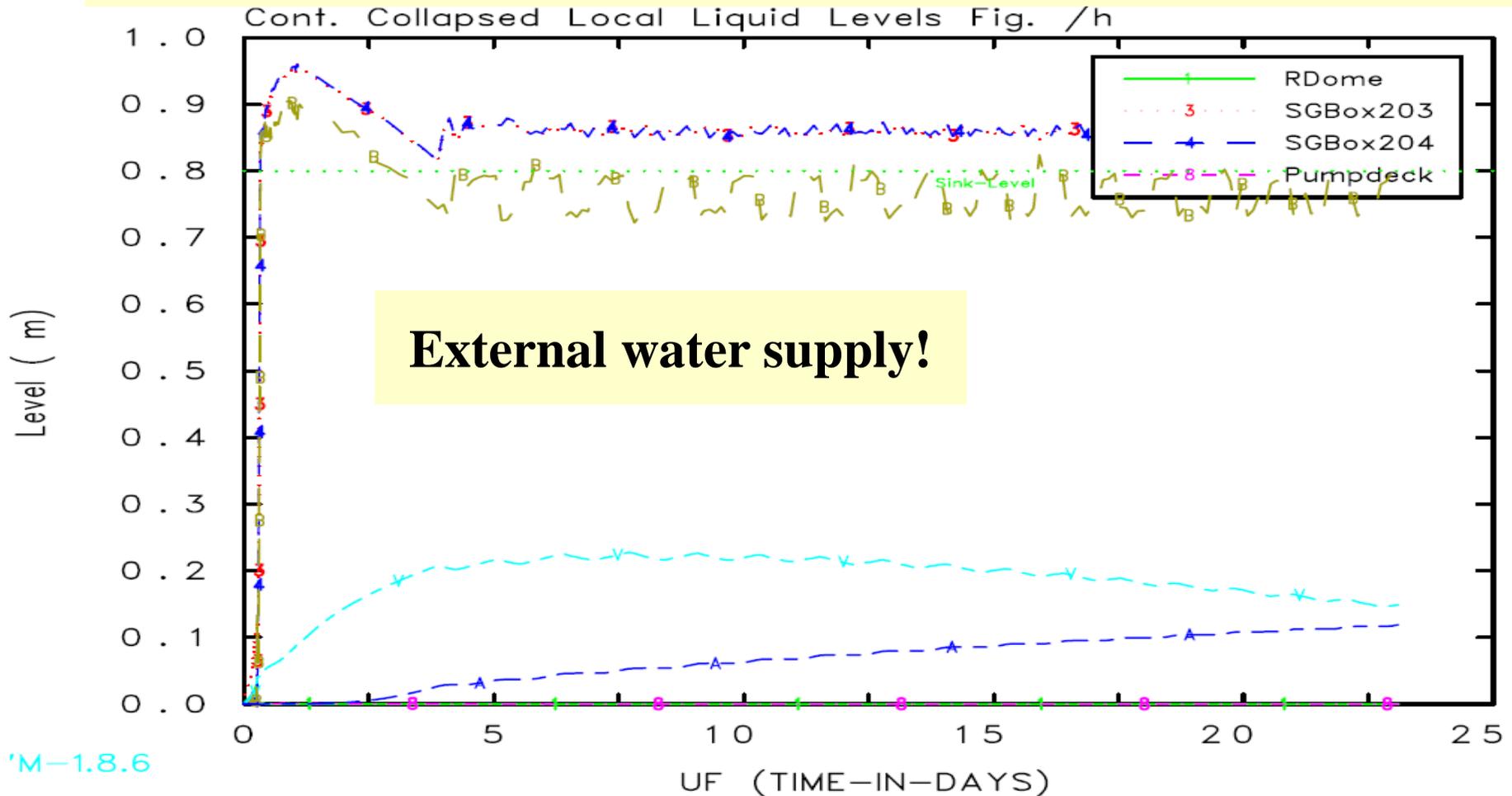**Long term Containment TH with Ext. Vessel cooling and FVent in Stand Alone Containment – Small LLOCA d=11mm : Levels**

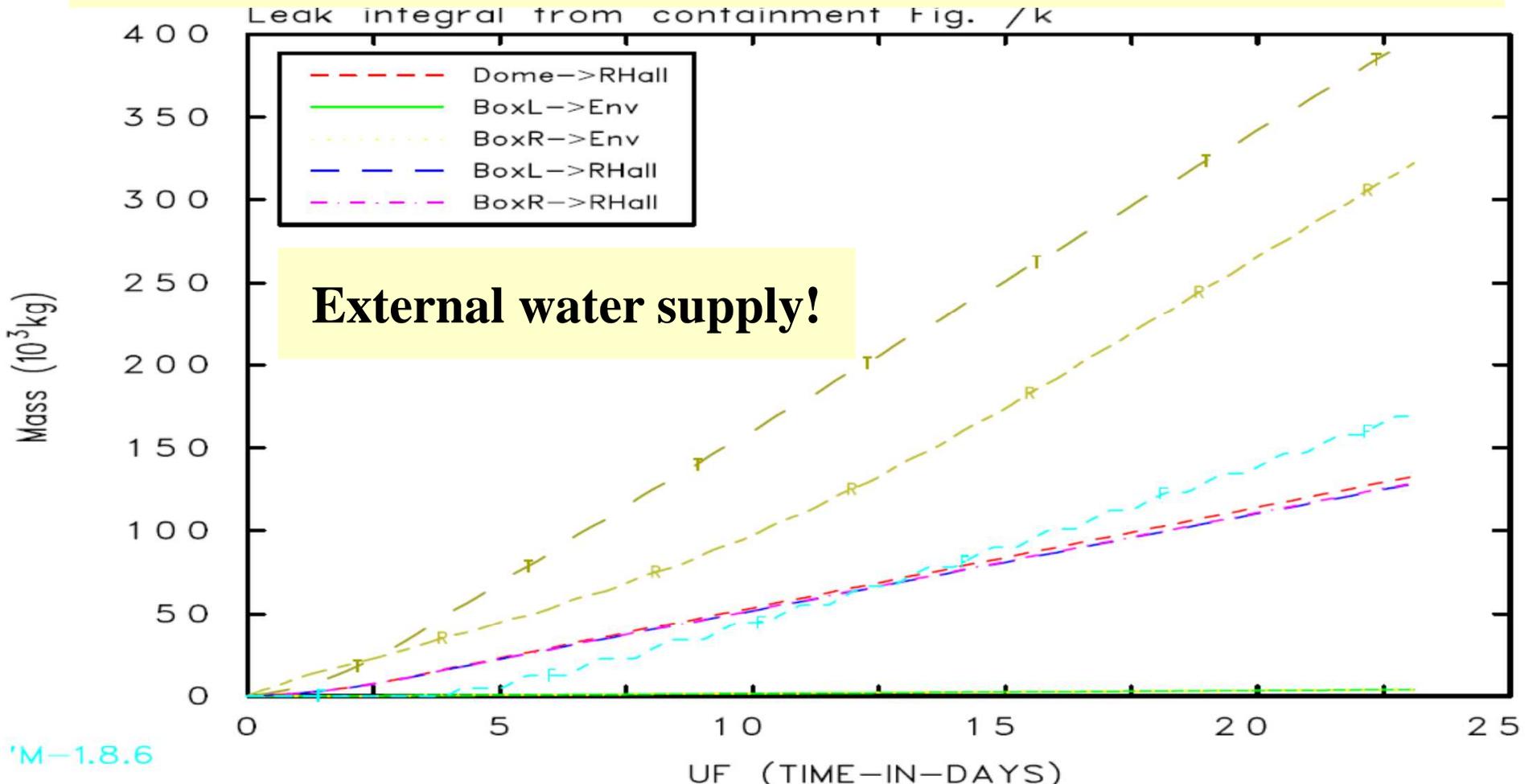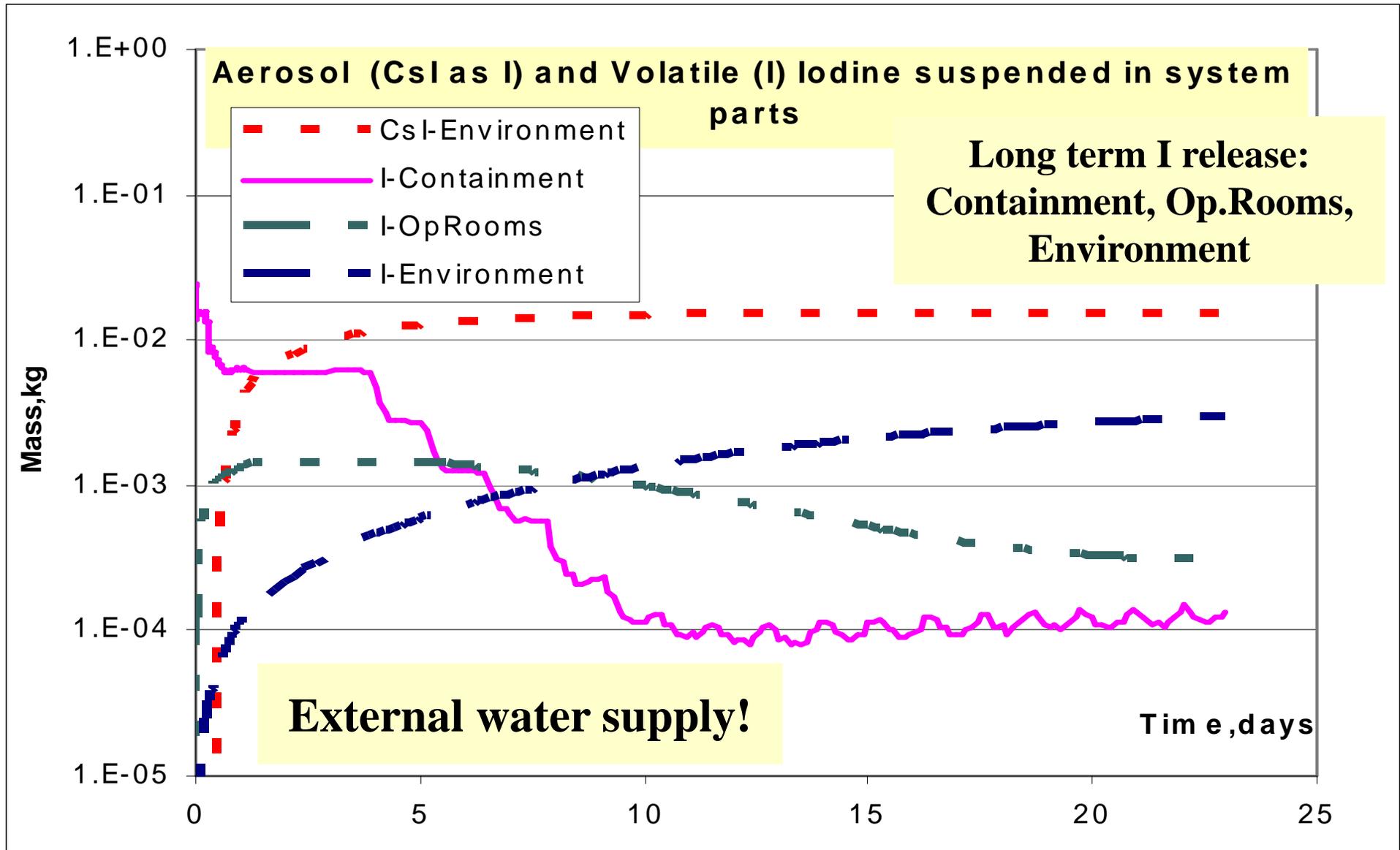**Long term Containment TH with Ext. Vessel cooling and FVent in Stand Alone Containment – Small LLOCA d=11mm : Leaks**

External water supply!

Small LLOCA d=11mm, Stand Alone Containment, No Alkalizing

Aerosol (CsI as I) and Volatile (I) Iodine suspended in system parts

Long term I release: Containment, Op.Rooms, Environment

Legend:
- CsI-Environment
- I-Containment
- I-OpRooms
- I-Environment

Mass, kg (y-axis): 1.E+00, 1.E-01, 1.E-02, 1.E-03, 1.E-04, 1.E-05

Time, days (x-axis): 0, 5, 10, 15, 20, 25

External water supply!

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Small LLOCA d=11mm, Stand Alone Containment, No Alkalizing

Volatile (I) Iodine release rate to environment

Long term I-131 release with decay: Environment

External water supply!

Orig. Inv%/d

Decayed Inv.TBq/d

Time, days

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Summary

Environment *after 3-25 days*

Aerosol I-131 ceases after 3 days

For relatively short lived isotopes a single release number for volatile I-131 is not informative

Release can be described by a rate:
- *10-20 TBq/d during 10-20 days*
- *5-7 TBq/d after 23 days*

MELCOR 1.8.6 In Vessel Retention and IPM model: Problems

In-Vessel Retention

– *Optimum No of axial levels in LP/LH for FOCUSING EFFECT*

– *Melting of LH nodes? Is it calculated? How to plot?*

IPM

– *Max 2 control volumes with IPM can be activated*

– *Mass balance error is between 8-100% (depends on sequence)*

– *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 (although there is nothing to compare with)*

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