FER MELCOR Activities

Presenter: Davor Grgić

Vesna Benčik, Davor Grgić, Siniša Šadek, Štefica Vlahović
Faculty of Electrical Engineering and Computing (FER)
University of Zagreb, Croatia

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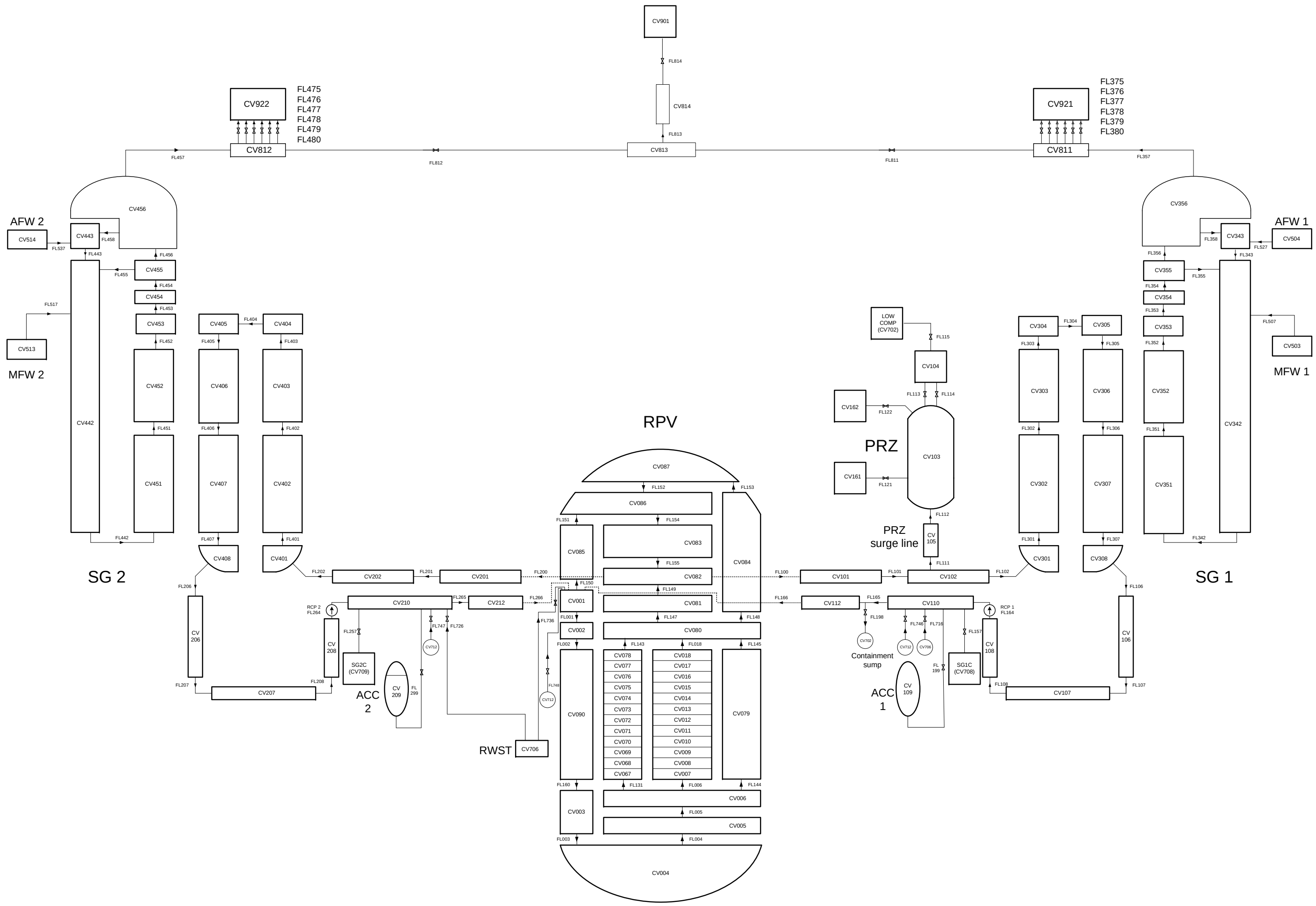
FER MELCOR Activities

- Development of NPP Krško input deck for MELCOR 1.8.6 and MELCOR 2.2 code
- Validation of NEK MELCOR 1.8.6 and MELCOR 2.2 input deck
- Modelling of Engineering Safety Features available for non-severe accident conditions and planned mitigation actions
- Verification of MELCOR input deck by comparison of non-severe accident sequences with RELAP5/MOD 3.3 code.
- Equipment survivability use

Content:

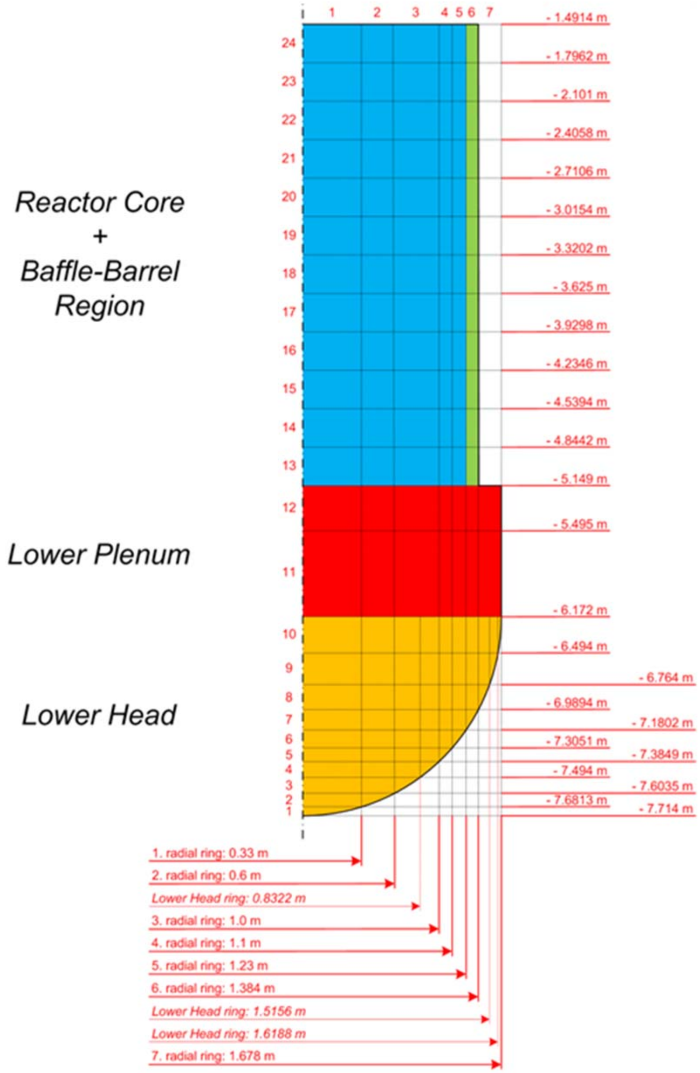
- NPP Krško nodalization for MELCOR 1.8.6 and MELCOR 2.2
- Verification of MELCOR input deck by comparison of 3 inch cold leg LOCA with RELAP5/MOD 3.3 code
- MELCOR 1.8.6 and MELCOR 2.2 analysis of SBO.
- Verification of containment model with Gothic
- Source term preparation
- Different ES applications

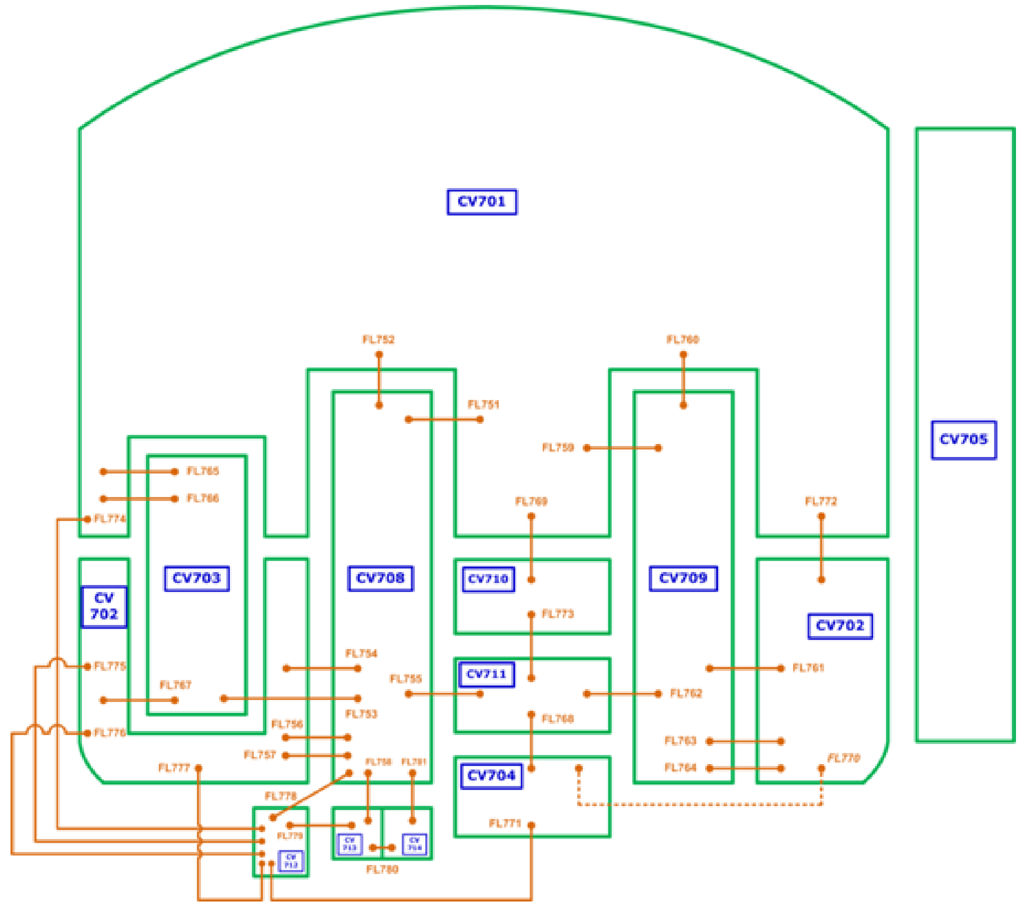
MELCOR nodalization scheme for NPP Krško



The core and lower plenum in COR package

NEK containment nodalization





NPP Krško 3 inch Cold Break LOCA Calculation using RELAP5/MOD 3.3 and MELCOR 1.8.6 Codes

Transient Description and Boundary Conditions

- Postulated accident is a 3 inch Loss of Coolant Accident (LOCA) in cold leg 1 (loop with pressurizer).
- Reactor trip from 100% power is actuated on low pressurizer pressure or high containment pressure signal.
- Trip of both RC pumps is actuated on reactor trip.
- Closure of main steam isolation valves and isolation of main feedwater are initiated on reactor trip.
- Emergency core cooling system is available (5 seconds delay for safety injection).
- Auxiliary feedwater system is available (60 seconds delay)
- Containment fan coolers and containment spray are available in MELCOR.

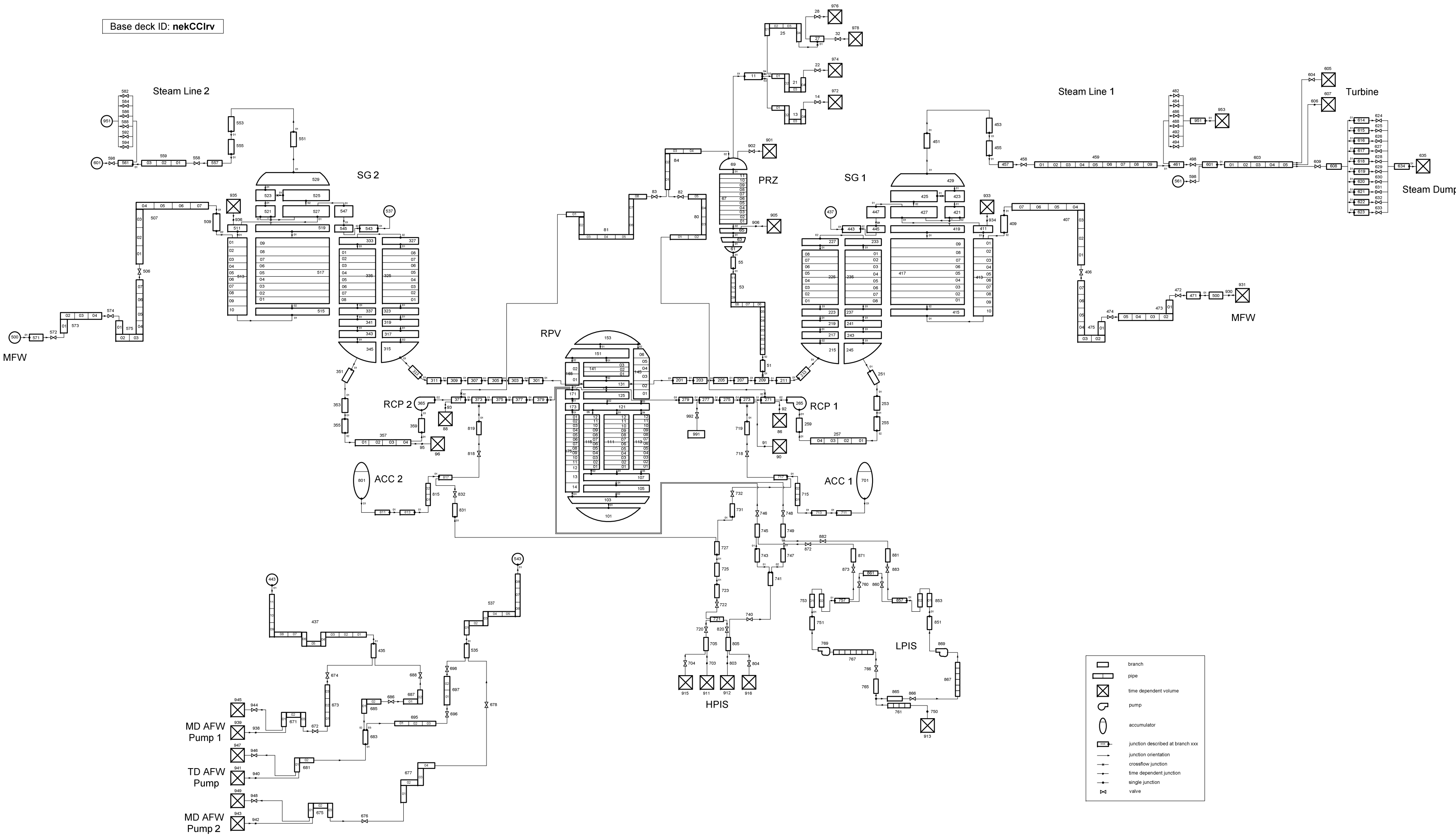
Parameters of RELAP5/mod 3.3 nodalization

PARAMETER	VALUE
1. NUMBER OF NODES	
- primary side	300
- secondary side	206
- total	506
2. NUMBER OF JUNCTIONS	
- primary side	313
- secondary side	230
- total	543
3. NUMBER OF HEAT STRUCTURES	
- primary side	245
- secondary side	138
- total	383
4. OVERALL NUMBER OF MESH POINTS	2127
5. NUMBER OF CORE ACTIVE STRUCTURES	12
6. HEAT TRANSFER AREA (m2)	
- core region	3103.9
- steam generator U-tubes	7343.0
7. NUMBER OF MESH POINTS	
- core slabs	16
- steam generator slabs	10
8. NUMBER OF CONTROL VARIABLES	732
9. NUMBER OF TRIPS	
- variable	197
- logical	221
- total	418
10. OVERALL PRIMARY SIDE VOLUME (m3)	195.3

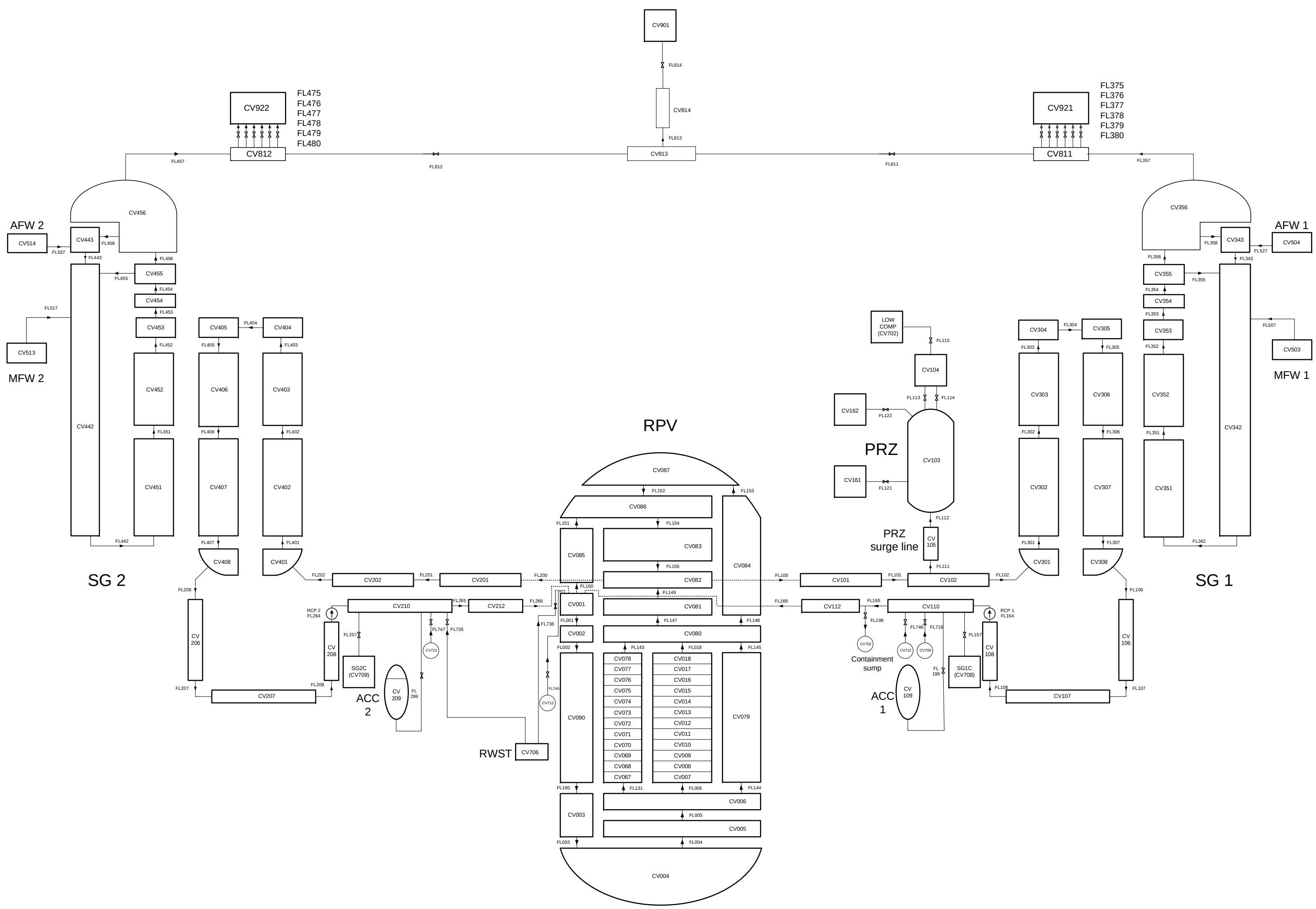
Parameters of MELCOR 1.8.6 nodalization

PARAMETER	VALUE
1. NUMBER OF VOLUMES	
- primary side	69
- secondary side	30
- containment	24
- total	123
2. NUMBER OF FLOW PATHS	
- primary side	93
- secondary side	38
- containment	43
- total	174
3. NUMBER OF HEAT STRUCTURES	
- reactor vessel	34
- primary side and SG U-tubes	46
- containment	20
- total	100
4. OVERALL NUMBER OF MESH POINTS	731
5. NUMBER OF CORE ACTIVE STRUCTURES	27
6. NUMBER OF MESH POINTS IN SG HEAT SLABS	12
7. NUMBER OF CONTROL FUNCTIONS	
- real valued	189
- logical	91
- total	280
7. NUMBER OF TABULAR FUNCTIONS	47

RELAP5/mod 3.3 nodalization scheme for NPP Krško



MELCOR 1.8.6 nodalization scheme for NPP Krško



Parameter	Unit	NEK cycle 28 reference	RELAP5 (1000 s)	MELCOR (1000 s)
1. Pressure	MPa			
Pressurizer		15.513	15.513	15.517
Steam generator		6.281	6.275/6.286	6.19/6.16
Accumulator		4.93	4.93	4.93
2. Fluid Temperature	K			
Cold leg		558.75	559.49/559.25	559.36/559.16
Hot leg		597.55	596.82/596.82	596.94/596.94
Accumulator		322.0	322.0	322.0
Feedwater		492.6	492.7	492.6
3. Mass Flow	kg/s			
Core		8899.7	8925.3	8876.5
cold leg		4697.4	4711.7/4710.7	4683.8 /4686.2
main feedwater		544.5	540.9/544.7	538.9/541.8
main steam line		544.5		538.9/541.8
DC-UP bypass (0%)		0.0	0.0	0.0
DC-UH bypass (0.346%)		32.5 (0.346%)	35.0 (0.371%)	32.38 (0.346%)
Buffle-barrel flow (1.0939%)		102.8 (1.094%)	103.1 (1.094%)	102.49 (1.094%)
RCCA guide tubes (3.32%)		311.9 (3.32%)	359.2 (3.812%)	358.5 (3.826%)
Core cavity (0.5067%)		47.6	-	-
4. Liquid level	%			
Pressurizer		55.7	55.8	55.8
Steam generator narrow range		69.3	69.3/69.3	69.3/69.4
5. Fluid Mass	t			
Primary system		-	131.3	131.8
Steam generator (secondary)		47.0	49.1/48.9	48.08/48.07
6. Power	MW			
Core		1994.0	1994.0	1994.0
Steam generator		1000.0	995.9/1003.0	997.1/1002.6

Results of steady state calculation

Transient results

Accident starts with the opening of the valve simulating 3 inch break in cold leg 1 (volume 110 in MELCOR, volume 275 in RELAP5)

Following the break opening RCS rapidly depressurizes. Reactor trip is initiated on low pressurizer pressure signal. Following actions are actuated on reactor trip: turbine trip, main steam isolation valve closure, main feedwater isolation, RC pump trip.

-Safety injection signal is actuated on low-2 pressurizer pressure signal; SI pumps are enabled with 5 seconds delay. Accumulator injection starts when RCS pressure drops below 4.93 MPa.

-Auxiliary feedwater is actuated on main feedwater isolation (60 seconds delay)

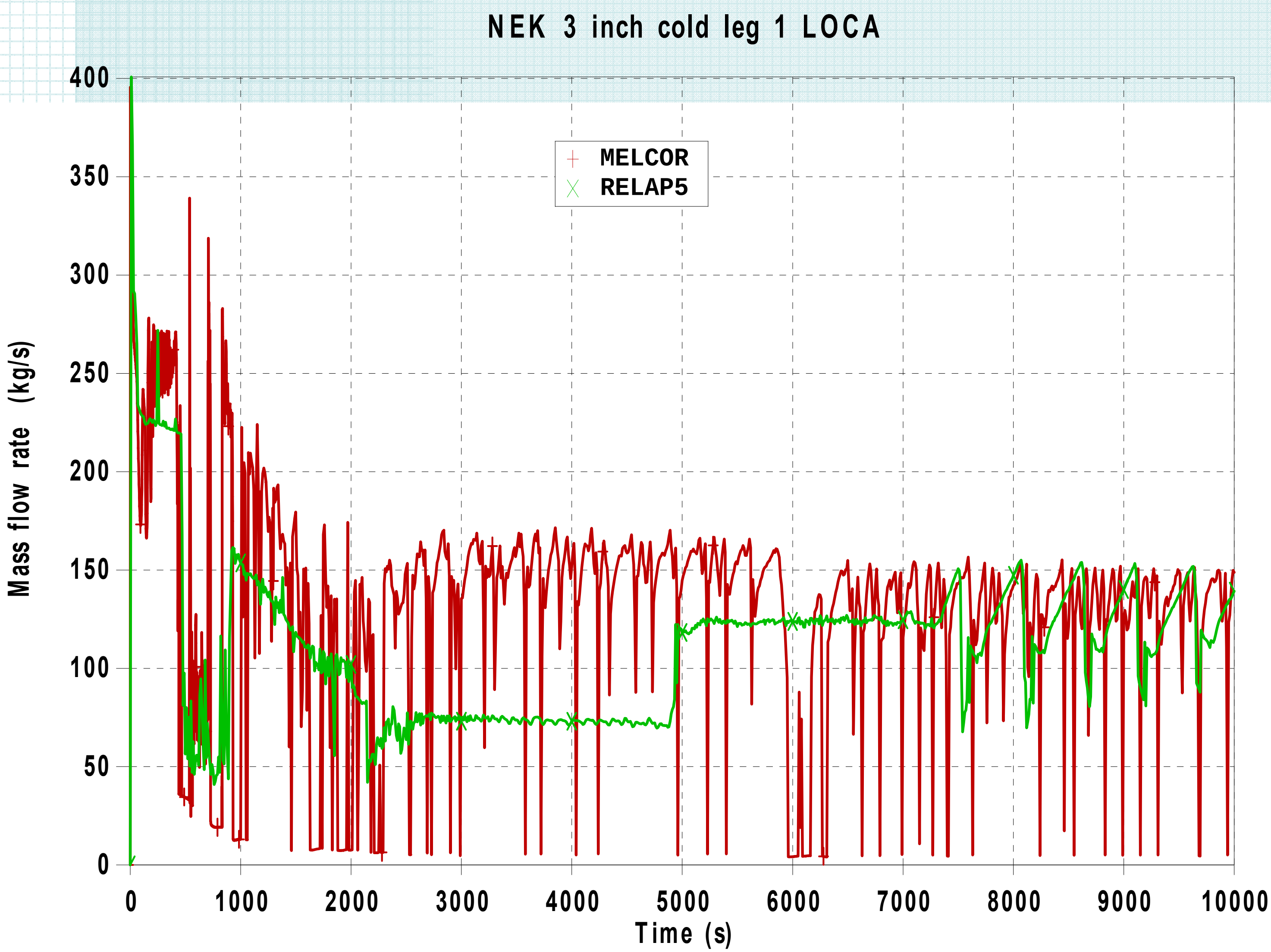
-At transient begin SG PORV open for a short time following turbine trip.

-The heat produced in the core is primarily removed through the break, although in the first phase of the transient heat is also removed by steam generators thus coupling the primary and secondary pressure. Along with RCS inventory depletion the heat transfer in steam generators stops and the primary pressure continues to decrease and decouples from secondary side.

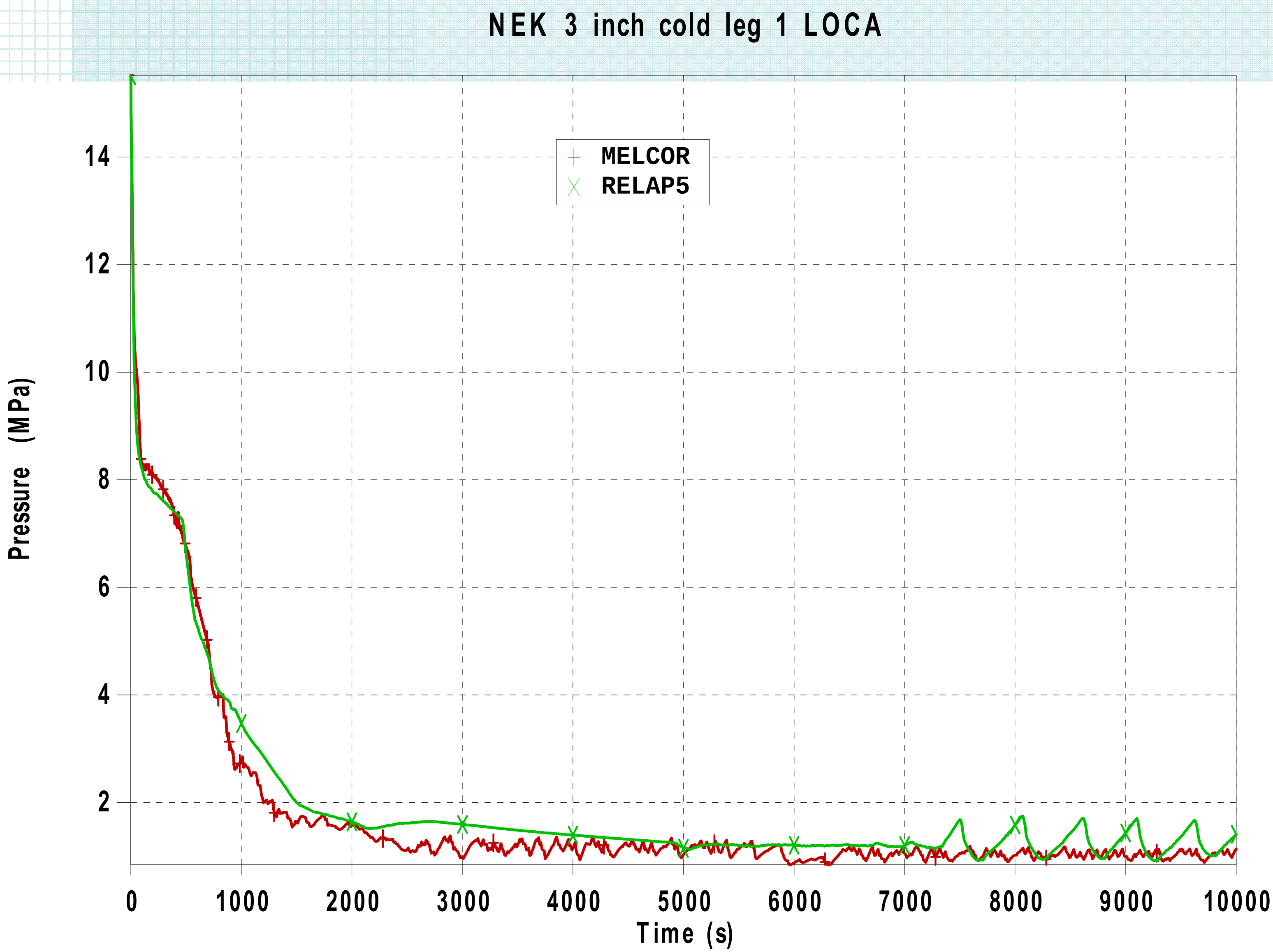
- Core dry-out occurs for a short period (260-500 s) in MELCOR but fuel cladding oxidation did not occur.

3 inch cold leg 1 LOCA – Time table of events

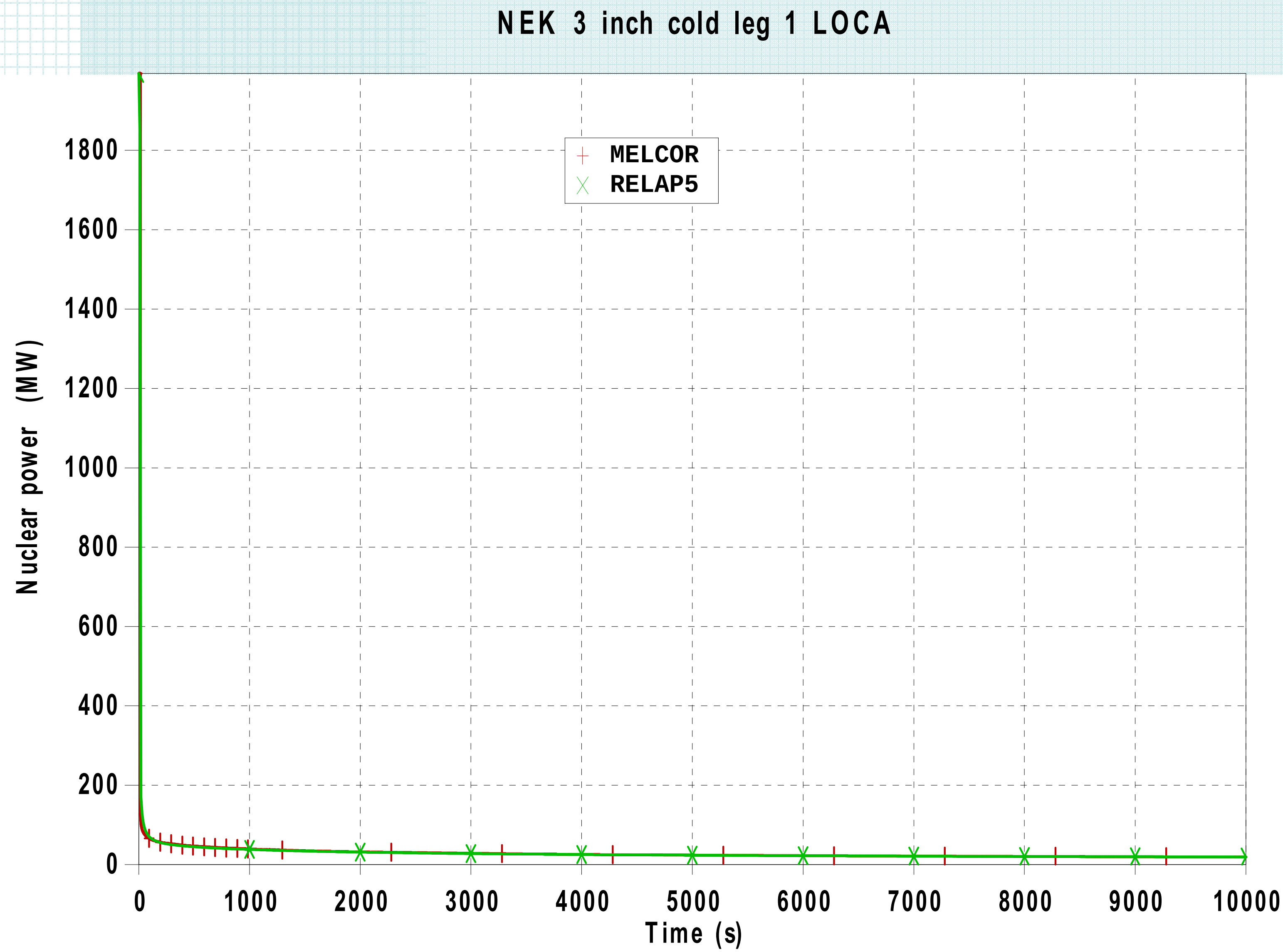
Event	RELAP5/mod 3.3	MELCOR 1.8.6
Transient begin	0.0	0.0
Reactor trip, RC pumps trip	12.8 s (on low PRZ pressure)	14.5 s (on low PRZ pressure)
Turbine trip, MSIV isolation, Main feedwater isolation	12.8 s (on reactor trip signal)	14.5 s (on reactor trip signal)
Safety injection signal	17.4 s (on low-2 PRZ pressure)	18.8 s (on low-2 PRZ pressure)
Safety injection enabled	22.4 s (5 seconds delay)	23.8 s (5 seconds delay)
RWST empty	-	5852
Safety injection-recirculation from sump	-	6152 (5 minutes delay)
Auxiliary feedwater injection enabled	72.8 (60 seconds delay)	74.5 (60 seconds delay)
Accumulator injection	650.0	690.0
Containment fan coolers enabled	-	88.1 (35 seconds delay)
Containment spray	-	-
PCT temperature	610 K (steady state value)	711 K



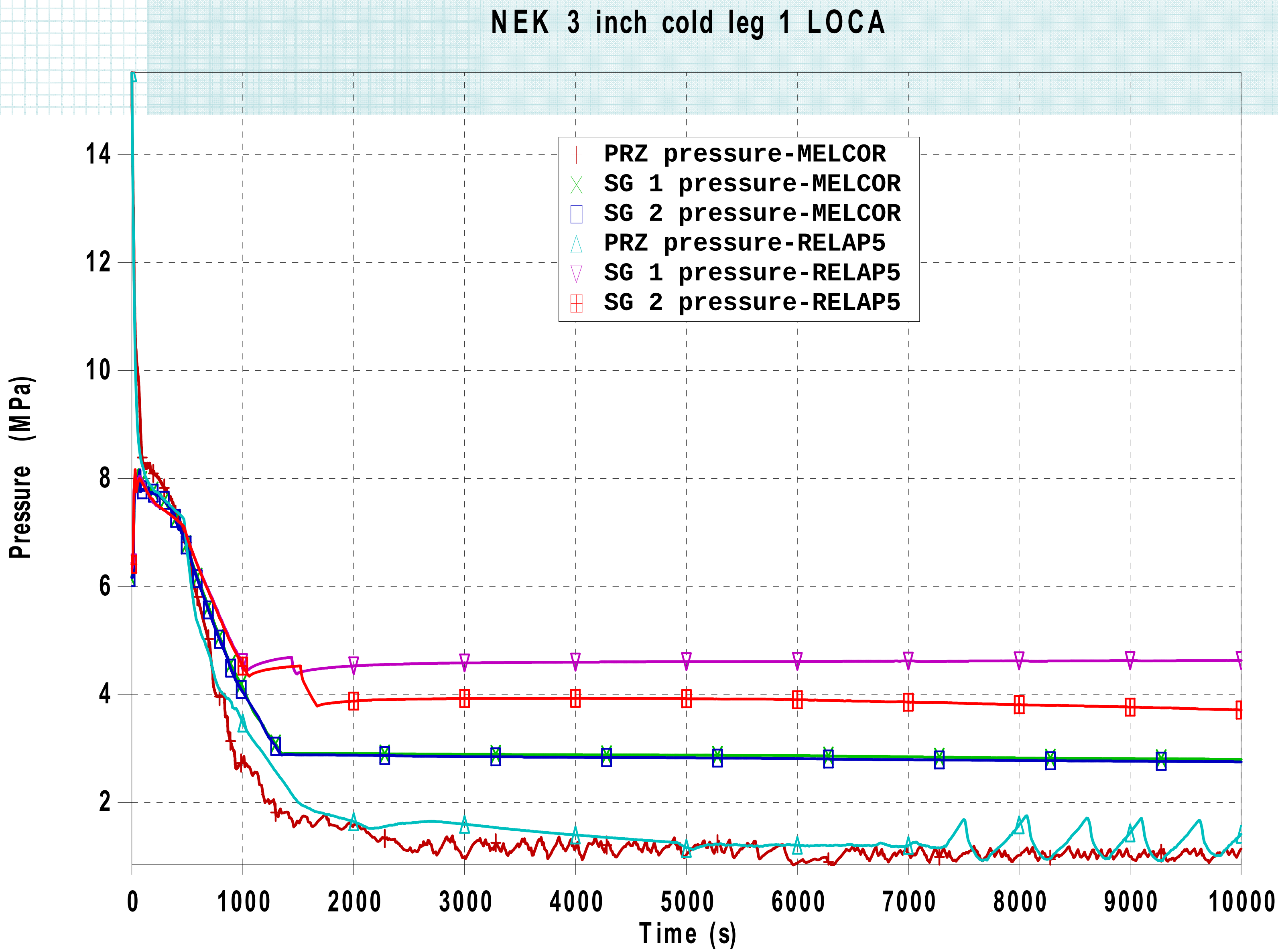
Break mass flow rate



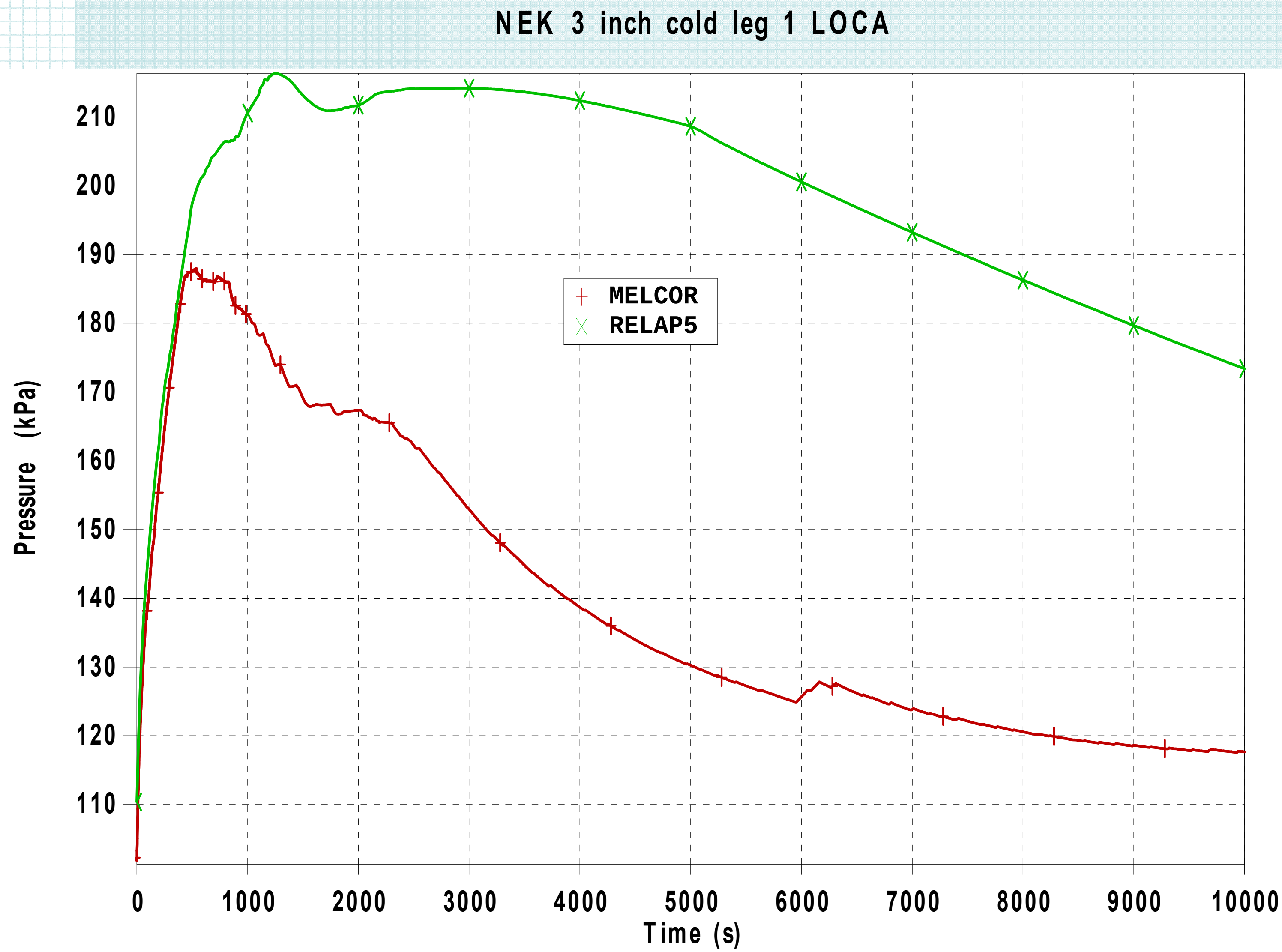
Pressurizer pressure



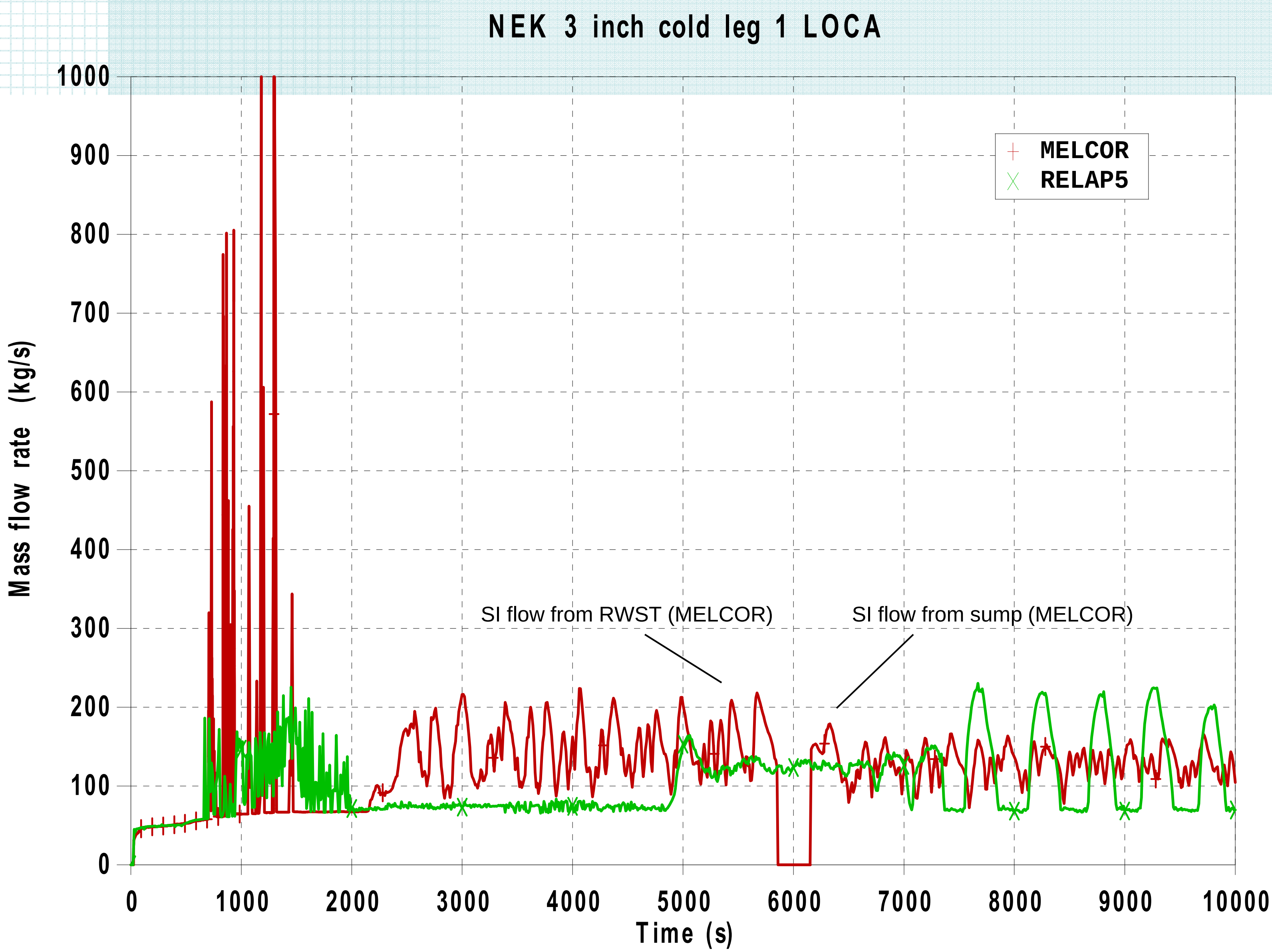
Nuclear power



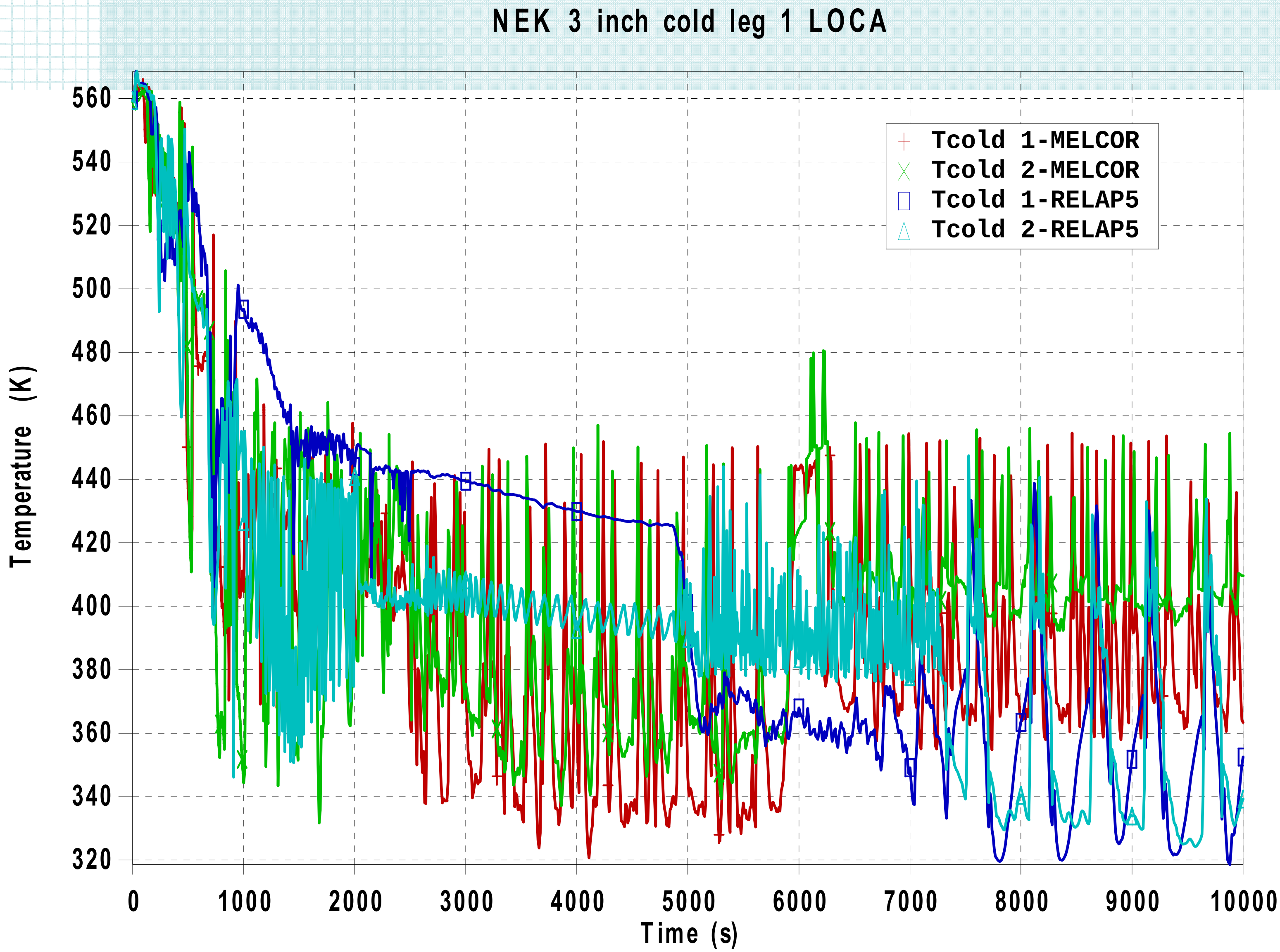
Pressurizer and SG pressure



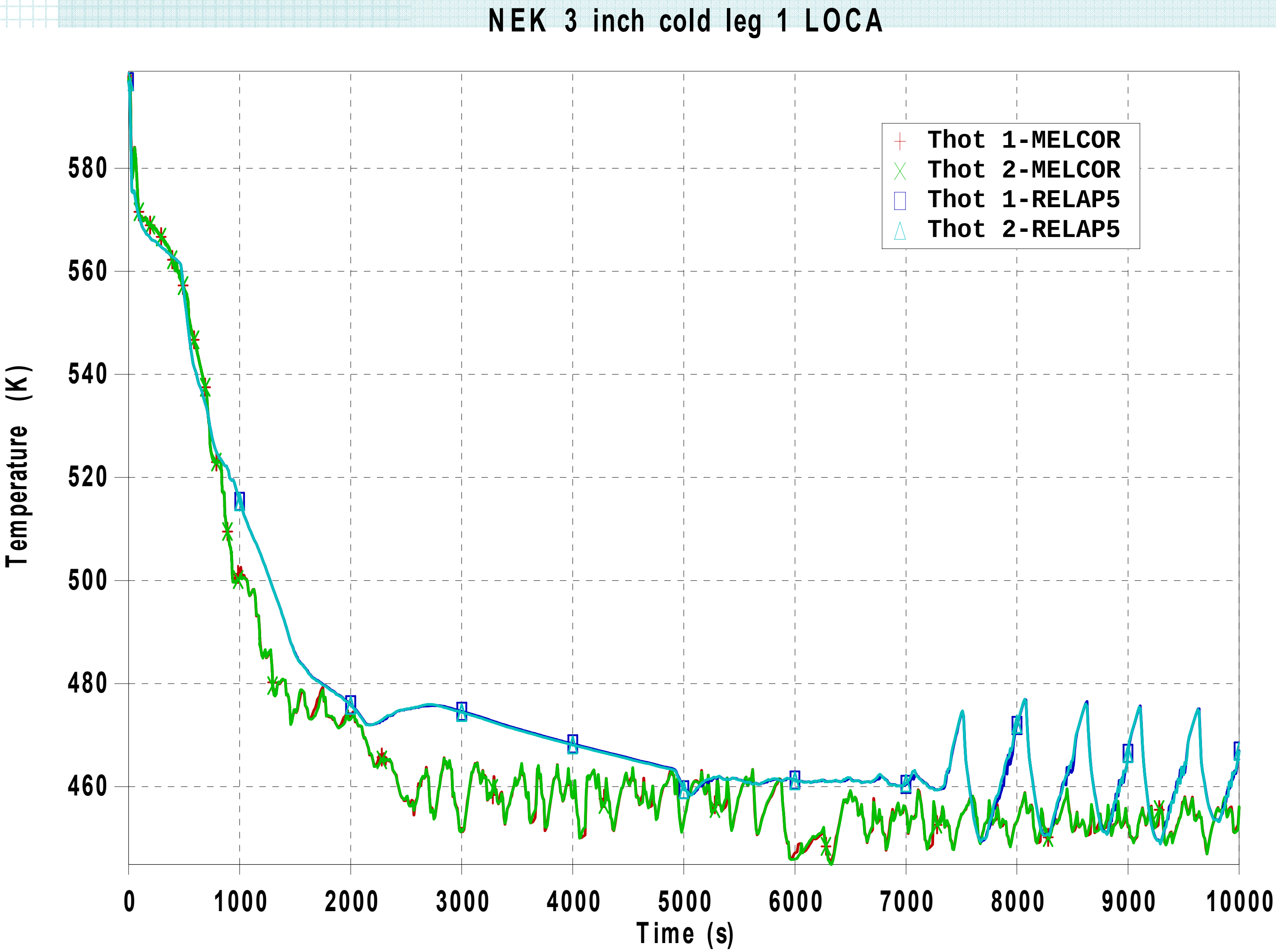
Containment pressure


NEK 3 inch cold leg 1 LOCA
MELCOR
RELAP5
SI flow from RWST (MELCOR)
SI flow from sump (MELCOR)
Mass flow rate (kg/s)
Time (s)
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

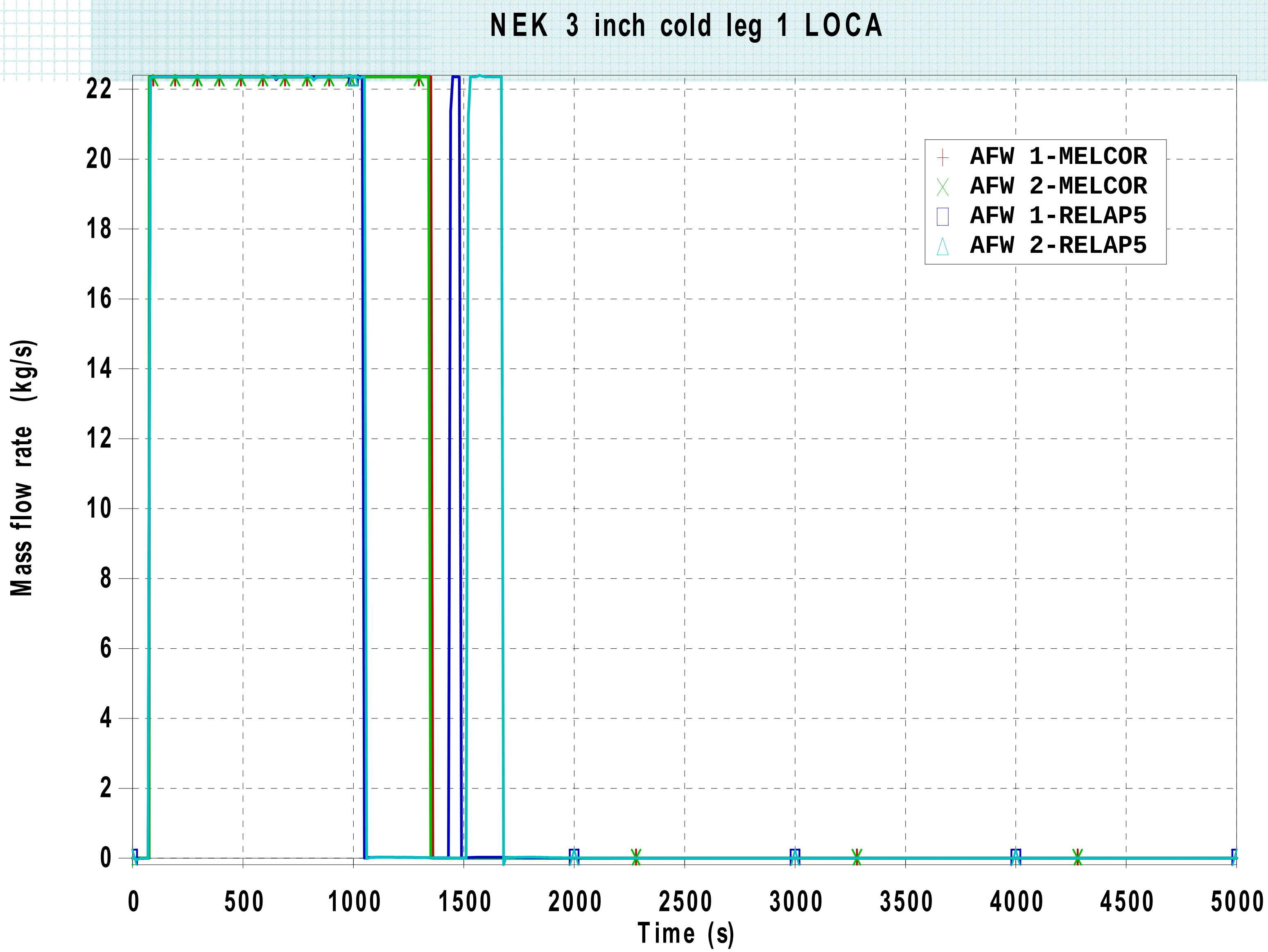
ECCS flow



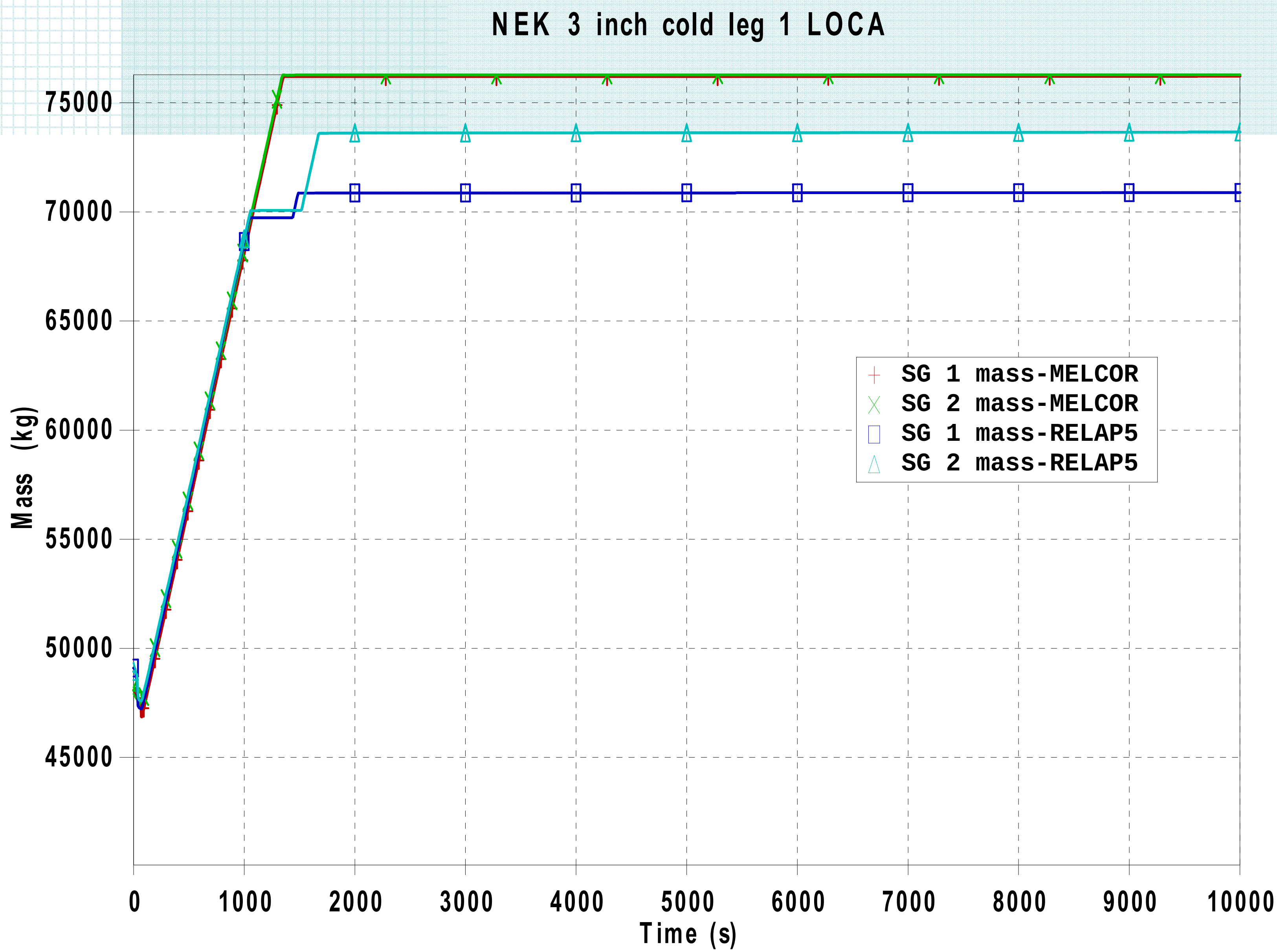
Cold leg temperature



Hot leg temperature

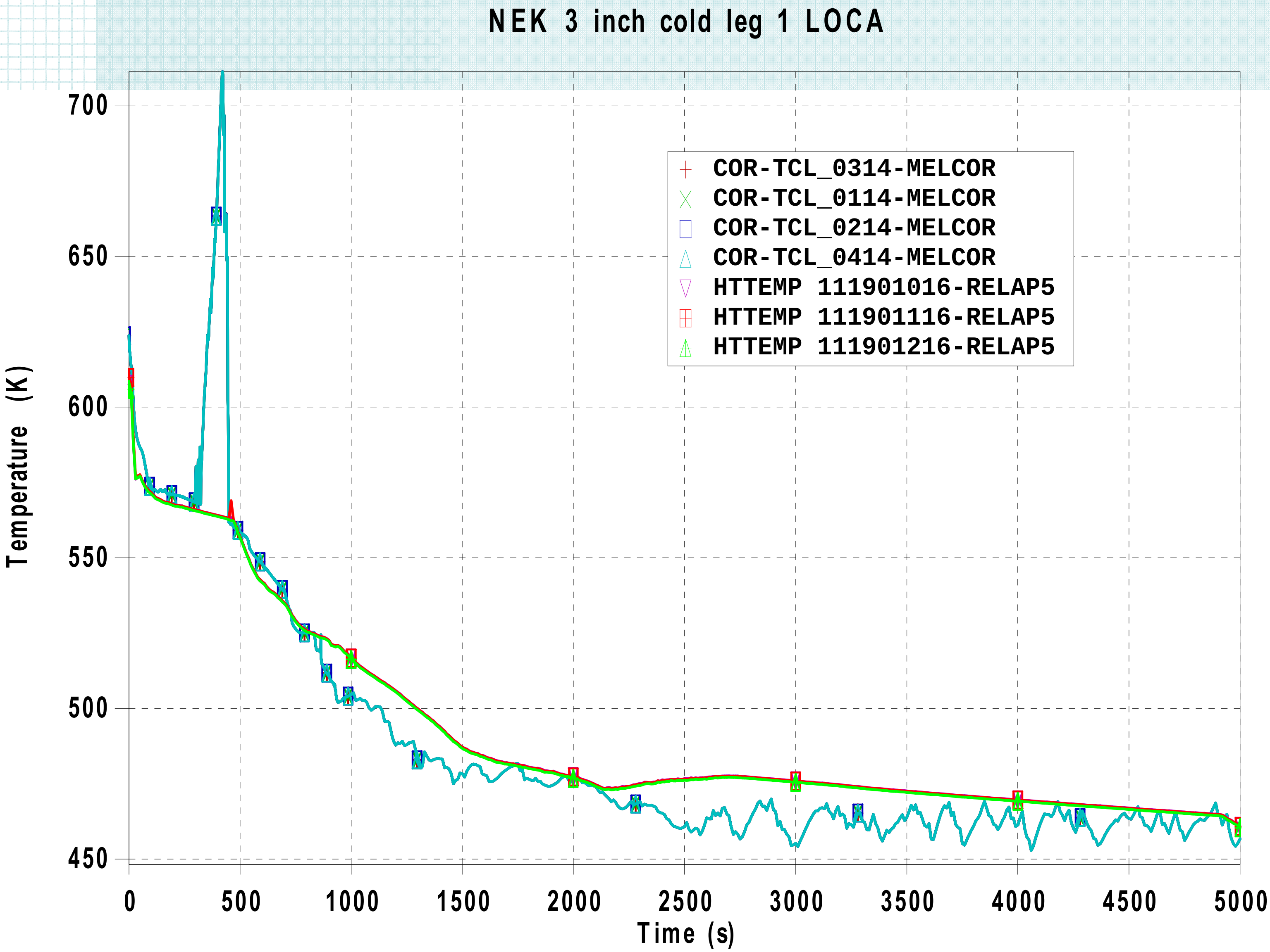


Auxiliary feedwater flow



NEK 3 inch cold leg 1 LOCA
Mass (kg)
75000
70000
65000
60000
55000
50000
45000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time (s)
SG 1 mass-MELCOR
SG 2 mass-MELCOR
SG 1 mass-RELAP5
SG 2 mass-RELAP5

SG mass



Fuel cladding temperature

3 inch cold leg break LOCA, Conclusion

- In MELCOR calculation larger break flow than in RELAP5 was obtained. This difference is mainly due to different choked flow models. Containment back pressure is lower in MELCOR than in RELAP5 due to fan coolers operation but this has a small influence on break flow.
- In MELCOR, lower RCS pressure and larger safety injection flow (LPIS) than in RELAP5 was obtained. This has influenced RCS temperatures.
- After reactor trip different heat transfer conditions in steam generator for RELAP5 and MELCOR were obtained. In MELCOR heat transfer from secondary to primary side was larger than in RELAP5 thus resulting in lower secondary pressure. Pressure drop on secondary side was stopped first after terminating the auxiliary feedwater flow.
- In MELCOR, fuel cladding temperature has increased (max. temperature=711 K) in the first phase of the transient, but fuel cladding oxidation did not occur.

NPP Krško Station Blackout (SBO) Calculation using MELCOR 1.8.6 and MELCOR 2.2 Codes

Parameter	Unit	NEK cycle 28 reference	MELCOR 1.8.6 (1000 s)	MELCOR 2.2 (1000 s)
1. Pressure	MPa			
Pressurizer		15.513	15.517	15.517
Steam generator		6.281	6.19/6.16	6.19/6.16
2. Fluid Temperature	K			
Cold leg		558.75	559.36/559.16	559.36/559.16
Hot leg		597.55	596.94/596.94	596.94/596.94
Feedwater		492.6	492.6	492.6
3. Mass Flow	kg/s			
Core		8899.7	8876.5	8876.5
cold leg		4697.4	4683.8 /4686.2	4683.8 /4686.2
main feedwater		544.5	538.9/541.8	538.9/541.8
main steam line		544.5	538.9/541.8	538.9/541.8
DC-UP bypass (0%)		0.0	0.0	0.0
DC-UH bypass (0.346%)		32.5 (0.346%)	32.38 (0.346%)	32.39 (0.346%)
Buffle-barrel flow (1.0939%)		102.8 (1.094%)	102.49 (1.094%)	102.49 (1.094%)
RCCA guide tubes (3.32%)		311.9 (3.32%)	358.5 (3.826%)	358.6 (3.827%)
Core cavity (0.5067%)		47.6	-	-
4. Liquid level	%			
Pressurizer		55.7	55.8	55.8
Steam generator narrow range		69.3	69.3/69.4	69.3/69.4
5. Fluid Mass	t			
Primary system		-	131.8	131.8
Steam generator (secondary)		47.0	48.08/48.07	48.08/48.07
6. Power	MW			
Core		1994.0	1994.0	1994.0
Steam generator		1000.0	997.1/1002.6	997.1/1002.6

Results of steady state calculation

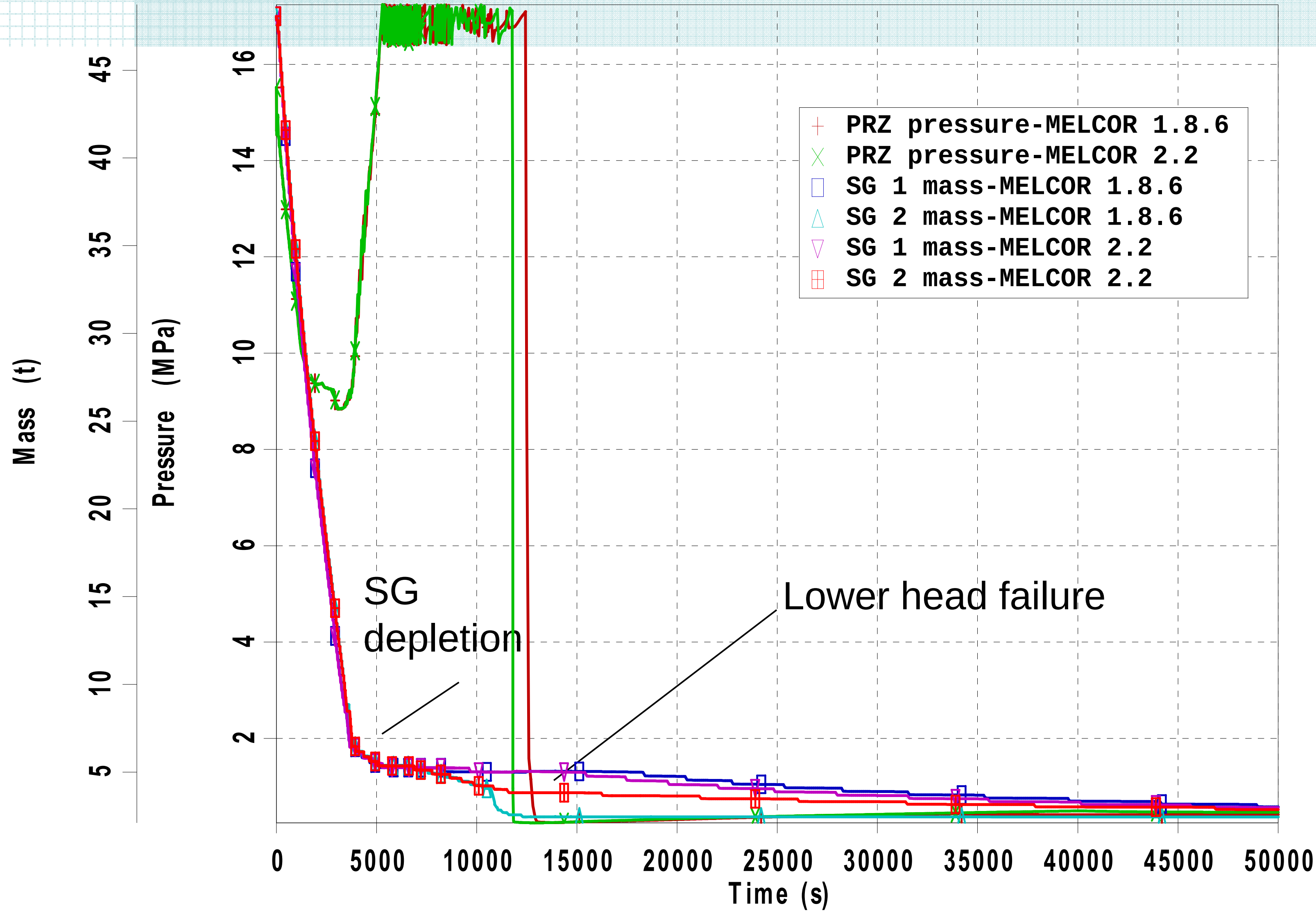
Transient Description

- Time=0: Reactor trip from 100% power, turbine trip, Main steam line isolation, Loss of main feedwater, RC pump trip, RC pump seal leakage
- Engineering Safety features (Auxiliary feedwater, Safety Injection, Containment fan coolers, Containment Spray) are not available.
- Only passive components are available: Accumulators, Passive Autocatalytic Recombiners and Passive Containment Filtered Vent System.
- SG safety valves and pressurizer safety valves are available.
- Accumulators will inject its content into RCS after RCS pressure drop (either RPV failure or creep failure – hot leg, PRZ surge line or SG tube)

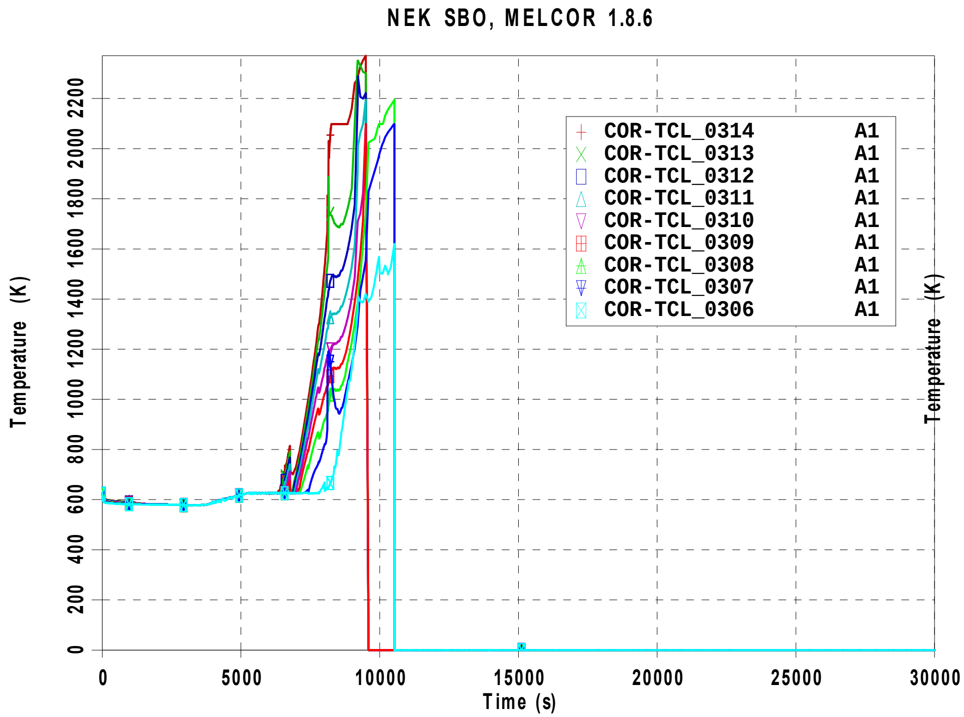
NEK SBO: Time table of events

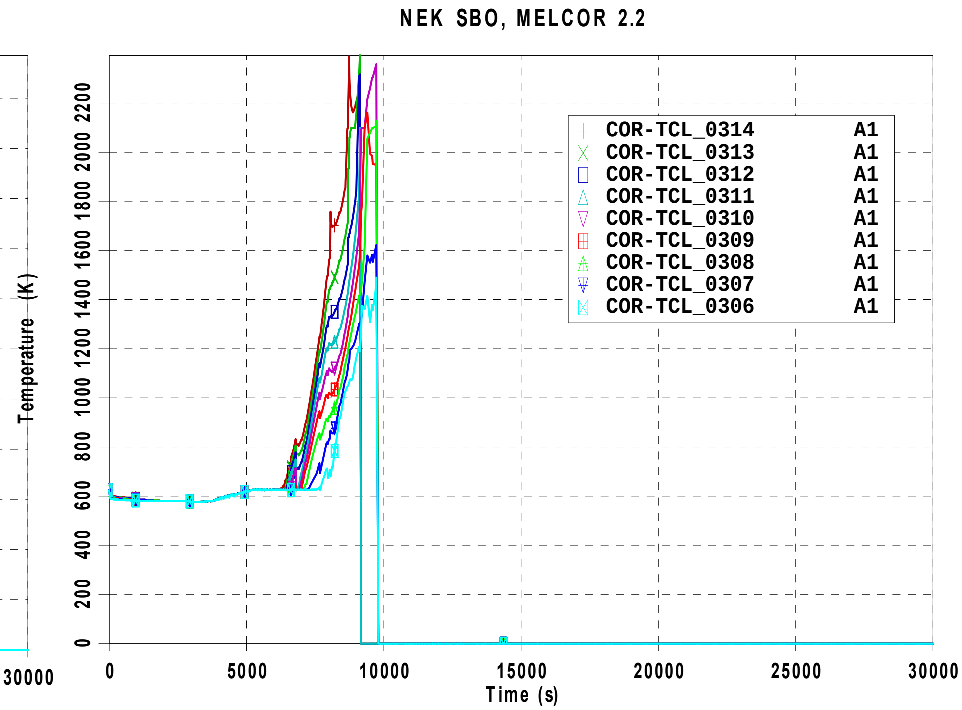
Event	MELCOR 1.8.6	MELCOR 2.2
Transient begin	0.0	0.0
SG empty	3920 sec	3920 sec
Lower head failure	12438 sec	11768 sec
Begin of melt ejection	13950 sec	11800 sec
PCFV actuation	15020 sec	13350 sec
Begin of PCFV ON/OFF behavior	18170 sec	16440 sec

NEK SBO



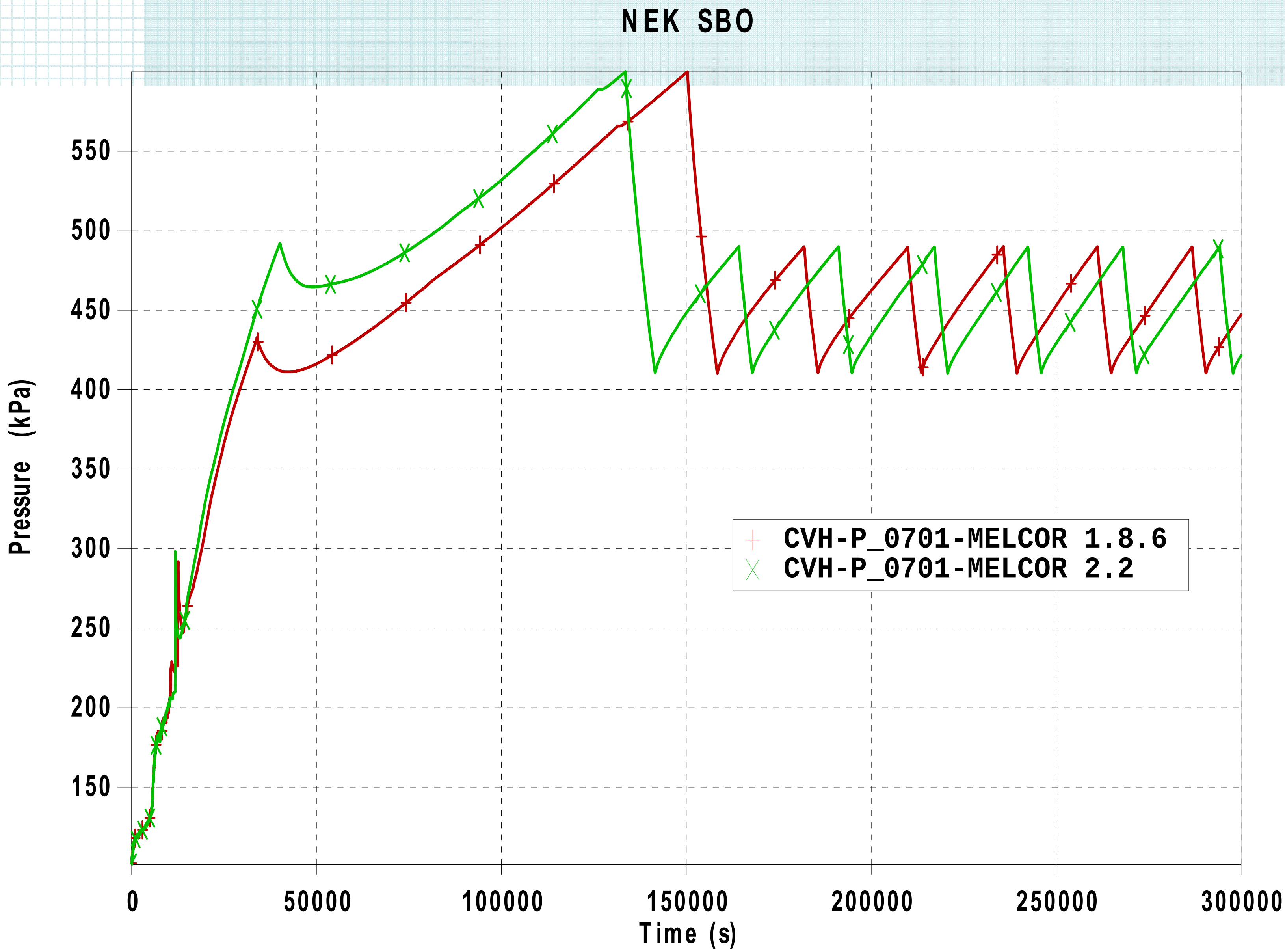
Pressurizer pressure and SG mass





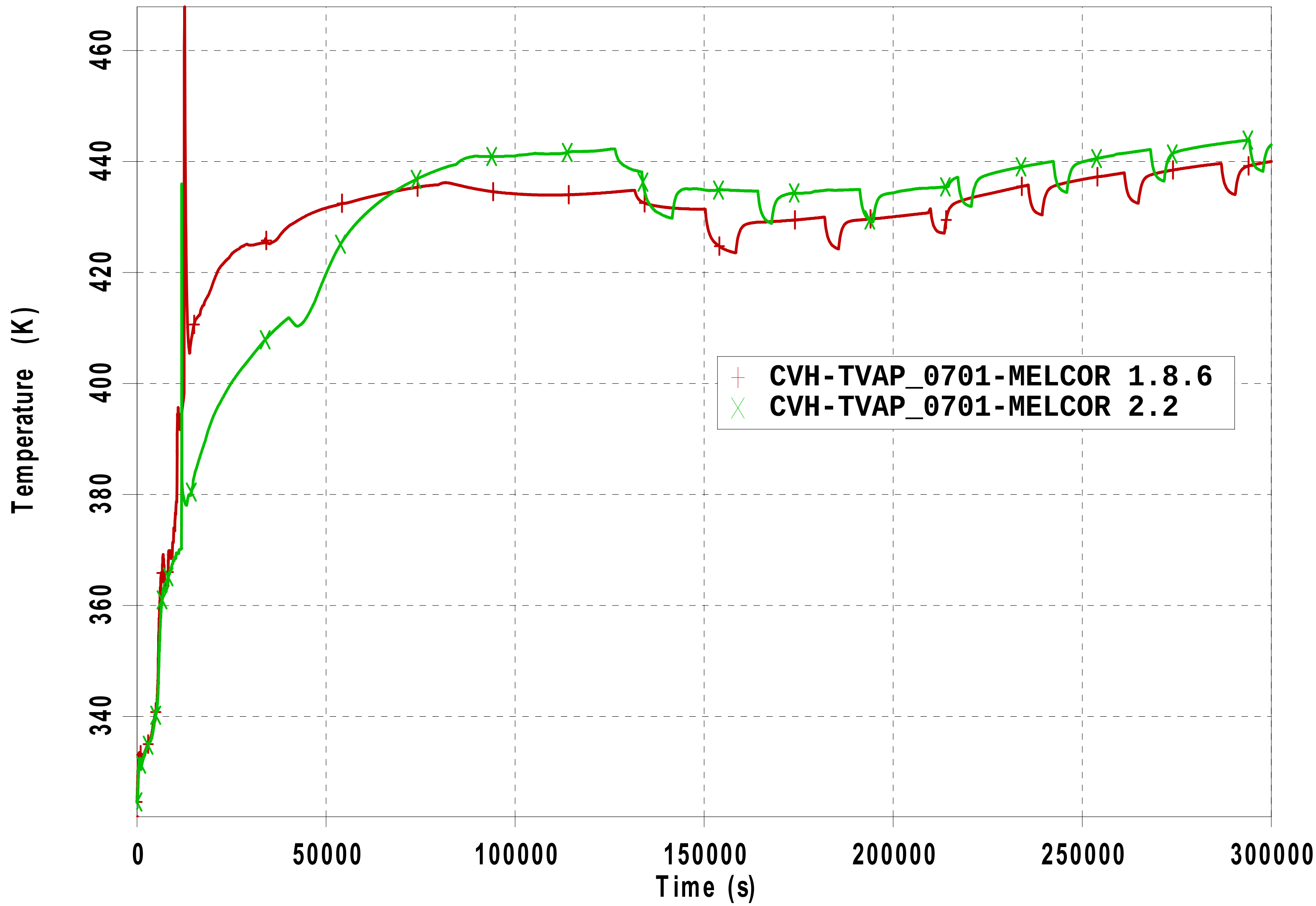
MELCOR 1.8.6: Fuel temperature 3rd ring

MELCOR 2.2: Fuel temperature 3rd ring

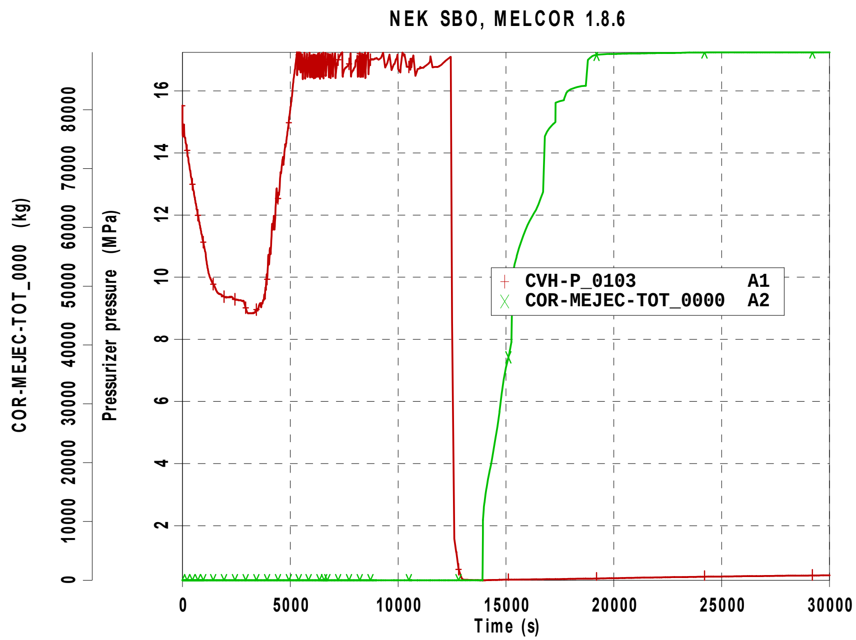


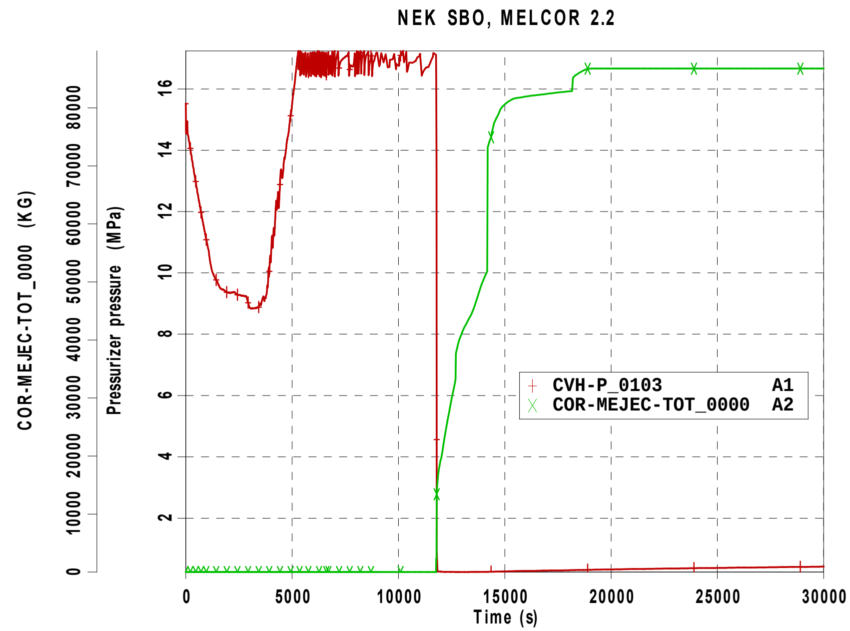
Containment (upper compartment) pressure

NEK SBO



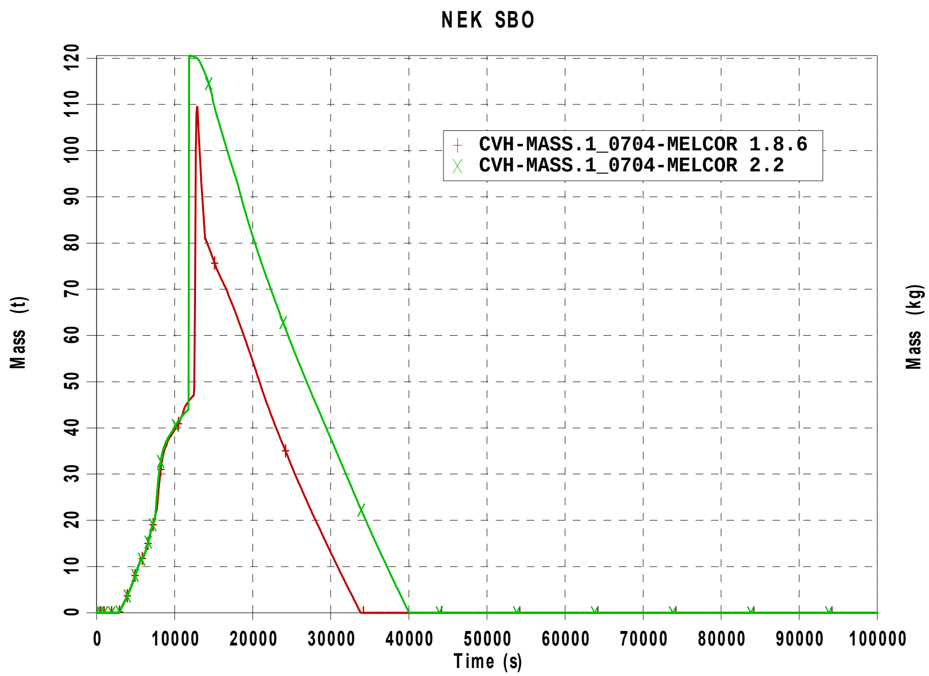
Containment (upper compartment) temperature



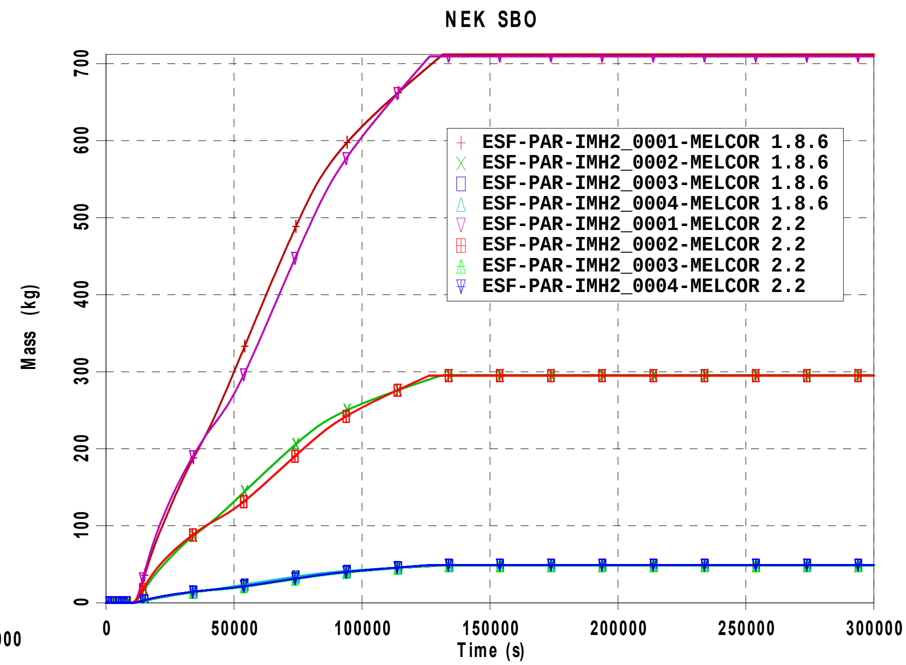


MELCOR 1.8.6: Pressurizer pressure, ejected mass to cavity

MELCOR 2.2: Pressurizer pressure, ejected mass to cavity



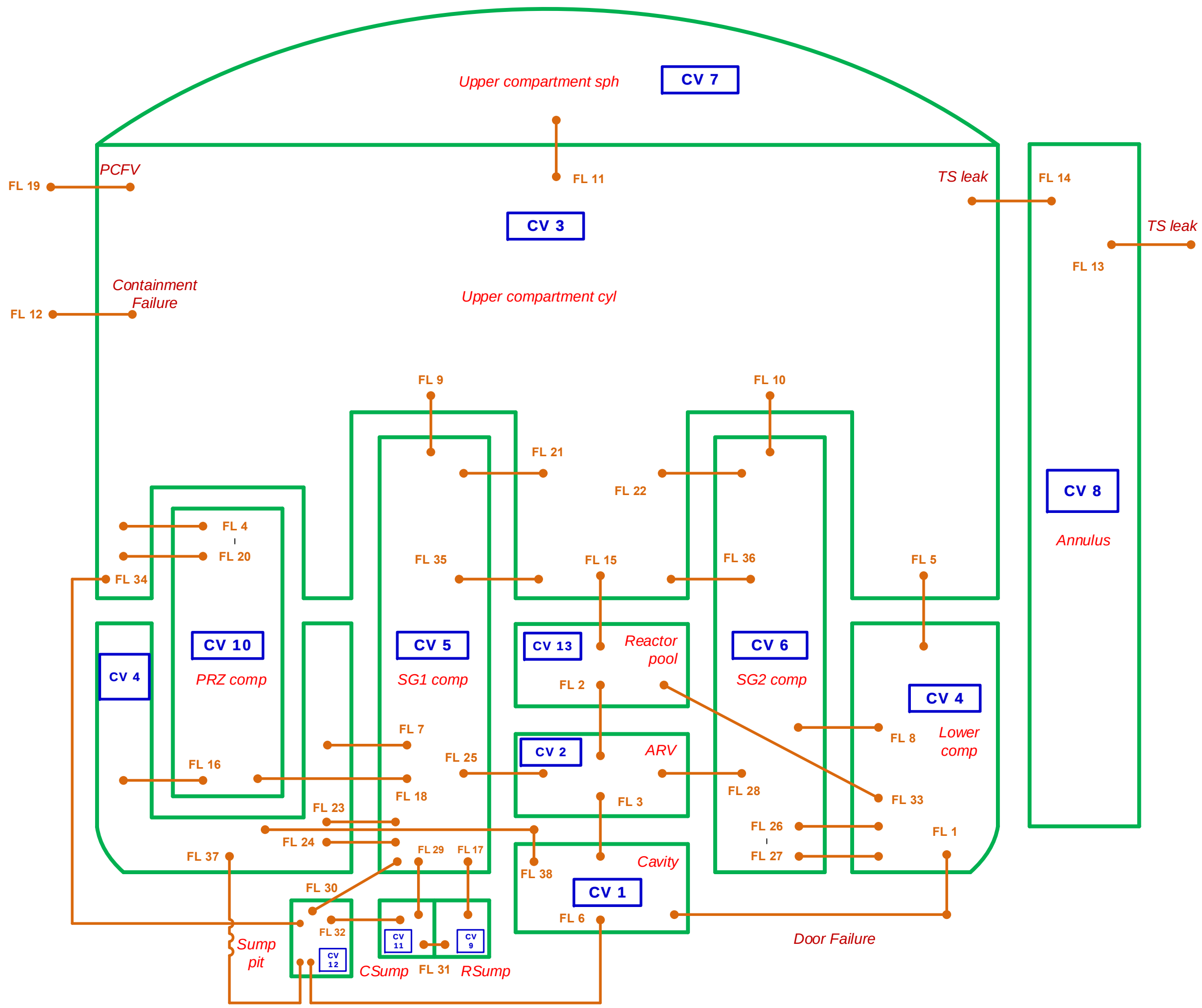
Cavity mass



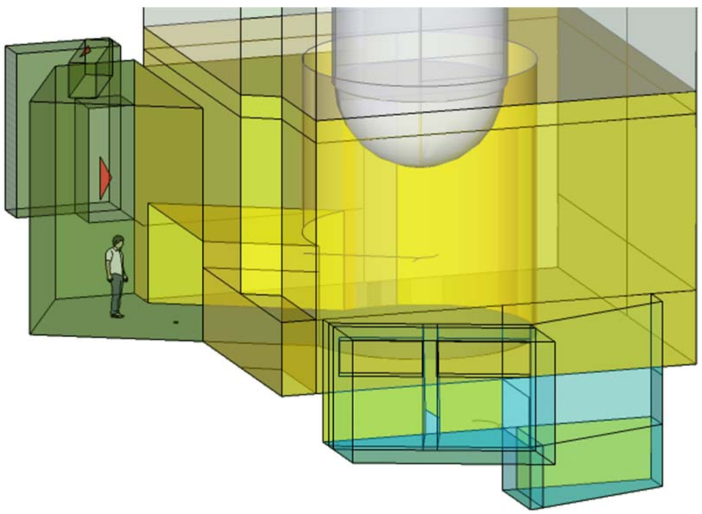
Removed hydrogen by PARs

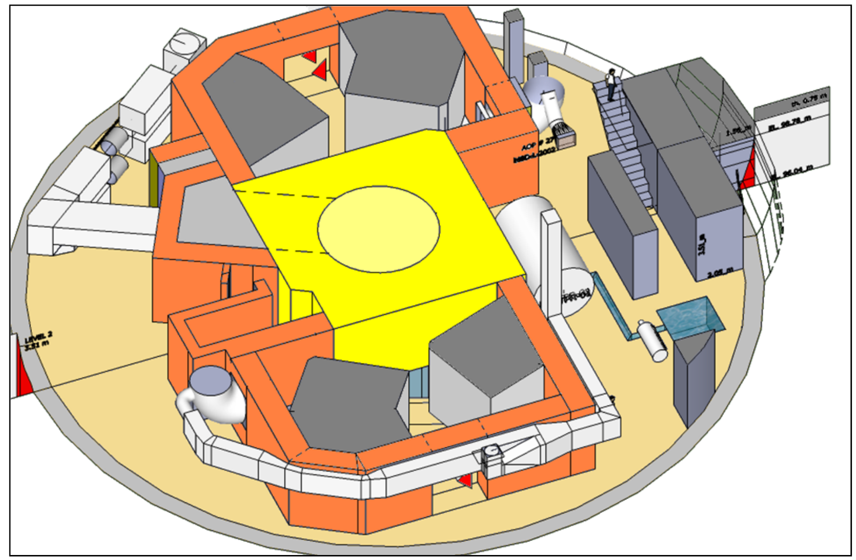
SBO, Conclusion

- MELCOR 2.2: Lower head failure at time=11768 sec and an immediate melt ejection to cavity that blocks flow path: sump pit-cavity. Water from the accumulators stays trapped in the cavity.
- MELCOR 1.8.6: Lower head failure at time=12438 sec and delayed melt ejection to cavity. Flow path: sump pit – cavity is free to expell a large amount of water from cavity to sump pit.
- As a consequence, in MELCOR 2.2 a larger amount of water evaporated in cavity and lead to larger first peak in containment pressure than in MELCOR 1.8.6. That has lead to delay in PCFV activation in MELCOR 1.8.6. Later, the ON/OFF PCFV operation had the same frequency for both codes.


CV 7
Upper compartment sph
FL 11
CV 3
Upper compartment cyl
PCFV
FL 19
Containment
Failure
FL 12
TS leak
FL 14
TS leak
FL 13
CV 8
Annulus
FL 9
FL 10
FL 21
FL 22
FL 4
FL 20
FL 34
FL 35
FL 15
FL 36
FL 5
CV 4
CV 10
PRZ comp
CV 5
SG1 comp
CV 13
Reactor
pool
FL 2
CV 6
SG2 comp
CV 4
Lower
comp
FL 8
FL 7
FL 16
FL 25
CV 2
ARV
FL 28
FL 18
FL 3
FL 33
FL 23
FL 24
FL 26
FL 27
FL 1
FL 37
FL 29
FL 17
FL 38
Cavity
CV 1
FL 30
FL 32
FL 6
Door Failure
Sump
pit
CSump
FL 31
RSump

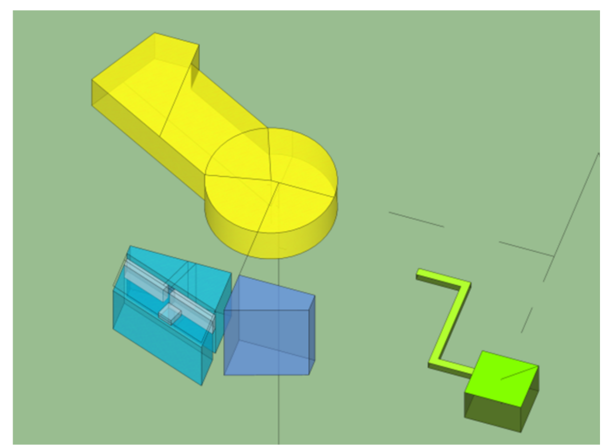
Cavity Layout and the MCCI

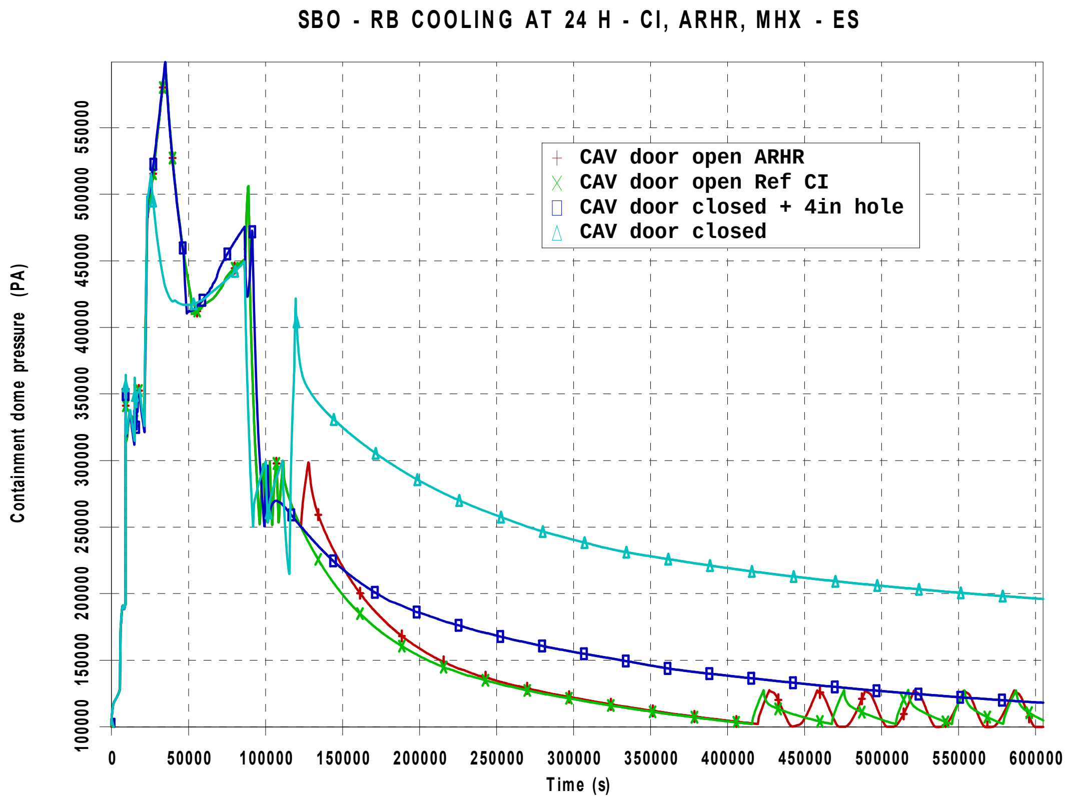


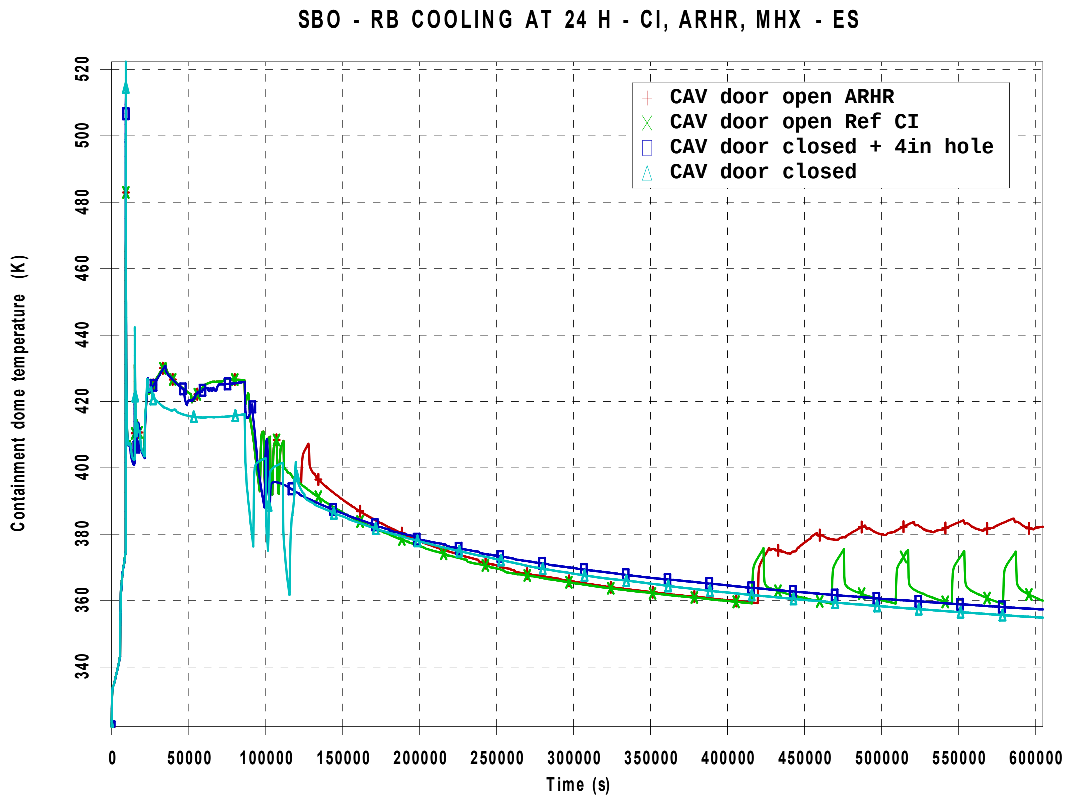


Concrete decomposition
(at temperatures 873 – 1173 K):
$CaCO_3 \rightarrow CaO + CO_2$ (endothermic reaction)

Iron rebar oxidation
(600 kg of iron in the 1 m^3 of the concrete):
$Fe + H_2O + 3.0\ kJ/kg_{(Fe)} \rightarrow FeO + H_2$
$Fe + CO_2 + 480\ kJ/kg_{(Fe)} \rightarrow FeO + CO$

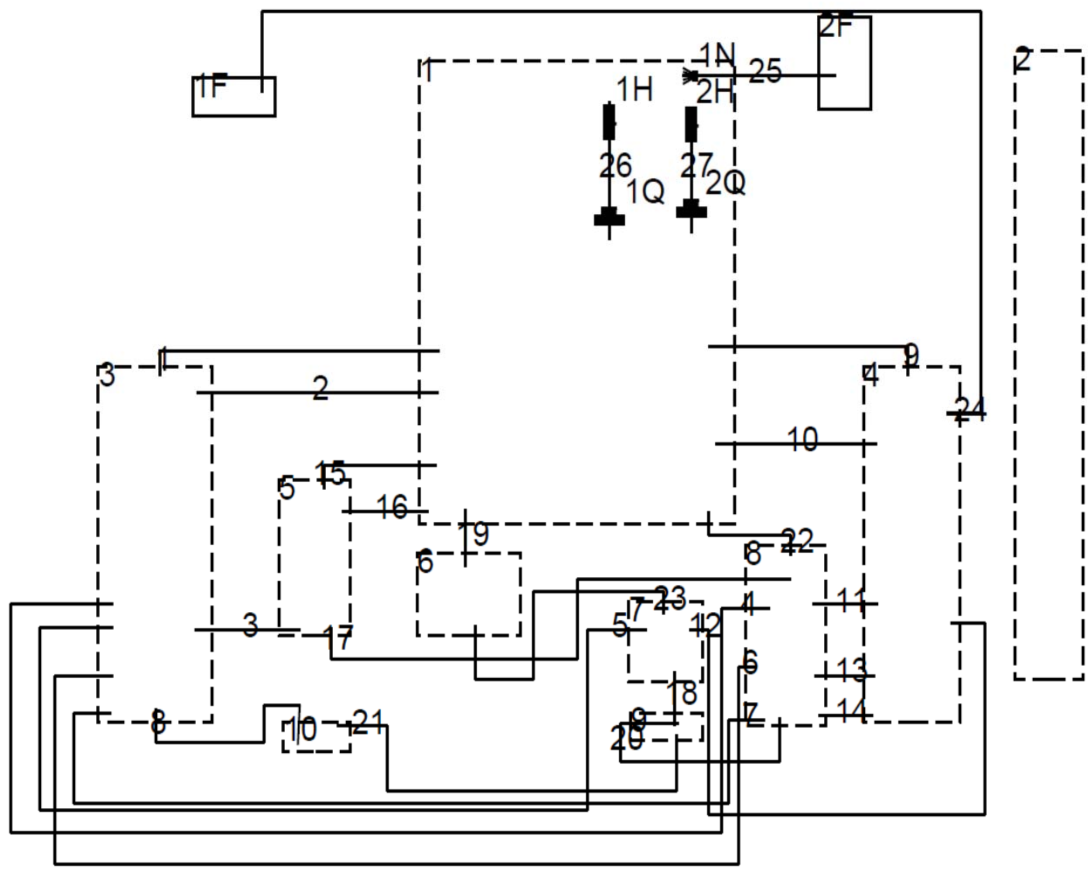



SBO - RB COOLING AT 24 H - CI, ARHR, MHX - ES
CAV door open ARHR
CAV door open Ref CI
CAV door closed + 4in hole
CAV door closed
Containment dome pressure (PA)
100000
150000
200000
250000
300000
350000
400000
450000
500000
550000
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
550000
600000
Time (s)

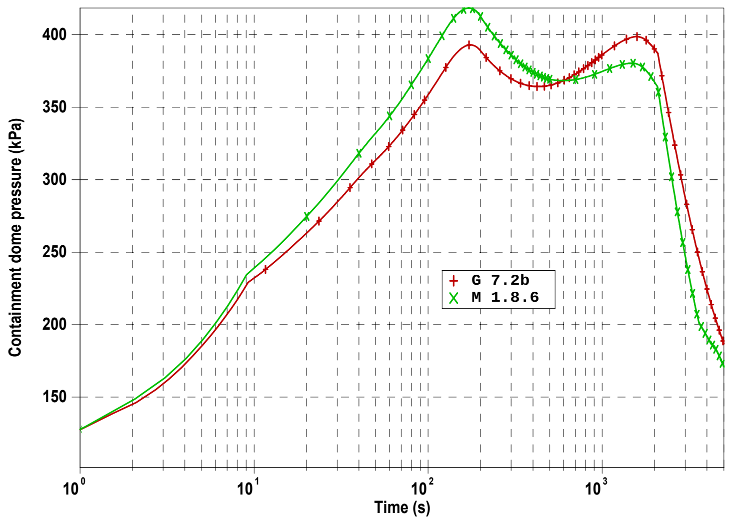

SBO - RB COOLING AT 24 H - CI, ARHR, MHX - ES
CAV door open ARHR
CAV door open Ref CI
CAV door closed + 4in hole
CAV door closed
Containment dome temperature (K)
Time (s)
520
500
480
460
440
420
400
380
360
340
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
550000
600000

Gothic Multivolume Model

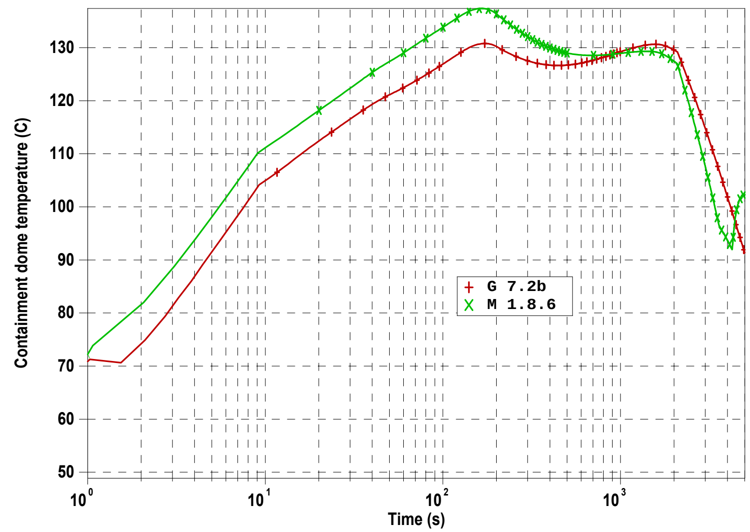
- Nodalization:
  - 10 control volumes
  - 2 boundary conditions
  - 27 flow paths
  - 74 heat structures
  - 2 RCFC units (volumetric fan + HX)
  - 1 spray train



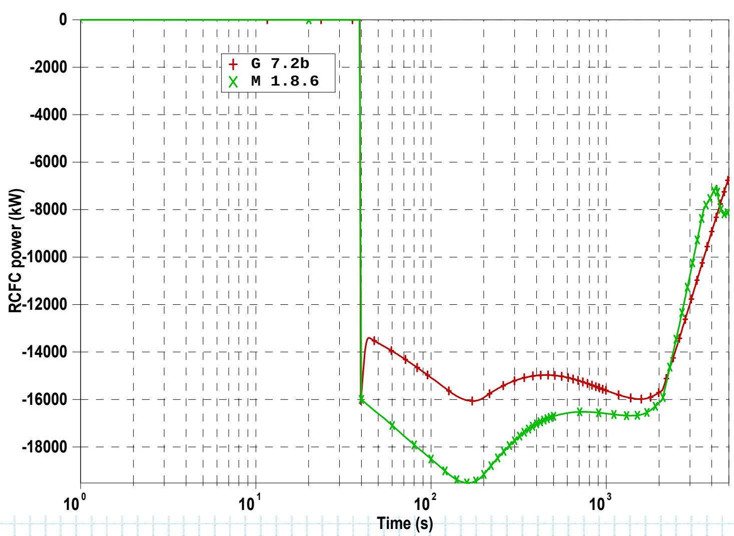
Results



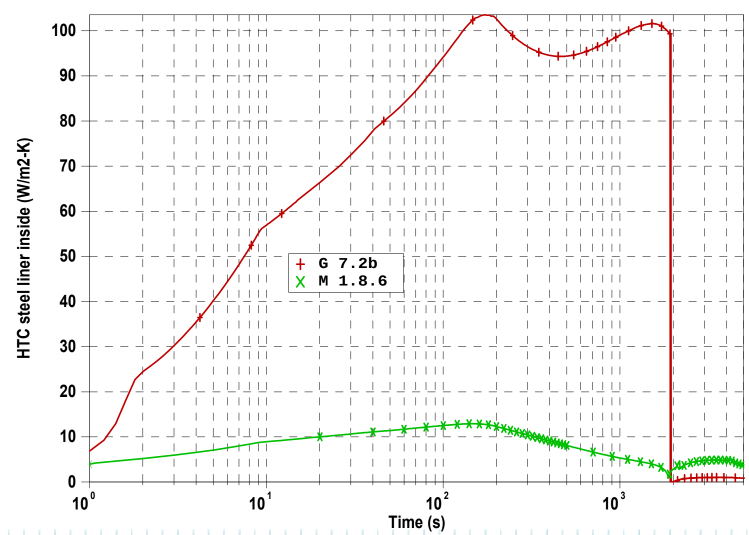
Containment dome pressure (kPa)
400
350
300
250
200
150
G 7.2b
M 1.8.6
10^0
10^1
10^2
10^3
Time (s)



Containment dome temperature (C)
130
120
110
100
90
80
70
60
50
G 7.2b
M 1.8.6
10^0
10^1
10^2
10^3
Time (s)



RCFC power (kW)
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
G 7.2b
M 1.8.6
10^0
10^1
10^2
10^3
Time (s)

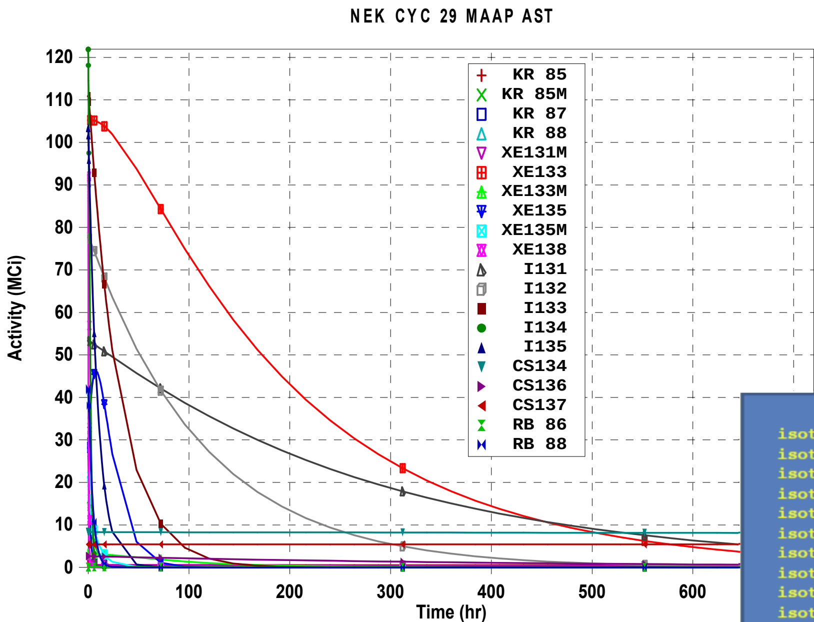


HTC steel liner inside (W/m2-K)
100
90
80
70
60
50
40
30
20
10
0
G 7.2b
M 1.8.6
10^0
10^1
10^2
10^3
Time (s)

RN - Core AST for 3 NEK Cycles

	C27	C28	C29
isotope no 1 : KR 85 value is	520171.5	520707.5	524745.9
isotope no 2 : KR 85M value is	0.1498336E+08	0.1521951E+08	0.1520713E+08
isotope no 3 : KR 87 value is	0.2901139E+08	0.2945319E+08	0.2943267E+08
isotope no 4 : KR 88 value is	0.4087067E+08	0.4149112E+08	0.4146220E+08
isotope no 5 : XE131M value is	591929.8	593614.1	596014.4
isotope no 6 : XE133 value is	0.1040027E+09	0.1075774E+09	0.1052319E+09
isotope no 7 : XE133M value is	3074410.	3370923.	3163163.
isotope no 8 : XE135 value is	0.2791422E+08	0.2793501E+08	0.2799284E+08
isotope no 9 : XE135M value is	0.2100783E+08	0.2143787E+08	0.2139732E+08
isotope no 10 : XE138 value is	0.9110478E+08	0.9278521E+08	0.9265628E+08
isotope no 11 : I131 value is	0.5293886E+08	0.5344533E+08	0.5328615E+08
isotope no 12 : I132 value is	0.7646938E+08	0.7820174E+08	0.7758126E+08
isotope no 13 : I133 value is	0.1089912E+09	0.1104552E+09	0.1108714E+09
isotope no 14 : I134 value is	0.1198459E+09	0.1221431E+09	0.1219520E+09
isotope no 15 : I135 value is	0.1016622E+09	0.1036409E+09	0.1034691E+09
isotope no 16 : CS134 value is	8100214.	8211168.	8314508.
isotope no 17 : CS136 value is	2613131.	2647152.	2669265.
isotope no 18 : CS137 value is	5345860.	5371182.	5417556.
isotope no 19 : RB 86 value is	107048.4	108252.3	109370.0
isotope no 20 : RB 88 value is	0.4148425E+08	0.4211710E+08	0.4208784E+08
isotope no 21 : RB 89 value is	0.5334850E+08	0.5415202E+08	0.5411610E+08
isotope no 22 : Y 90 value is	4251015.	4258458.	4293483.
isotope no 23 : Y 91 value is	0.7149228E+08	0.7135879E+08	0.7144807E+08
isotope no 24 : Y 92 value is	0.7354084E+08	0.7473803E+08	0.7466714E+08
isotope no 25 : Y 93 value is	0.8391542E+08	0.8537906E+08	0.8524572E+08
isotope no 26 : ZR 95 value is	0.9311774E+08	0.9310887E+08	0.9318614E+08
isotope no 27 : ZR 97 value is	0.9046394E+08	0.9214810E+08	0.9202740E+08
isotope no 28 : NB 95 value is	0.9366908E+08	0.9351273E+08	0.9355737E+08
isotope no 29 : MO 99 value is	0.1004054E+09	0.1020079E+09	0.1021298E+09
isotope no 30 : TE127 value is	5434436.	5656210.	5480388.
isotope no 31 : TE127M value is	697372.1	699458.1	699248.2
isotope no 32 : TE129 value is	0.1628303E+08	0.1661478E+08	0.1657857E+08
isotope no 33 : TE129M value is	2428630.	2440888.	2440790.
isotope no 34 : TE131M value is	7502142.	7650792.	7679834.
isotope no 35 : TE132 value is	0.7506917E+08	0.7622121E+08	0.7630412E+08
isotope no 36 : TE134 value is	0.9220405E+08	0.9385202E+08	0.9373302E+08
isotope no 37 : SB127 value is	5404012.	5498407.	5503466.
isotope no 38 : SB129 value is	0.1653634E+08	0.1690039E+08	0.1685964E+08
isotope no 39 : SR 89 value is	0.5606305E+08	0.5595125E+08	0.5603235E+08
isotope no 40 : SR 90 value is	4093977.	4097837.	4131076.
isotope no 41 : SR 91 value is	0.6831599E+08	0.6940594E+08	0.6933222E+08
isotope no 42 : SR 92 value is	0.7324207E+08	0.7443243E+08	0.7436236E+08
isotope no 43 : BA139 value is	0.9809754E+08	0.9994314E+08	0.9979550E+08
isotope no 44 : BA140 value is	0.9527527E+08	0.9581531E+08	0.9598611E+08
isotope no 45 : RU103 value is	0.7790748E+08	0.7831671E+08	0.7831919E+08
isotope no 46 : RU105 value is	0.5054820E+08	0.5185105E+08	0.5169680E+08
isotope no 47 : RU106 value is	0.2247923E+08	0.2269312E+08	0.2277230E+08
isotope no 48 : RH105 value is	0.4519338E+08	0.4559042E+08	0.4643525E+08
isotope no 49 : TC 99M value is	0.8869087E+08	0.9204519E+08	0.8976137E+08
isotope no 50 : CE141 value is	0.9072406E+08	0.9090987E+08	0.9100380E+08
isotope no 51 : CE143 value is	0.8415030E+08	0.8552840E+08	0.8558574E+08
isotope no 52 : CE144 value is	0.6640406E+08	0.6616176E+08	0.6634290E+08
isotope no 53 : PU238 value is	135413.7	138637.2	141289.0
isotope no 54 : PU239 value is	17643.93	17692.44	17732.78
isotope no 55 : PU240 value is	22385.16	22622.81	22798.68
isotope no 56 : PU241 value is	5355599.	5424096.	5434228.
isotope no 57 : NP239 value is	0.9955558E+09	0.1016936E+10	0.1014476E+10
isotope no 58 : LA140 value is	0.9796410E+08	0.9840705E+08	0.9862507E+08
isotope no 59 : LA141 value is	0.8962767E+08	0.9130798E+08	0.9117287E+08
isotope no 60 : LA142 value is	0.8700290E+08	0.8861234E+08	0.8848649E+08
isotope no 61 : ND147 value is	0.3589255E+08	0.3613177E+08	0.3620120E+08
isotope no 62 : PR143 value is	0.8475665E+08	0.8503933E+08	0.8521966E+08
isotope no 63 : AM241 value is	5685.771	5812.345	5894.213
isotope no 64 : CM242 value is	1195870.	1236393.	1258511.
isotope no 65 : CM244 value is	92334.48	96631.28	100879.3

Plant/time specific isotopic AST for core and SFP

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isotope no   1 :  KR 85 value is    2830606.
isotope no   2 : KR 85M value is   0.1010337E-03
isotope no   3 :  KR 87 value is    0.000000
isotope no   4 :  KR 88 value is   0.9404835E-10
isotope no   5 : XE131M value is    537025.2
isotope no   6 :  XE133 value is   0.5081996E+08
isotope no   7 : XE133M value is    572477.7
isotope no   8 :  XE135 value is    924.0756
isotope no   9 : XE135M value is   0.4346192
isotope no  10 :  XE138 value is    0.000000
isotope no  11 :   I131 value is   0.2976197E+08
isotope no  12 :   I132 value is   0.1767195E+08
isotope no  13 :   I133 value is    436338.0
isotope no  14 :   I134 value is    0.000000
isotope no  15 :   I135 value is    2.713417
isotope no  16 :  CS134 value is   0.1644154E+08
isotope no  17 :  CS136 value is    1816951.
isotope no  18 :  CS137 value is   0.4708686E+08
isotope no  19 :  RB 86 value is    82418.08
isotope no  20 :  RB 88 value is   0.1050234E-09
isotope no  21 :  RB 89 value is    0.000000
isotope no  22 :   Y 90 value is   0.3404086E+08
isotope no  23 :   Y 91 value is   0.6529821E+08
isotope no  24 :   Y 92 value is   0.2218537E-05
isotope no  25 :   Y 93 value is    934.1150
isotope no  26 :  ZR 95 value is   0.8526901E+08
isotope no  27 :  ZR 97 value is    98380.98
isotope no  28 :  NB 95 value is   0.9193740E+08
isotope no  29 :  MO 99 value is   0.1746566E+08
isotope no  30 :  TE127 value is    2184612.
isotope no  31 : TE127M value is    689268.0
isotope no  32 :  TE129 value is    1364335.
isotope no  33 : TE129M value is    2095957.
isotope no  34 : TE131M value is    161725.6
isotope no  35 :  TE132 value is   0.1715215E+08
isotope no  36 :  TE134 value is    0.000000
isotope no  37 :  SB127 value is    1575780.
isotope no  38 :  SB129 value is   0.4303171E-04
isotope no  39 :  SR 89 value is   0.5017956E+08
isotope no  40 :  SR 90 value is   0.3400630E+08
isotope no  41 :  SR 91 value is    365.5141
isotope no  42 :  SR 92 value is   0.2443898E-10
isotope no  43 :  BA139 value is    0.000000
isotope no  44 :  BA140 value is   0.6484011E+08
isotope no  45 :  RU103 value is   0.6832914E+08
isotope no  46 :  RU105 value is   0.2758141E-03
isotope no  47 :  RU106 value is   0.2899825E+08
isotope no  48 :  RH105 value is    2038195.
isotope no  49 : TC 99M value is   0.1682420E+08
isotope no  50 :  CE141 value is   0.7773817E+08
isotope no  51 :  CE143 value is    2569492.
isotope no  52 :  CE144 value is   0.7441254E+08
isotope no  53 :  PU238 value is    1935245.
isotope no  54 :  PU239 value is    204264.1
isotope no  55 :  PU240 value is    290833.3
isotope no  56 :  PU241 value is   0.3826934E+08
isotope no  57 :  NP239 value is   0.1307932E+09
isotope no  58 :  LA140 value is   0.7398141E+08
isotope no  59 :  LA141 value is   0.1774350E-04
isotope no  60 :  LA142 value is    0.000000
isotope no  61 :  ND147 value is   0.2306991E+08
isotope no  62 :  PR143 value is   0.6497990E+08
isotope no  63 :  AM241 value is    1195580.
isotope no  64 :  CM242 value is    1322429.
isotope no  65 :  CM244 value is    1041043.
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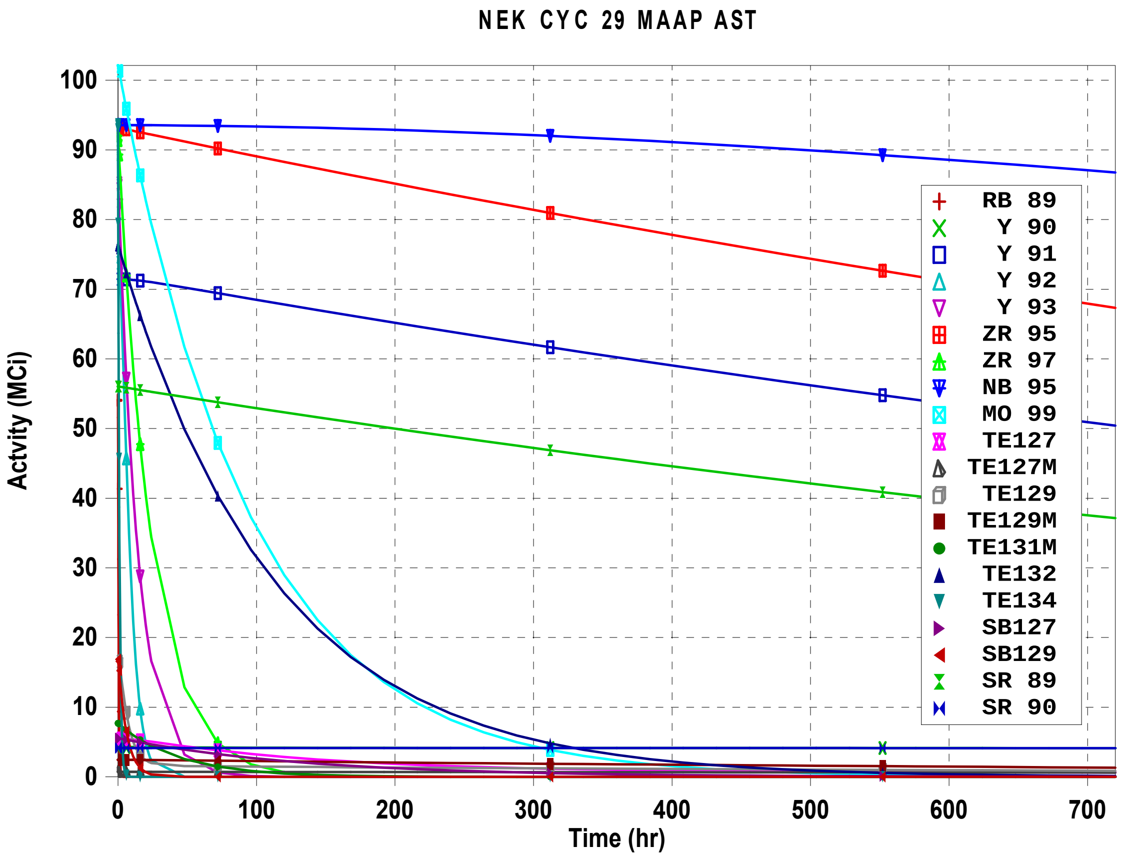
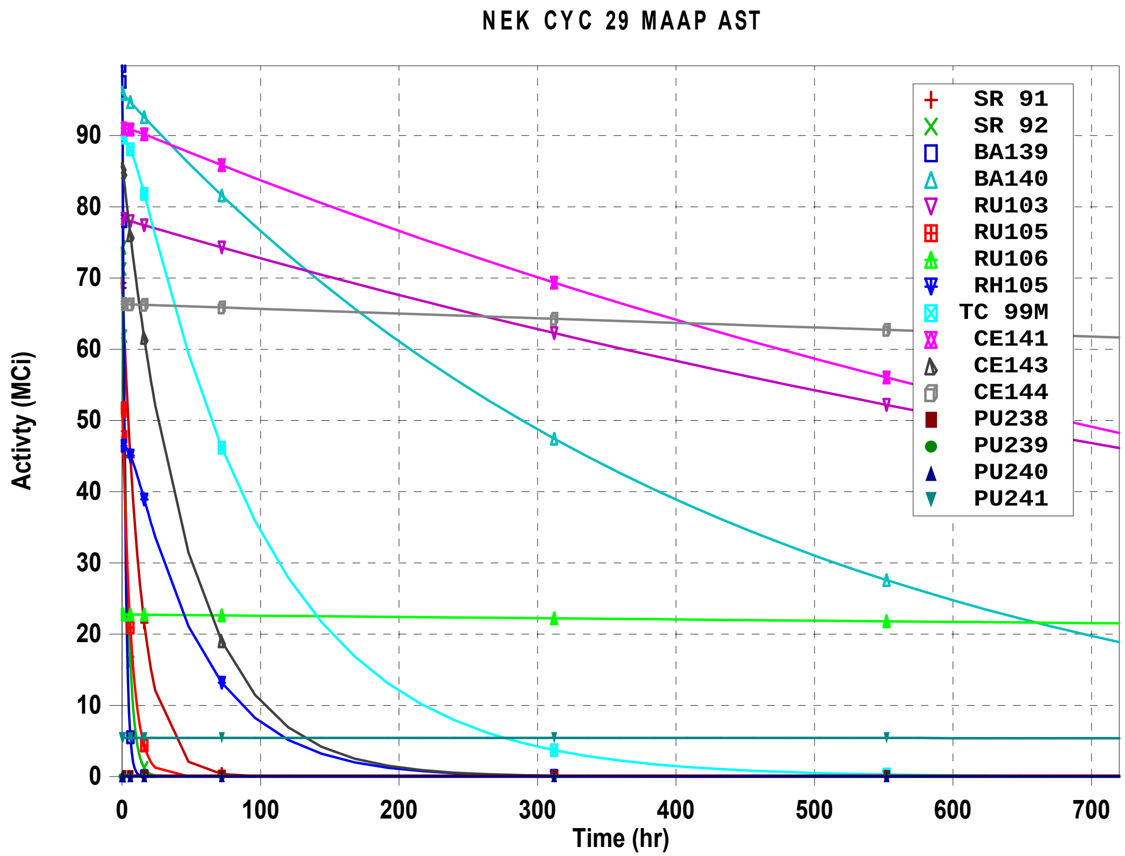
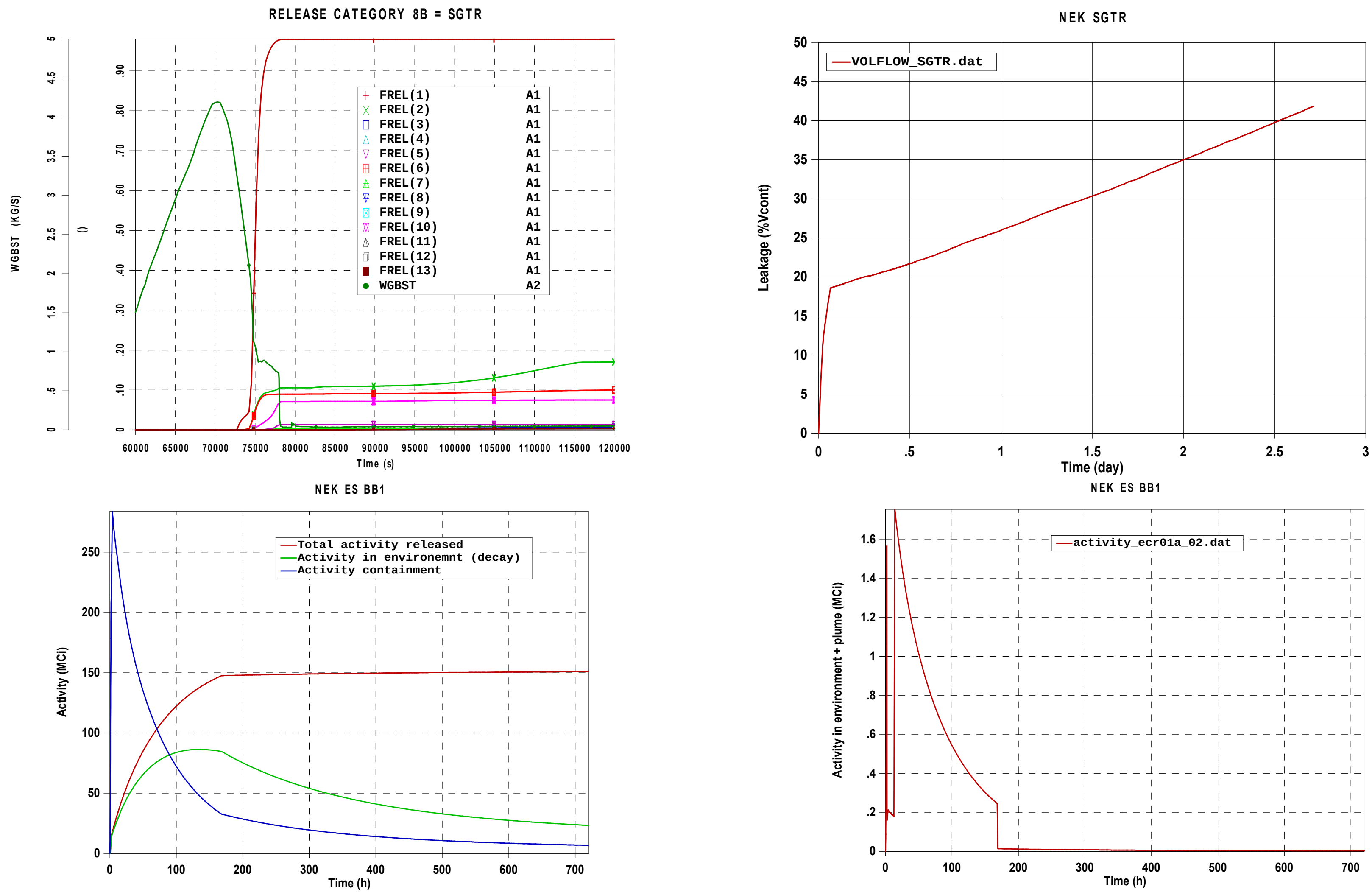


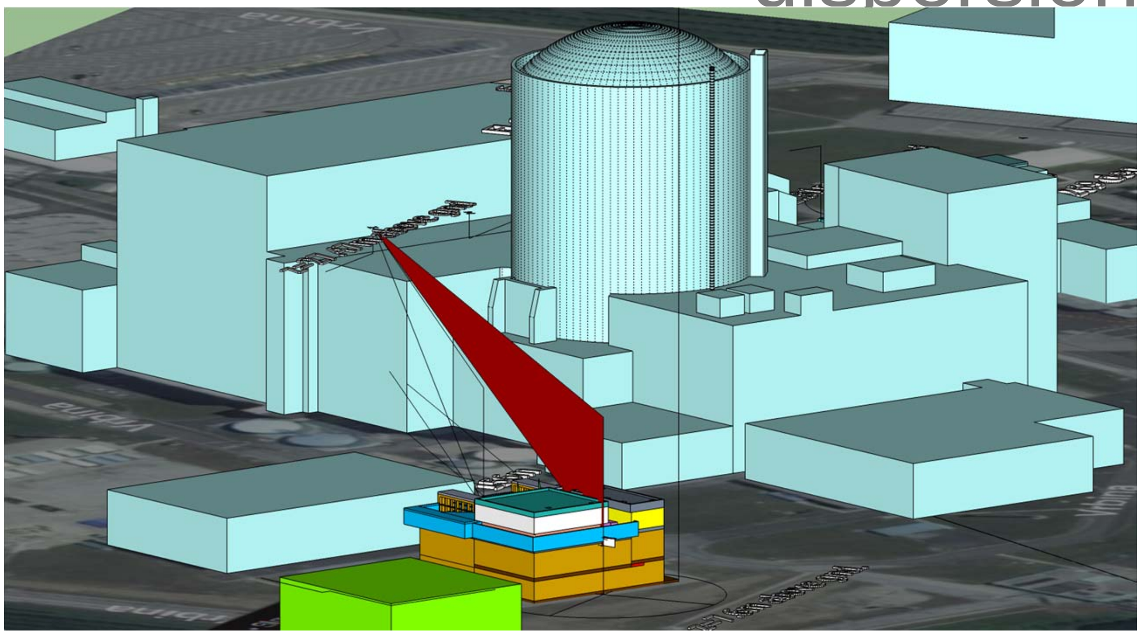
NEK CYC 29 MAAP AST
Actvity (MCi)
Time (hr)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
RB 89
Y 90
Y 91
Y 92
Y 93
ZR 95
ZR 97
NB 95
MO 99
TE127
TE127M
TE129
TE129M
TE131M
TE132
TE134
SB127
SB129
SR 89
SR 90

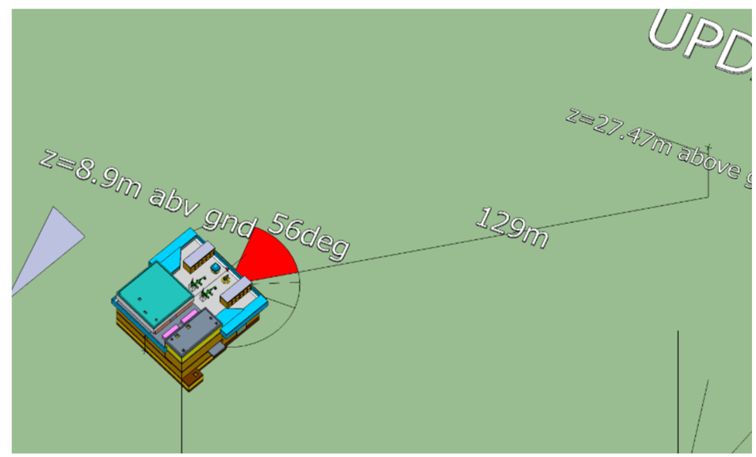

NEK CYC 29 MAAP AST
Activty (MCi)
Time (hr)
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
700
SR 91
SR 92
BA139
BA140
RU103
RU105
RU106
RH105
TC 99M
CE141
CE143
CE144
PU238
PU239
PU240
PU241

MAAP 4.0.9 and RADTRAD 3.03



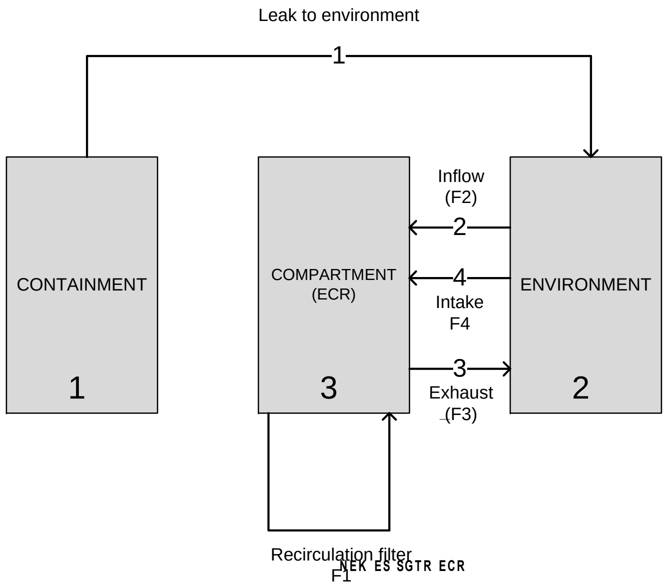
RADTRAD and ARCON96 release and dispersion

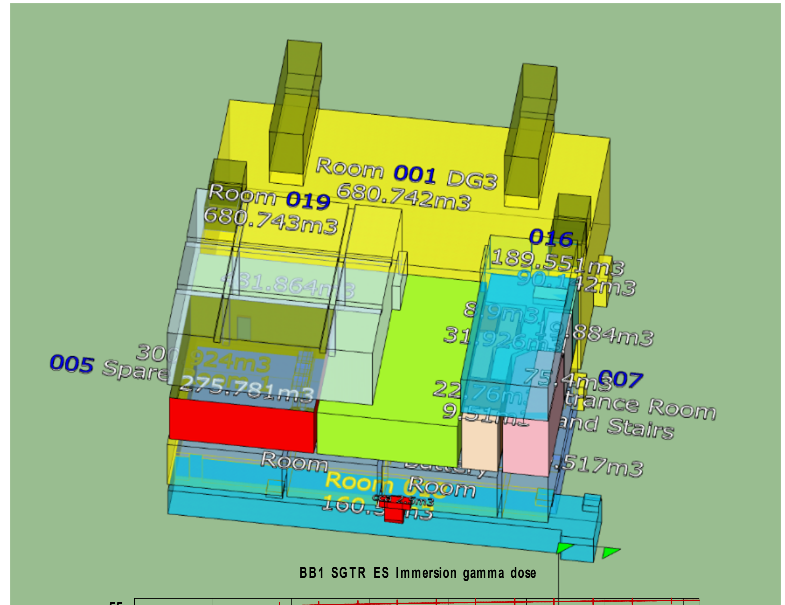


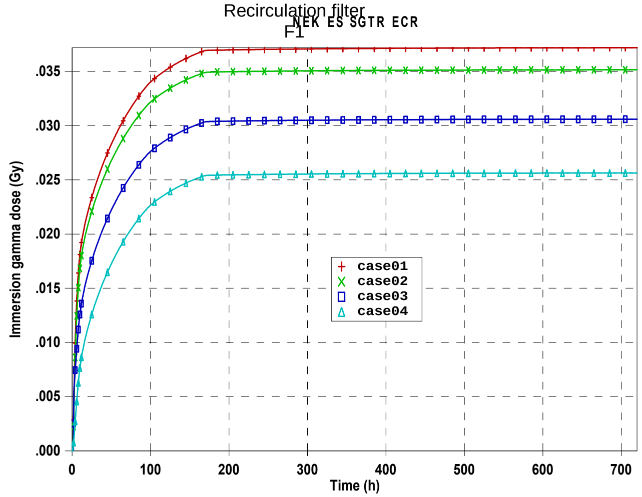


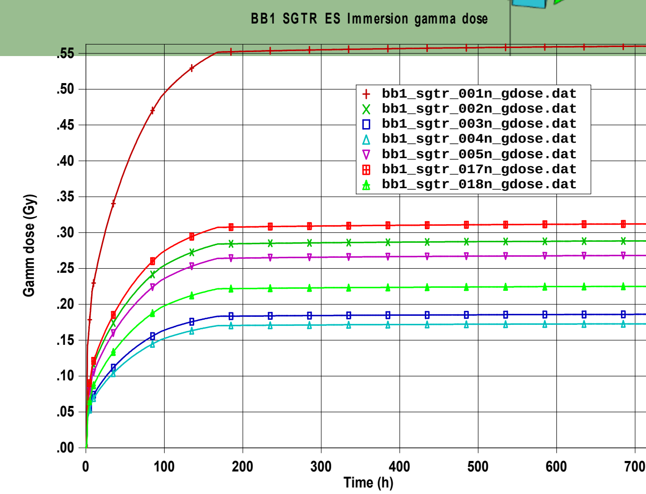
Time interval	ECR/TSC intake χ/Q (s/m^3)	ECR/TSC roof χ/Q (s/m^3)
0 – 2 h	2.15E-04	3.09E-04
2 – 8 h	1.46E-04	2.05E-04
8 – 24 h	6.91E-05	9.90E-05
1- 4 days	6.71E-05	9.05E-05
4 -30 days	5.18E-05	7.18E-05

RADTRAD compartment model used in calculation

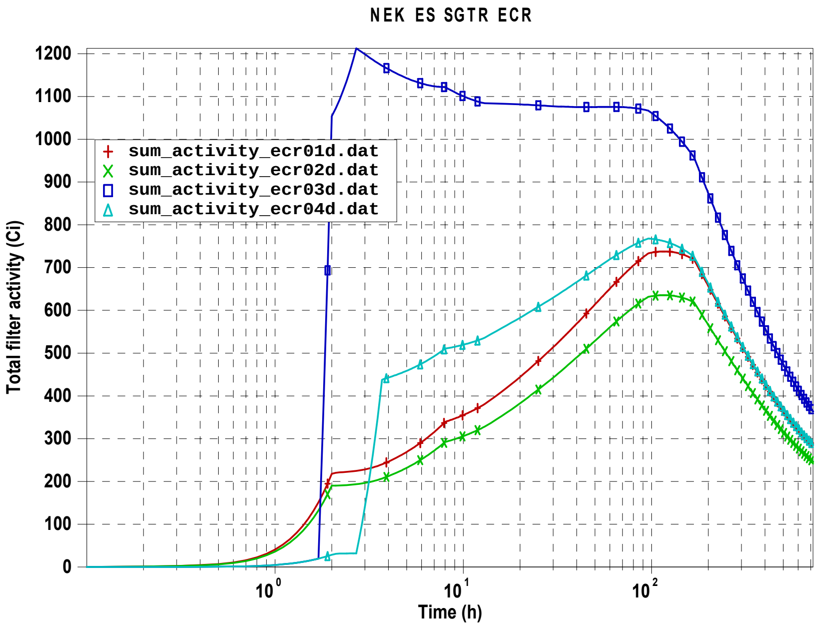


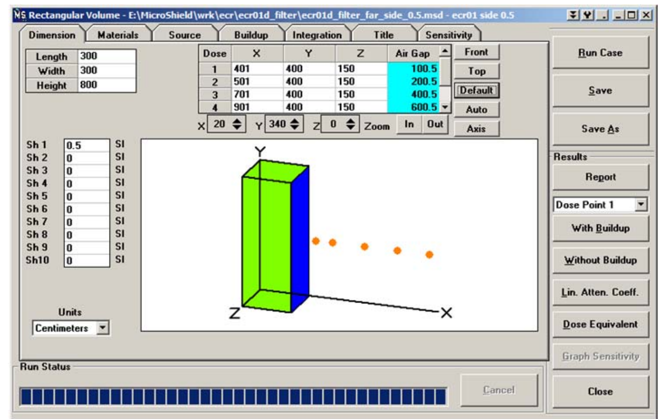


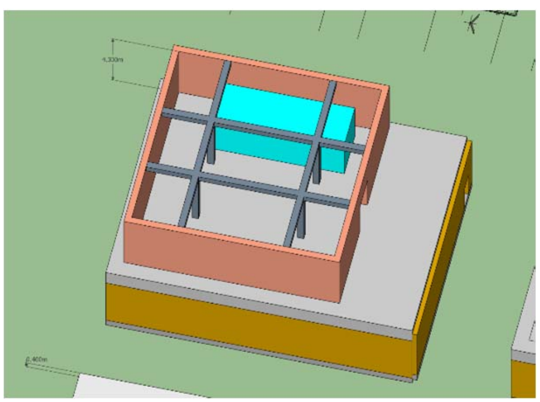


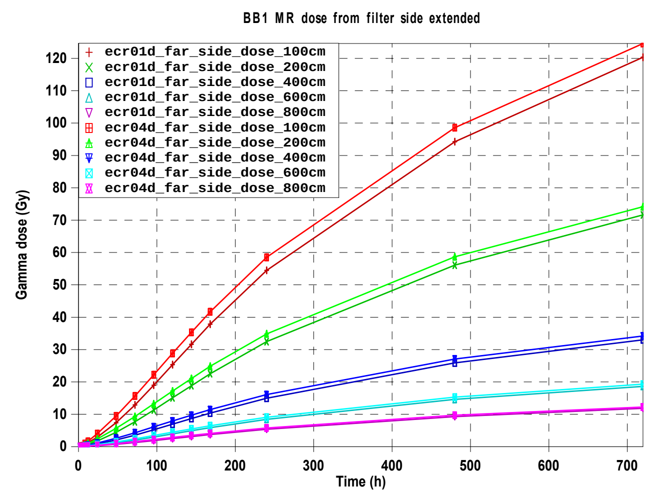


ECR HVAC filter doses, 4th HVAC sequence

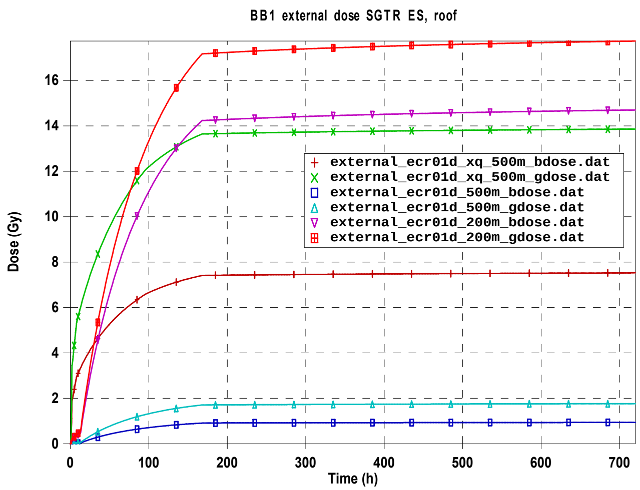


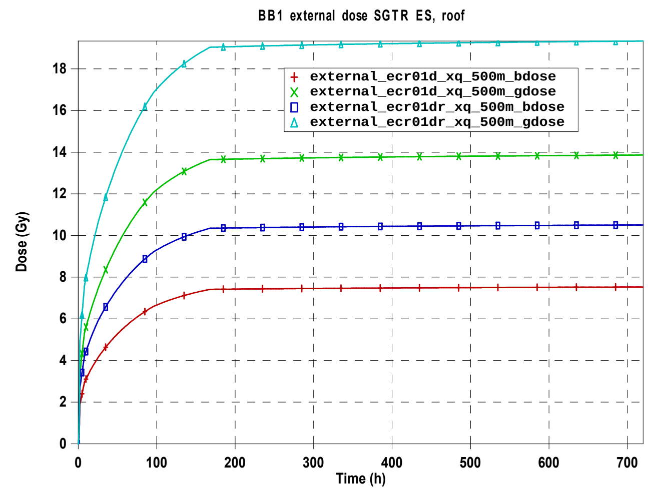


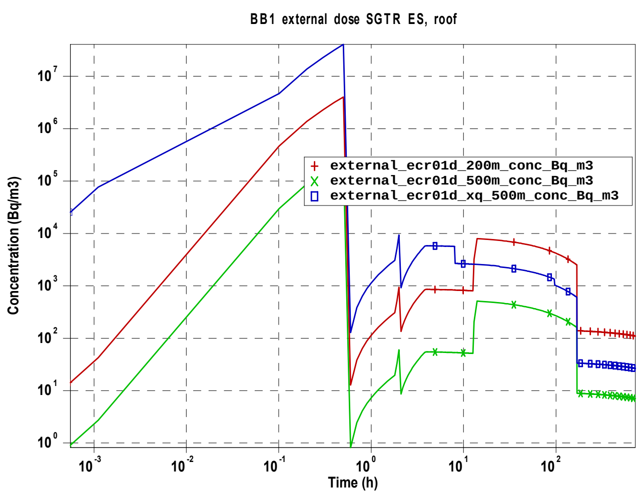


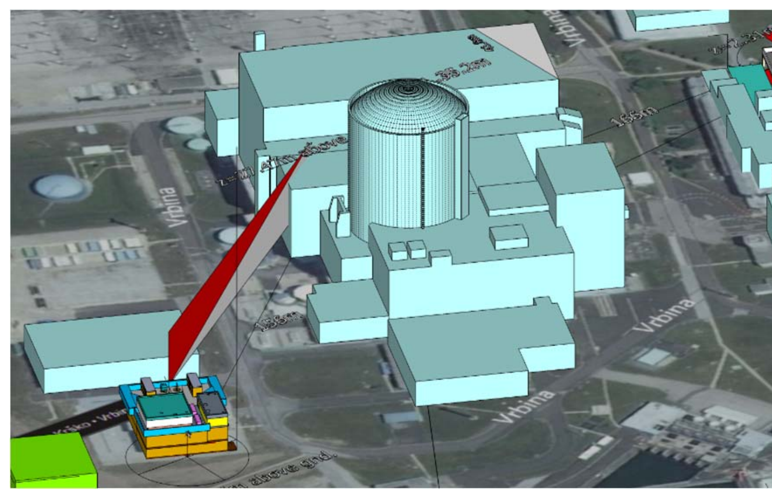


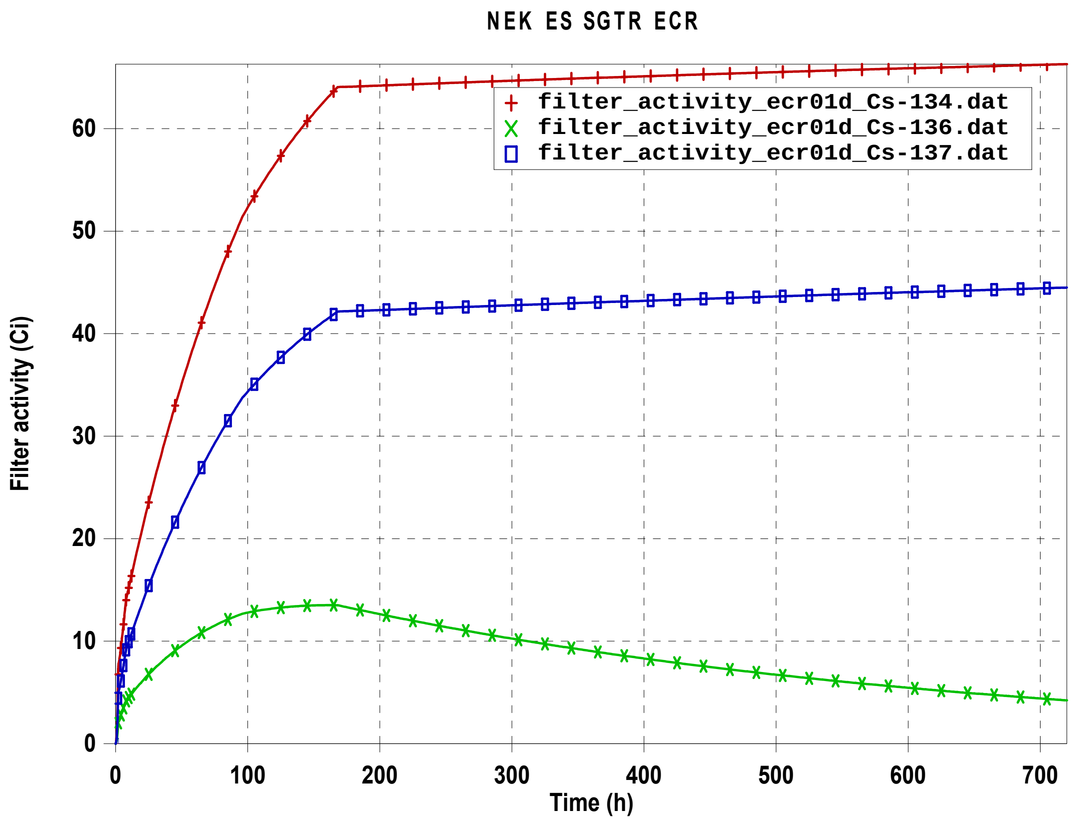
Dose at BB1 top (hemisph R=200, 500m, homogenouse or X/Q)

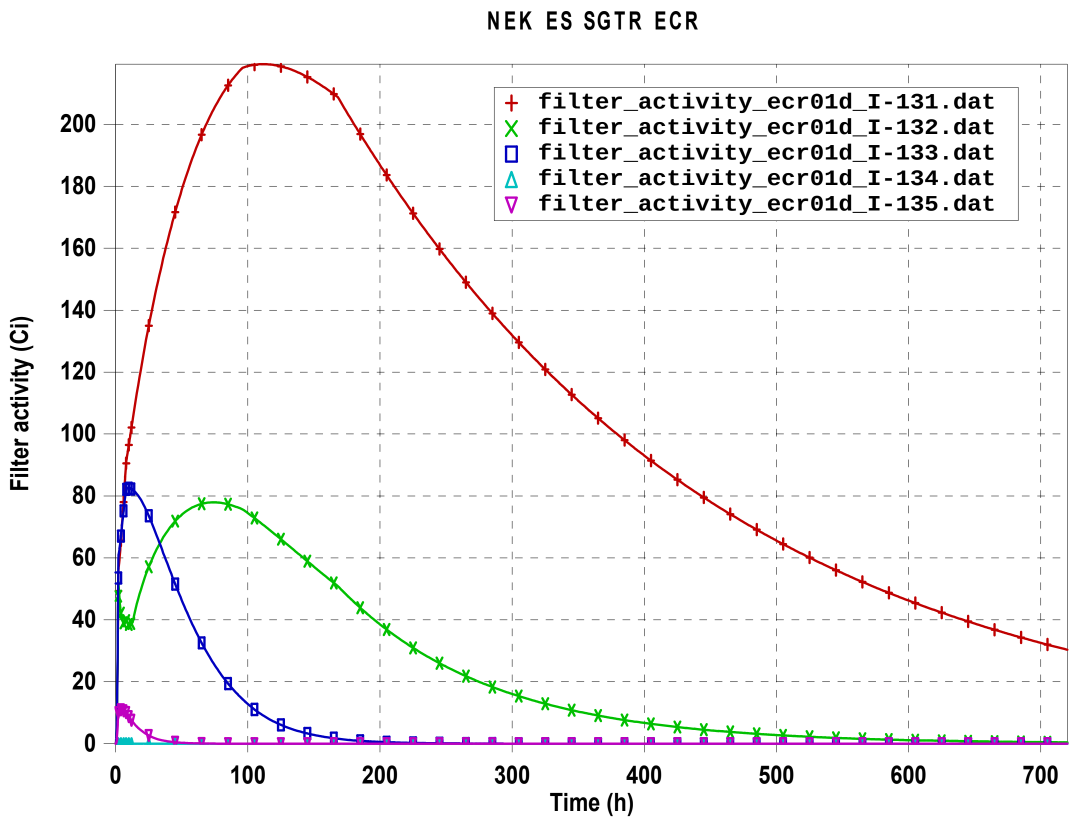









NEK ES SGTR ECR
filter_activity_ecr01d_Cs-134.dat
filter_activity_ecr01d_Cs-136.dat
filter_activity_ecr01d_Cs-137.dat
Filter activity (Ci)
0
10
20
30
40
50
60
0
100
200
300
400
500
600
700
Time (h)



NEK ES SGTR ECR
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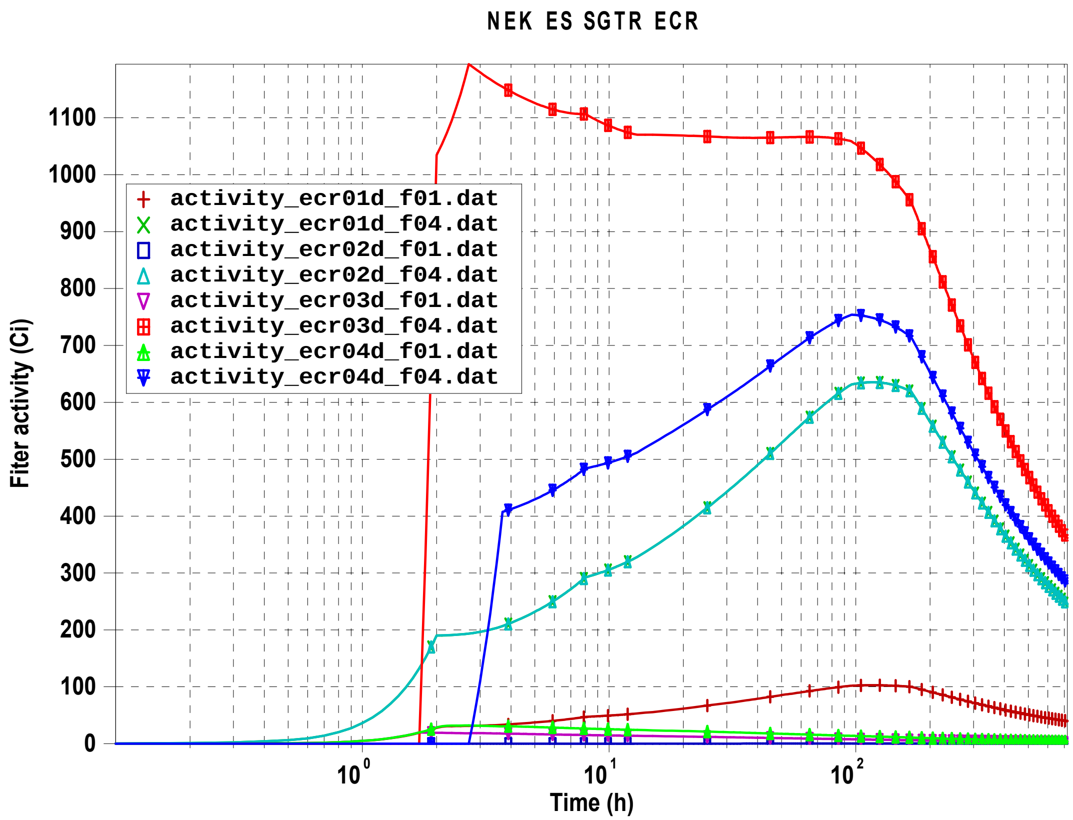
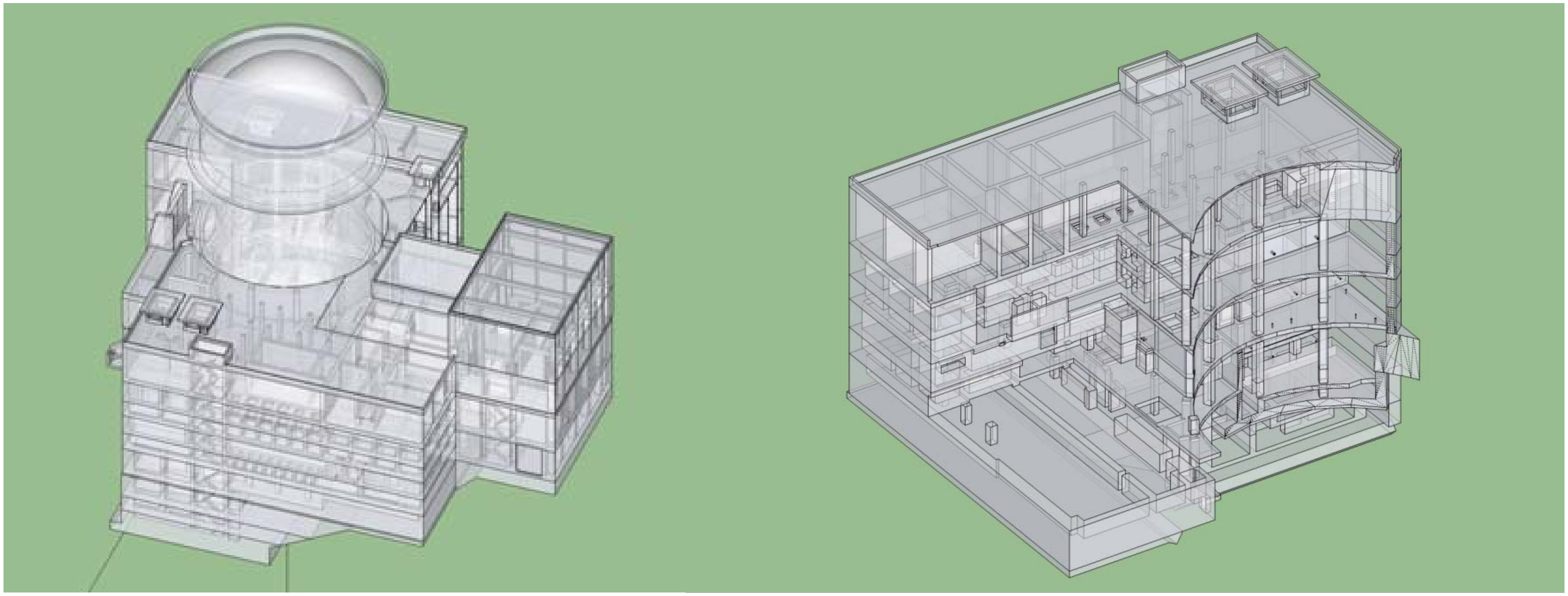
filter_activity_ecr01d_I-132.dat
filter_activity_ecr01d_I-133.dat
filter_activity_ecr01d_I-134.dat
filter_activity_ecr01d_I-135.dat
Filter activity (Ci)
Time (h)
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700

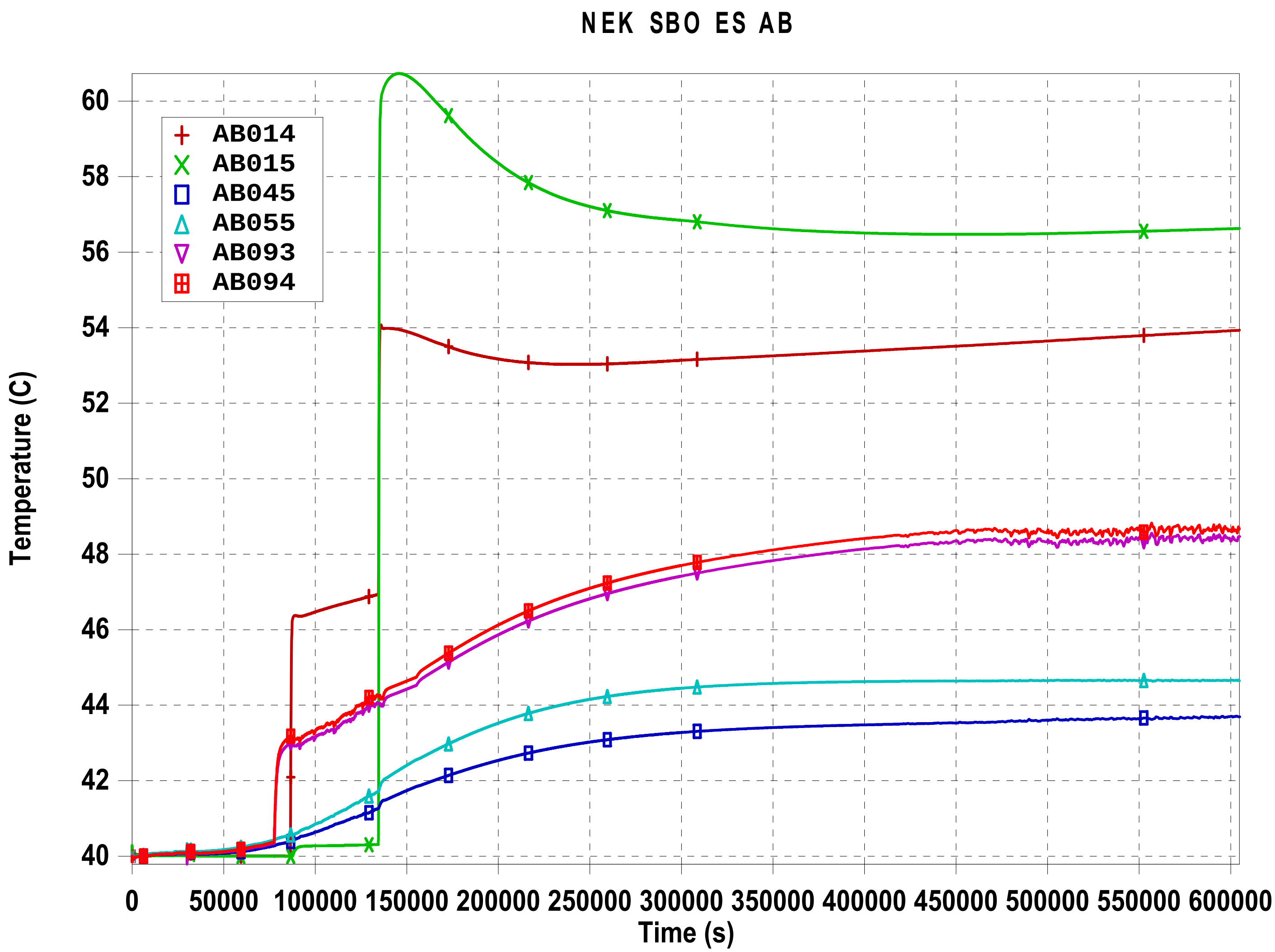

NEK ES SGTR ECR
Fiter activity (Ci)
Time (h)
activity_ecr01d_f01.dat
activity_ecr01d_f04.dat
activity_ecr02d_f01.dat
activity_ecr02d_f04.dat
activity_ecr03d_f01.dat
activity_ecr03d_f04.dat
activity_ecr04d_f01.dat
activity_ecr04d_f04.dat
0
100
200
300
400
500
600
700
800
900
1000
1100
10^0
10^1
10^2

NEK AB

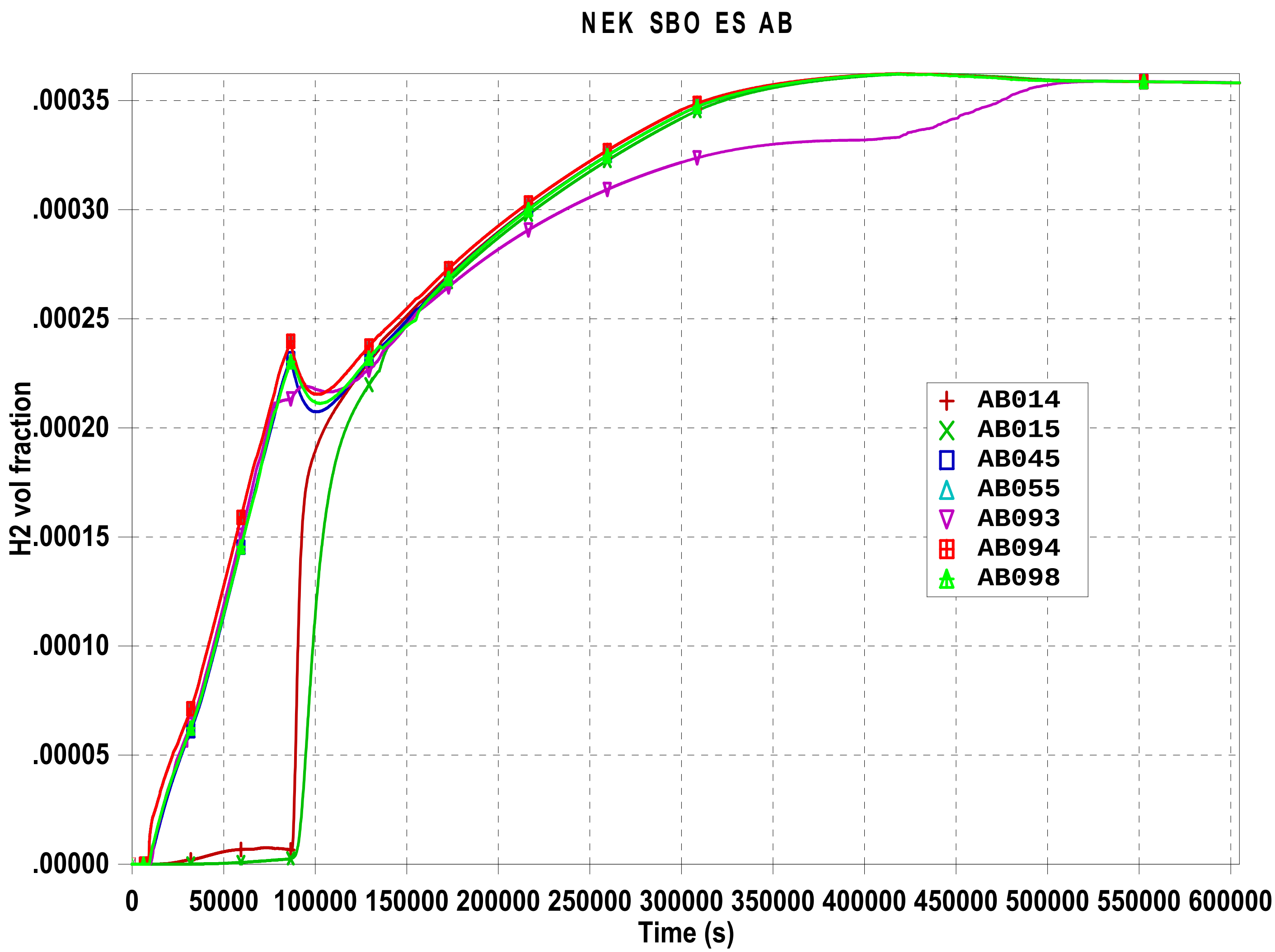
- NEK Equipment Survivability for DEC
- model similiar to the model developed in GOTHIC
- AB model has 115 control volumes, 202 flow paths and 510 heat structures, control functions are used for door opening on pressure difference



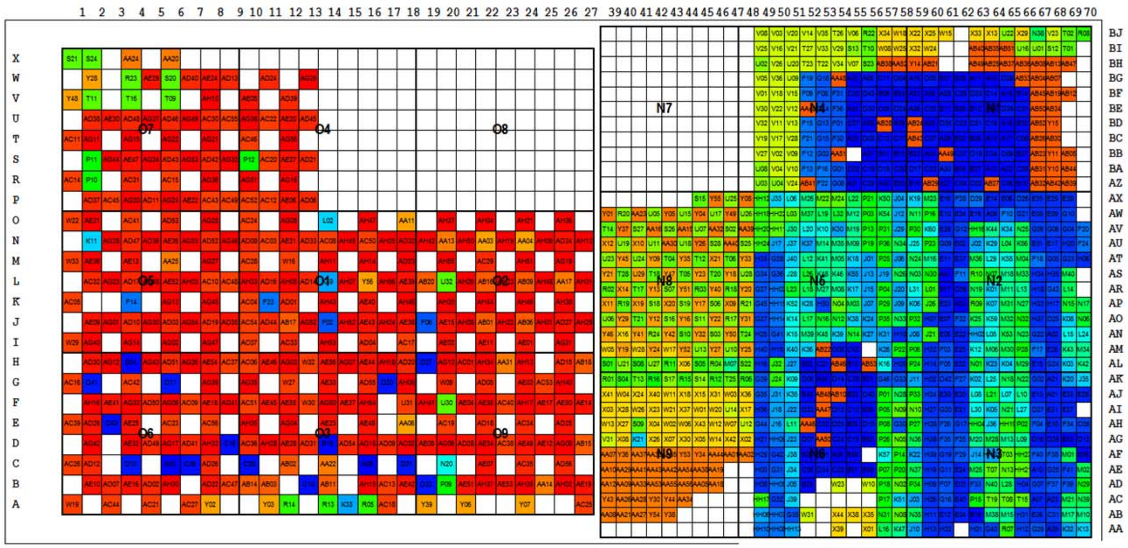
SBO accident – Temperatures in AB



SBO accident – H_2 concentration in AB

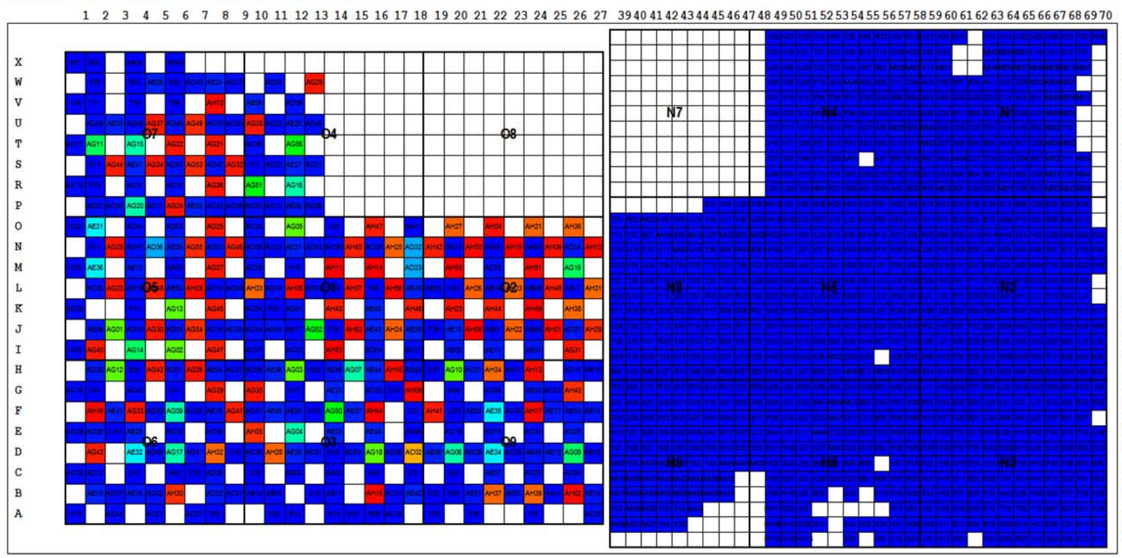


NEK SFP calculation



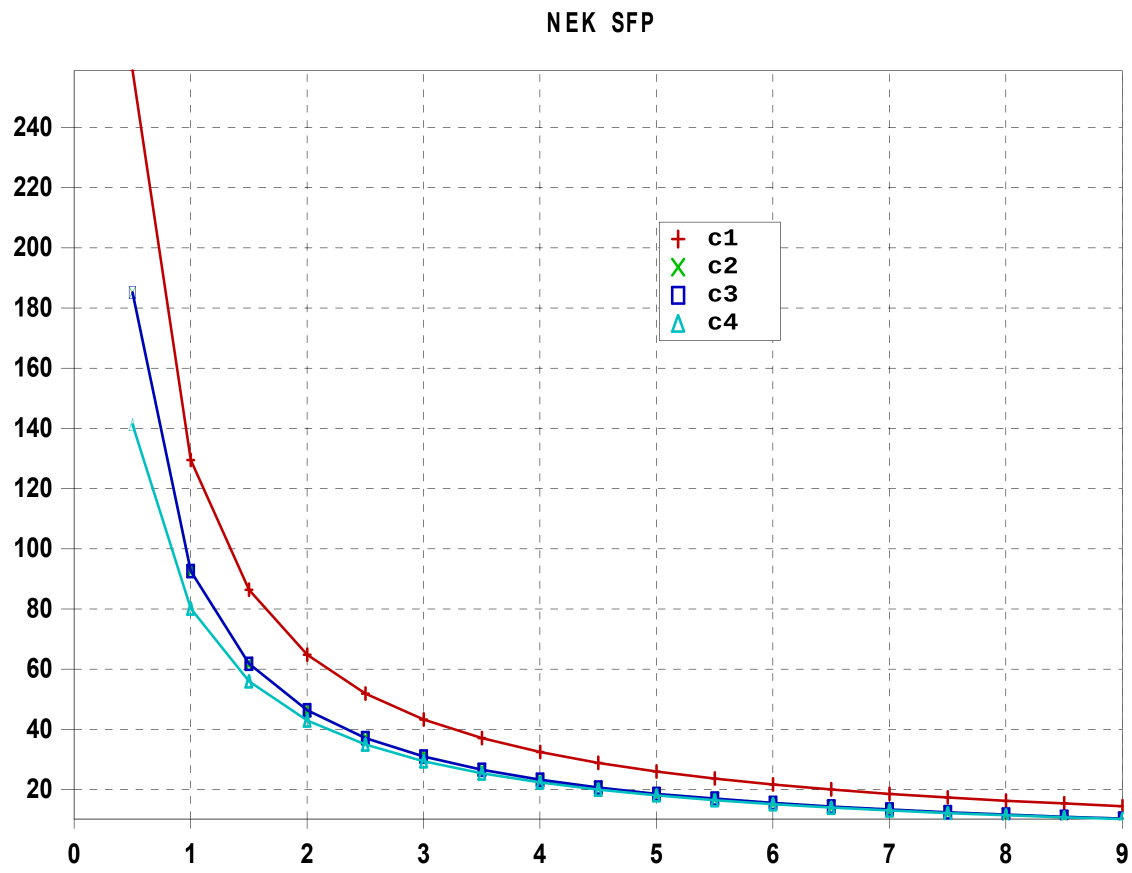
NEK SFP between two cycles
→ 9 days after shutdown

FAs 9 - 12150 days old

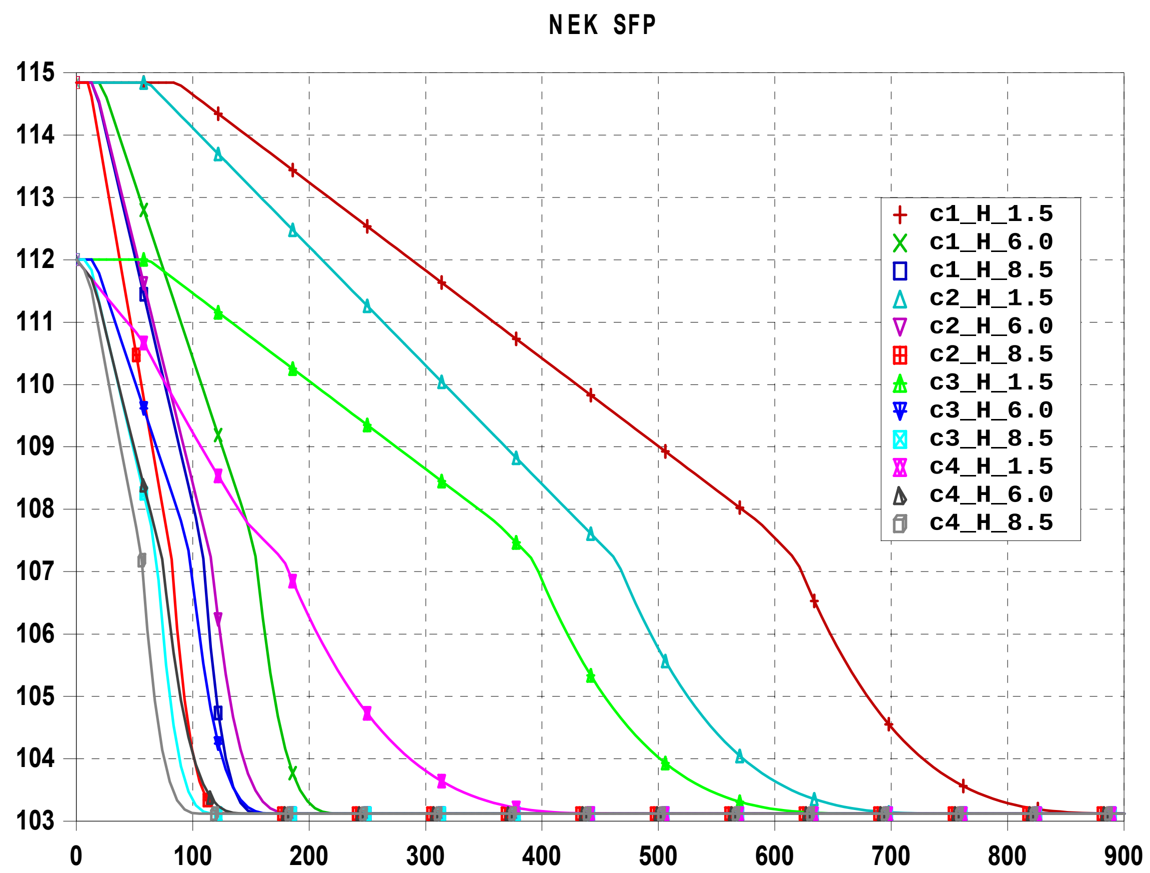


POWER	POWER SPAN	TOTAL
OLD	98 W – 52.82 kW	5.71 MW
NEW	89 W – 2.03 kW	0.573 MW
TOTAL		6.283 MW

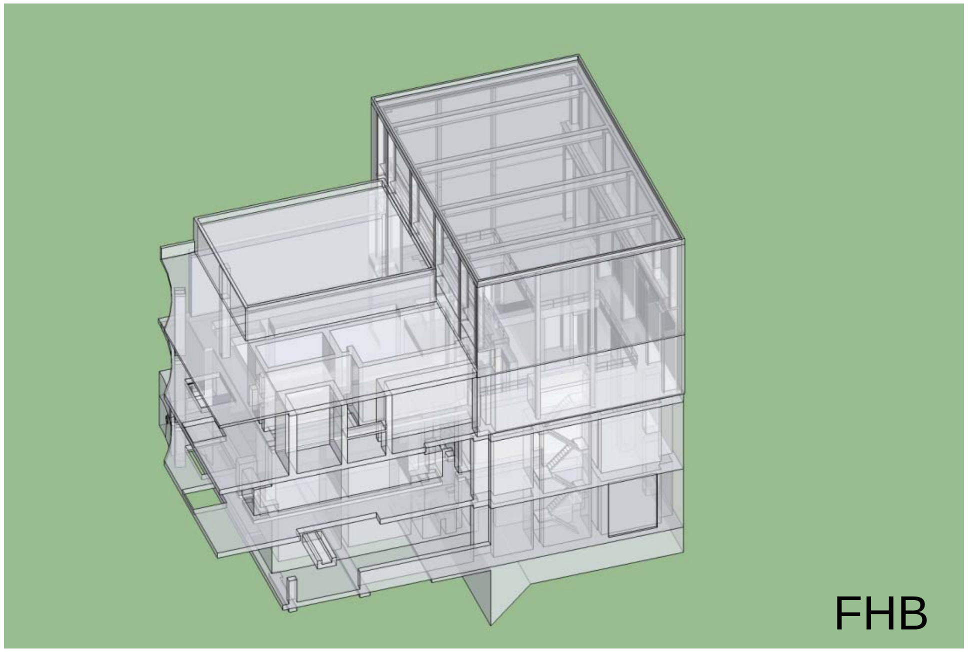
Time to boiling (h) vs. Decay heat (MW) for different scenarios



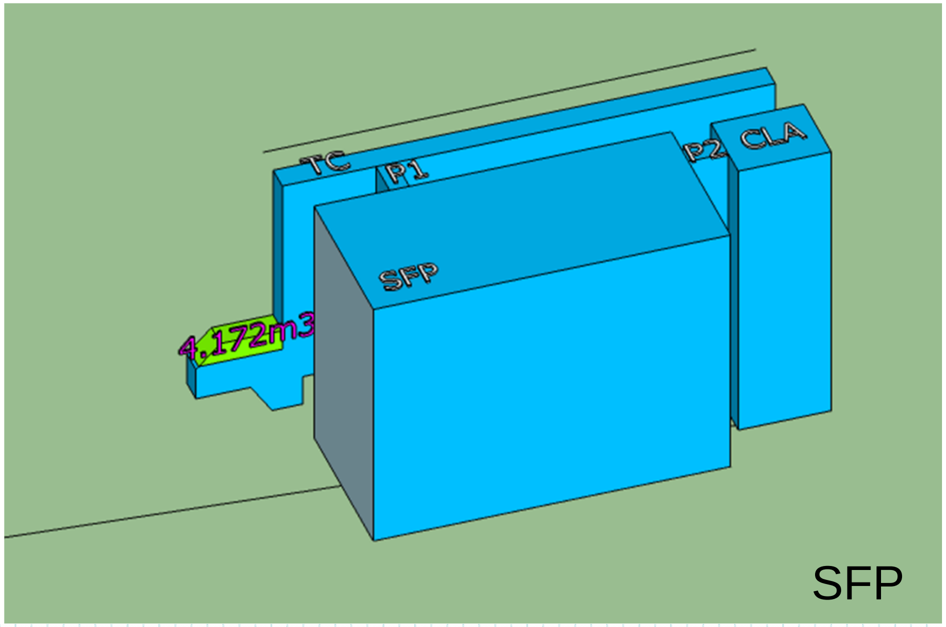
Elevation of water in pool (m) vs. time (h) for different scenarios and different level of decay heat (MW)



NEK SFP (3)

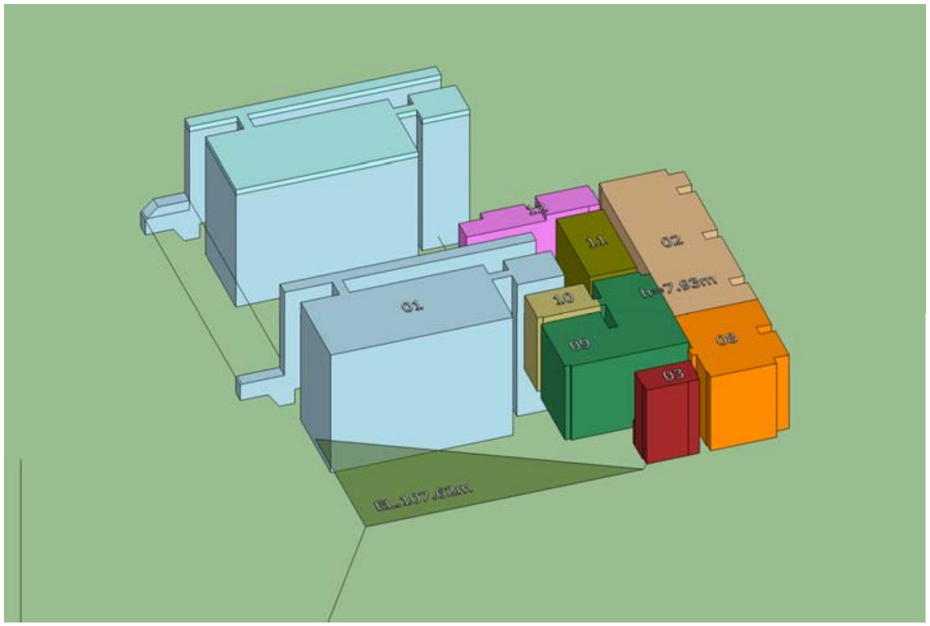


FHB

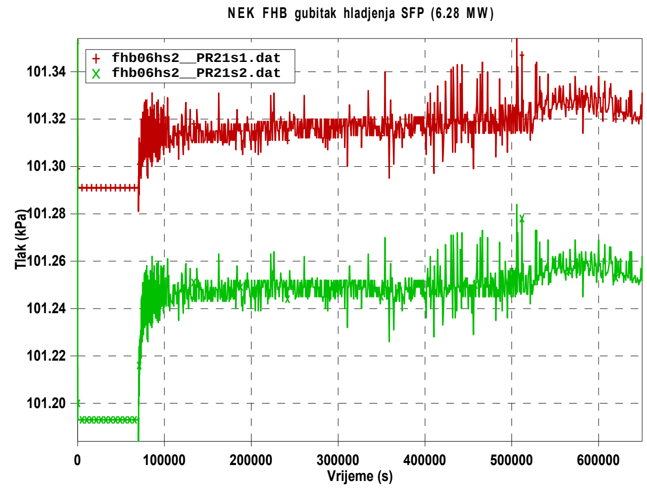


SFP

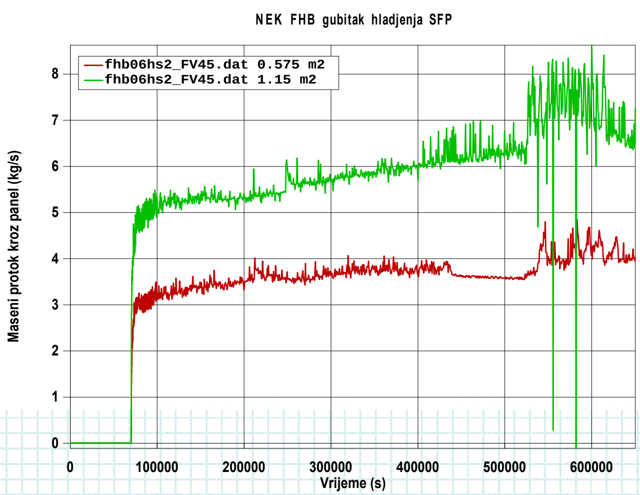
FHB model



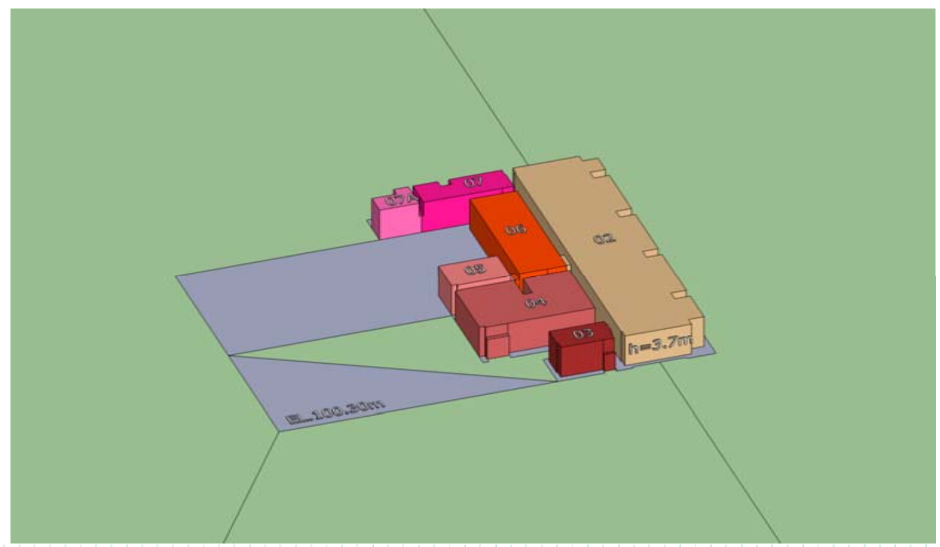
01
02
11
10
09
08
03
h=7.93m
EL.107.62m



NEK FHB gubitak hladjenja SFP (6.28 MW)
fhb06hs2__PR21s1.dat
fhb06hs2__PR21s2.dat
Tlak (kPa)
101.34
101.32
101.30
101.28
101.26
101.24
101.22
101.20
0
100000
200000
300000
400000
500000
600000
Vrijeme (s)

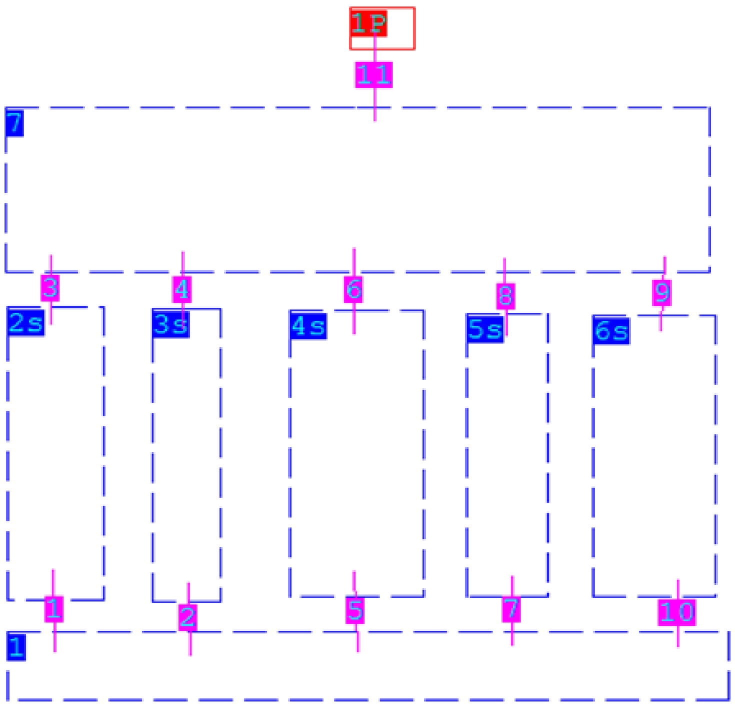


NEK FHB gubitak hladjenja SFP
fhb06hs2_FV45.dat 0.575 m2
fhb06hs2_FV45.dat 1.15 m2
Maseni protok kroz panel (kg/s)
8
7
6
5
4
3
2
1
0
0
100000
200000
300000
400000
500000
600000
Vrijeme (s)

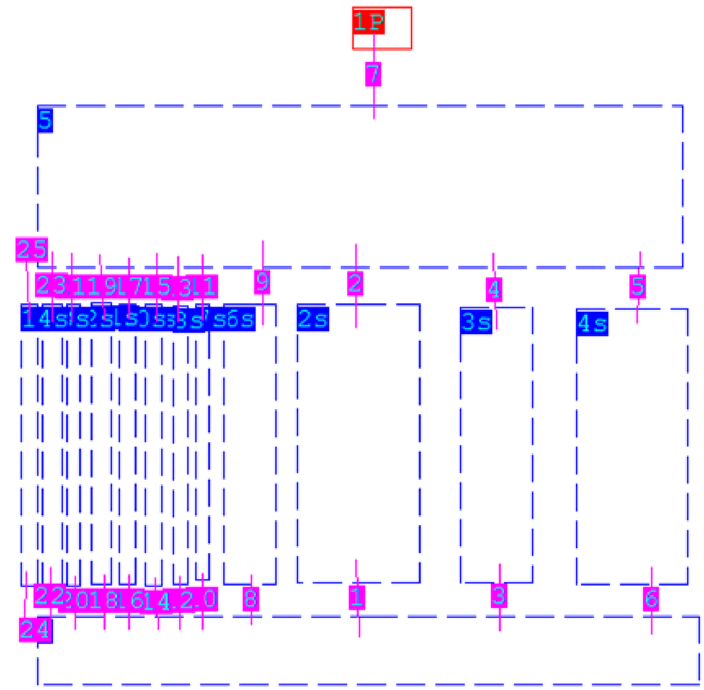


07
06
02
05
04
03
h=3.7m
EL.100.30m

SFP GOTHIC models

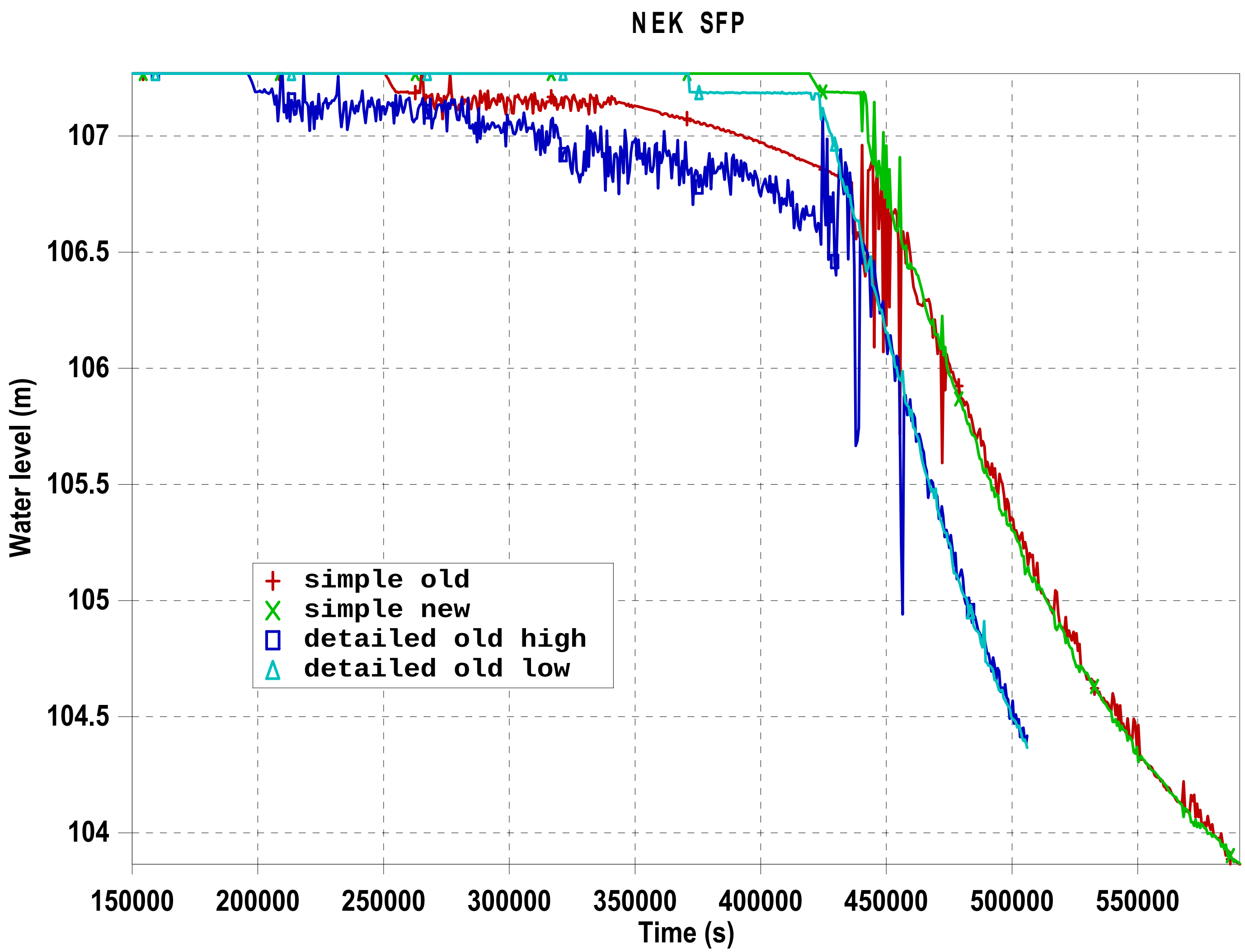


SFP model - simple

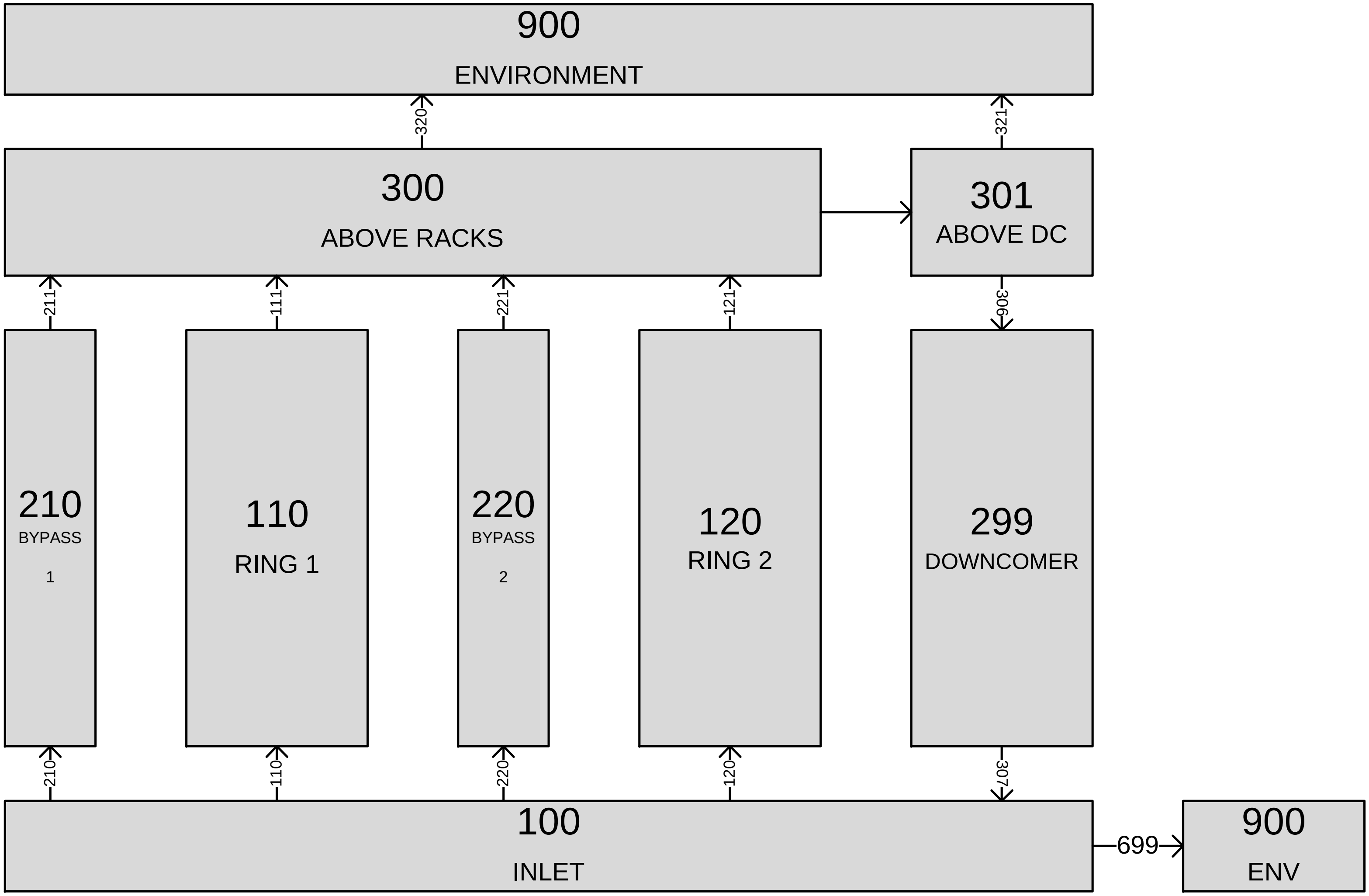


SFP model - detailed

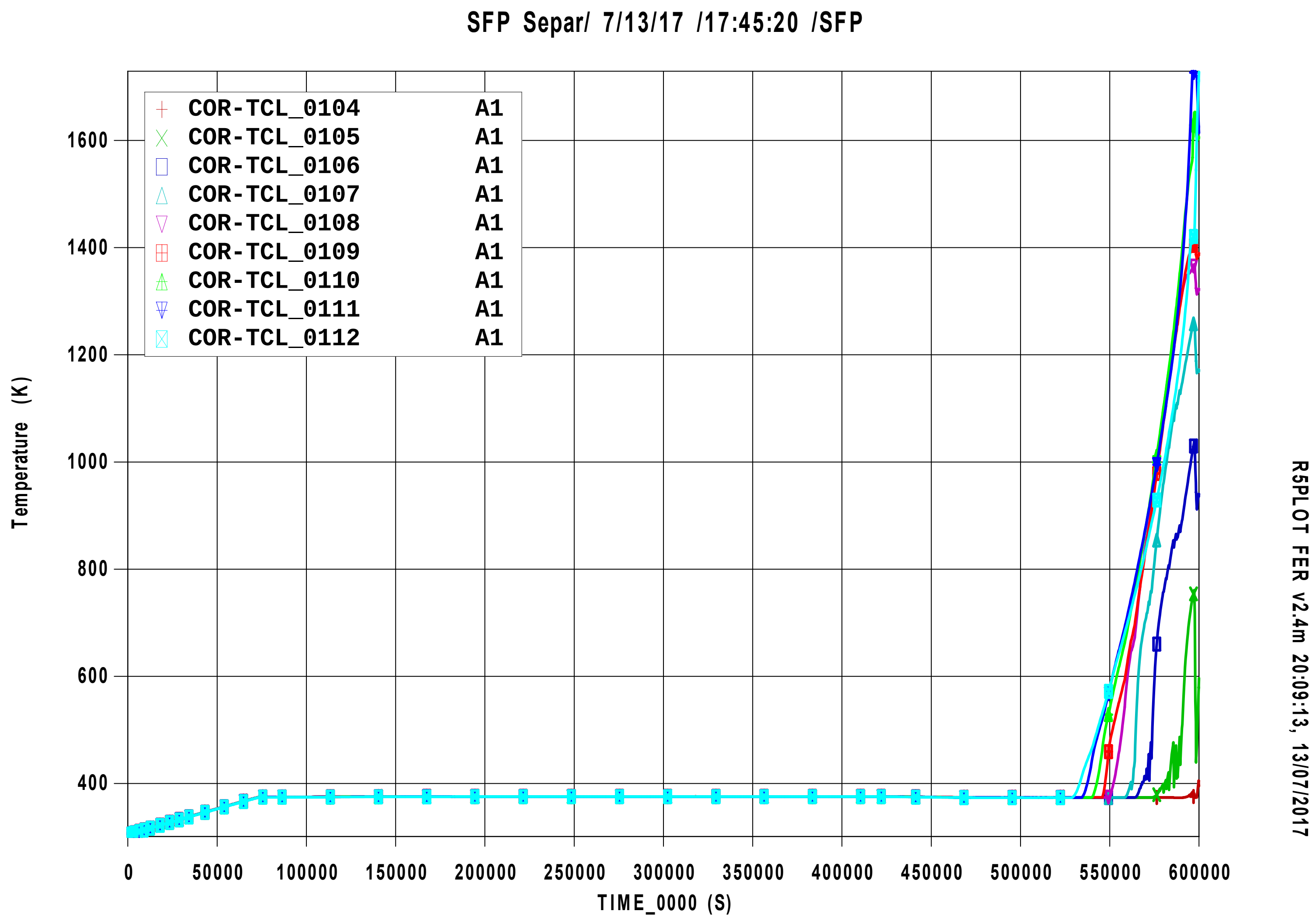
SFP GOTHIC calculation



MELCOR SFP model



Without spray - 1 cm^2 break



Without and with spray - 1 cm^2 break