NPP Krško limiting Station BlackOut (SBO) Accident Radiological Consequences

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Contents

- SBO transient description for the High Pressure (HP) and Low Pressure (LP) scenario.
- Initial and boundary conditions
- Results of MELCOR 1.8.6 analysis for SBO accident.
- Calculation of radiological consequences for SBO case using RADTRAD code.

Station BlackOut (SBO)
Transient description

The postulated SBO accident includes:

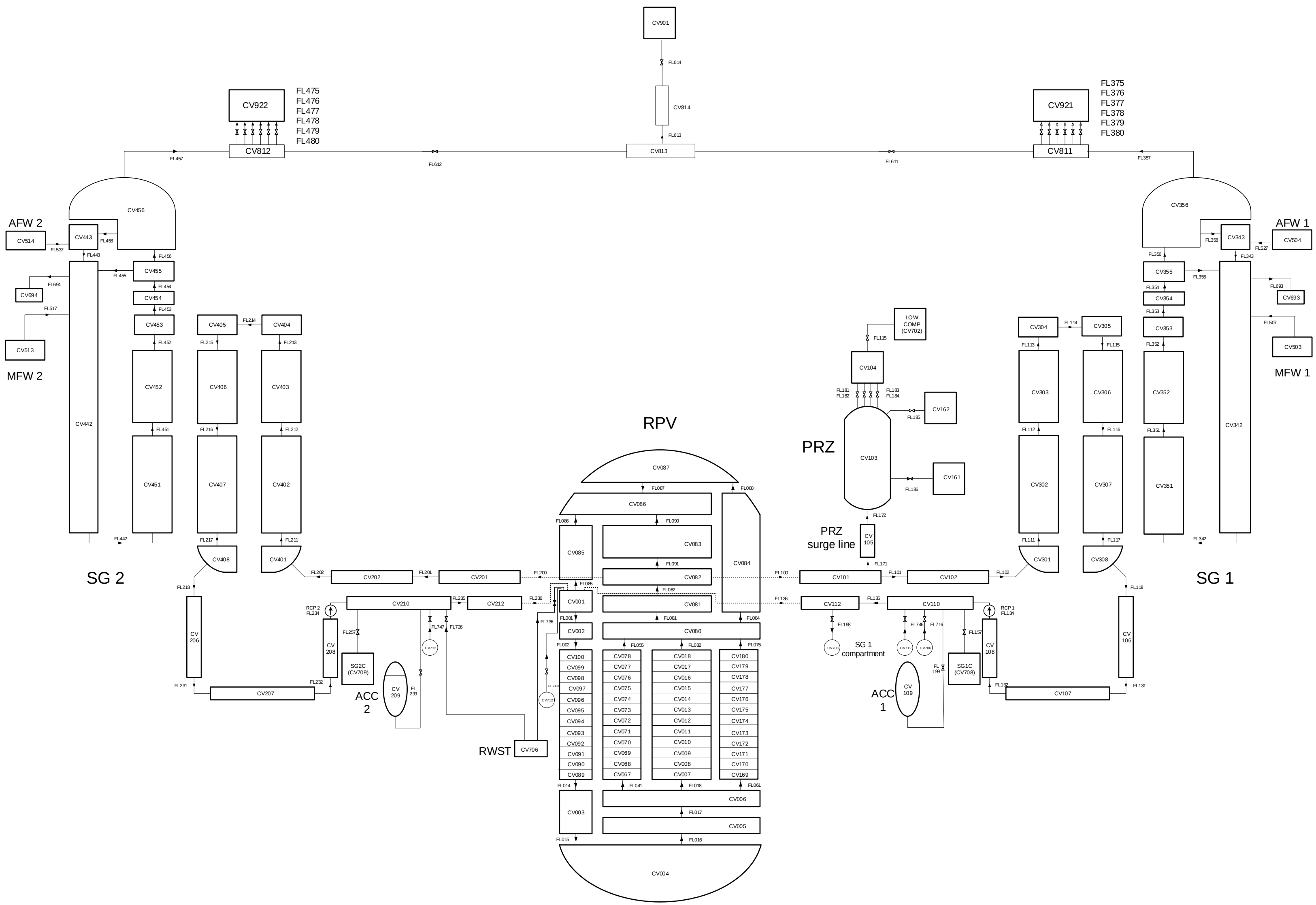
- Reactor trip from 100% power
- Trip of both RC pumps
- Main feedwater isolation
- Turbine trip
- Main steam line isolation

In the Low Pressure (LP) scenario, 9720 seconds after transient begin hot leg creep rupture in the loop with pressurizer was assumed. Lower Head Failure (LHF) occurred at low pressure after hot leg creep rupture.

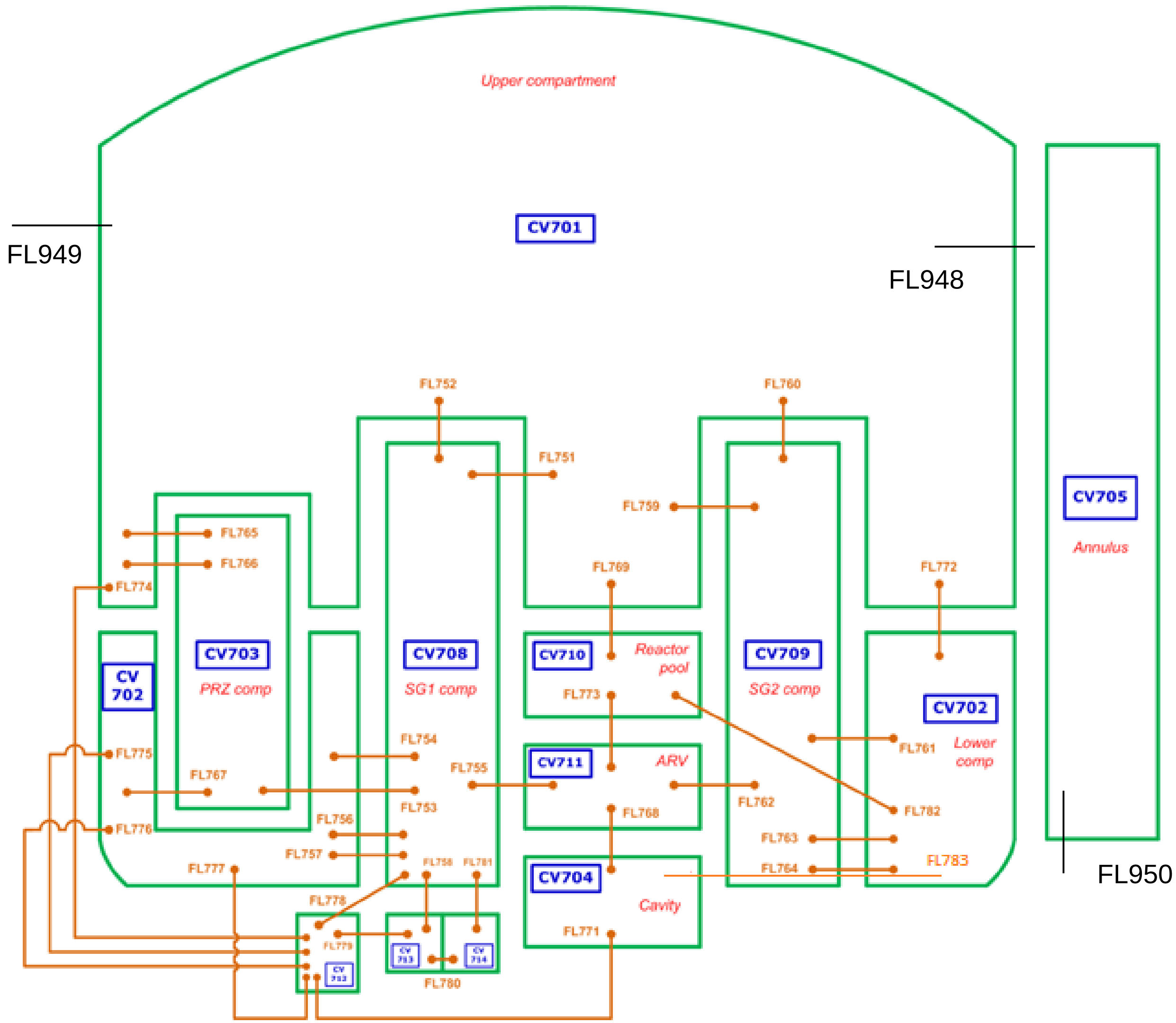
In the High Pressure (HP) scenario LHF occurred at high RCS pressure.

Transient was analyzed using qualified NPP Krško nodalization for MELCOR code.

NEK nodalization of primary and secondary system for MELCOR code



NEK nodalization of containment for MELCOR code



FL948, FL949, FL950- Leakage flow paths

Station BlackOut (SBO)
Transient boundary conditions

Main assumptions/boundary conditions:

- AFW pumps are not available.
- Safety injection not available
- Steam dump turned off
- Charging and letdown turned off
- Pressurizer safety valves are enabled, pressurizer PORVs not available
- SG safety valves available, SG PORVs not available
- Pressurizer heaters turned off
- Containment spray not available until 86400 seconds after transient begin when one train of containment spray was enabled.
- Containment fan coolers not available
- Main steam line isolation

In the Low Pressure (LP) scenario, 9720 seconds after transient begin hot leg creep rupture in the loop with pressurizer was assumed.

Available systems are the passive systems:

- Accumulators
- Pressurizer safety valves
- SG safety valves
- Passive Containment Filter Vent (PCFV) system
- Passive autocatalytic recombiners (PARs)

Station BlackOut (SBO) - Transient scenario

- SBO started with reactor trip as well as turbine trip and the trip of both reactor coolant (RC) pumps and main feedwater (MFW) pumps.

- The primary pressure decreased immediately after transient begin since the leakage on RC pump seals was initiated due to SBO.

- On the secondary side the SG safety valves open thus providing heat sink as long as there was inventory in steam generators. Since the AFW is not available the heat sink will eventually be lost.

- The primary pressure rises due to loss of heat sink and the pressurizer safety valves open. Thus, the primary inventory is being depleted due to both discharge through the pressurizer safety valves and due to leakage on RC pump seals. Consequently, core heat-up followed by Reactor Pressure Vessel (RPV) failure is expected due to loss of RCS inventory and loss of heat sink.

- 24 hours after transient begin containment spray (one train) is put in operation. After RWST had been depleted the suction of containment spray pumps is realigned from RWST to containment sump.

Station BlackOut (SBO) – HP and LP scenario)

- In the Low pressure (LP) scenario 9720 seconds after transient begin the hot leg creep failure in the first loop (loop with pressurizer) occurred. The accumulators discharge into the RCS and the water covers the molten material in the RPV lower head. This enables the cooling of the melt in the RPV and the lower head failure (LHF) occurred significantly later (16500 seconds after transient begin) than in the High pressure scenario (11825 seconds after transient begin).
- Following the LHF the accumulators and RPV emptied into the cavity (HP scenario). In the LP scenario only RPV inventory emptied into the cavity. Consequently, in the HP scenario much more efficient cooling of the melt in the cavity is enabled than in the LP scenario. As a consequence, in the LP scenario the PCFV opened earlier (16.02 hours after transient begin) than in the HP scenario (19.9 hours after transient begin). In the LP scenario the PCFV opened twice before start of containment spray and in the HP scenario PCFV opened once. Consequently, the discharged mass to the environment was larger in the LP scenario (89060 kg) than in the HP scenario (54560 kg).

- **Thus, the LPO scenario will be analyzed as the limiting SBO case for calculation of radiological consequences**.

Analysis of SBO – Time table of main events

Event	**SBO (with hot leg creep rupture – Low pressure scenario)**	**SBO, High pressure scenario**
SBO (Loss of onsite and offsite power)	0 s	0 s
The core has uncovered	4800 s	4800 s
SGs depleted	5530 s	5530 s
Zr-water reaction begin	7460 s	7460 s
Begin of UO2 melting	8860 s	8860 s
Hot leg 1 creep rupture	9720 s	-
Lower head failure (LHF)	16505 s	11825 s
Accumulators (1/2) empty	9758 s	12001 s
Reactor cavity dry-out	29860 s	38890 s
PCFV rupture disc broken	57671 s	71627 s
Begin of mitigation (containment spray)	86400 s	86400 s
Discharged mass through the PCFV	89060 kg	54560 kg

Analysis of SBO, MELCOR 1.8.6

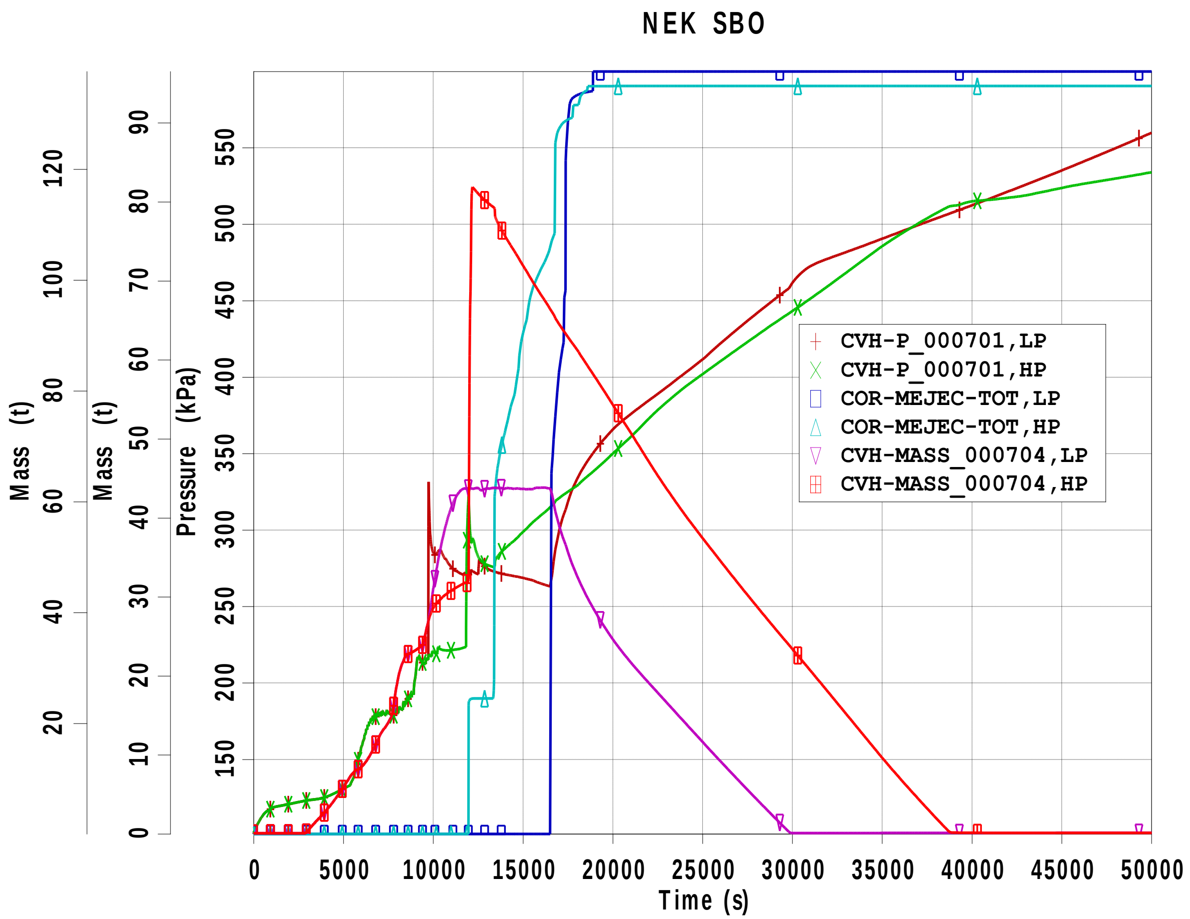


Figure 1: Containment pressure, ejected mass to cavity and mass of water in the cavity, (0-50000 s)

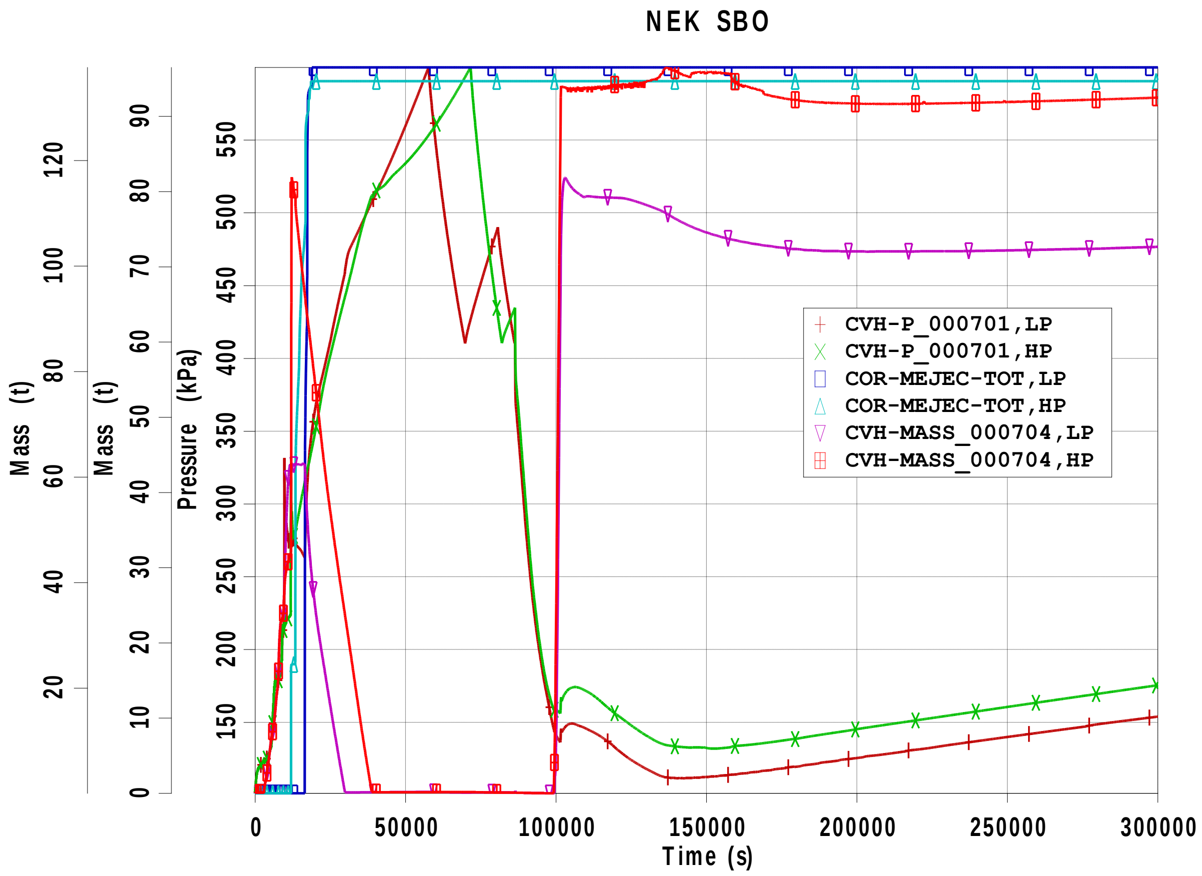


Figure 2: Containment pressure, ejected mass to cavity and mass of water in the cavity, (0-300000 s)

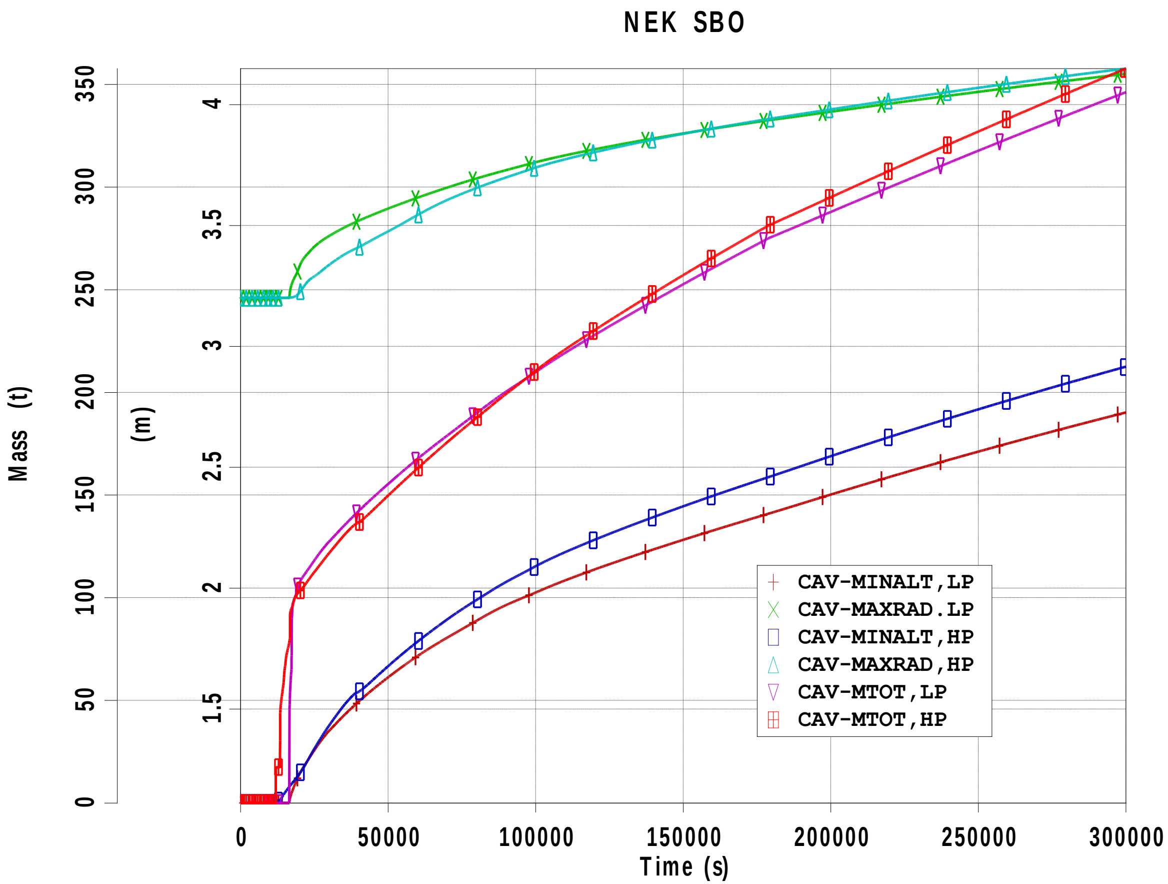


Figure 3: Minimum cavity altitude and maximum radius and total mass in cavity

Analysis of SBO, MELCOR 1.8.6

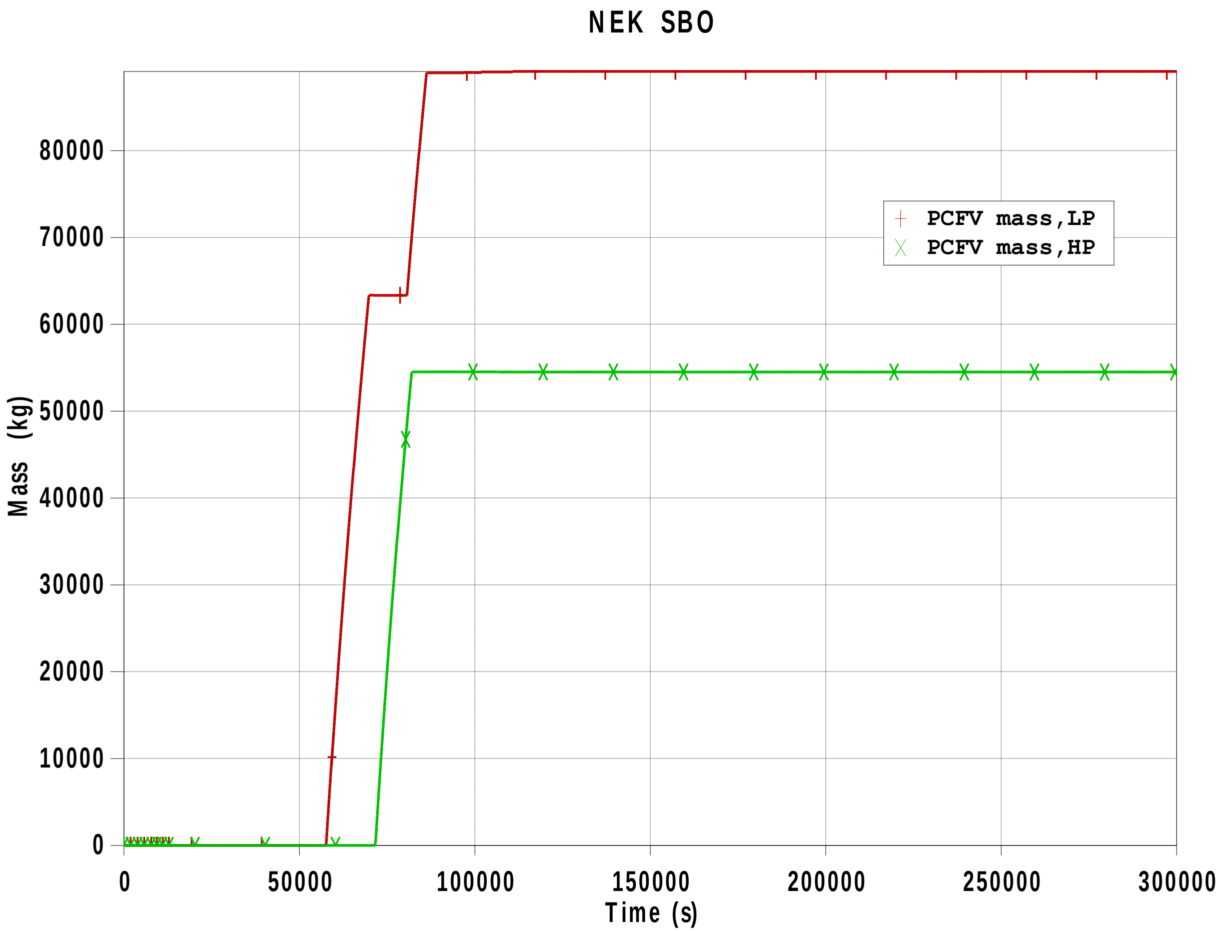


Figure 4: Discharged mass through PCFV

Analysis of SBO, MELCOR: Conclusion remarks

- The analysis of SBO accident was performed for the High pressure (HP) scenario where the lower head failure occurred at high RCS pressure and for Low pressure scenario where the hot leg creep rupture was simulated 9720 seconds after transient begin.

- For LP scenario, the water from the accumulators was injected into RCS before lower head failure. The cooling of the corium in the RPV lower head was enabled and that led to delayed lower head failure (4.58 hours after transient begin) when compared with HP scenario (3.28 hours).

- For HP scenario, after lower head failure, the accumulators emptied over the corium in the cavity thus enabling efficent cooling. Containment pressure rises due to evaporation of the water in the cavity on one side and due to MCCI on the other side. After the water in the cavity had evaporated the containment pressure continued to rise at slower rate due to MCCI only.

Analysis of SBO, MELCOR: Conclusion remarks, cont.

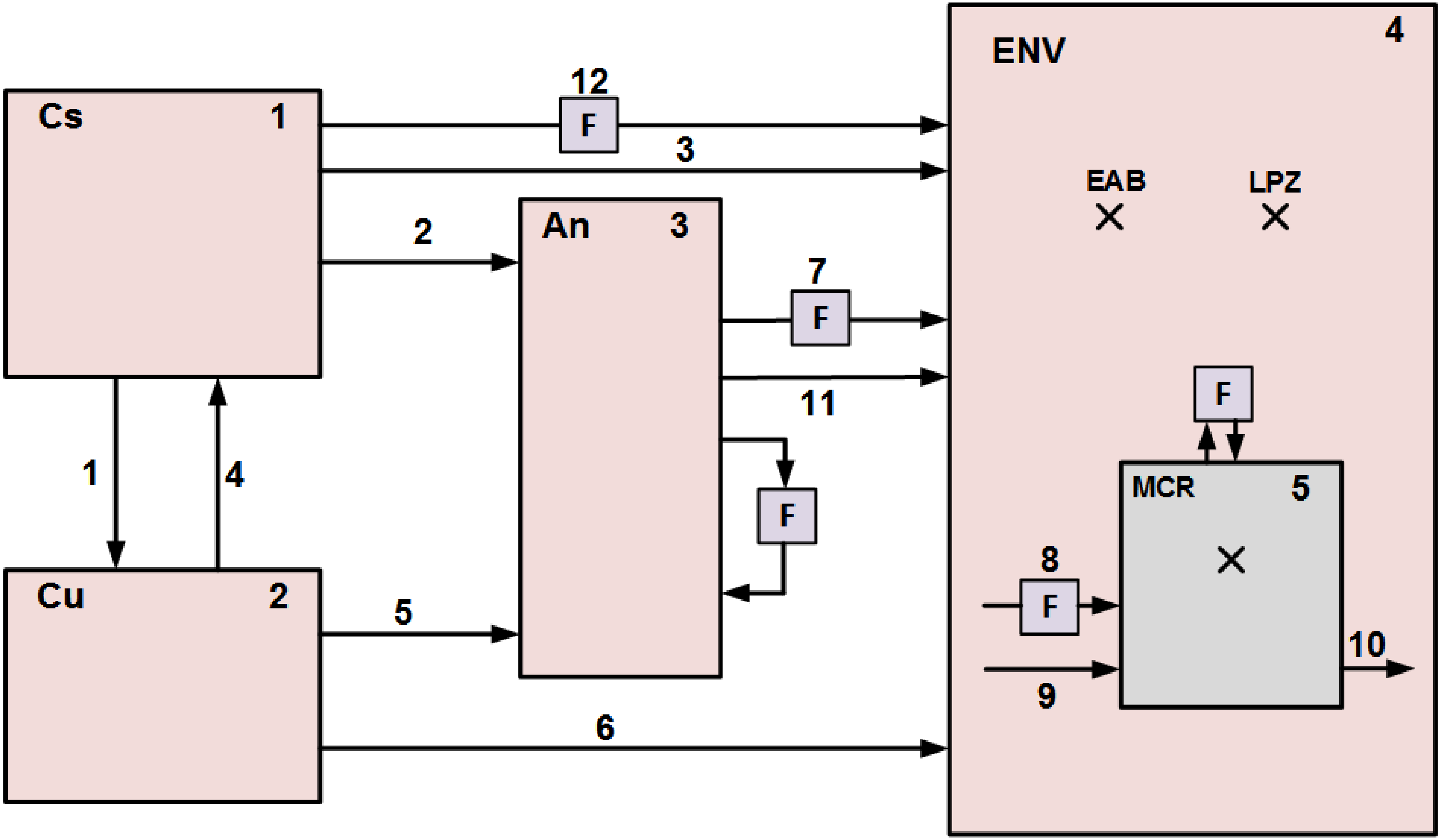
- For LP scenario, the amount of water in the cavity after LHF was smaller than for the HP case and the cooling of the corium was less efficient than for the latter case. After water in the cavity had evaporated, containment pressure in the LP case continued to rise at the steep rate. For LP scenario, the PCFV opening occurred 16.02 hours after transient begin, and for HP scenario the PCFV opened 19.9 hours after transient begin. For LP scenario, the PCFV opened for the second time before start of mitigation (24 hours after transient begin.

- **For LP scenario the PCFV opened twice before the start of mitigation and the amount of discharged inventory to environment was larger (89060 kg) than for HP scenario (54560 kg). Consequently, the LP scenario will be the limiting case for the radiological consequences analysis.**

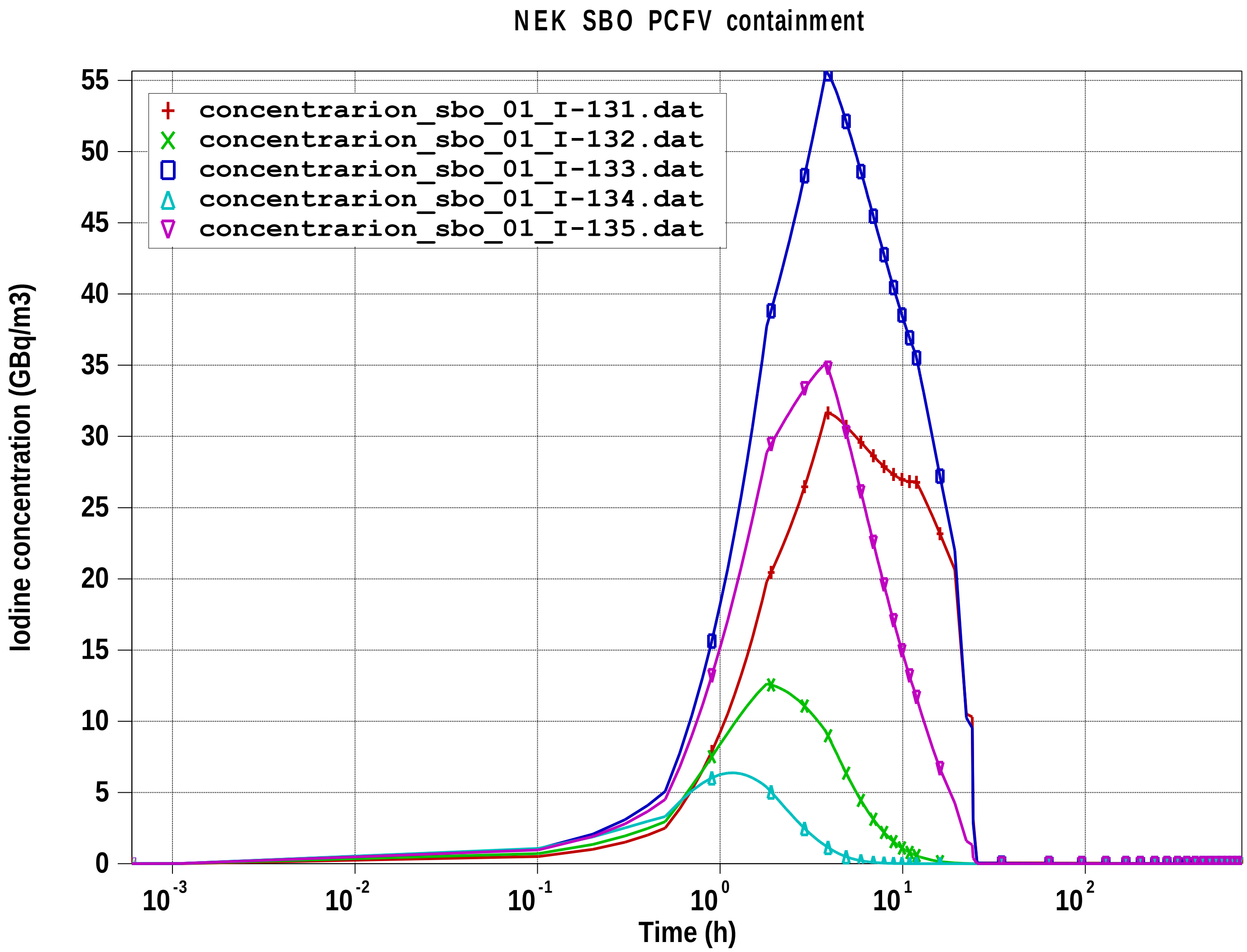
Methodology for dose calculation

- Plant specific fuel source term (ORIGEN calculation)
- RADTRAD model of release radioactivity (AST and RG-1.183 assumptions) from the fuel to the containment and from the containment to the environment
- - SBO based on plant specific MELCOR calculation of related sequence
- Atmospheric dispersion
- -X/Q relative concentrations calculated using numerical weather prediction model WRF and detailed lagrangian particle model used in RADTRAD for dose calculation
- -RODOS (JRodos) modules for selected weather sequences

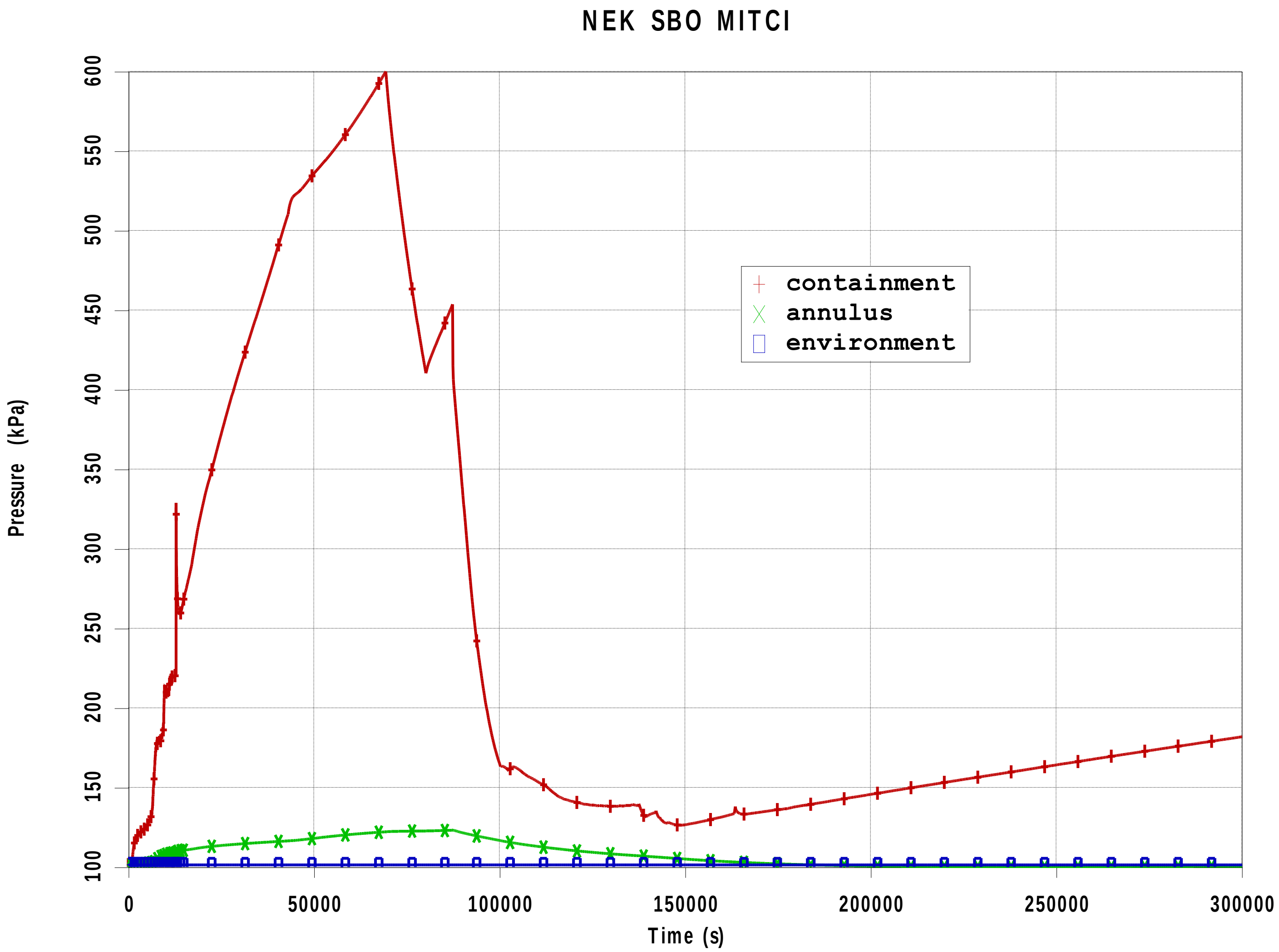
Radtrad nodalization for NEK SBO PCFV



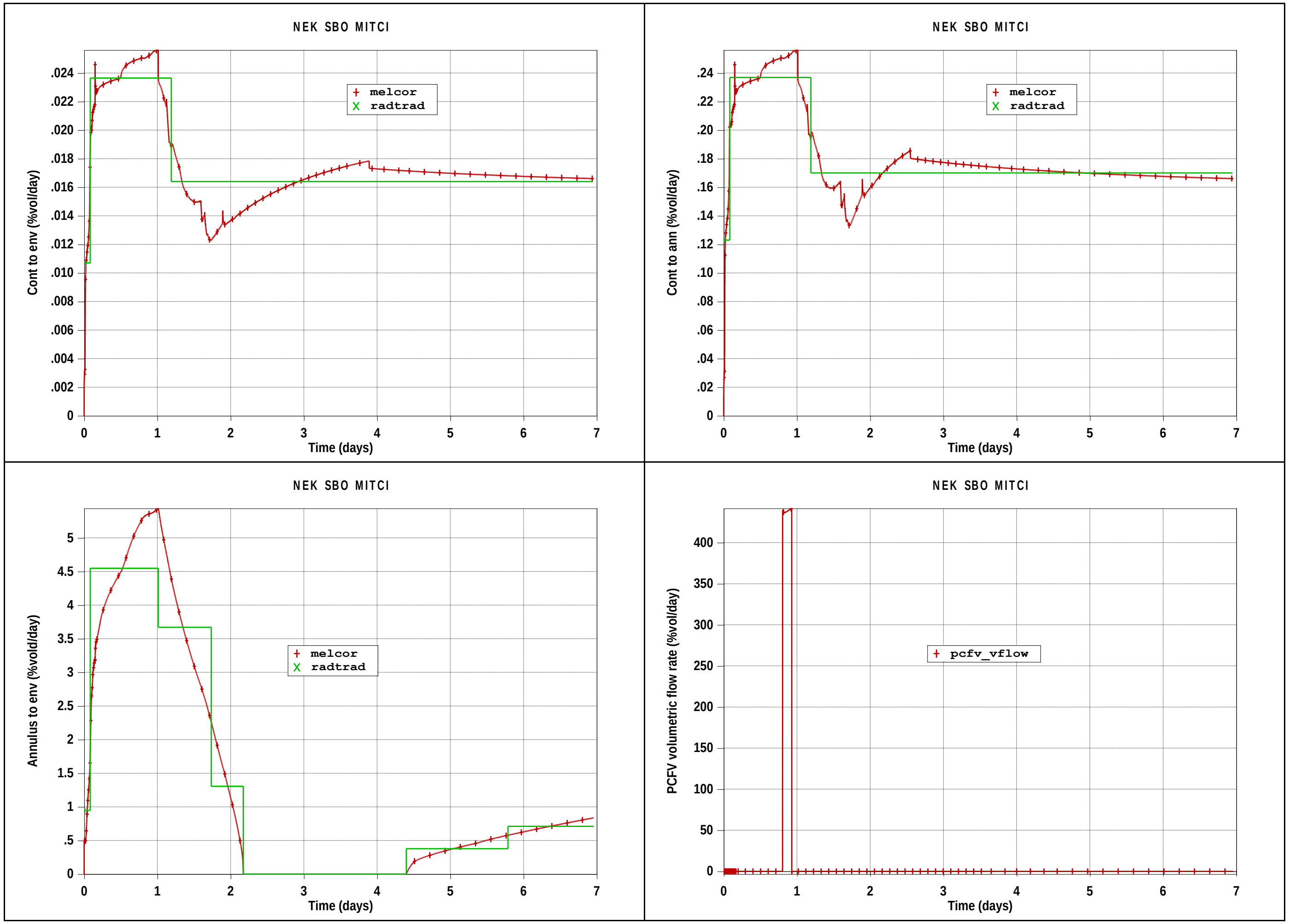
Iodine concentrations in containment during HP SBO sequence



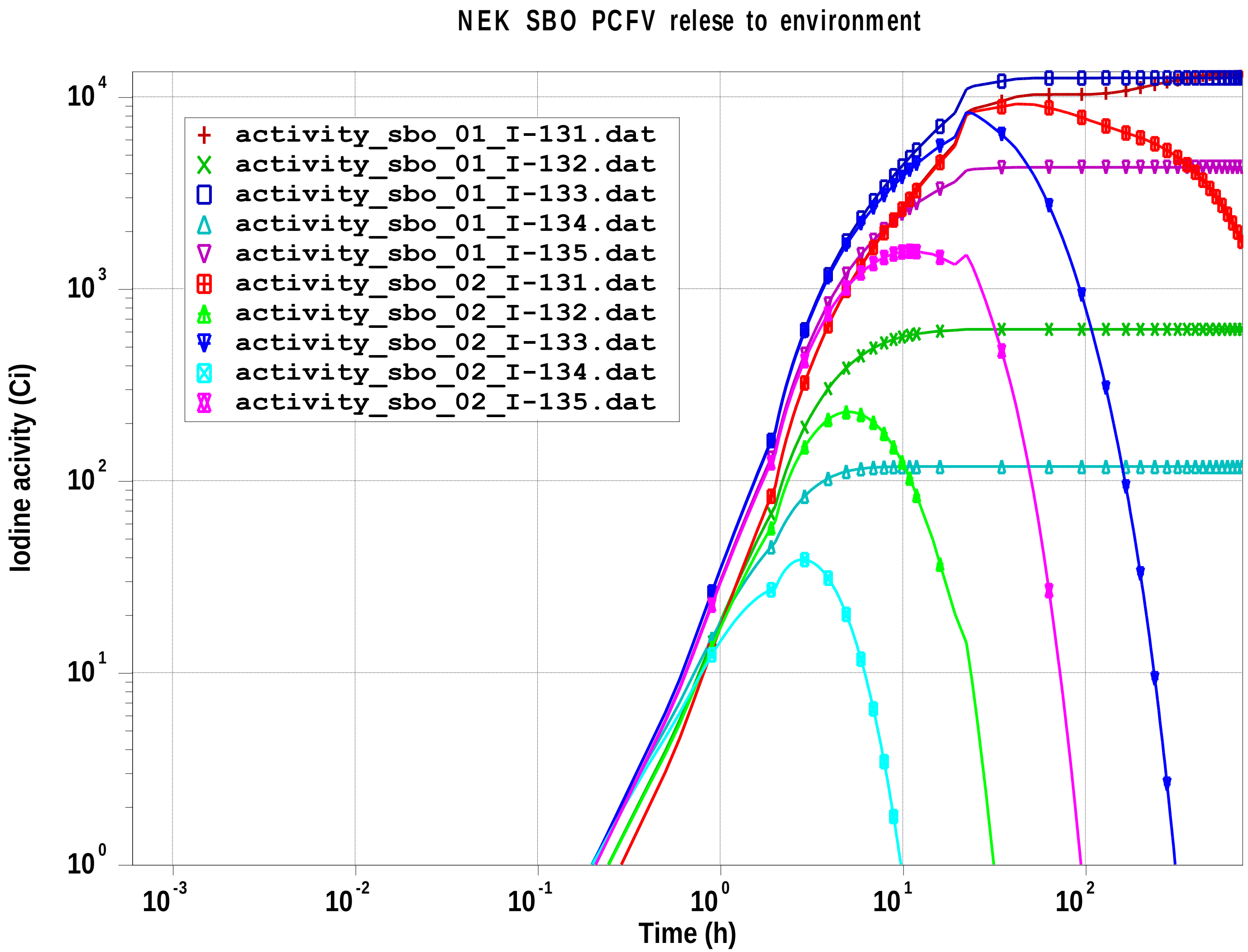
Release related pressures



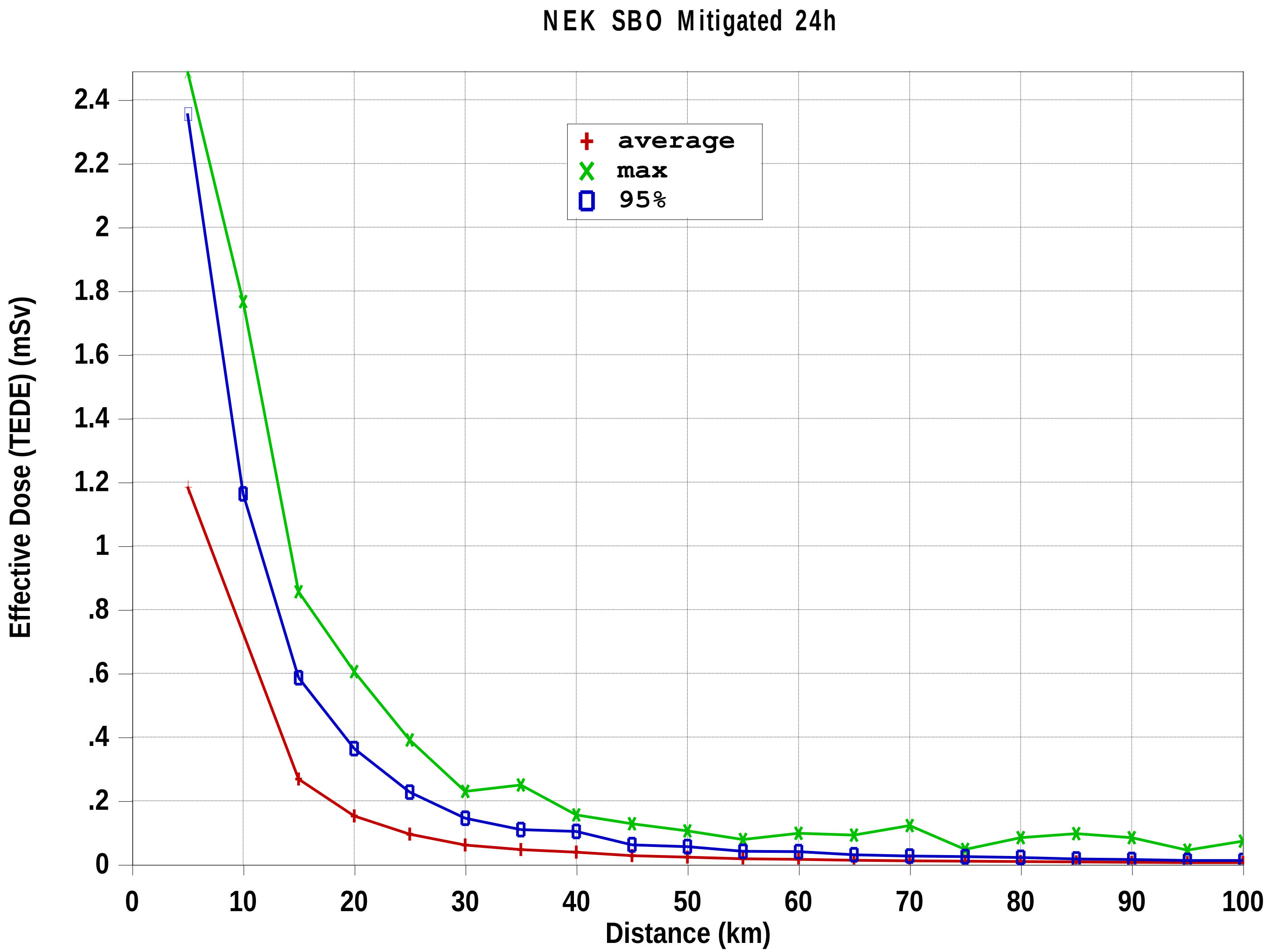
Release rate (paths: 3,6 2,5 11, 12)



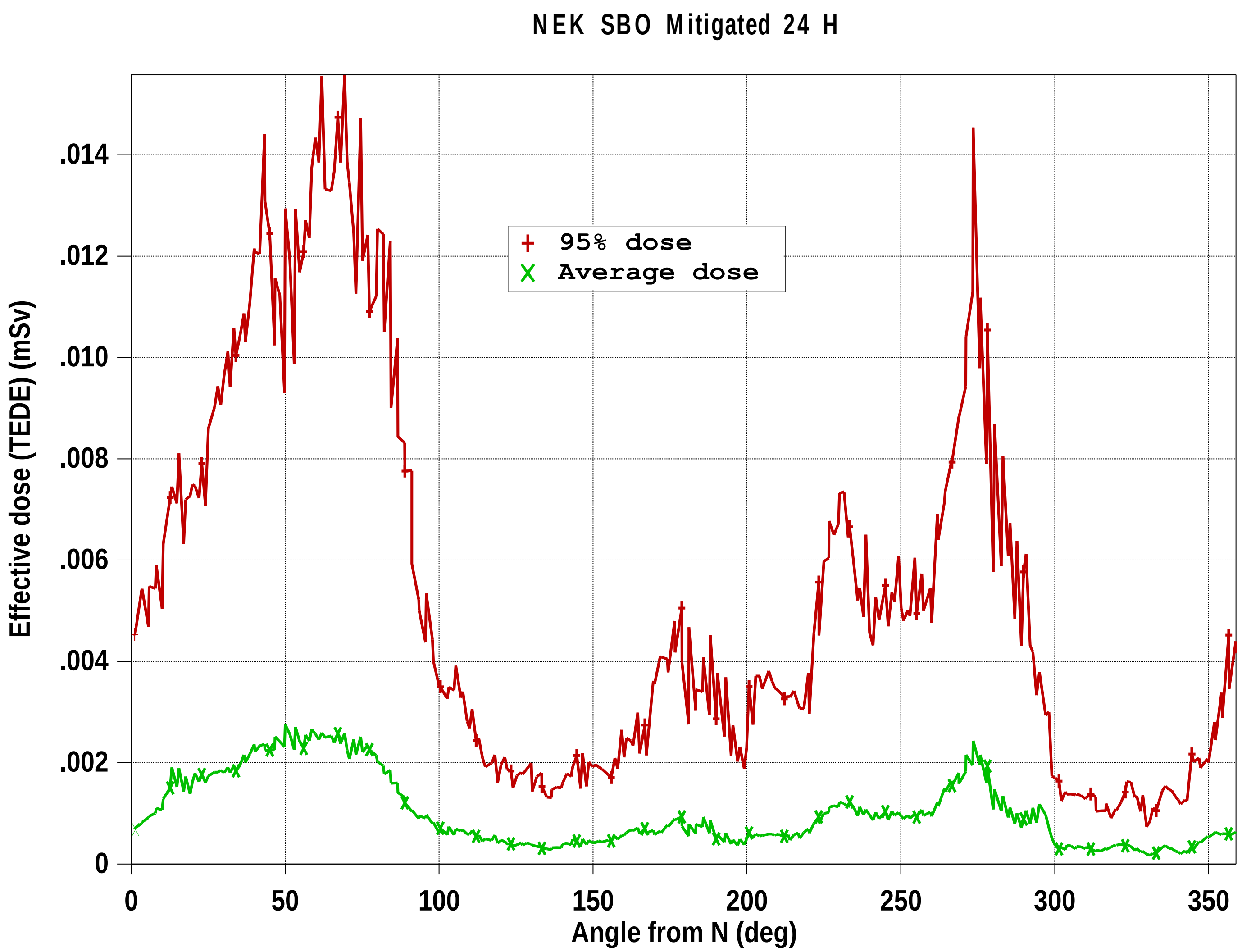
Iodine activity released to the environment and present in the environment, log



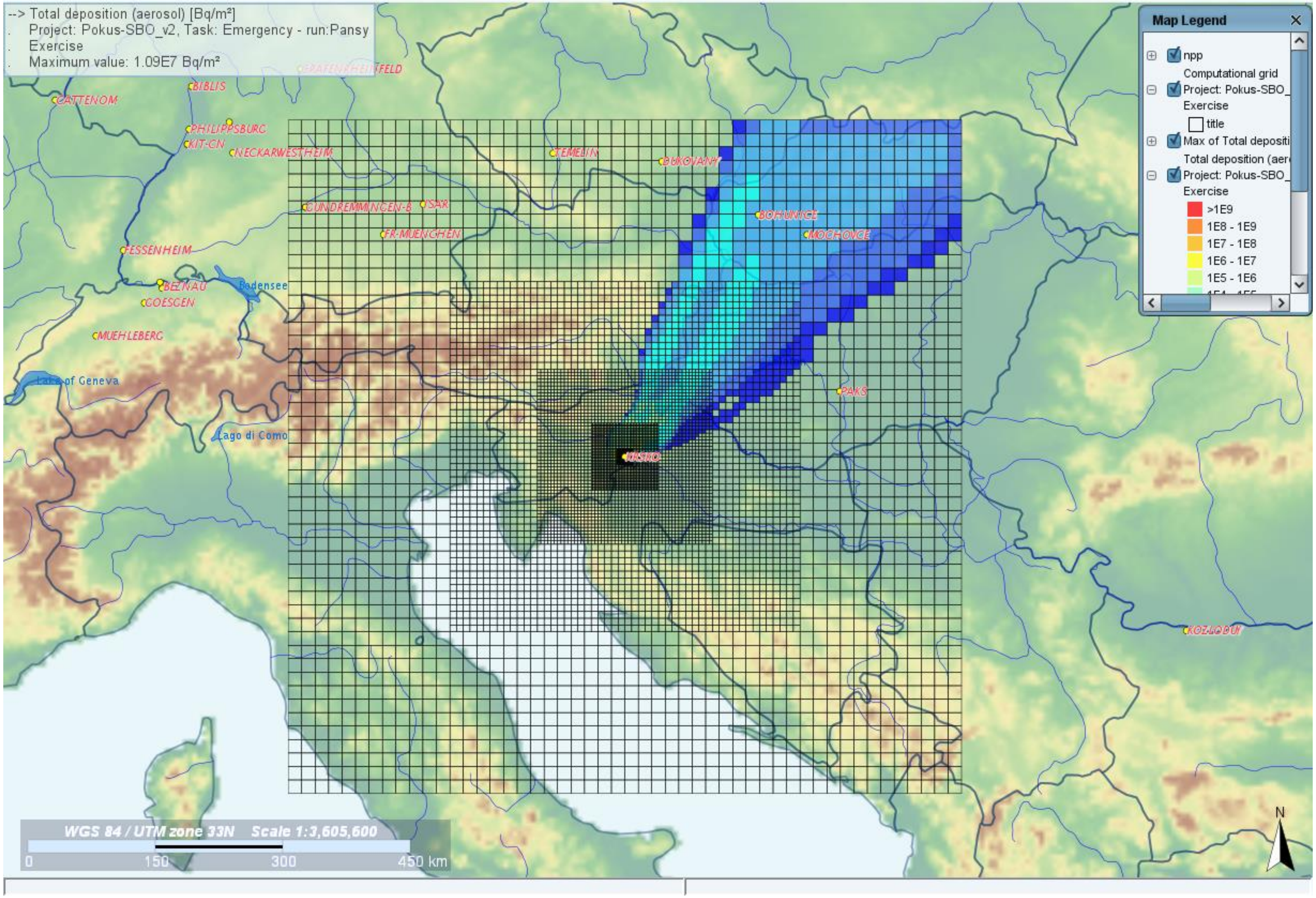
TEDE 30 days dose vs. distance as calculated by RADTRAD using MEIS X/Q factors (avg, max and 95% 2D to 1D conversion)



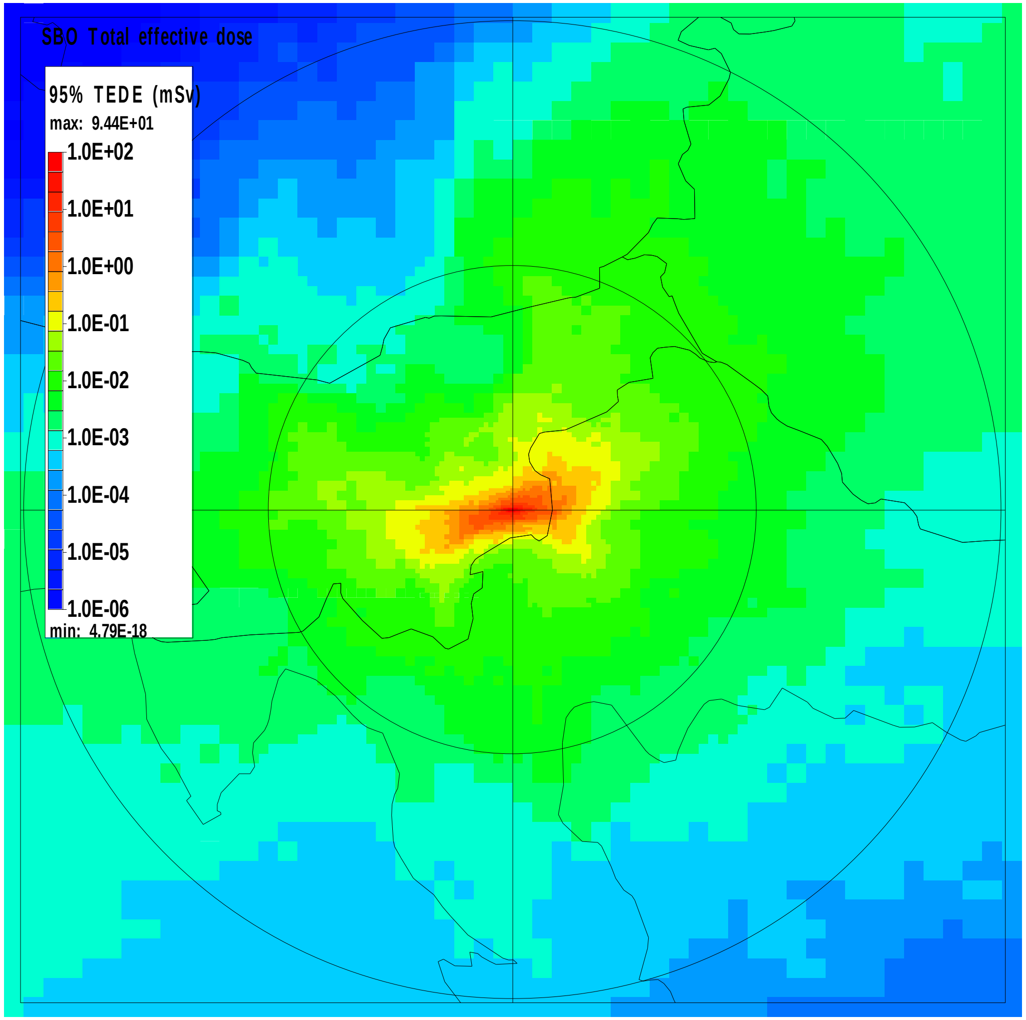
SBO 95% effective dose and average dose at 100 km radius versus angle from north



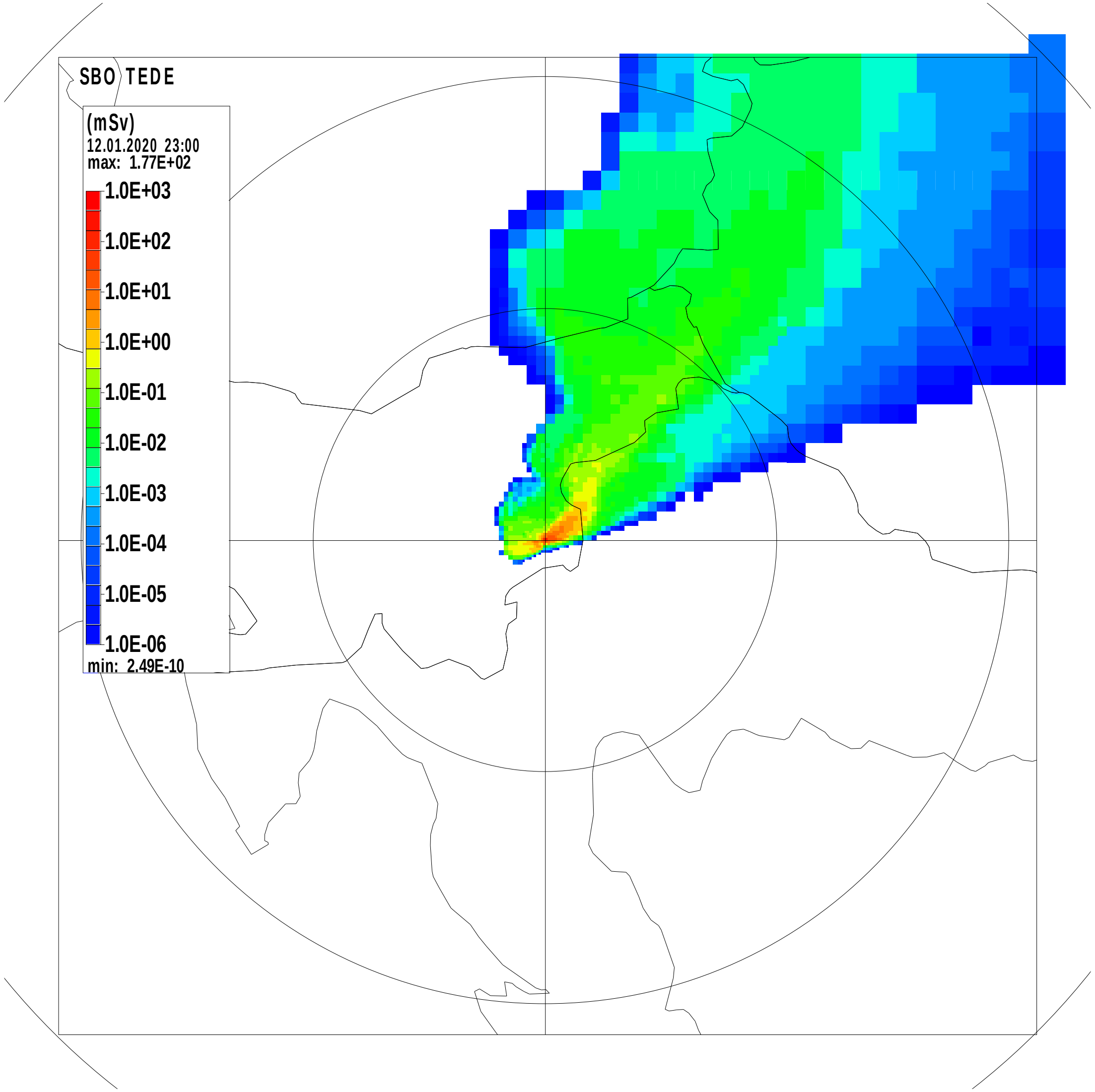
Overlay of RODOS calculation grid centered at NEK and map of the region



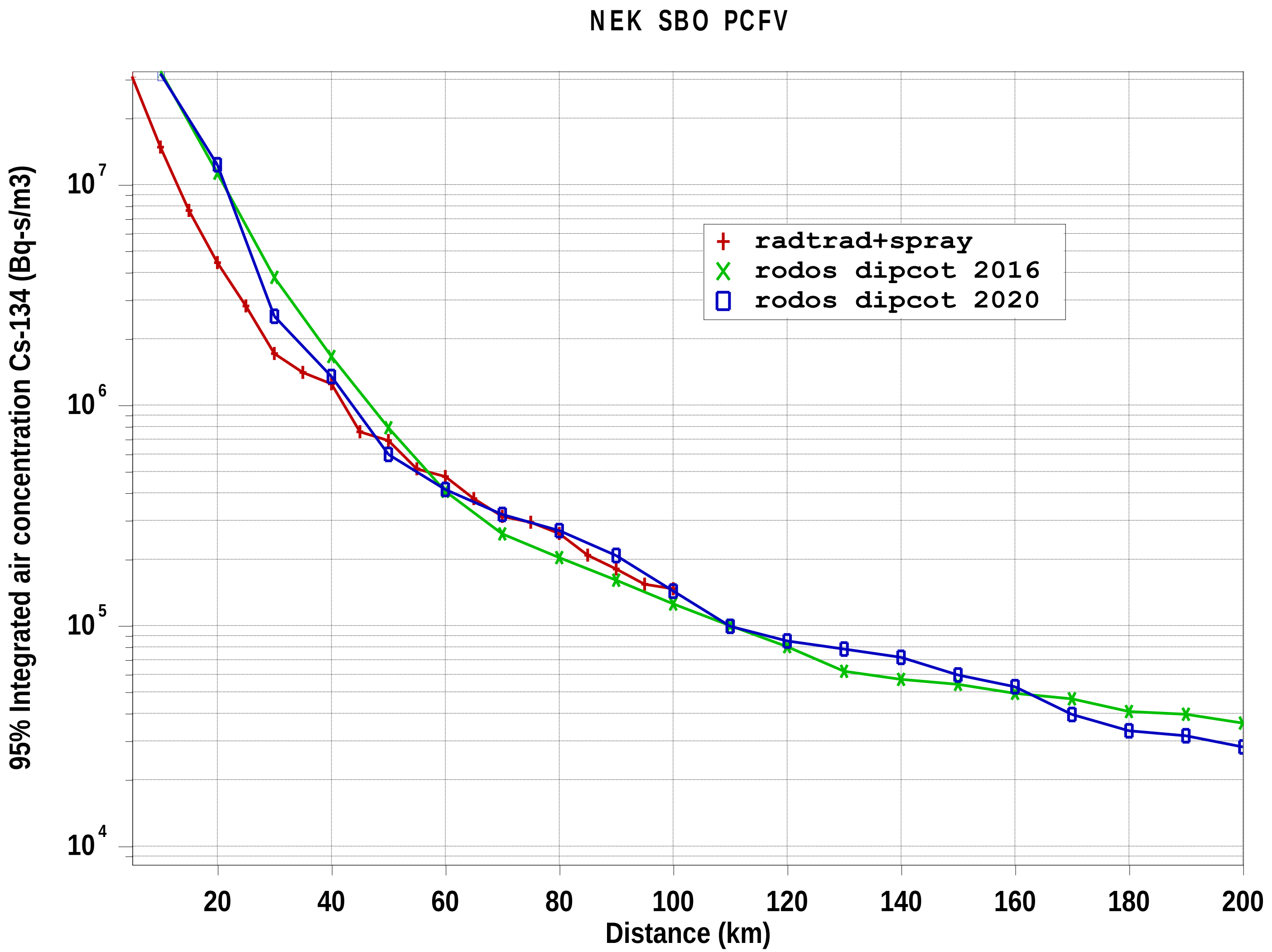
95% SBO TEDE values for distances up to 200 km, DIPCOT for year 2020



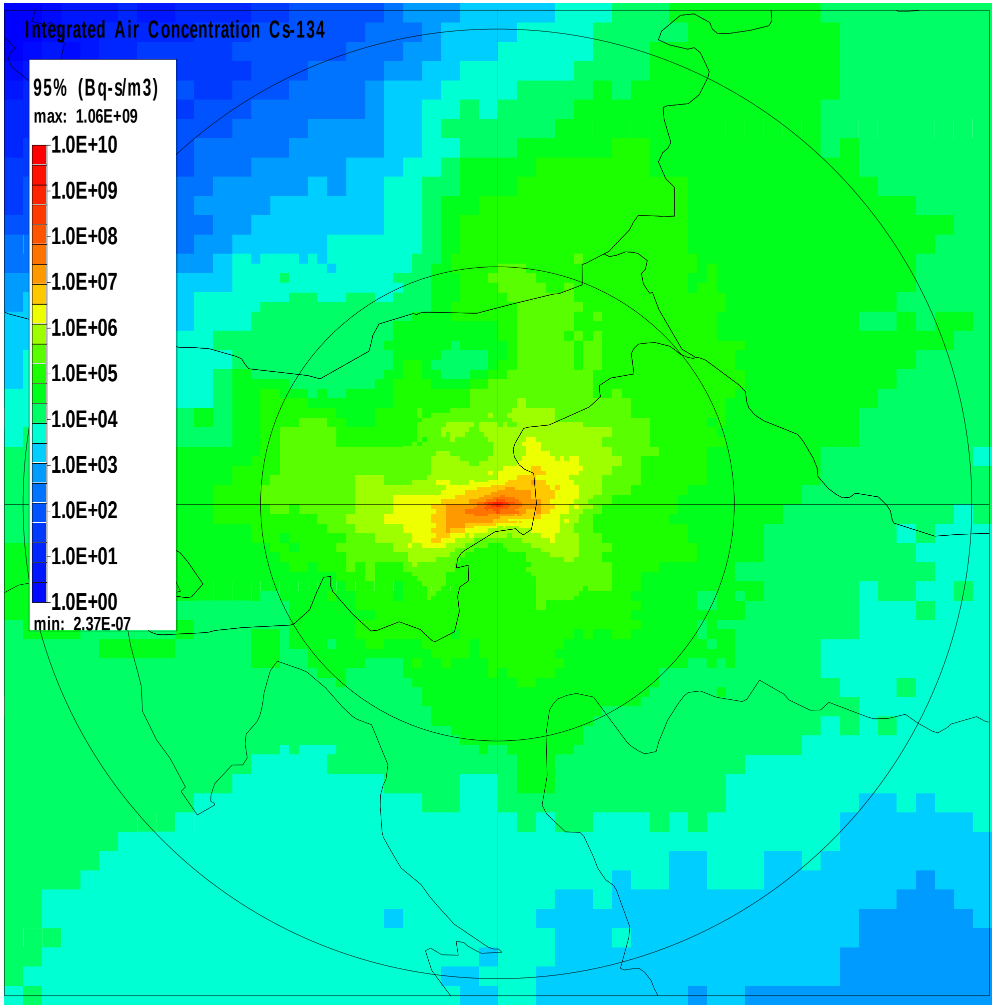
TEDE values for distances up to 200 km, release started at 12.01.2020 23:00



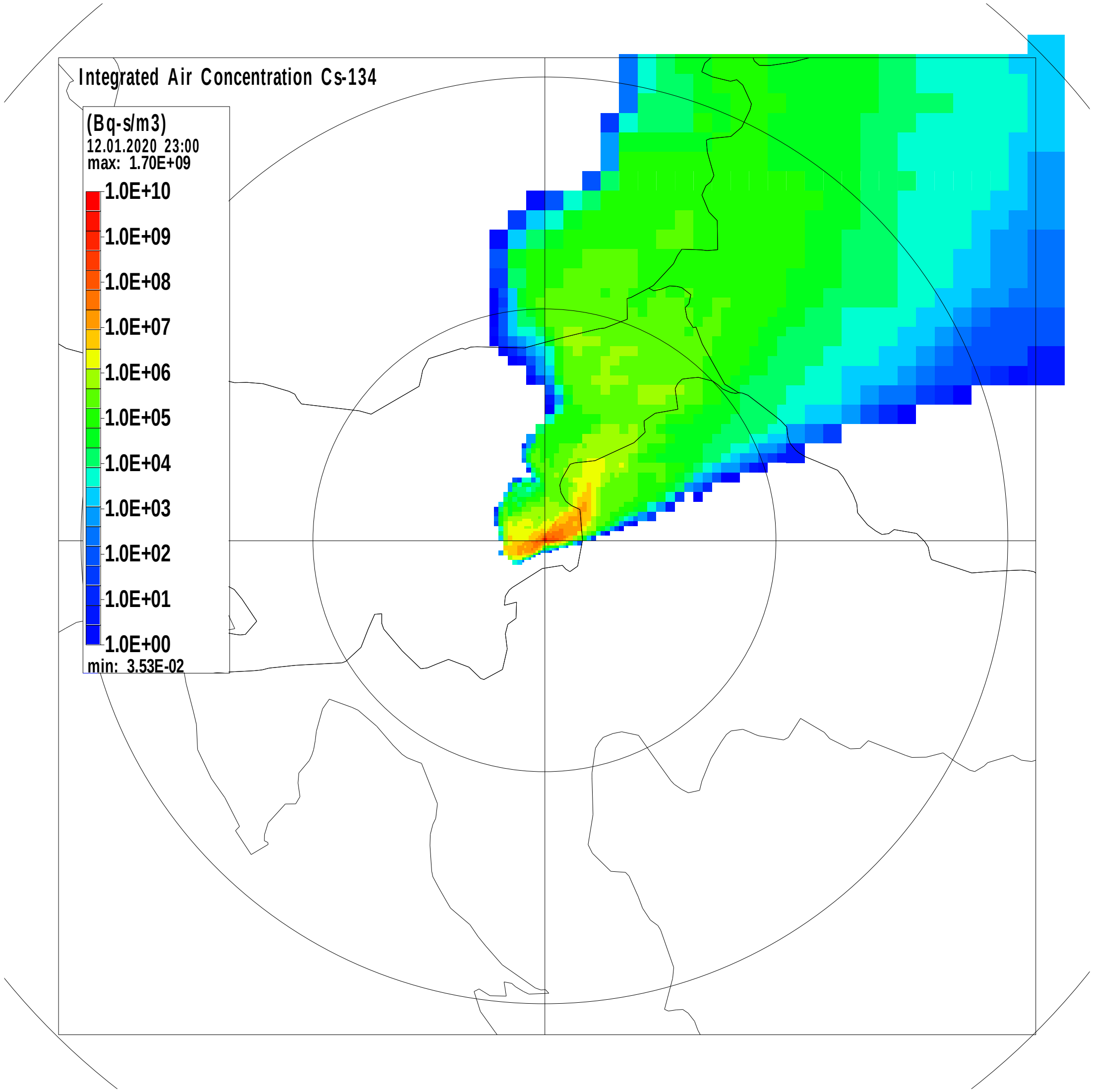
Integrated air concentration (95th percentile spatial values) of Cs-134 (Bq-s/m3) for SBO



SBO 95% Integrated air concentration of Cs-134 (Bq-s/m3), DIPCOT for year 2020



Cs-134 Integrated air concentrations for distances up to 200 km, release started at 12.01.2020 23:00



Conclusion

- MELCOR 1.8.6 analysis SBO transient analysis for the High Pressure (HP) and Low Pressure (LP) scenario.
- Calculation of radiological consequences for the SBO release using RADTRAD code for externally calculated averaged or 95% X/Q factors
- Explicit calculation of doses using RODOS for randomly selected weather sequences to obtain average or 95% doses
- Similar calculation will be performed using MACCS2