SFP model – WWER-1000

Kaliopa Mancheva

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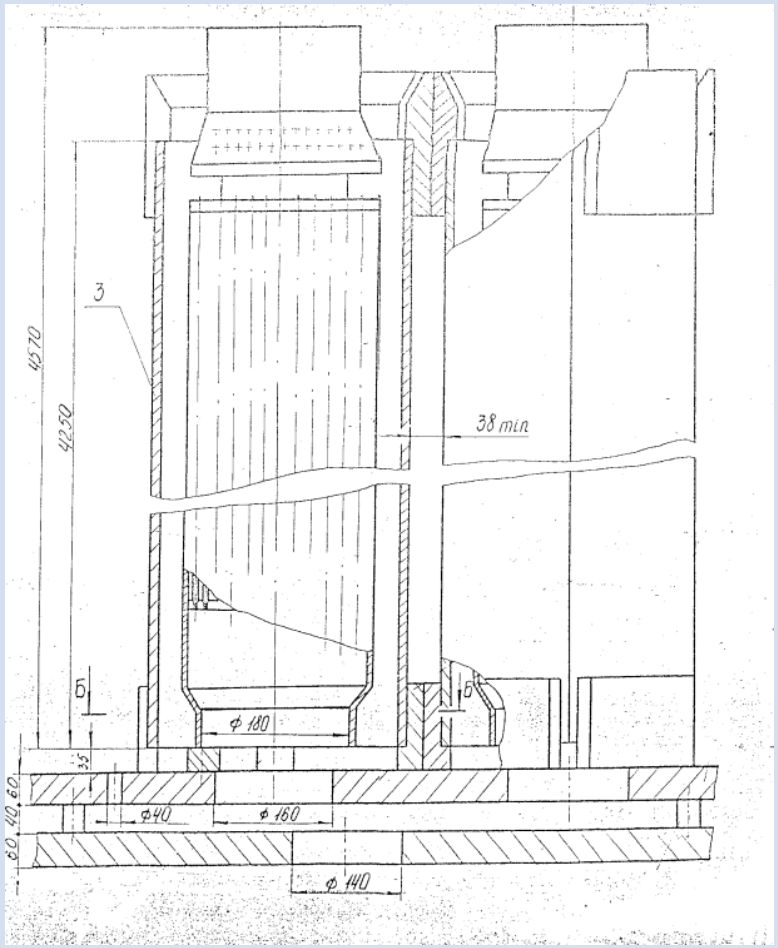
General information

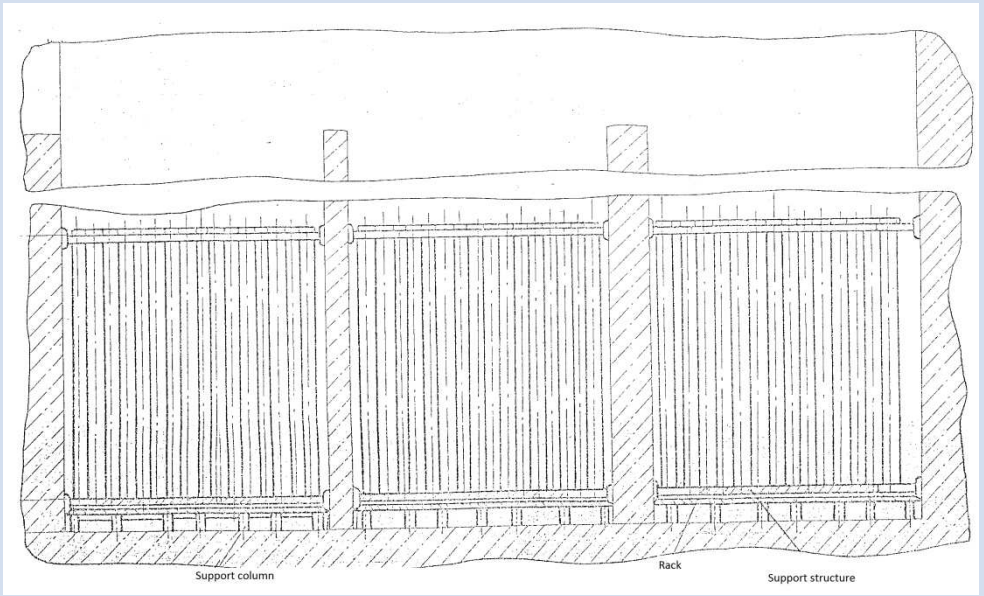
- SFP model was developed as part of PSA level 2 study for unit 5 and 6 of KNPP
- 5 accident scenarios taken from PSA level 1:

Scenario	Containment status	Cooling system (TG)	Alternative cooling system (SS, TB30, 0TM)	Spray System
1	Isolated	Failed	Failed	Up to tank depletion
2	**Isolated**	**Failed**	**Failed**	**Failed**
3	Isolated	Failed	Up to tank depletion	Failed
4	Not Isolated	Failed	Failed	Failed
5	Not Isolated	Failed	Up to tank depletion	Failed

Spent Fuel Pool configuration



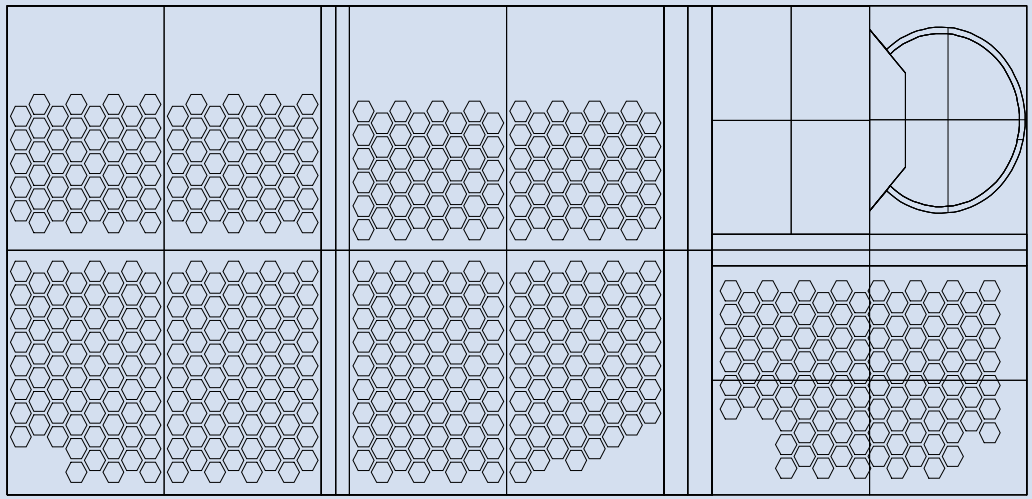
SFP Rack



Real configuration

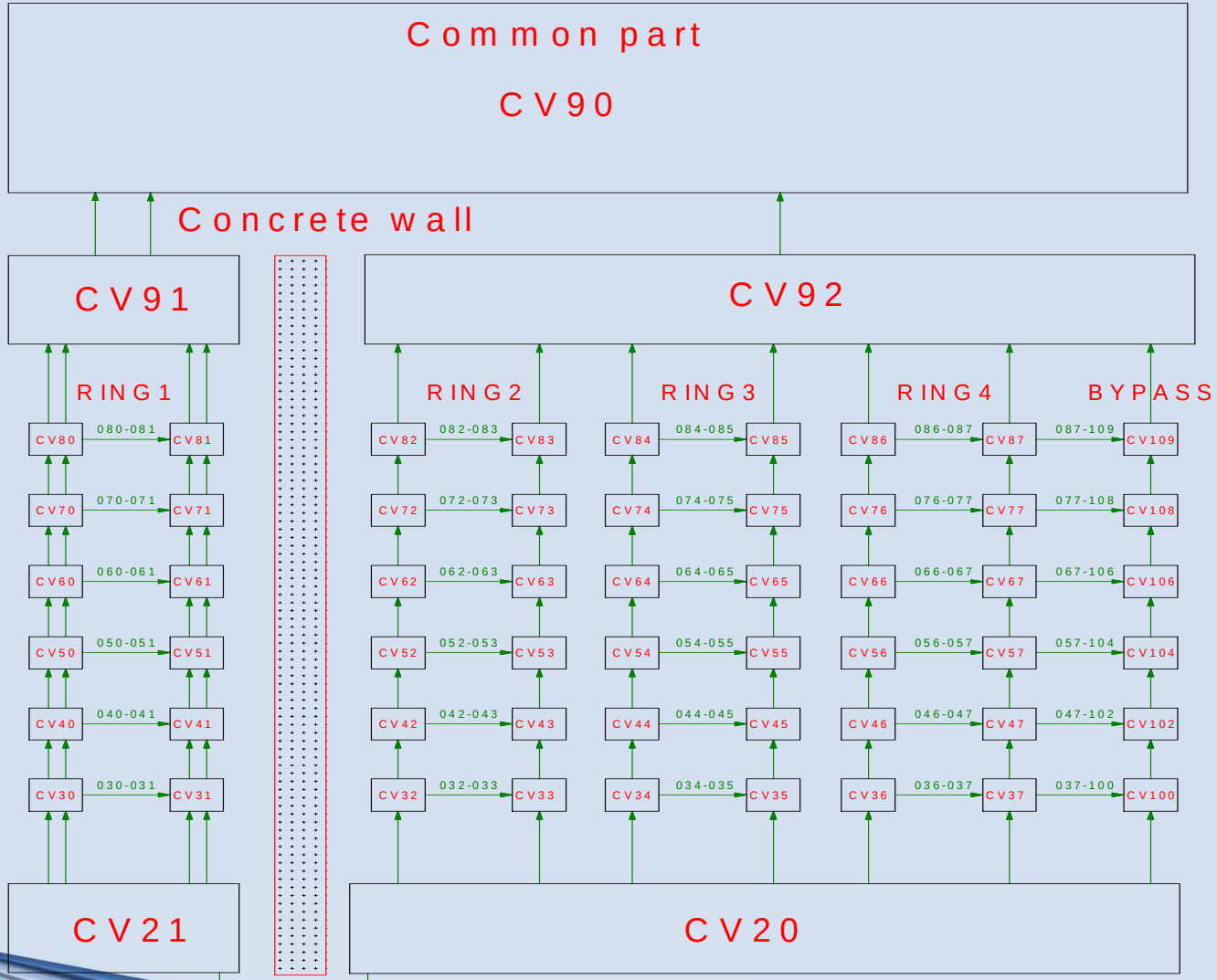
Spent Fuel Pool model - general

- DATA:
  - Reactor type – SFP-BWR
  - FA number - 563
  - Control rods B_4C – difference from reactor (^{10}B included in rack steel)
  - Lower head – flat
  - All racks are occupied with FA (163 from reactor core)
  - Axial power profile - uniform – 9-th day after reactor shutdown
  - Water level – 28,8 m (about 2,5 m above racks)



Fuel assembly distribution

Spent Fuel Pool – CV nodalization



Spent Fuel Pool – core

- Radial rings:
  - 1 ring – 163 assemblies (assemblies removed from reactor Qw > 1.00E4 [W])
  - 2 ring – 149 assemblies (1.00E3 ≤ Qw ≤ 3.00E3 [W])
  - 3 ring – 125 assemblies (Qw ≤ 1.00E3 [W])
  - 4 ring – 126 assemblies (3.00E3 ≤ Qw ≤ 1.00E4 [W])
  - 5 ring –outer volumes (free of assemblies)
- Axial distribution:
  - 1 ÷ 7 (support construction)
  - 8,19 and 20 (1 lower and 2 upper unheated core part)
  - 9 ÷ 18 (heated core part)

Spent Fuel Pool – core

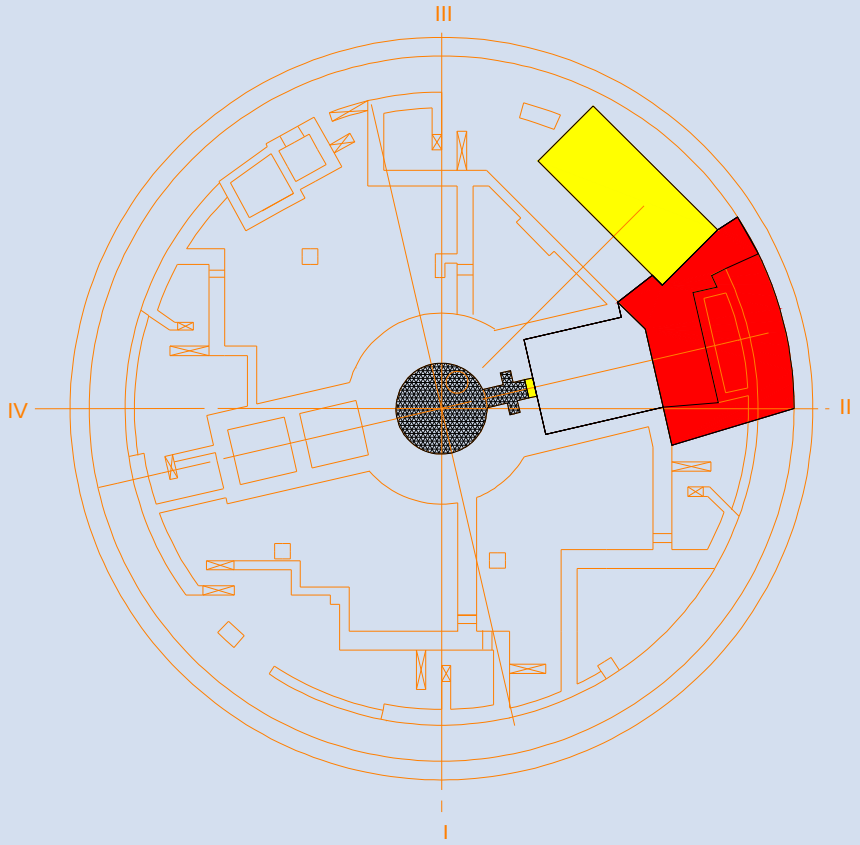
Lower elevation	Height	UPPER_1	UPPER_2	UPPER_3	UPPER_4	UPPER_5	
25.553	0.172	120	220	320	420	BOK_15	**Unheated core part**
25.286	0.267	119	219	319	419	BOK_14	
24.933	0.353	**118**	**218**	**318**	**418**	BOK_13	
24.58	0.353	**117**	**217**	**317**	**417**	BOK_12	
24.227	0.353	**116**	**216**	**316**	**416**	BOK_11	
23.874	0.353	**115**	**215**	**315**	**415**	BOK_10	
23.521	0.353	**114**	**214**	**314**	**414**	BOK_9	
23.168	0.353	**113**	**213**	**313**	**413**	BOK_8	**Heated core part**
22.815	0.353	**112**	**212**	**312**	**412**	BOK_7	
22.462	0.353	**111**	**211**	**311**	**411**	BOK_6	
22.109	0.353	**110**	**210**	**310**	**410**	BOK_5	
21.756	0.353	**109**	**209**	**309**	**409**	BOK_4	
	0.316	108	208	308	408	BOK_3	**Unheated core part**
21.44							
	0.06	107 Support plate	207 Support plate	307 Support plate	407 Support plate	507 Support plate	BOK_2
21.38							
	0.04	106 Support columns	206 Support columns	306 Support columns	406 Support columns	506 Support columns	BOK_1
21.34							
	0.06	105 Support plate	205 Support plate	305 Support plate	405 Support plate	505 Support plate	
21.28							
	0.145	104 Support columns	204 Support columns	304 Support columns	404 Support columns	504 Support columns	
21.135							
	0.145	103 Support columns	203 Support columns	303 Support columns	403 Support columns	503 Support columns	**CV020**
20.99							
	0.145	102 Support columns	202 Support columns	302 Support columns	402 Support columns	502 Support columns	
20.845							
	0.145	101 Support columns	201 Support columns	301 Support columns	401 Support columns	501 Support columns	
20.7							

Spent Fuel Pool – cavity model

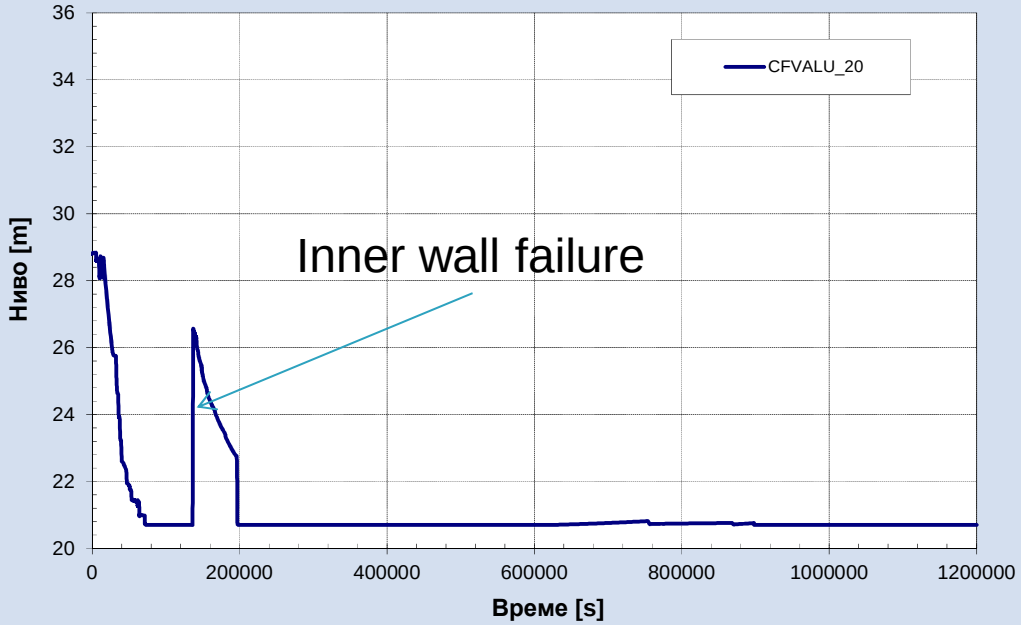
- Cavity 1 – volume of the smaller pool –volume CV488 connected to cavity 1 simulates ring 1 + bypass part
- Cavity 2 :
  - Represents partially volume of the bigger pool – same volume as for LP is used (CV020)
  - Spreading model of debris
- Dependent failure of the support structures in bigger pool is simulated based on the debris surface(CAV_ASURF)

Spent Fuel Pool – cavity model cont'd

- Cavity 3 – the containment rooms bellow SFP
- Cavity 4 – volume of the transport corridor - activates in case of transport hatch failure

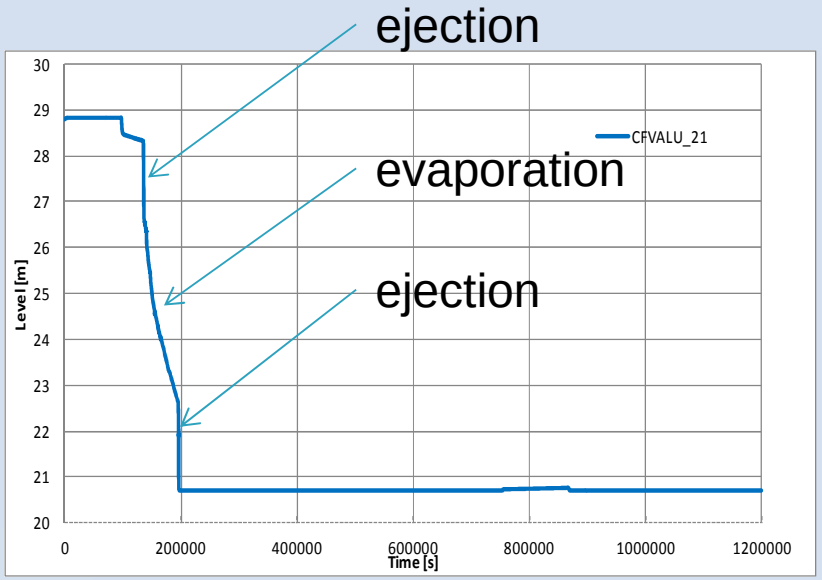


Spent Fuel Pool – results



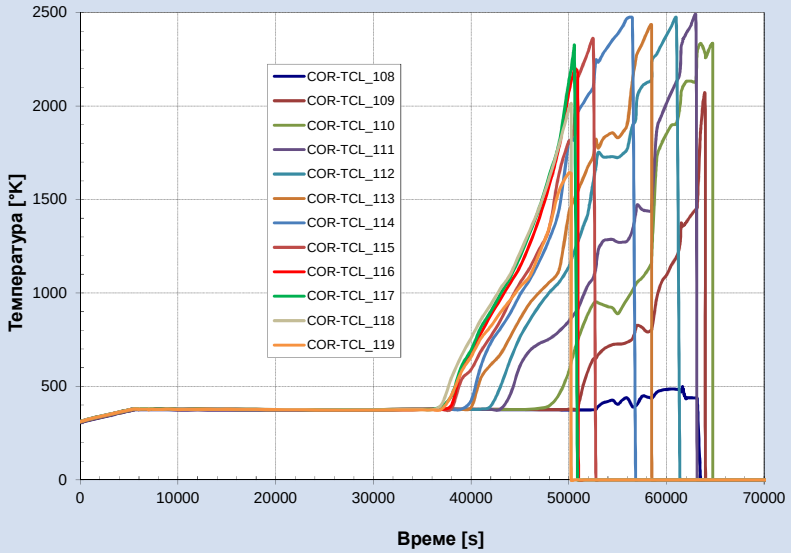
Water Level in smaller pool

- Water in smaller pool (ring 1) evaporates first
- Water in bigger pool is ejected after inner wall failure



Water Level in bigger pool

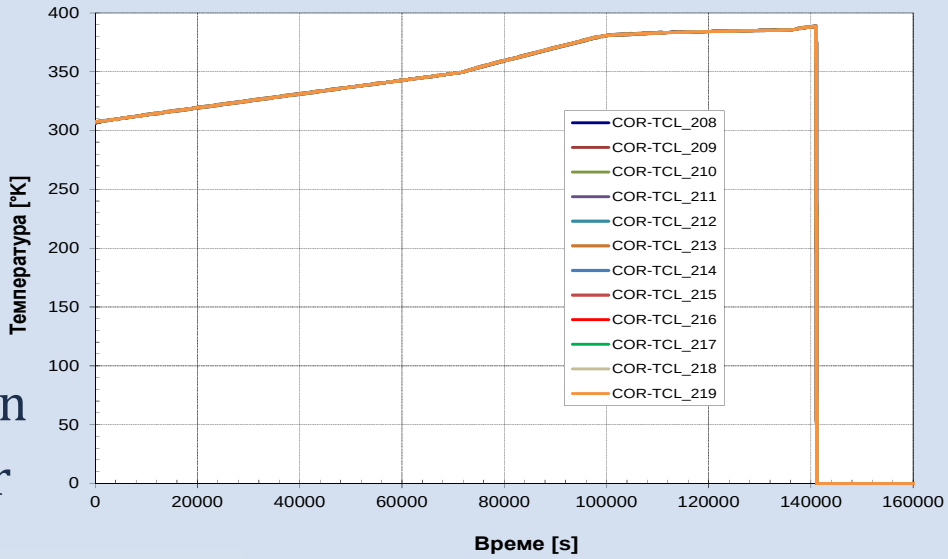
Spent Fuel Pool – results (contd.)



Clad temperatures in smaller pool

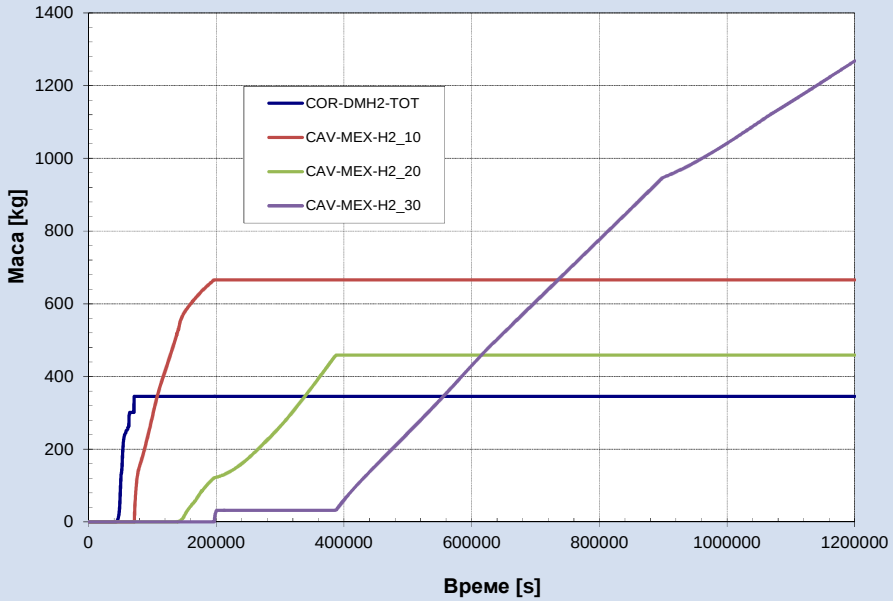
- Fuel assemblies in ring 1 (smaller pool) fails by temperature criterion
- Fuel assemblies in ring 2-4 (bigger pool) fails due to support column failure

Clad failure by CF actuation



Clad temperatures in bigger pool – ring 2

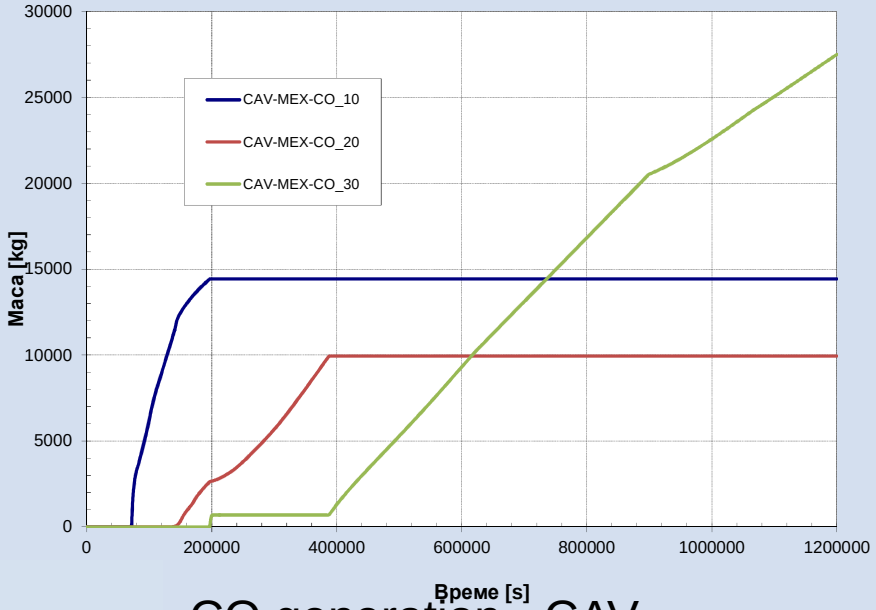
Spent Fuel Pool – results (contd.)



Hydrogen generation – COR and CAV

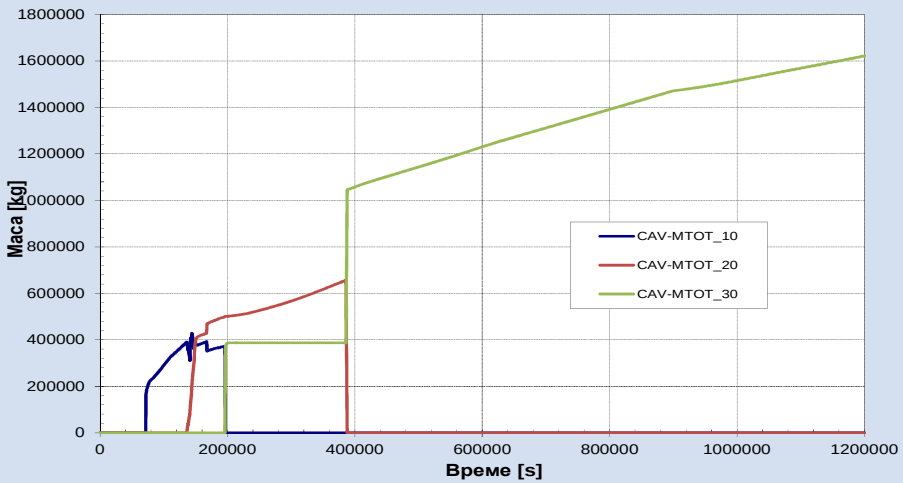
- Hydrogen generation is not significantly less than in reactor

- CO generation is an issue in KNPP due to concrete chemical composition



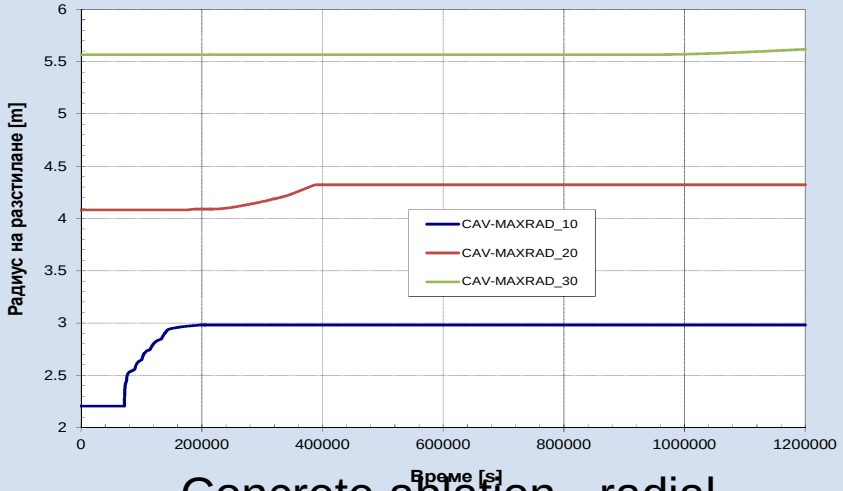
CO generation - CAV

Spent Fuel Pool – results (contd.)

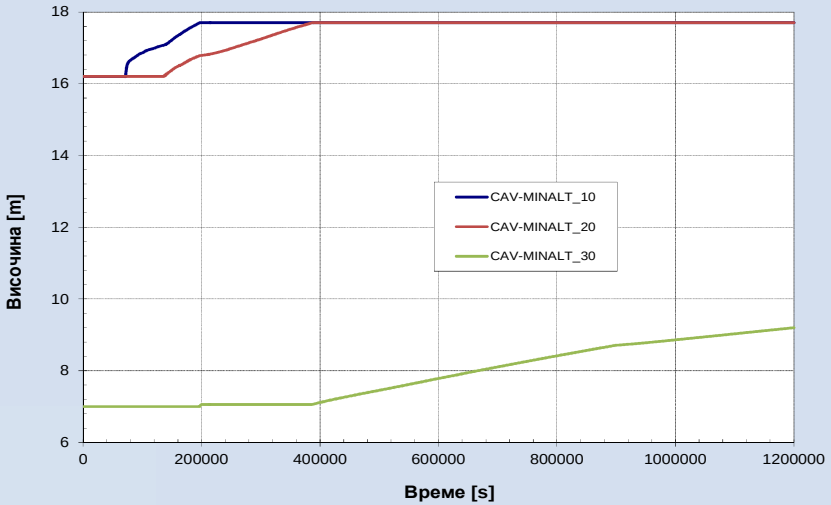


Debris mass in cavities

- SFP outer walls failure – about 2.3 days (55 hours)
- Very slow radial ablation – debris temperature is low (1540 K)

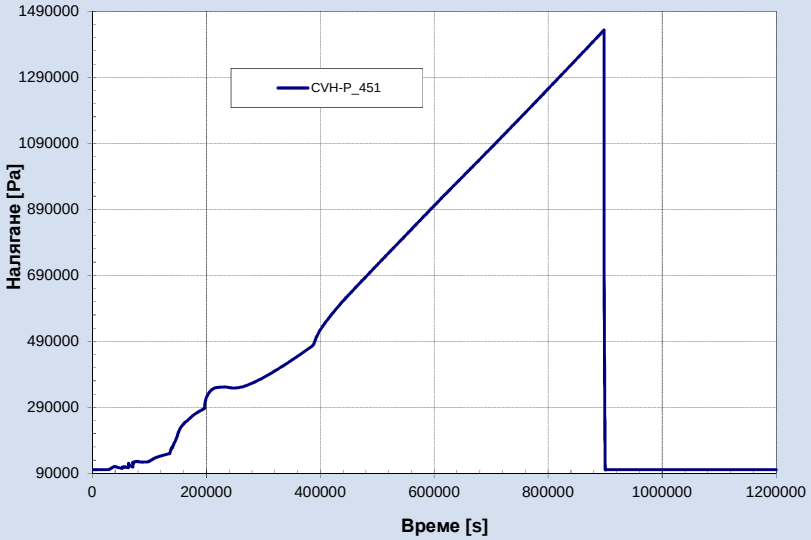


Concrete ablation - radial

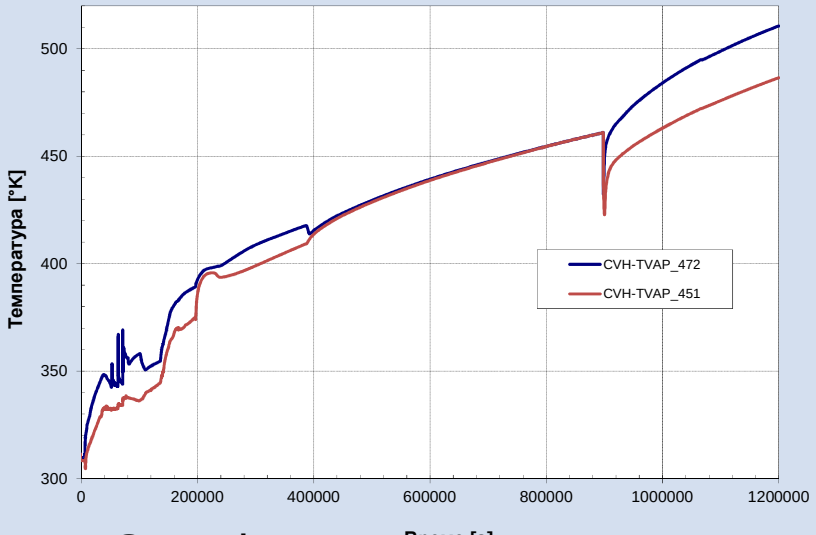


Concrete ablation - axial

Spent Fuel Pool – results (contd.)

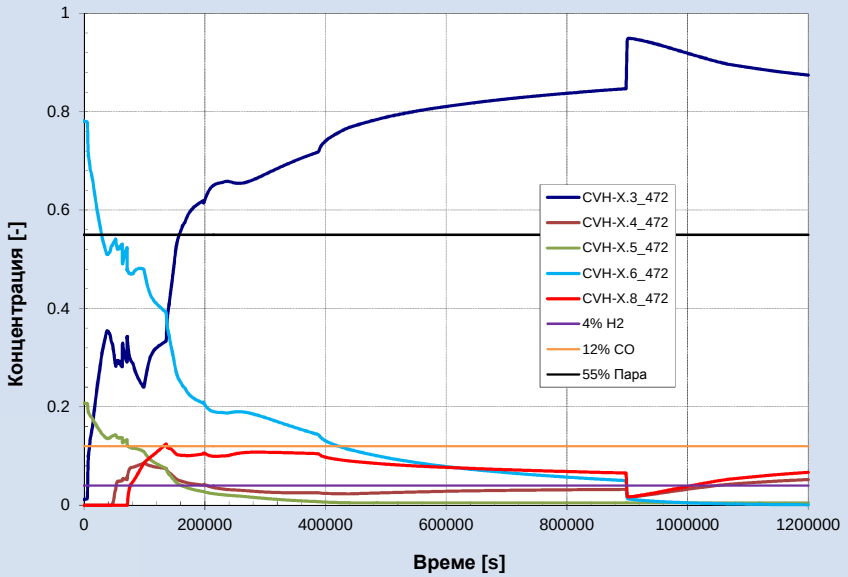


Containment pressure



Containment temperature

- Containment pressure meet failure criteria at 10.4 days
- Atmosphere temperature < 200 C
- Flammable gas concentrations – 41 hours after IE



Containment gas composition

Spent Fuel Pool – problems and questions

- ?WWER SFP are divided into 3 main pools (4-th one is for fresh fuel)
- ? Simulation of debris interaction with solid structures – after inner wall failure
- ? Non-supporting structures are forbidden for SFP-BWR
- B_4C oxidation problem– run failure (**bug 1088**)
- Cavity overfilled – overcome with time step change. This behaviour of the model stays unresolved

Example of cavity overfilled problem

TRANSFER PROCESS EDIT

NUMBER OF IN TRANSFER PROCESSES = 8

IN TP	NUMBER OF MASSES IN	NUMBER OF THERMO IN	H IN - H OUT (J)
101-A	6	9	-1.53237E+12
101-B	17	1	0.00000E+00
301-A	5	9	0.00000E+00
301-B	17	1	0.00000E+00
401-A	5	9	0.00000E+00
401-B	17	1	0.00000E+00
501-A	5	9	0.00000E+00
501-B	17	1	0.00000E+00

IN TP	MATL NUMBER	MASS IN - MASS OUT (KG)
101-A	1	0.00000E+00
	2	-4.52523E+05
	3	-8.46115E+05
	4	0.00000E+00
	5	0.00000E+00
	6	4.50940E+02

IN TP	MATL NUMBER	MASS IN - MASS OUT (KG)
101-B	1	-2.08897E+00
	2	-1.15161E+00
	3	-7.31975E+02
	4	-6.32131E-01
	5	-1.37216E+00
	6	-1.36156E+03
	7	-1.38686E+03
	8	-5.18548E+03
	9	-2.81536E+03
	10	-7.70171E+04
	11	-1.81261E-01
	12	-6.54818E+00
	13	0.00000E+00
	14	0.00000E+00
	15	0.00000E+00
	16	0.00000E+00
	17	0.00000E+00

The mass out is much more than mass in (MELCOR 4877 release)

CONTACT DETAILS

Headquarters:
10, Vihren str.
Sofia 1618
Bulgaria
Tel. + 359 2 8089 703
Fax: +359 2 9507 751
riskeng@riskeng.bg
www.riskeng.bg

THANK YOU!