

Spent Fuel Pool (SFP) Loss of Heat Sink Severe Accident calculated by MELCOR and GASFLOW

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- Introduction
- Accident sequences
- Calculation tools
- MELCOR results of activity release
- GASFLOW Flow pattern in case of open Spent Fuel Pool (SFP)
- Application of GASFLOW results to MELCOR



- MAIN GOAL: Provide SFP Severe Accident release data for PSA-1 and PSA-2
- INITIAL and BOUNDARY Conditions are the PSA-1 states

No	Description	Shutdown type	Decay power (kW)	Total water (m ³)
01	SFP full loaded	Full repair	3600	335
05	Regular (yearly) refueling	Regular	1600	160

- LIMITING cases will be analyzed
 - **1. SFP fully loaded (lower racks: 676 FA + a full core on upper racks)**
 - 5. Regular refueling (676 FA on lower racks incl. 78 freshly unloaded FA)

The Task



- Cases to be analysed
- SFP open or covered by concrete plates;
- SPF loading is full or regular;
- Ventilation state:
 - No ventilation in operation discharge to environment via the RHall
 - Ventilation path without filter via the stack
 - Ventilation path WITH FILTER via the stack
- ANALYSES PERFORMED
 Fully loaded SFP
 (676 FA lower racks + full core in upper racks
 GASFLOW flow pattern calculation for MELCOR Flowpath selection

Regular refueling (676 FA in lower racks incl. 78 freshly unloaded ones) MELCOR release calculations

MELCOR SFP Regular refueling – activity release



- MELCOR 1.8.6 used for loss of heat sink SFP accident
- CONDITIONS
- Decay power: 1604 kW
- 676 FA (78 freshly unloaded)
- 156 m3 water
- Time since shutdown: 345h
- Ventilation:
 - absent discharge to RH
 - Delivery from outside+ Discharge without filter via the stack
 - Delivery from outside+ Discharge WITH filter via the stack

MELCOR SFP model





- Concentric rings
 approach
- 7 fuel rings
- 8. ring is a downcomer

MELCOR Thermal hydraulic model





- SFP covered by concrete plates – release through the gap between the plates and or to ventilation path
- First the water heat-up then it boils away
- SFP SS platted concrete walls are modelled as CORE BOUNDARY HS

MELCOR CORE model

		HS	HS 60200	HS 60300	HS 60400	HS 60500	HS 60600	HS 60700	HS 60800	Î H	5601-60 eight 0.3	8			Bottom	Тор	Botton	Тор
		COR Node	COR Node	COR Node	COR Node	COR Node	COR Node	COR Node		node height m	e bott. m	node top m	Rad. HS					
41		141	241	341	441	541	641	741	841	1.67	13.40	15.07	141		13.1	14,77	20.70	22.37
40		140	240	340	440	540	640	740	840	6.08	7.320	13.4	140	-	7.02	13.10	14.62	20.70
39		139	239	339	439	539	639	739	839	0.177	7.143	7.320	139	-	6.84	7.02	14.44	14.62
38		138	238	338	438	538	638	738	838	0.125	7.014	7.143	198	-	6.71	6.84	14.31	14.44
37		137	237	337	437	537	637	737	837	0.20107	6.812	0.010	137		6.51	6.71	14.11	
36		136	236	336	436	536	636	736	836	0.20167	6.611	6.812	138		6.31	6.51	13.91	14.11
35		135	235	335	435	535	635	735	835	0.20167	6.409	6.611	135		6.11	6,31	13.71	13.91
34		134	234	334	434	534	634	734	834	0.20167	6.207	6.409	134		5.91	6.11	13.51	13.71
22		133	233	333	433	533	633	733	833	0.20167	6 006	6.207	133		5.71	5.91	12 21	13.51
			222	222	422	622	632	722	000	0.20167	6.000	6.006	992		5.52	5.74	10.01	13.31
32		132	232	332	432	332	632	132	832	0.20167	5.804	5.804	1000	-	5.50	5.71	13.10	13.10
31		131	231	331	431	531	631	731	831	0 20187	5.602	5 602	1310		5.30	5.50	12.90	12.90
30		130	230	330	430	530	630	730	830	0.20107	5.401	5.002	130	-	5.10	5.30	12.70	12.00
29		129	229	329	429	529	629	729	829	0.20107	5.199	0.401	129		4.90	5:10	12.50	12.70
28		128	228	328	428	528	628	728	828	0.20167	4.997	5.199	128		4.70	4.90	12.30	12.50
27		127	227	327	427	527	627	727	827	0.20167	4 796	4.997	127		4.50	4 70	12.10	12.30
-				0700		620	1026	7/20	0.20	0.20167	4 604	4.796	128		4.70	4.50	** 00	12.10
20		425	125	320	420	320	620	7/19	020	0.469	4.334	4.594	125	-	9.23	4,00	11.00	11.89
24		124	224	224	424	524	624	724	824	0.1	4.025	4.125	124	-	3.73	3.83	11 33	11.43
23		123	223	323	423	523	623	723	823	0.045	3.980	4.025	123		3.68	3.73	11.28	11.33
										0.485		3.980	E toto					11.28
													122					
22		122	222	322	422	522	622	722	822		3.495		1		3.20	3.68	10.80	
21	TopNozzle	121	221	321	421	521	621	721	821	0.1//	3.318	3.495	121		3.02	3.20	10.62	10.80
20		4.90		970		620		7/70	020	0.129	2 400	3.318	120	-	2.00	2.02	10.40	10.62
20									920	0.20167	9.100	3,189	a series and		2.00	5.02	10.40	10.49
19	Fuel 12	• 119	· 219	1 319	• 419	• 519	• 619	• 719	, 819		2.987		193		2.69	2.89	10.29	
18		118	1 218	• 318	• 418	• 518	• 618	• 718	. 818	0.20107	2.788	2.3874	118		2.49	2.69	10.09	10.29
17		, 117	, 217	, 317	417	, 517	. 617	. 717	. 817	0.20167	2.584	2.7857	117		2.28	2.49	9.88	10.09
16		. 116	. 216	. 316	. 416	. 516	. 616	. 716	. 816	0.20167	2.382	2.584	116		2.08	2.28	9.68	9.88
15	Puers -	115	215	345	. 415	515	615	745	815	0.20167	2 404	2.3824	115		1.00	2.00	0 40	9.68
	Fuel 8					544		744		0.20167		2.1807	14.6		1.00	2.00	0.10	9.48
14	Fuel 7	1111 1 114	. 214	, 314	414	. 314	. 614	• /14	614	0.20167	1.979	1.979	Carlo Da		1.68	1.88	9.28	9.28
13	Fuel 6	113	,213	313	.413	513	_613	713	813	0.20187	1.777	17774			1.48	1.68	9.08	0.00
12	Puel Part	112	212	312	412	512	612	712	812	0.20101	1.576	LITT	112		1.28	1.48	8.88	3.00
11		111	211	311	411	511	611	711	811	0.20167	1.374	1.5757	111	COR	1.07	1.28	8.67	8.88
10		110	210	310	410	510	610	710	810	0.20167	1.172	1.374	110		0.87	1.07	8.47	8.67
9	Fuel 3	105	209	009	409	509	609	209	ens	0.20167	0.971	1.1723	108		0.67	0.87	8.27	8.47
	Fuel 2		-	HIGHHAN	-		-		+++++++++++++++++++++++++++++++++++++++	0.20167		0.9707	108		0.480	0.97*	0.07	8.27
7	Fuel turner	108	208	368	408	507	508	708	808	0.009	0.763	0.769	107		0.409	0.449	8.080	8.069
										0.016		0.760	and			a. red	0.000	8.060
6			206	306	406	596	806	706	806	0 222	0.744	0.744	100		0.444	0.460	8.044	8 044
9	inset +	105	205	505 204	405	505	605	705	805	0.222	0.522	0.5	100		0.222	0.22	7.822	7.822
34/1		103	203	303	403	503	603	703	803	0.1	8.2	0.3	103	1	0.00	Viat	7.50	7.60
2	Inlat	102	202	302	402	502	602	702	802	0.1	u.t	0.2		4			7.40	7.50
1	une:	101	201	301	401	501	601	701	801	0.1	8	0.1	C.R.A	-	Referer	ice cells	7.30	7.40
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- SFP interpreted as a core
- Calculations up to SFP bottom liner failure

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- Charging + discharge ventilation without filter
- Charging + discharge
 ventilation WITH filter
- Vent ducts modelled with CVs FL and HS
- Filter capacity (default DF):
 - Aerosols: 1000
 - Vapor:100

MELCOR Thermalhidraulics: typical results



SFP walls and ceiling	SFP phases	Time,h	Time,h
	Initial event (loss of heat sink)		0
	Upper pool saturated		12.3
	Top fuel uncovery		55.4
	FA exit temperature over 550C		71.7
	Water level below 1m		73.5
SFP concrete cover plates over			
1273K		86.6	
	Ring1 Zr-H2O reaction		74.5
	Ring1 gap release		74.7
	FA bottom dry		83.1
SFP wall>1273K		86.3	
	Ring1 lower support plate fails		91.1
	Ring1 lower support plate melts		91.5
	SFP bottom steel liner fails		93.9
	Lower pool dry-out		101.2

Preparations for SFP without cover but with ,,air curtain"



No	Task	Cover	Charge	Configuration
		NO		RH
10.	SFP FP release		Full/Regular	Vent without filtration
				Vent with filtration
		NO		RH
11.	SFP FP release		Full/Regular	Vent without filtration
				Vent with filtration
	SFP FP release	NO	Full/Regular	RH
12.				Vent without filtration
				Vent with filtration

Problems with FP release interpretation NUBIK

NG release fraction to environment is smaller than that of CsI

Results show that fraction of NG remains in fuel

however no intact fuel remains in the core



GASFLOW calculations for SFP with ,,air curtain" to prepare MELCOR input data

GASFLOW model





Calculation procedure



Goal: Determine the fraction of boil-away flow directed to RH despite the "air curtain" at SFP water level



- Steam source from SFP:
 - From -200s: evaporation 11.8 g/s steam
 - 200s-400s boil-away: 1595 g/s (266 g/s), 100°C
 - 400s- : reduced g/s superheated steam
 - 600s- : 1% NG to avoid condensation effect
 - 1000 s- : after initial transient the NG discharged to RH linearly increases
 - Determination of fraction to RH: Rate of mass increase dischaged to RH related to massrate at SFP water level exit



Ventilation states

- Discharge by ventilation without filters, air curtain injects to RH
- Discharge by ventilation without filters, No air curtain
- Discharge by ventilation WITH filters, air curtain injects to RH
- Discharge by ventilation WITH filters, NO air curtain

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SFP state

- a. Fully loaded
- b. Regular refueling

General results

Current x-z pia



- During evaporation air curtain prevents steam discharge to RH from SFP
- Hot boil-away steam breaks the air curtain -



Qualitative results





- "air curtain" suck-away results in a suction of air from RH to SFP
- At the same time there is a outward flow at SFP top to the RH

