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Сравнителен анализ на тежка авария LOCA Dy100 за ВВЕР1000-В320 изчислена с ASTEC V1.1 и SCDAP/RELAP5

Comparative Severe Accident Analysis of VVER1000-B320 LOCA DN100 computed by ASTEC V1.1 and SCDAP/RELAP5

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1 Introduction

This paper presents the modeling approach for LOCA 100mm sequence for VVER1000-B320 type of reactor with the integral ASTEC computer code and SCDAP/RELAP5 computer code.

As a basic input deck the reference input file for Balakovo NPP from the released ASTEC CD, June 2004 has been applied. As a first part of the calculations for the SBLOCA sequence the ASTEC v1.1 modules CESAR, DIVA and CPA have been activated in a coupled mode.

For SCDAP/RELAP5 calculation input deck for VVER1000-B320 has been applied which meant to be closer to the initial boundary conditions applied for ASTEC VVER1000 input deck.

2 Input data, availability and functioning of the systems

Table 2.1 presents the initial state of reactor system.

Table 2.1

No	Parameters	ASTEC Value	SCDAP/RELAP5
1	Core power, MW	3000	3000
2	Primary pressure, MPa	15.7	15.7
3	Average coolant temperature at reactor outlet, °C	320.55	318.2
4	Maximal coolant temperature at reactor inlet, °C	290.35	286.7
5	Mass flow rate through one loop, kg/s	4363.1	4460
6	Pressure in SG, MPa	6.418	6.21
7	Pressure in MSH, MP	6.38	6.6
8	Steam mass flow rate through SG, kg/s	409.6	409.6

The main events according to SBLOCA sequence for VVER 1000 are:

1/ 0s: opening of the break, scram, stop of pumps
2/ 10s: turbine isolation
3/ 10s: loss of FWSGs
4/ 135s: spray system in direct mode

3 Modeling assumptions

3.1 Short description of ASTEC V1.1:

For the LOCA sequence calculation the ASTEC v1 modules CESAR, DIVA and CPA have been activated in a coupled mode.

Firstly, there appeared several questions around FPs release (in SOPHAEROS module). The code seemed not to complete the initialization phase. There appeared a problem in calculation of the temperature around 4375s of the transient. So then the focus was just on the rest three modules- CESAR, DIVA and CPA.

Four Main cooling pumps are modeled. The pumps' hydraulic torque is set to 47500J.rad. The reference volume flow rate is 4363kg/s. Four BRU-A with a maximum section of 0.0225m^2 are modeled. The pressure threshold for break opening is 7.16MPa and the pressure threshold for break closing is 6.13MPa. The initial pressure in the accumulator is 5.89MPa. The containment is separated into 5 volumes (the last one is the environment).

The break is modeled on the cold leg of the reactor with a break section of 100mm.

3.2 Short description of reactor-WWER-1000 nodalization model for SCDAP/RELAP5

The more important features of the model are as follows:
Primary side is presented with four different loops.
The core region is presented by two components. The first presents the hottest fuel assembly and the second presents the other 162 fuel assembly. Each of the components are axially divided into 10 parts.

The reactor downcomer is separated into four regions, each of them connected to one cold leg. Cross-flow junctions allow azimuthally flow among the regions.

The pressurizer is connected to loop No4 through the surge line and loop No1 through the spray line.

The CCFL is modeled at the surge line junction to the pressurizer.

The full ECCS system and its injecting points are modeled including HPIS, LPIS and HA characteristics (number of pumps and their flow rate capacity as a function of primary pressure, systems actuation set points and delay, temperature of injected water, pumps tanks water volume etc.) as designed.

The SG secondary side arrangement takes into account the tube bundle water regions, the volume including the water level above tubing, the SG collectors, the steam dome and the internal downcomer. The side volumes between the heat exchanger tubes and boiler walls are added to allow recirculation in the model. These downcomer volumes also enable circulation inside the tube bundle volumes and in the side regions. The junctions between the tube bundle volumes and side volumes are cross flow type.

SG – tube bundle is represented as 5 stack volumes at the height (5 layers).Horizontal tube bundle is divided into 2 major parts (to account for hot and cold collector). Each of these parts is subdivided into 8 volumes at its length.

The steam lines and main steam header are modeled according to their real lay out.

4 Results

4.1 ASTEC V1.1-p2 SBLOCA 100mm

Table 4.1.1

No	Event	SBLOCA 100 +RADL Time, s
1	Opening of break with D =100 mm- cold leg	0.0
2	Reactor scram	0.0
3	MCP are switched off	0.0
4	Turbine stop valves (TSV) are closed	11.2

5	Start of coolant injection by hydro-accumulators	90.3
6	Beginning of oxidation	2547.0
7	Start of FP release from fuel pellets	3848.0
8	First total core uncovery	4527.0
9	First corium slump	5094.0
10	Lower head vessel failure	15620.0
11	End of transient	20000.0

On the following figures (Figure 1 to 16 odd numbers) are presented the graphical results for LOCA 100mm with Hydroaccumulators injection calculation with the ASTEC code. For the first seconds of the transient calculation the primary pressure starts rapidly to decrease due to the initiating event- loss of coolant through the break. A plateau could be observed around 900-1200s. This is the moment of primary and secondary coupling. On Figure 3 could be seen the behaviour of the secondary side. Reactor inlet and outlet temperatures (Figures 5 and 7) are decreasing and around ~2400s a constant value could be observed after 5000s for the next 3000s. The beginning of oxidation is started at 2547s, also the core uncovery. At 5000s a decrease and immediately rapid increase is detected in reactor outlet temperature- this is the time of large corium slumping. The start of fission products release from the fuel pellets is detected around 3848s of the transient. The lower head vessel failure is reached at 15620s. The cumulated hydrogen mass is around 234kg (Figure 15).

4.2 SCDAP/RELAP5 SBLOCA 100mm

Table 4.2.1

No	Event	SCDAP/RELAP5 Time, s
1	Opening of break with ID =30 mm in cold leg	0.0
2	Reactor scram	0.0
3	MCP are switched off	0.0
4	Turbine stop valves (TSV) are closed	15.0
5	First core uncovery	3300.0 (voiding at core upper part)
6	Beginning of oxidation	4314.0
7	Start of FP release from fuel pellets	4420.0
8	First corium slump	4664.0

10	Lower head vessel failure	n/a
11	End of transient	5600.0

The main events are shown in table 4.2.1. For the first ~240s the primary pressure start to decrease due to two main reasons: the fist one is the initial event loss of coolant from primary circuit and the second one is removed heat through steam generators (Figure 2). Between 240 and 600 seconds increase op primary pressure is observed. The reason of this increase is that removed heat from break is not enough to compensate the decay heat and the heat coming from steam generators. At ~610 second two phase fluid with gas fraction more than 60 % start to release through break (figure 10). Now removed heat through break is enough to compensate the decay heat and SG “heating” and primary pressure start to decrease. At 1000 second primary pressure reach 6 MPa and safety injection system start to inject coolant in primary circuit. This leads to faster primary pressure decrease and to reaching of saturation temperature of primary coolant. At ~4314 second condition for zirconium oxidation by steam appears (figure 14). Generated hydrogen is 100 kg. (figure 16). At 5220s molten material appear due to UO2 dissolution by liquid zircaloy and melting of UO2. The calculation was terminating after penetration of molten material in lower head at 5600 second.

5 Conclusions

A SBLOCA 100mm comparison between ASTEC v1.1 and SCADAP/RELAP5 has been presented.

ASTEC predicts vessel failure at 15620s. ASTEC and SCDAP/RELAP5 give close but not similar results- this could be observed on the trends. The comparison of 100mm-break shows that SCDAP/RELAP5 predicts clear phenomenological changes in primary pressure evolution and molten pool formation. Similar hydrogen production mass for both codes around 5000s is detected.

6 References

1. ASTEC input deck for VVER 1000, IRSN, June 2004.

2. ASTEC Guidelines, IRSN, 2003.

3. P. Chatelard, F. Fichot, M. Barrachin, V. Guillard, S. Mélis, M. Zabiégo, B. Lefèvre ICARE/CATHARE : A computer code for analysis of severe accidents in LWRs , Release Guide and User's Manual Note technique DRS/SEMAR 00/01 and 00/02 (June, 2000)

4. SCDAP/RELAP5/MOD3.2 Code Manual Volume III: User's Guide and Input Manual NUREG/CR-6150

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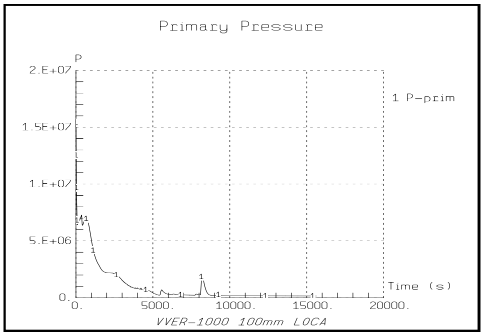

Figure 1 ASTEC LOCA 100 Primary pressure

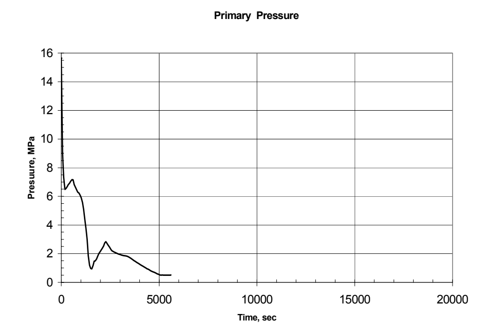

Figure 2 SCDAP/R5 LOCA 100 Primary pressure

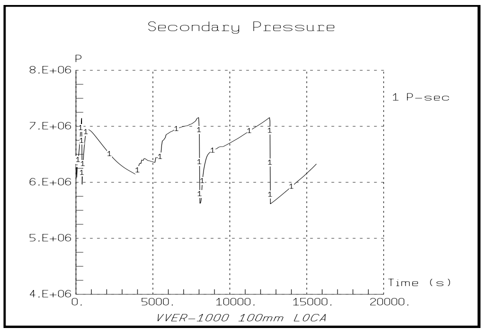

Figure 3 ASTEC LOCA 100 Secondary pressure

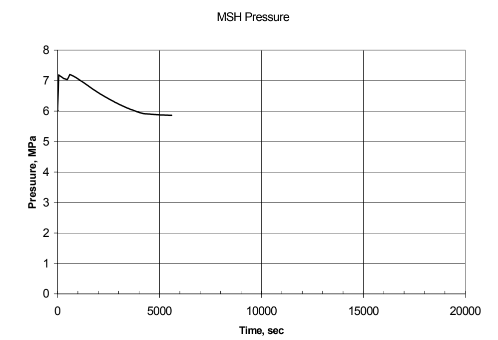

Figure 4 SCDAP/R5 LOCA 100 Secondary pressure

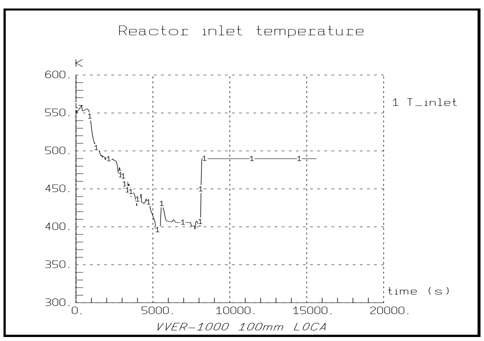

Figure 5 ASTEC LOCA 100 Reactor inlet temperature

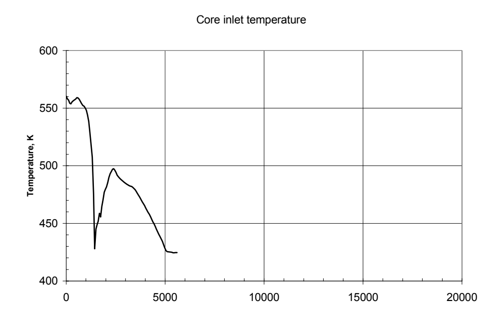

Figure 6 SCDAP/R5 LOCA 100 Reactor inlet temperature

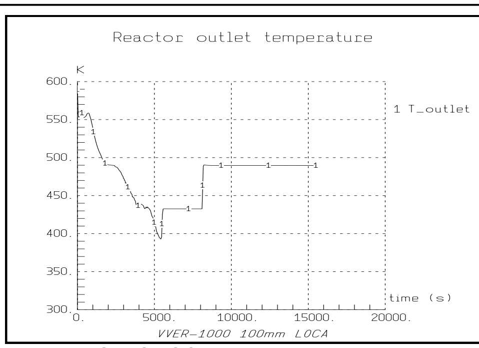

Figure 7 ASTEC LOCA 100 Reactor outlet temperature

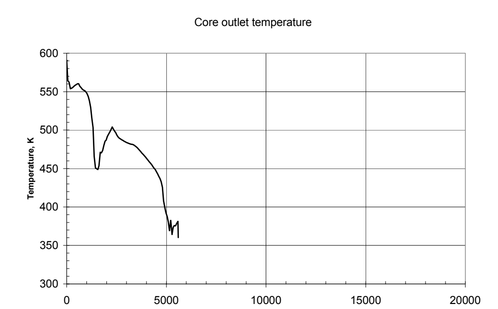

Figure 8 SCDAP/R5 LOCA 100 Reactor outlet temperature

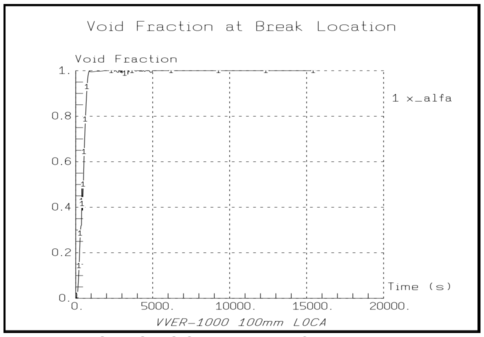

Figure 9 ASTEC LOCA 100 Void fraction at break location

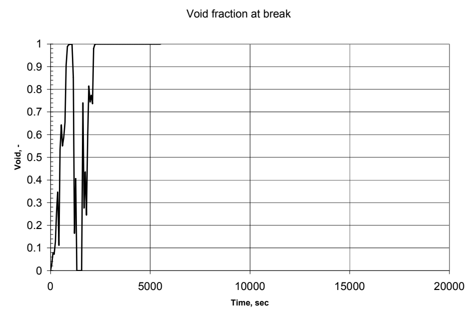

Figure 10 SCDAP/R5 LOCA 100 Void fraction at break location

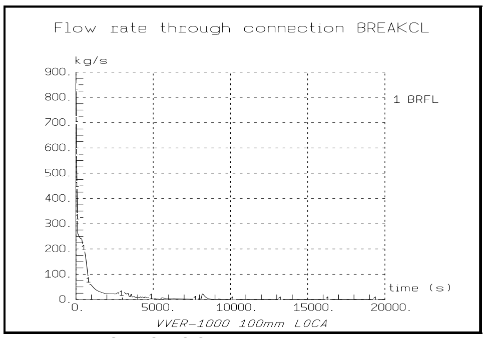

Figure 11 ASTEC LOCA 100 Flow rate through connection BREAKCL

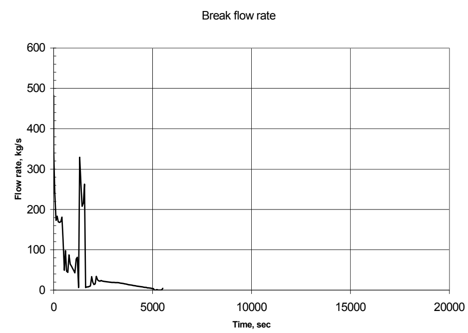

Figure 12 SCDAP/R5 LOCA 100 Break flow rate

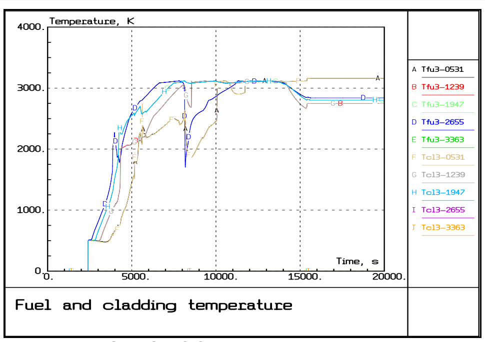

Figure 13 ASTEC LOCA 100 Fuel and cladding temperature

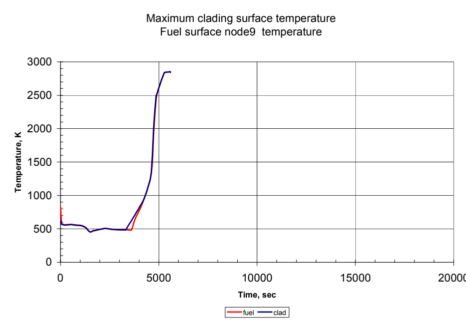

Figure 14 SCDAP/R5 LOCA 100 Fuel and cladding temperature

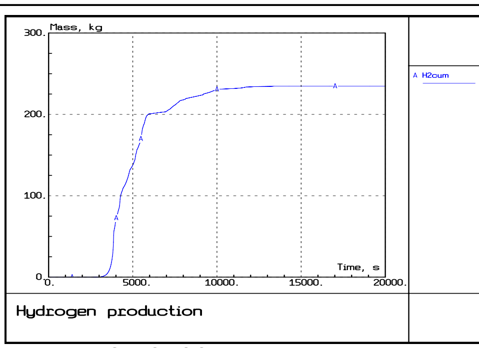

Figure 15 ASTEC LOCA 100 Hydrogen production

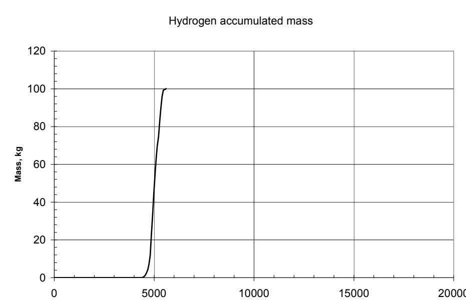

Figure 16 SCDAP/R5 LOCA 100 Hydrogen production