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# **BUBBLE CONDENSER EXPERIMENTAL QUALIFICATION PROJECT AND CONSEQUENCES**

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**Sixth International Information Exchange Forum  
on Safety Analysis for NPP of VVER and RBMK Types  
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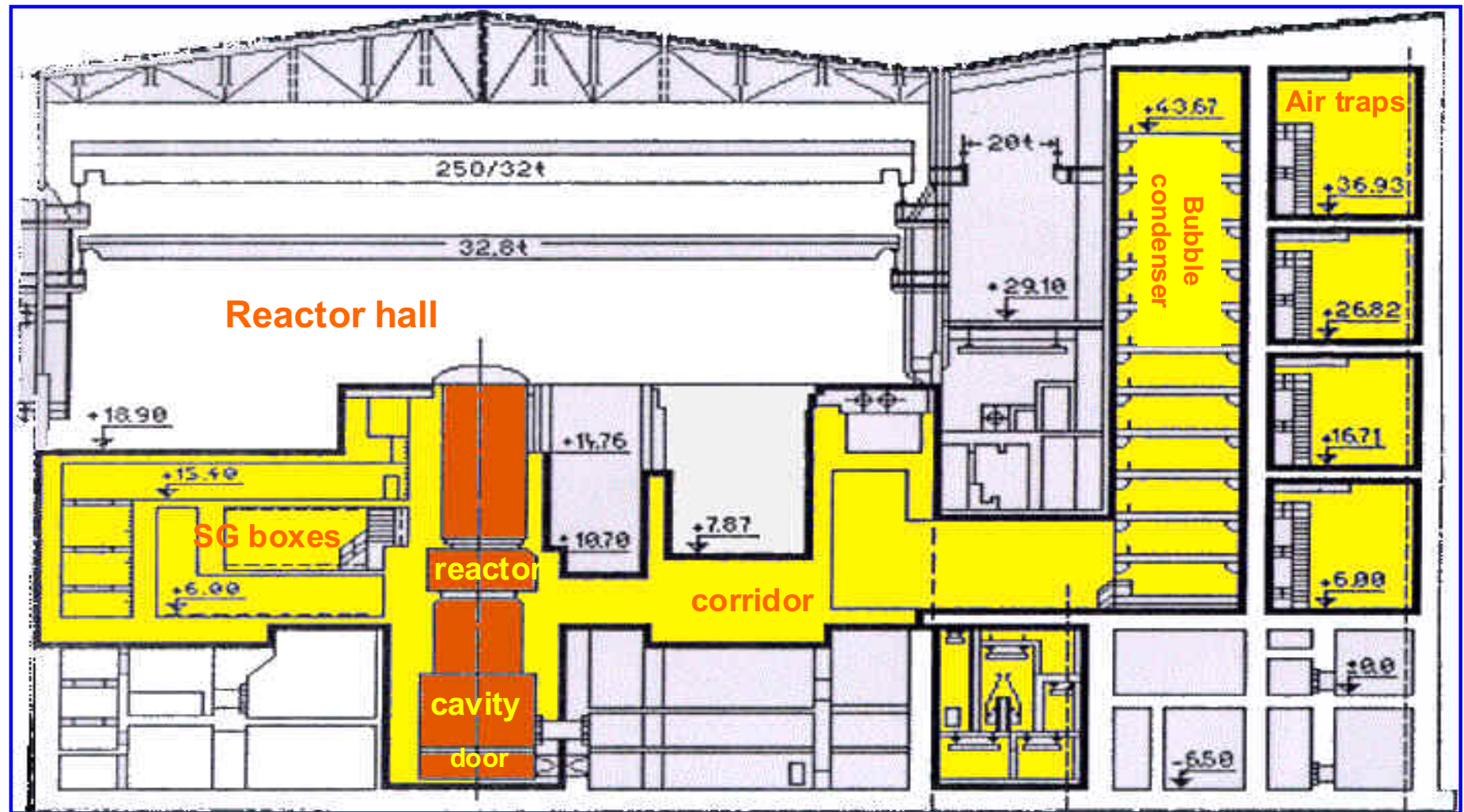


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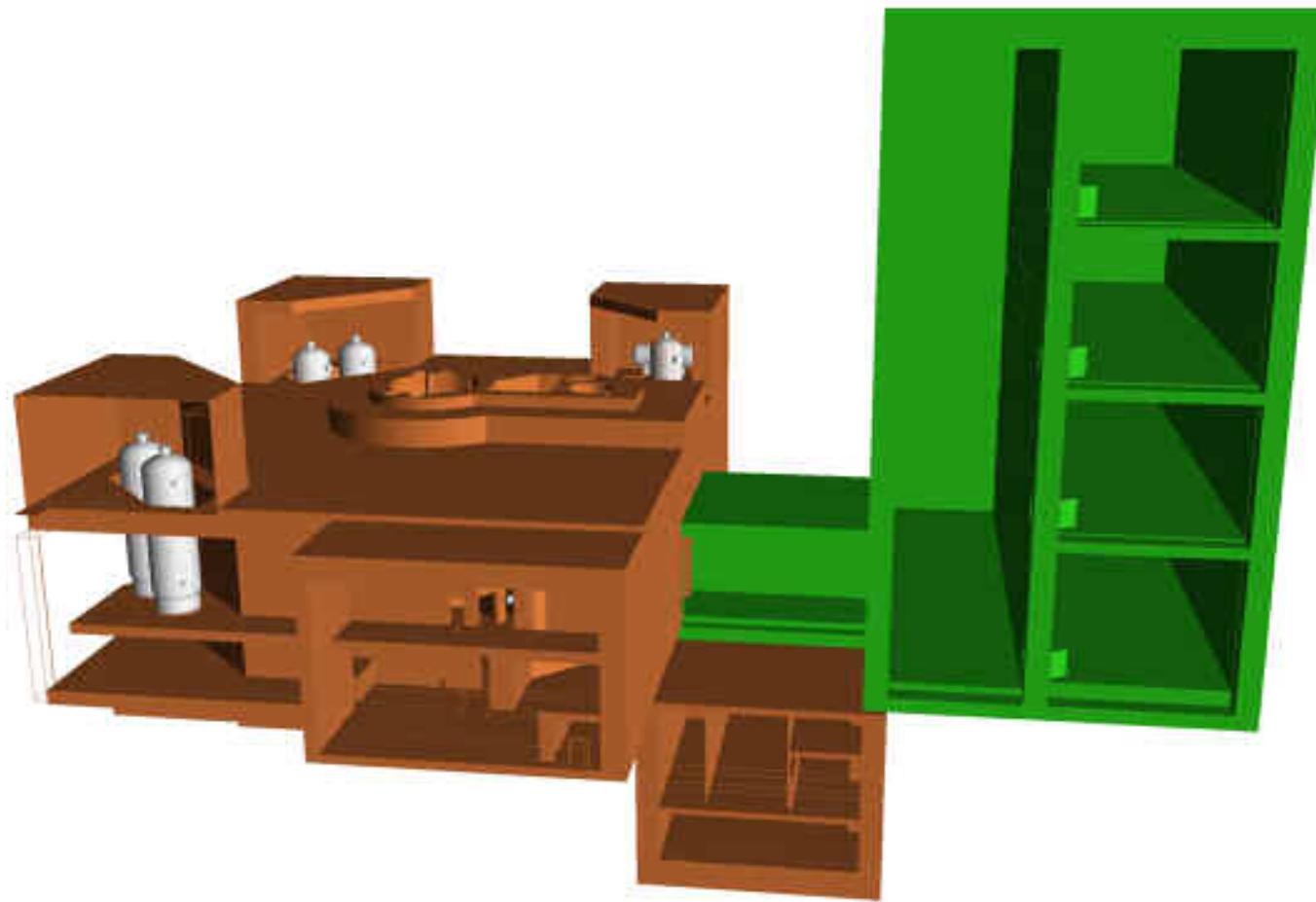


## CONTAINMENT BUILDING WITH THE BUBBLE CONDENSER





## 3D MODELL OF HERMETIC ZONE





## 1. PRELIMINARIES AND HISTORY OF THE BUBBLE CONDENSER EXPERIMENTAL QUALIFICATION (BCEQ) PROJECT

1991-94: OECD Support Group on VVER-440 BC Containment Research Work → supplementary research work needed.

1994: EC launched the PHARE project (NUC 93428) BC Qualification Feasibility Study, completed in early 1996 → need for additional research.

1996: PHARE project PH2.13/95 for BCEQ launched.

1997: BCEQ awarded to a Consortium consisting of Siemens/KWU, EdF and Empresarios Agrupados. As local eastern subcontractors

- EREC (Moscow, Russia)
- VUEZ (Levice, Slovak Republic)
- SVUSS (Bechovice, Czech Republic) selected.



- 1998: Start of the construction of the EREC facility.
- 1999: EREC test facility ready in June, with 7 months delay.
- 1999: 3 tests performed in September-October, Users team and TAC meeting → Final report in December.
- 2000: Berlin meeting of the OECD group and TAC. Significant differences in opinions.

## 2. SPECIFIC GOALS OF THE PHARE PROJECT

To provide for NPPs of the Beneficiaries:

- representativeness of the results for all BC “operating conditions” (LOCA conditions)
- adequacy and representativeness of the results for concerned national Safety Authorities
- general suitability of experimental results for code validation and assessment.



### **3. TASKS OF THE PHARE PROJECT**

- 3.1. To study thermohydraulic processes and fluid structure interactions for prototype BC of Paks NPP during DBA transients (on EREC large-scale test facility).
- 3.2. Experimental qualification of BC mechanical structures, specifically for Dukovany and Bohunice structural configuration (on VUEZ small-scale test facility).
- 3.3. Supplementary analytical studies requested from SVUSS in Prague, NRI (Czech R.) and VEIKI (Budapest, Hungary).

### **4. RESULTS OF THE PHARE PROJECT**

Project completed with the following observations:

- not all foreseen experiments, but the maximal ones were done
- post-test evaluation: BC functions confirmed for max. DBA case.



## 4.1. EREC investigations

3 LBLOCA test simulated Paks NPP performed:

- Test No.1: integral performance of LBLOCA
- Test No.4. initial phase of LBLOCA with higher steam content
- Test No. 5: initial phase of LBLOCA with higher air content.

Tests demonstrated that the max. pressure in the boxes and pressure difference over the BC lower than predicted:  $\Delta p_{mes.}(22 \text{ kPa}) < \Delta p_{limit}(30 \text{ kPa})$ .  
→ BC functionality and the physical parameters are far below the values, which could create any risk to the BC → Results are relevant for Dukovany and Bohunice NPP.

## 4.2. VUEZ investigations

Integrity of gap-cap systems and their capacities to withstand the requested differential pressure up to 30 kPa without loss of integrity demonstrated. Non-destructive examinations of the welds performed after the test did not indicate the existence of cracks.



Pre-test structure-dynamic calculation results were in good agreement to the measured values. Under the conditions of the performed experiments no leaks occurred.

### 4.3. Analytical studies

OECD group on Berlin-meeting recommended to perform further post-test calculations and to carry out further tests. Critical remarks were that post-test analyses not completed and extended discussion needed concerning:

- non-uniformities in temperature and flow velocity distributions
- differences in values of  $dp$  between test and calculation
- assessment of conservatism (test facility  $\leftrightarrow$  real BC).

In October 2000 VEIKI performed detailed post-test calculations. This work made by GASFLOW 3D computational fluid dynamics (CDF) code, which facilitated the development of detailed nodalization for the CONTAIN code.  
→ First two critical remarks made by OECD group have been answered.



## 5. PRESENT STATUS OF BC PROBLEM

### *4 questions asked by HAEA should be answered:*

Q1: Only 3 LBLOCA tests performed - Whether any additional tests are needed?

A1: Yes. To perform additional test has been decided 4-plant co-operation (Paks, EBO, EMO and EDU) on the common budget. 3 additional tests proposed.

Q2: Scaling of energy discharge rate and its effects – Are we on the conservative side or not?

A2: Before the new tests the heat-balance-issue should be closed by EREC report. Clarification of the blow-down flow rate problem (VTI tube measurement on EREC test-facility) remained to be solved.

Q3: Interpretation and relevance of unexpected uniformities in temperature and velocity distributions – Could GASFLOW 3D calculations convince experts?

A3: Yes. GASFLOW calculations made by VEIKI have solved the problem of pressure differences using a specific input, which is able to model the elastic compression of the BC walls and corresponding internal pressure rise.

Q4: Conservatism of test conditions of EREC facility should be proved.

A4: Integration of relevant international activities and consensus of experts is needed!



## 5.1. International activities

EU Council Report – Nuclear Safety in the Context of Enlargement (June 2001). Regarding BC systems Council Report emphasizes completing regulatory review – full verification of the performance of BC system for all design basis accidents:

- PHARE support to the NRA of the Candidate Countries – new TSO Project started.
- OECD NEA Steering Committee for Nuclear Energy – BC Steering Group with Operating Agents (NPPs) formed.

Final aim: to establish clear relationship between numerical results and regulatory requirements on containment function until the end of 2003.

Steering Group meetings: - 1. meeting in Paris (November 2001)  
- 2. meeting in Budapest (March 2002).

→ After BP-meeting the SG agreed that VEIKI post-test calculations have provided a satisfactory answer to the issue of non-uniformities of temperature and flow distributions observed in the experiments.



## 5.2. New trilateral (SL, CZ, HU) project

1. Meeting: Paks NPP, Hungary, August 2001 (EDU, EMO, EBO, Paks)  
→ proposal for scope of the test: 1 MSLB and 2 MBLOCA scenarios.  
→ agreement on the price and on the schedule.
2. Meeting: Bohunice, Slovakia, February 2002 (EDU, EMO, EBO, Paks, VUJE Tnava, NRI Rez)  
→ agreement on scope of the test and distribution of analytical work:

### Pre-test analyses

Transient	Plant calculations		EREC Test Facility calc.	
	Blow down	Containment*	Blow down	Containment*
MSLB	PAKS	ALL	EREC	ALL
MB LOCA	EDU	ALL	EREC	ALL
SB LOCA	EBO, EMO	ALL	EREC	ALL

\* Institutions (VUJE, NRI, VEIKI) will use for calculations own containment codes (TRACO, DRACYS, CONTAIN).



## Post-test analyses

		EREC Test Facility Calculations	
Transient	Responsibility	Blow-down corrected with the measured data**	Containment
MSLB	PAKS	EREC	ALL
MB LOCA	EDU	EREC	ALL
SB LOCA	EBO, EMO	EREC	ALL

\*\* Some modifications in the instrumentation (relocation and adding of a few new sensors) would improve the outcome of the further tests significantly.

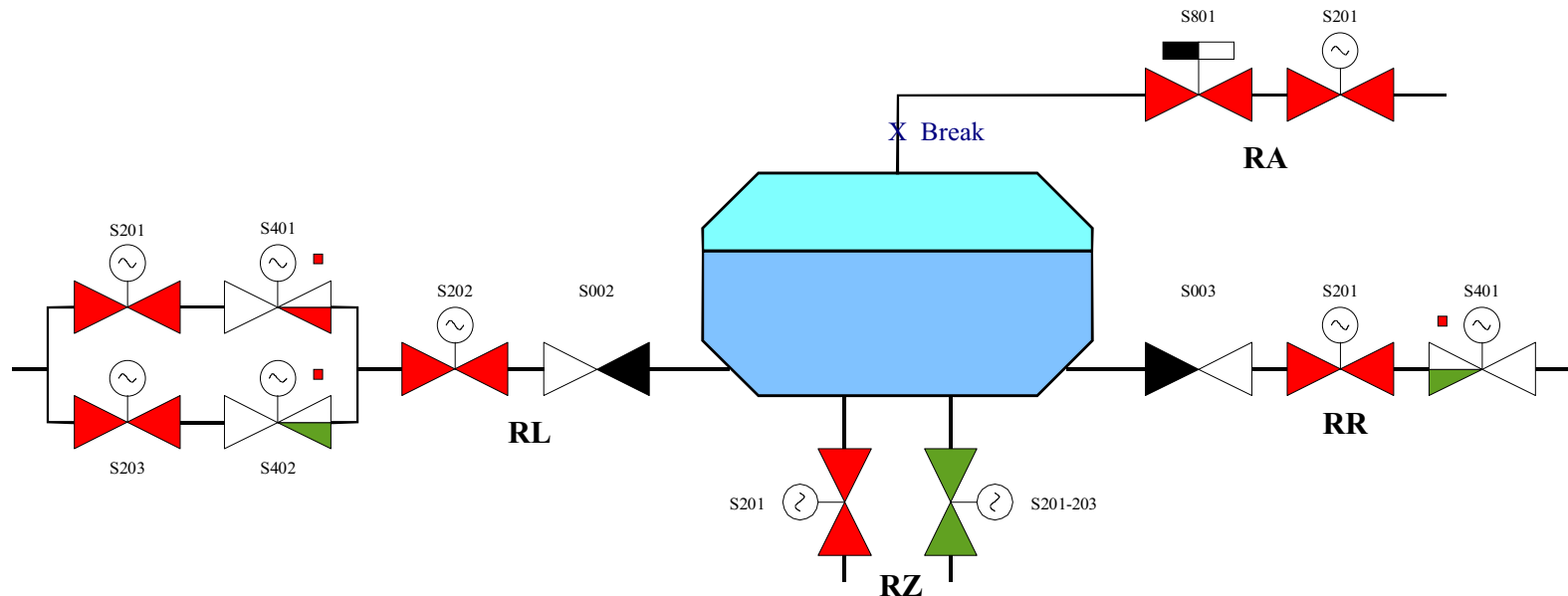
3. Meeting: Budapest, Hungary, February 2002 (EDU, EMO, EBO, Paks, VUJE Tnava, NRI Rez, VEIKI)
  - agreement on scenarios planned to be tested and finalisation of them
  - specification of the test boundary conditions
  - discussion about Trilateral Contract and Appendixes.



## MSLB:

Scenario has been investigated by Paks NPP. Calculated 4 cases with APROS 5.01 code using maximum possible breaksize and different combination of failure of steam line and feedwater line isolation valves, after “ $dp > 5$  bar” signal actuation.

→ To get a significant blowdown effect to the containment during this type of accident should be assumed anyway simultaneous failure of 2 valves. Specific PSA calculations gave results about frequency of particular consequence for each case. The most frequent case - steam line isolated and feedwater line remained opened on the faulted SG – have been chosen to be tested.





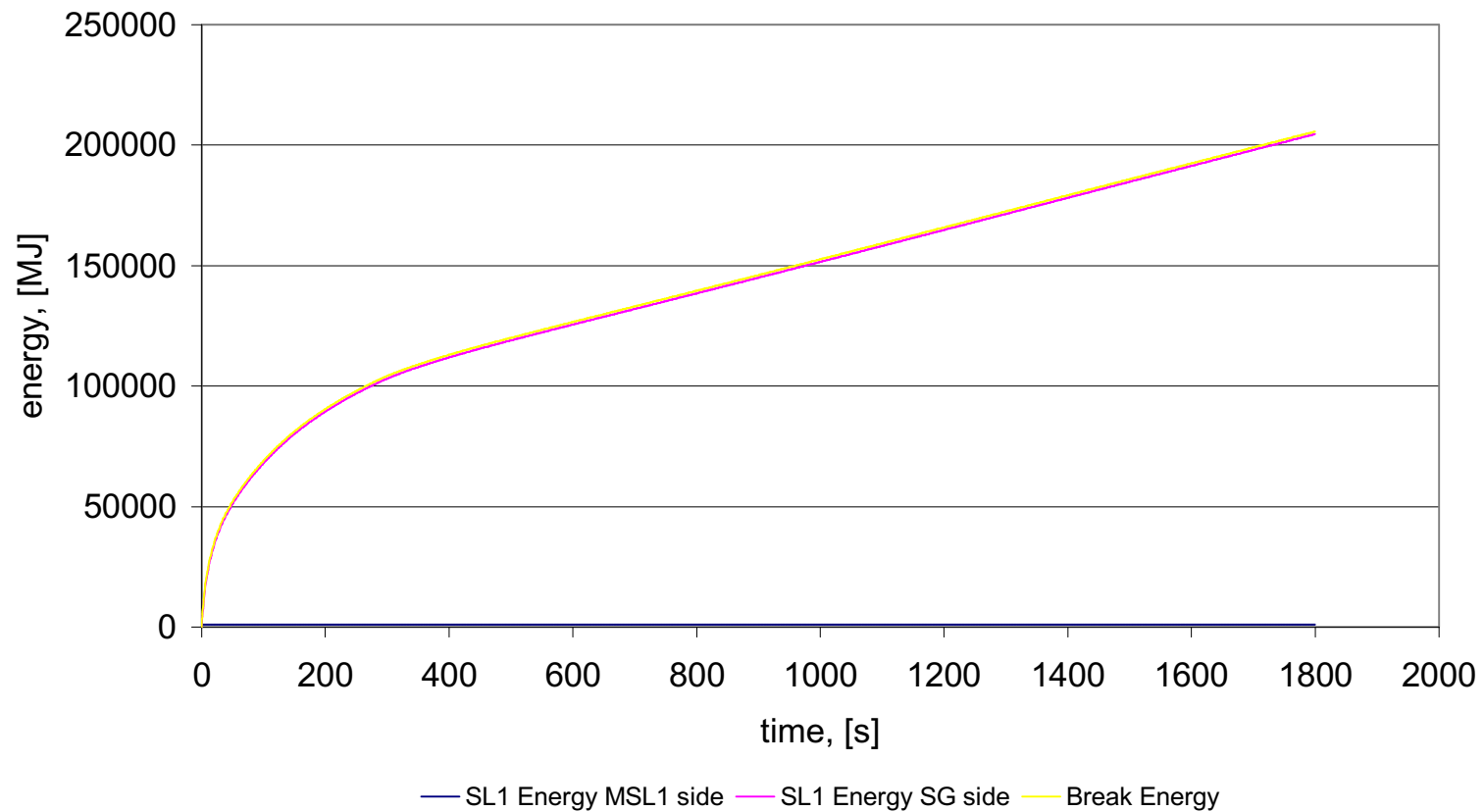
## Chronology of events:

- 0. s Guillotine MSL break above the SG1  
( $A = 0,24 \text{ m}^2$  all 5 pipe at SG outlet is broken).
- 2. s Scram signal by  $p_{\text{box}} > 1,1 \text{ bar}$ , all MCPs are stopped.
- 4. s GFDP signal ( $dp_{\text{MSH1-SG1}} > 5 \text{ bar}$ )  $\rightarrow$  faulted SG from steam line isolated but FWIVs fail to close, long time feedwater supply is assumed.
- 12. s Both turbine trip 10 s after scram.
- 20. s Primary pressure  $< 112 \text{ bar}$  (2. scram signal).
- 143. s ECCS signal PR level  $< 2,4 \text{ m}$  (cooling from secondary side)  $\rightarrow$  HPIS injection starts.
- 146. s Primary pressure min. = 103 bar.
- 500. s SG1 pressure  $< 1,1 \text{ bar}$ .
- 1800. s End of calculation, FW tanks are not empty.



MSLB on SG1, *steam line closed, feedwater line is opened* (2 valves stuck opened after  $dp > 5$  bar signal). Frequency: about  $4,5 \cdot 10^{-8}$  1/year.

Energy released through the break





## **MBLOCA 1:**

Scenario has been investigated by NRI Rez. Calculated 3 different LOCA cases with RELAP 5.2 code: 207 mm break on PR surge line, 233 mm break on HA surge line and 90 mm cold leg break. There was agreement to test the LOCA case without water spill back from BC trays because of better mass-energy balance measures. According to the preliminary calculations a hypothetical line break with diameter 200 mm has been chosen to be tested. Assumptions to use 2 ECCS system and 3 HA injection as more conservative from point of view of containment have been accepted.

## **MBLOCA 2:**

Scenario has been investigated by VUJE Trnava. After discussion 90 mm cold leg break calculated with RELAP 5.2 code has been chosen to be tested. Assumptions to use 2 ECCS system and 3 HA injection but do not use any cont. spray system have been accepted. This test could be useful for code validation and investigation of condensation phenomena on the walls caused by pressure increase.