Models of operator actions for avoiding the risk of deep vacuum in the Confinement in case of a 200 mm LOCA on units 3 and 4 of NPP Kozloduy with reactorsVVER-440/V230

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Abstract

The authors present a set of models of operator actions for avoiding the risk of deep vacuum in the Confinement in case of a 200 mm LOCA on VVER-440/V230. The models are based on the plant operating experience. The actions performance and efficiency are analysed with representative CONTAIN calculations. The results form the basis for development and validation of Emergency Operating Procedures for LB LOCA accidents at units 3 and 4 of NPP Kozloduy.

1. Introduction

This report presents briefly a study, performed by Energoproekt-plc and NPP Kozloduy-plc, in the frame of the efforts for validation of the Symptom-oriented Emergency Operating Procedures.

The risk of deep vacuum is one of the issues in the qualification of NPP Kozloduy units 3,4 for a design basis accident "200 mm LOCA". It is related to the specific features of the Accident Localization System (ALS) of these units.

The ALS of KNPP units 3, 4 is composed of the **Confinement**, the **Flaps** and the **Spray** system.

The **Confinement** is a set of interconnected compartments with a total free volume of ~ 11000 m^3. The main compartment is the Steam Generators Box (SGB) – with a free volume of ~ 8000 m^3, which contains the Steam Generators and the main primary piping. The average thickness of the outside confinement walls is 1 m (reinforced concrete with 4mm steel lining on the inside). The integral confinement un-tightness is estimated as a D=65 mm opening.

The **Flaps** are simple counter-weight devices, which react immediately to the sharp pressure build-up in the first 10 seconds of the LOCA: 1 small flap (0.212 m^2) opens at P>1.6 bar (abs)
8 large flaps (1.003 m^2 each) open at P>1.8 bar (abs).

The **Spray** system includes three channels, each composed of a pump, heat exchanger and piping. Each Spray Pump (PSS) takes a nominal flow rate of 200 kg/s (720 t/h) water from the Emergency Water Storage Tank (EWST - 800 m^3 of borated water) via the heat exchanger and delivers it to the spray nozzles in the SGB. The PSS start signal is generated automatically at P>1.2 bar (abs). **Once started, the PSS may stop only after operator's intervention.**

The Flaps function and the Spray function are practically separate in time. This separation makes a fundamental difference in the impact of the Flaps and Spray on the confinement pressure profile:

The **Flaps open immediately** to release air and steam from the SGB, thus reducing the peak pressure, built-up by the large release of primary coolant during the first seconds of a LB LOCA.

The **Spray** start-up sequence takes between 35 and 65 s - depends on the electric power supply (off-site power or Diesel generators)

The Spray condensates the steam in the SGB at a time, when the primary side is already depressurized and the release of coolant has dropped down by two orders of magnitude. At this time most of the air from the SGB has been removed through the flaps. The SGB volume is filled up with practically pure steam and condensation rapidly brings the pressure down to vacuum.

2. Acceptance criteria

The SGB should receive the primary coolant outflow in case of a LB LOCA, and the status of the Critical Safety Function "Confinement Integrity" is presented by the integrity status of the SGB.

The **design limits** of the SGB are presented in [1, 5], as follows:
Pressure (abs): minimum 0.8 bar; maximum 2 bar Temperature: maximum 150 ^oC.

A set of **ultimate integrity limits** is developed in [6] after analysis of the structure strength of all compartments, as follows:

	Maximal abs. pressure (concrete strength)	2.55 bar:
	Minimal abs. pressure (concrete strength)	0.23 bar
	Minimal abs. pressure (steel lining strength)	0.62 bar.

The **acceptance criteria for this analysis** are defined with the purpose to provide long-term safe status of the confinement, considering the specific features of the VVER-440/V-230 ALS:

Pressure (abs): minimum 0.8 bar; maximum 2.bar Temperature: below 150 ^oC;

The **operator actions success criteria** are selected, considering the inability of the operator to influence the first 60 seconds of the accident development:
Pressure after the action: min 0.8 bar max 1.6 bar (avoid flaps opening).
(The sensitivity studies showed, that the temperature does not exceed 120 ^oC even in the case of a complete failure of the spray system to start, so this criterion is met with a large margin).

3. Selection of the LOCA location

In VVER-440/230 there are two types of real pipes with equivalent diameter of 200 mm:
- the surge lines to the Pressurizer (PRZ) (two lines from the hot leg of loop No.1);
- the Low Pressure Injection lines (connected to the cold legs of loops No. 1, 3 ,5).

The comparison between the primary mass and energy releases for ruptures of both types of pipes [3] is presented on figures 3.1.1 and 3.1.2.

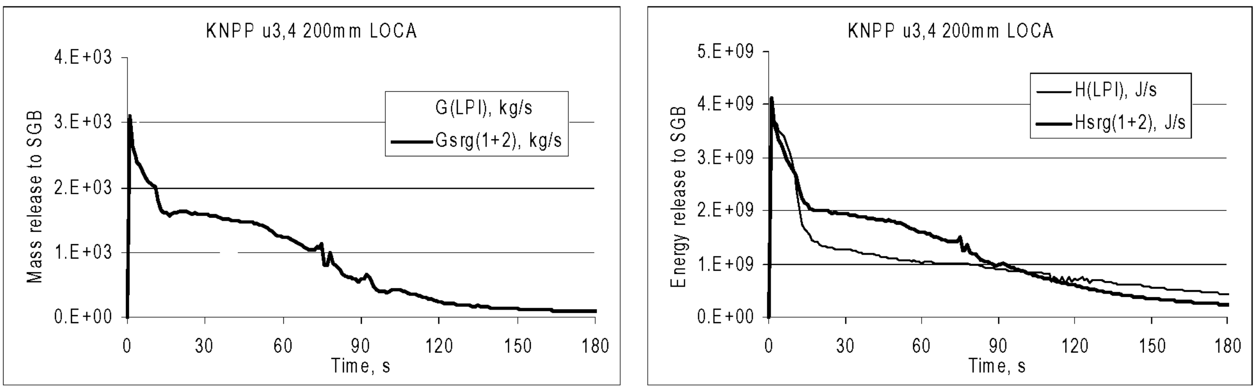


Fig. 3.1.1 & 3.1.2: Primary coolant mass and energy release from the broken pipes
Note: **srg(1+2)** means "Total release from the hot leg and the PRZ after a Surge line break"

Figures 3.1.11 and I.4.2 clearly show, that **the Surge line break is more adverse to the SGB**:
- larger release during the first 60 s (pressure peak); smaller release after 90 s (vacuum).

4. ALS response and operator action alternatives

The pressure peak, following a LB LOCA causes a large air release through the confinement flaps, leaving the SGB full of steam in the first 5 min of the accident. Shortly after the SS start up, operator action (decrease the SS flow rate) becomes absolutely necessary for the prevention of deep vacuum in the confinement. According to the EOP, the operator must stop one or more spray pumps when the confinement pressure has decreased to 0.9 bar (abs).

The simulation of various sequences of PSS trips is presented on Table 4.1 and Fig. 4.1

Simulated PSS trip sequences Table 4.1

Sequence (active PSS)	**3-0**	**3-2-1-0**	**3-1-0**	**3-1**
0.5 min	**3**	**3**	**3**	**3**
5.5 min	**0**	**2**	**1**	**1**
7. min	0	**1**	1	1
12 min	0	**0**	**0**	1

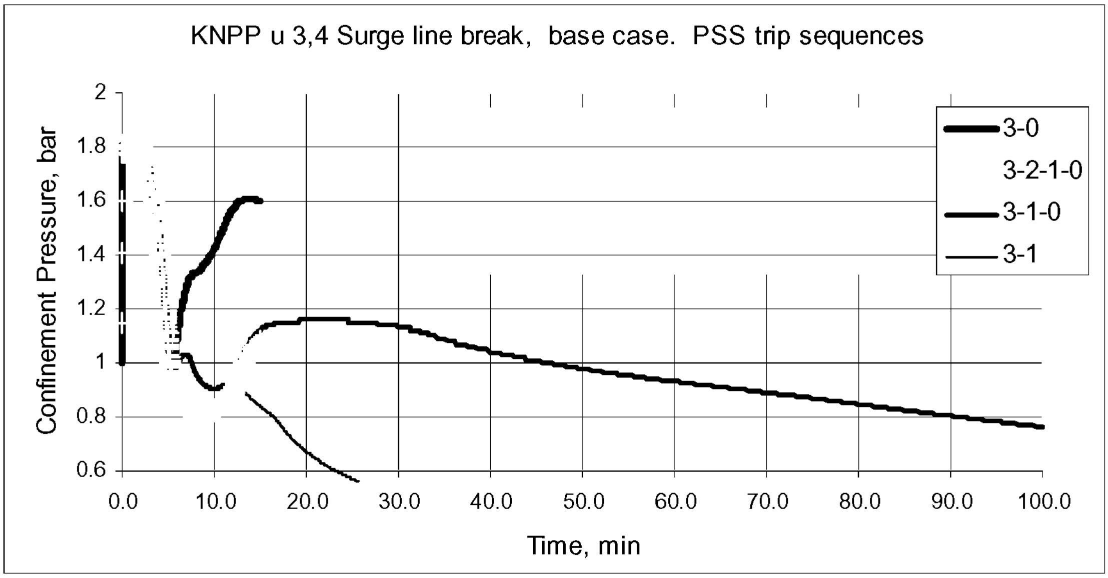


Fig. 4.1 - PSS trip sequences

The graphs on Fig. 4.1 lead to the following **resolutions:**

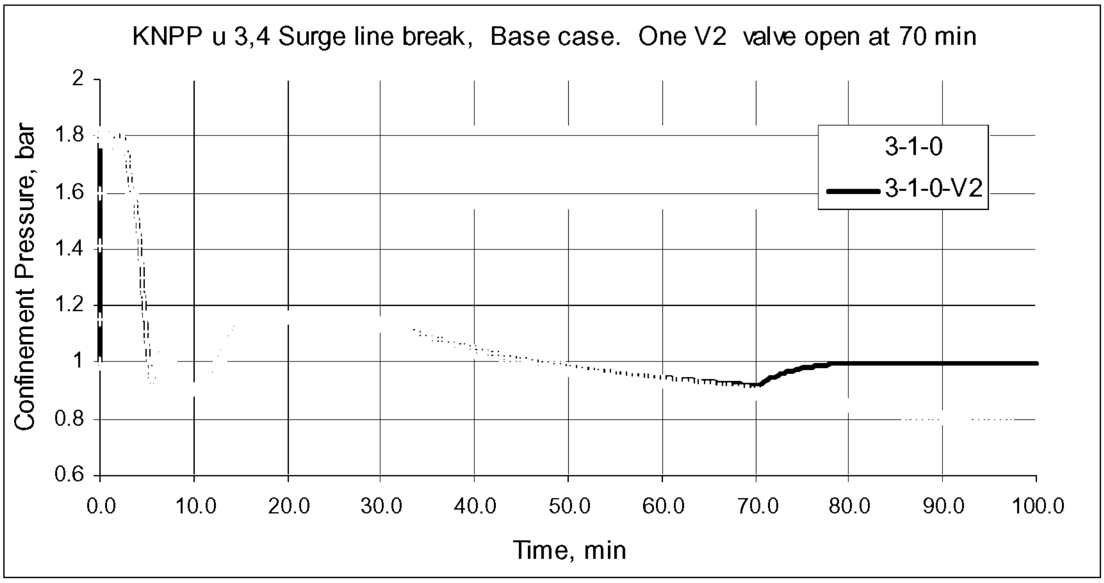
a) In order to avoid vacuum in the short term, the operator must stop all PSS by an appropriate sequence.

b) According to the acceptance criteria, sequences 3-2-1-0 and 3-1-0 are “successful”. Considering the operator’s convenience (at least 5 min between two consecutive actions), the sequence **3-1-0** is more realistic and should be applied in the emergency procedure.

c) In order to avoid vacuum in the in the long term (1hour and later), the operator must provide influx of air to the confinement system – e.g. - by opening one of the fifteen cut-off valves, which stay closed during normal operation (VV2-A26, VV2-A27, VV2-A30 ÷ 46: used for ventilation during outage: D=0.250 m, A=0.049 m^2). This action, combined with the 3-1-0 sequence, results in the pressure profile, presented on Fig. 4.2 below.

After the establishment of a stabilized confinement pressure within the acceptance criteria, the spray system could be started again – for the purpose of aerosol scrubbing in the SG box.

The technical feasibility of the suggested approach to resolution of the vacuum risk problem has been qualitatively estimated as “quite reasonable” by KNPP experts.



5. Conclusions

A quantitative evaluation of the confinement vacuum risk during a 200 mm LOCA accident is performed for units 3 and 4 of NPP Kozloduy. The evaluation is based on results from analyses of the primary side parameters with the RELPA5/3 code and analyses of the confinement parameters with the CONTAIN 1.1 code.

The possible operator actions for elimination of deep vacuum during the first 20 min are modeled and compared. The optimal sequence of PSS trip actions is defined by comparative calculations for the confinement pressure behavior.

A technically feasible approach is suggested for elimination of the deep vacuum risk in the long term – after 1 hour accident time. The efficiency of the approach is proven by a representative calculation of the confinement pressure profile.

6. Literature

[1] Set of design and operation data for units I-IV, provided by KNPP for the “LOCA 200” project

[2] ENERGOPROEKT-PLC , A complex analysis of 200 mm LOCA accidents for KNPP units I-IV. Rev. 1., Sofia, July 2000 (in Bulgarian language)

[3] NPP Kozloduy, unit 3. Operational instruction for the SPDS system ЕИ.ТИА.36.В (in Bulgarian language)

[4] ENERGOPROEKT-PLC contract No.SC-96/01-CT 94-94-1047.00 with RISKAUDIT Int. Assistance BNSA – 3&4 (Kozloduy Units 3,4), Task 1 Confinement Structures, Rev.2, 1997