# Probabilistic Risk Assessment for Spent Fuel Pool Decommissioning in the J. Bohunice V1 NPP

**by**

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# Introduction

- **The first working nuclear power plant in Slovak Republic is situated near the village of J. Bohunice in West Slovakia.**
- **The plant consists of four reactor units. The first two units (the J. Bohunice V1 plant) are equipped with Russian WWER440/230 type reactor which was designed in the early 1960s.**
- **After decision of the Slovak government the V1 plant will be permanently shutdown in the end of 2008.**

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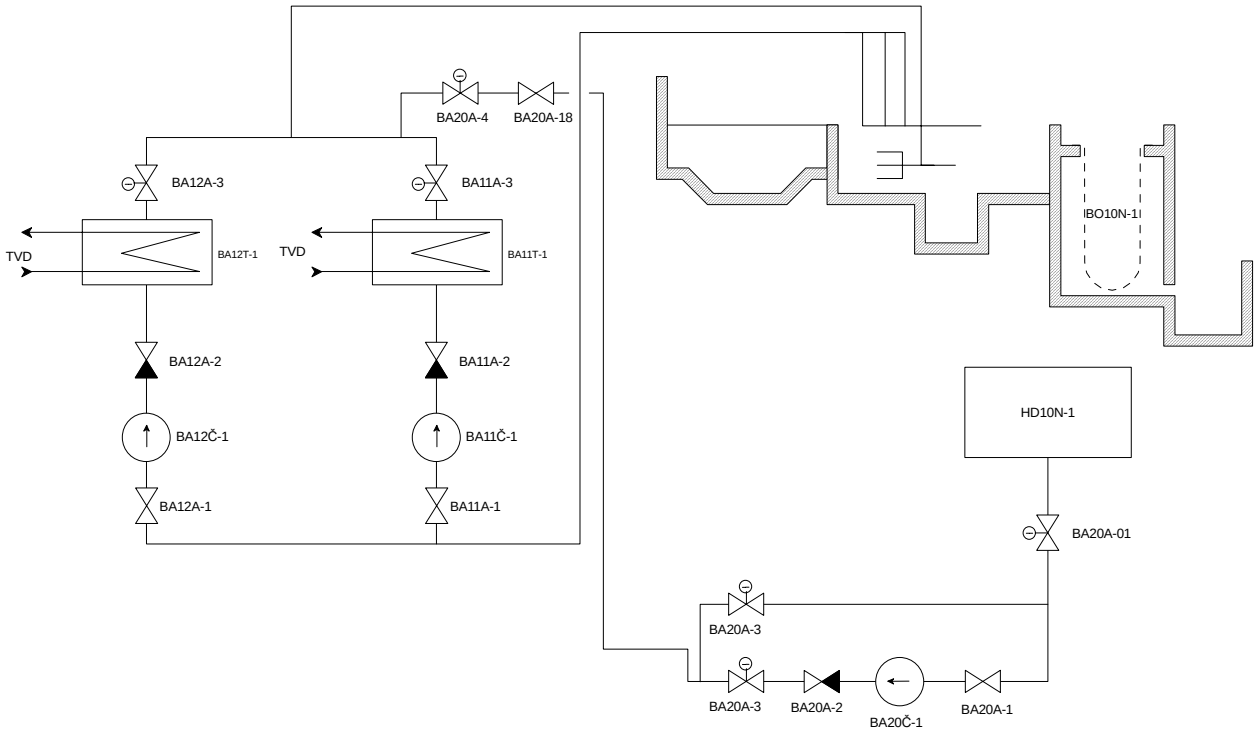
# Introduction

- The time schedule for termination of the J. Bohunice V1 plant operation has two phases.
- In the first phase from the beginning of 2007 to the end of 2008 the reactor of the Unit 1 is shutdown and its operation is terminated.
- The Unit 2 is in power operation or shutdown modes for refuelling outage.
- The second phase is the time period after 2008. Both units will be shutdown; the operation of the second unit will be also terminated.

# Introduction

- **After the permanent shutdown of the unit 1 in December 2006, immediate fuel unloading and fuel transportation to the spent fuel pool (SFP) was planned.**
- **A study was prepared to evaluate of SFP accident risk at the decommissioning plant.**
- **The study was undertaken to develop a risk-informed technical basis for the Slovak Nuclear Regulatory Authority. The main results of the study are summarized in this paper.**

# The spent fuel pool



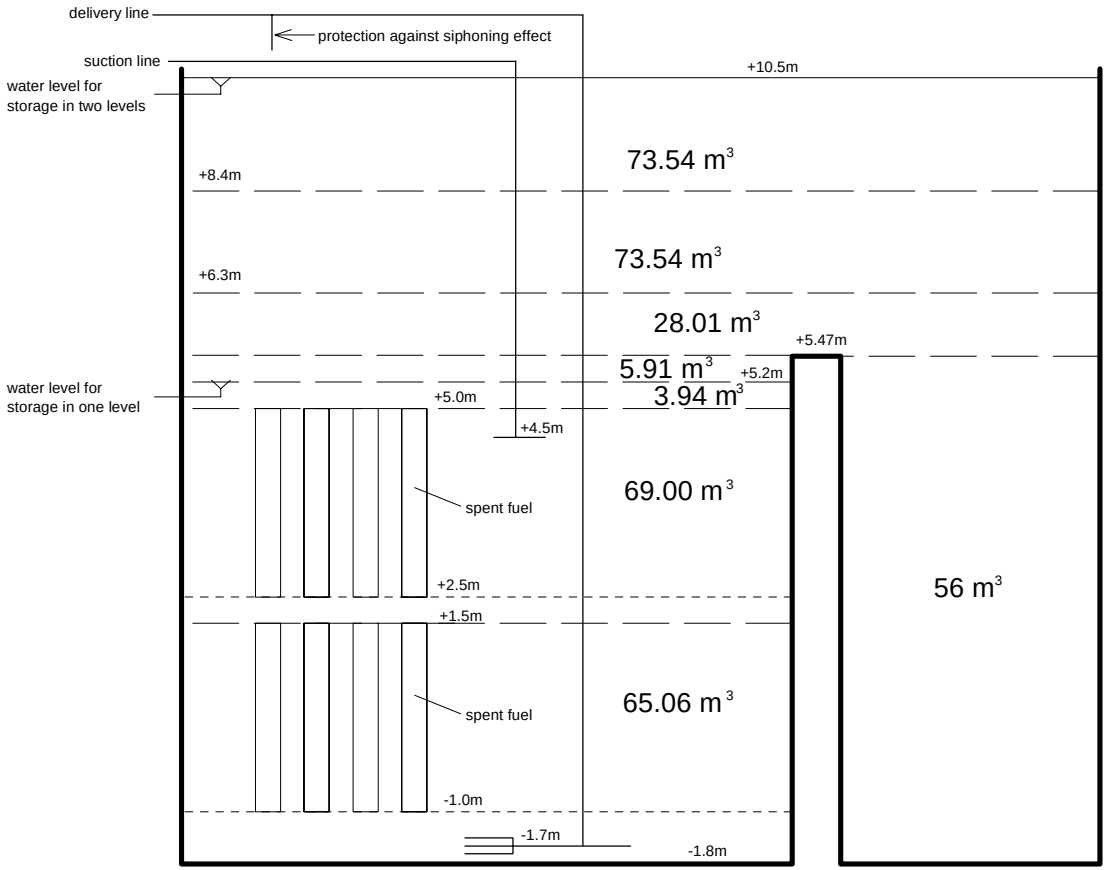
# The spent fuel pool

- The spent fuel pool cooling system is consisting of motor-driven pumps, heat exchangers, the ultimate heat sink, a makeup tank, and isolation valves.
- Coolant is drawn from the SFP by one of the two pumps, passed through the heat exchanger, and returned to the pool.
- The essential service water system is used on the secondary side of the heat exchanger for heat removal.
- A filtration system is connected to the spent fuel pool. Small amount of water is diverted to the filtration process and is returned into the discharge line within a selected time periods.
- During loss of the SFPC system or loss of pool inventory, inventory can be made up using the HD10N-1 tank.
- In addition, several other water sources are available to compensate losses from the SFP (CD system, RB system, HD60N-1 tank and mobile water source). The analysis takes into account all water sources.

# The spent fuel pool

- The fuel can be stored in two levels in the pool.
- During normal plant operation the second level is used only in operating mode 7, when there is check of the reactor vessel and all fuels are located to the spent fuel pool (once per 4 years for several hours).
- The delivery line of the SFPC system is ended at the level of -1.7 m and it is protected against siphoning effect.
- The suction line is ended at the level of +4.5 m. It is not protected against siphoning effect. Given a piping rupture in the suction line of SFPC system, the fuel stored in the second level can be uncovered due to the siphoning effect.
- There is a weak point in the design. The single failure criterion is not met for the case when the fuel is stored in two levels. After termination of the Unit 1 operation a solution was needed for this problem.

# The spent fuel pool



# The risk assessment

- **The probabilistic safety analysis of the SFP was performed for the following scenarios:**
  1. **the suction line is modified so, that the suction is on the level of +8.4 m, the fuel is stored in both levels, the water level is on +10.5 m (this solution allows to meet the single failure criterion for the SFP),**
  2. **the suction line is not modified, the suction is on the level of +4.5 m, the fuel is stored in both levels, the water level is on +10.5 m (the fuel is uncovered given a piping rupture in the suction line),**
  3. **the suction line is not modified, the suction is on the level of + 4.5 m, the fuel is stored only in one level, the water level is on +5.2 m (the fuel is not uncovered given a piping rupture in the suction line),**
  4. **the suction line is not modified, the suction is on the level of + 4.5 m, the fuel is stored only in one level, the water level is on +10.5 m (the fuel is not uncovered given a piping rupture in the suction line).**

# The risk assesment

- **The following initiating events are identified for the SFP:**
  - **loss of cooling,**
  - **loss of coolant,**
  - **loss of offsite power,**
  - **internal fires,**
  - **extreme meteorological conditions,**
  - **impact of neighbouring industry,**
  - **heavy load drop,**
  - **aircraft crash,**
  - **seismic event.**

# Loss of cooling
# Time to fuel uncovery – scenario 1 and 2

| Decay time [day] | Decay heat [kW] | Time to fuel uncovery [h] |
|---|---|---|
| 10 | 3 384 | 37 |
| 15 | 2 855 | 45 |
| 20 | 2 525 | 49 |
| 50 | 1 636 | 76 |
| 100 | 1 123 | 111 |
| 365 | 428 | 292 |
| 730 | 233 | 536 |
| 1 095 | 154 | 813 |

# Loss of coolant

| Break No. | Scenario | Time to fuel uncovery |
|---|---|---|
| 1 | 1 | 24 h 10 min |
| 2 | | 24 h 12 min |
| 3 | | 25 h 17 min |
| 4 | | 24 h 29 min |
| 1 | 2 | 16 min |
| 2 | | 20 min |
| 3 | | 11 h |
| 4 | | 67 min |
| 1 | 3 | 12 h 49 min |
| 2 | | 12 h 48 min |
| 3 | | 15 h 46 min |
| 1 | 4 | 13 h 6 min |
| 2 | | 13 h 8 min |
| 3 | | 26 h 4 min |
| 4 | | 13 h 56 min |

# Internal fire

- Loss of SFP cooling caused by internal fires.
- Fire in the room V110/1 leads to this event.
- There is automatic fire detection but no automatic fire suppression for the SFP cooling area. Manual fire suppression is needed. Recovery times are the same as for loss of cooling.

# Other IE

- **The other initiating events:**
  - **extreme meteorological conditions,**
  - **impact of neighbouring industry,**
  - **heavy load drop,**
  - **aircraft crash and**
  - **seismic event were screened out from the analysis due to negligible impact on the risk.**

# The results

- **The fuel damage frequency was calculated for the different scenarios:**
  - **scenario 1: 2.55E-8/y**
  - **scenario 2: 3.73E-5/y**
  - **scenario 3: 3.27E-8/y**
  - **scenario 4: 2.62E-8/y**

# The results

- The large early release frequency is the same as the fuel damage frequency because the SFP is located outside the confinement.
- In case of scenario 1 the most dominant initiating event is the loss of cooling, (54.9%), then loss of coolant (22.5%), loss of offsite power (18.1%) and fire in the room V110/1 (4.5%).
- The highest risk is in scenario 2 with dominant contribution from loss of coolant (99.99%).
- The contribution to the risk in case of scenario 3 is the following: loss of cooling (42.8%), loss of coolant (34.9%), loss of offsite power (18.7%) and fire in the room V110/1 (3.6%).
- The contribution to the risk in case of scenario 4 is the following: loss of cooling (53.4%), loss of coolant (24.9%), loss of offsite power (17.4%) and fire in the room V110/1 (4.3%).

# The results

- The results of the study indicate that the risk at SFP is low when the fuel is located only in one level (scenario 3 and 4).
- If the fuel storage is in two levels, the risk is high (scenario 2).
- In scenario 1 modification of the design is needed (modification of suction line) to achieve low risk with the fuel located in two levels.
- The risk is highest in scenario 2.
- Given piping break of the suction line, fuel uncovery can occur within 16 minutes.
- In addition, the single failure criterion is not met.

# Conclusions

- After termination of the Unit 1 operation the fuel would be located in two levels because the SFP is not empty.
- Fuel from the former campaigns is located there. However, the results of risk assessment have shown us that the risk of fuel storage in two levels is high.
- Design modification of the spent fuel pool is needed. Alternative solution for this problem is to leave the fuel in the reactor vessel for a limited time period and to remove the residual heat in operating mode 5.
- Probabilistic safety analysis was performed also for this solution and the conclusion was to have the fuel located in the reactor vessel for the time period of one year.
- Then, the SFP will be empty and the fuel from the reactor vessel can be stored in one level.