

Safety of New Nuclear Power Plants

Example: VVER-1200/V491

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Workshop on the Paks II NPP Project
Budapest, Energiaklub, 08.10.2014

New NPP in Paks: Reactor Type

In the EIA Scoping Document (October 2012), five reactor types were listed for consideration:

- AP1000 (Toshiba-Westinghouse)
- AES-2006/MIR-1200 (Atomstroyexport)
- EPR (Areva)
- ATMEA1 (Areva-Mitsubishi)
- APR1400 (Korean Electric Power Corporation)

Subsequently, it was decided to select the Russian reactor type MIR-1200, also known as AES-2006 or VVER-1200.

New NPP in Paks: Reactor Type

The VVER-1200 is a third-generation reactor, based on VVER technology. Forerunner types include VVER-440/V213 (e.g. Paks 1-4) and VVER-1000/V320 (e.g. Temelín 1-2).

There are two variants of the VVER-1200:

- VVER-1200/V392M, designed by Atomenergoproekt Moscow, 2 units under construction at the Novovoronezh-2 site
- VVER-1200/V491, designed by Atomenergoproekt St. Petersburg, 2 units under construction at the Leningrad-2 site

V392M tends to depend more on passive safety systems, V491 more on active safety systems; there are a number of other design differences.

It appears that the VVER-1200/V491 is to be built at Paks. In Finland, there are plans to build a V491 at Hanhikivi (positive government decision Sept 18, 2014; parliament has yet to agree)

Safety Objectives for new NPPs

The Western European Nuclear Regulators' Association (WENRA) defined a common position on safety objectives for new NPPs in 2010.

The WENRA safety objectives should ensure that new NPPs will fulfill higher standards across Europe, compared to the existing plants, especially through design improvements.

To clarify the meaning of the safety objectives, the Reactor Harmonization Working Group (RHWG) of WENRA developed positions on selected key issues, particularly relevant for new reactors.

Safety of VVER-1200/V491

Safety Objectives

In the Austrian Expert Statement on Hanhikivi, the WENRA safety objectives were applied to the V491. The following points were assessed, with a focus on design aspects:

- What can be asserted regarding fulfilment of the safety objectives, on the basis of available information?
- Which issues remain unclear regarding fulfilment?
- Are there potential challenges which could make fulfilment of the WENRA safety objectives difficult or impossible?

The assessment was sufficient to provide a rough overall picture.

Generally, it became clear that significant efforts have been undertaken by the designer to fulfil the safety objectives; but available information does not permit a definitive assessment. Many challenges have been identified.

Safety of VVER-1200/V491

SO 1: Norm. Operation, Abn. Events

- *Reducing the frequencies of abnormal events by enhancing plant capability to stay within normal operation.*
- *Reducing the potential for escalation to accident situations by enhancing plant capability to control abnormal events.*

Challenge: Designer's approach is "improving system and equipment characteristics by abandoning excessive conservatism and optimizing design margins". However, larger operational margins are appropriate for reducing the frequency of abnormal events → conflict between safety and economics?

Challenge: Embrittlement behaviour of reactor pressure vessel over 60 years still requires attention.

Safety of VVER-1200/V491

SO 2: Accidents Without Core Melt

- *Ensuring that accidents without core melt induce no off-site radiological impact or only minor radiological impact (in particular, no necessity of iodine prophylaxis, sheltering nor evacuation).*
- *Reducing, as far as reasonably achievable,*
 - the core damage frequency taking into account all types of credible hazards and failures and credible combinations of events;*
 - the releases of radioactive material from all sources.*
- *Providing due consideration to siting and design to reduce the impact of external hazards and malevolent acts.*

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SO 2: Accidents Without Core Melt

Challenges:

- Conservative selection of assumptions for dealing with design basis accidents, beyond what is customary for Gen II plants;
- systematic consideration and controlling of internal hazards;
- systematic consideration and controlling of multiple failures;
- redundancy of all systems of AC emergency power;
- demonstrating the fulfilment of the limit for core damage frequency, taking into account all relevant initiating events, and uncertainties.

Safety of VVER-1200/V491

SO 3: Accidents With Core Melt

- *Reducing potential radioactive releases to the environment from accidents with core melt, also in the long term, by following the qualitative criteria below:*
 - *accidents with core melt which would lead to early or large releases have to be practically eliminated;*
 - *for accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public (no permanent relocation, no need for emergency evacuation outside the immediate vicinity of the plant, limited sheltering, no long term restrictions in food consumption) and that sufficient time is available to implement these measures.*

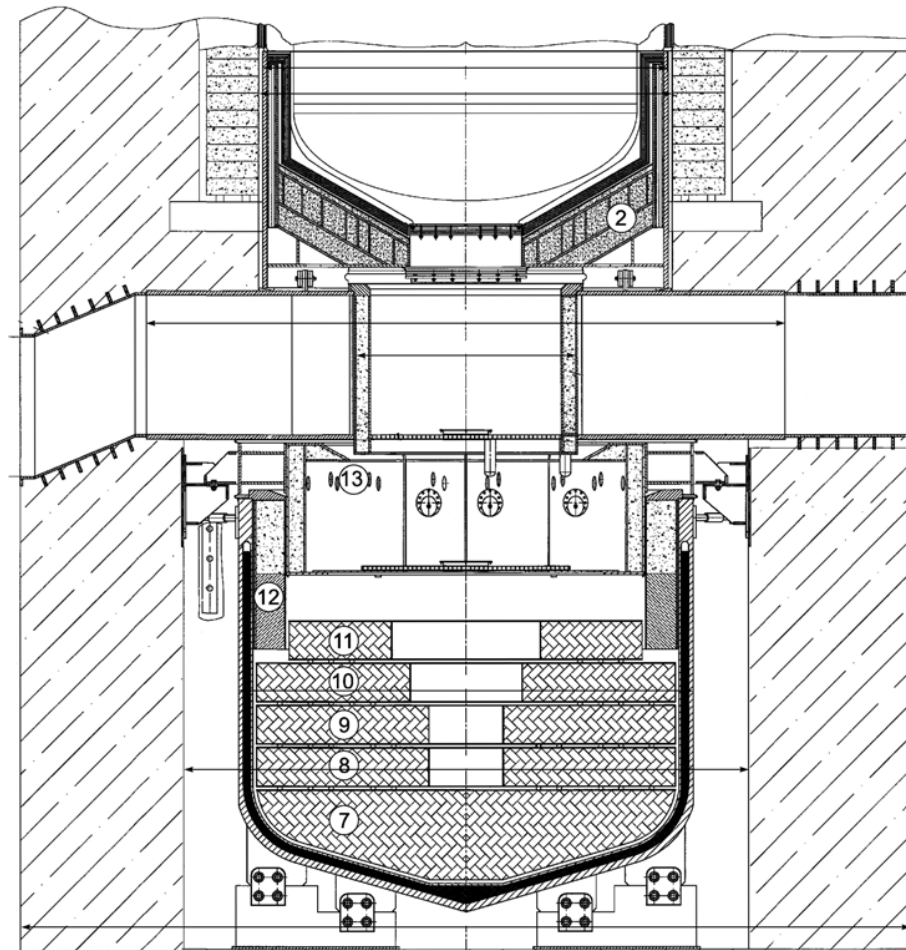
Safety of VVER-1200/V491

SO 3: Accidents With Core Melt

Challenges:

- There are open questions regarding the reliable function of the “core catcher” – regarding description of accident scenarios, timing of core flooding to avoid steam explosion and guaranteeing inversion of metallic and oxydic layers in catcher vessel.
- A number of hazardous phenomena are claimed to have been avoided by design, but there is no proof that they can be regarded as “practically eliminated” as required by the safety objective. (For example, steam explosion, hydrogen detonation, re-criticality, direct containment heating.)

Core Catcher



Safety of VVER-1200/V491

SO 4: Independence of DiD Levels

Enhancing the effectiveness of the independence between all levels of defence-in-depth, in particular through diversity provisions (in addition to the strengthening of each of these levels separately as addressed in the previous three objectives), to provide as far as reasonably achievable an overall reinforcement of defence-in-depth.

Challenges:

There is a number of important systems foreseen for severe accidents, which are also used on other levels of DiD: The primary depressurization system, and two passive cooling systems. (This is also relevant for SO 3.)

Separation of the I&C systems for different levels of DiD is not clear according to available information.

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SO 5: Safety and Security Interfaces

Ensuring that safety measures and security measures are designed and implemented in an integrated manner. Synergies between safety and security enhancements should be sought.

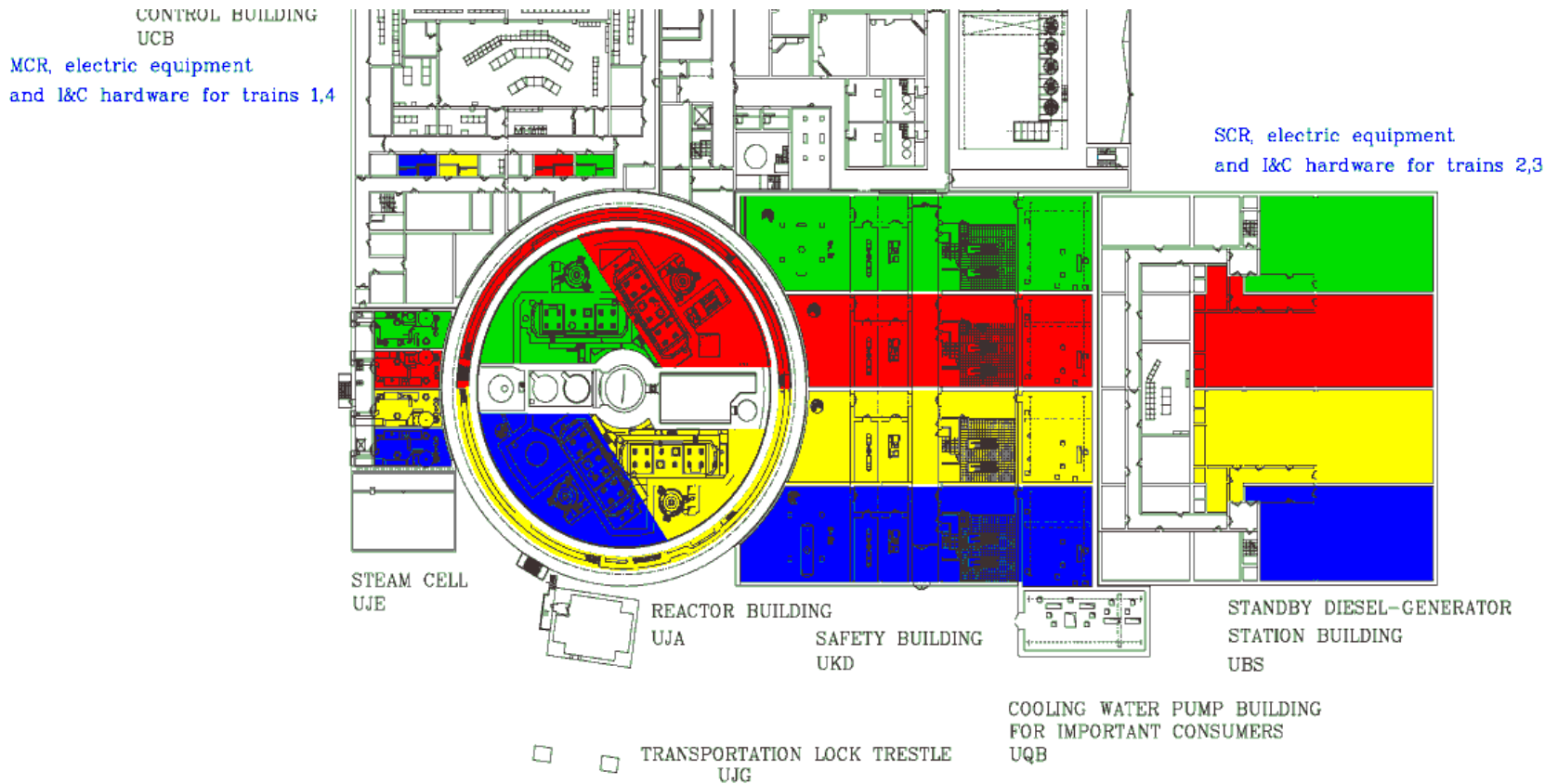
Challenges:

The safety building which houses all four redundant trains of the safety systems, is not designed against airplane crash. The four trains are located side-by-side.

No discussion of the possible effects of combustion and/or explosions of aircraft fuel on vital structures and systems can be found in the available documents.

→ Demonstration of availability of the required safety functions after the crash of a large airplane constitutes a challenge.

Safety Building Trains



Safety of VVER-1200/V491

Safety Objectives 6 and 7

SO 6 concerns radiation protection and waste management. These topics are important, but of little relevance for possible adverse effects on Austria. Therefore, this SO was not deeper discussed in the Expert Statement.

SO 7 concerns leadership and management for safety. It goes beyond the design aspects of the plant, and was not discussed in the Expert Statement.

Safety of VVER-1200/V491

Are Large Releases Possible?

Atomstroyexport claims that the frequency of a large release (LRF) is $1.8 \times 10^{-8}/\text{yr}$, well below the limit of $10^{-7}/\text{yr}$.

BUT:

- This published result includes full-power operation and internal initiators only. Low-power and shutdown states can contribute significantly to LRF, as can external events.
- No indication is given for the uncertainty of this result.
- Most important: The numerical results of PRA studies should not be taken at face value. PRAs are beset with uncertainties, and cannot completely capture reality.

Digression on Probabilistic Studies

The following factors cannot at all, or not adequately, be taken into account in a PRA:

- Unexpected loads from internal occurrences
 - Bad safety culture
 - Common cause failures
 - Problems at the interface between civil engineering and systems engineering
 - Unexpected external events
- It is inadmissible to exclude accidents in NPPs from further consideration, solely on the basis of PRA results.

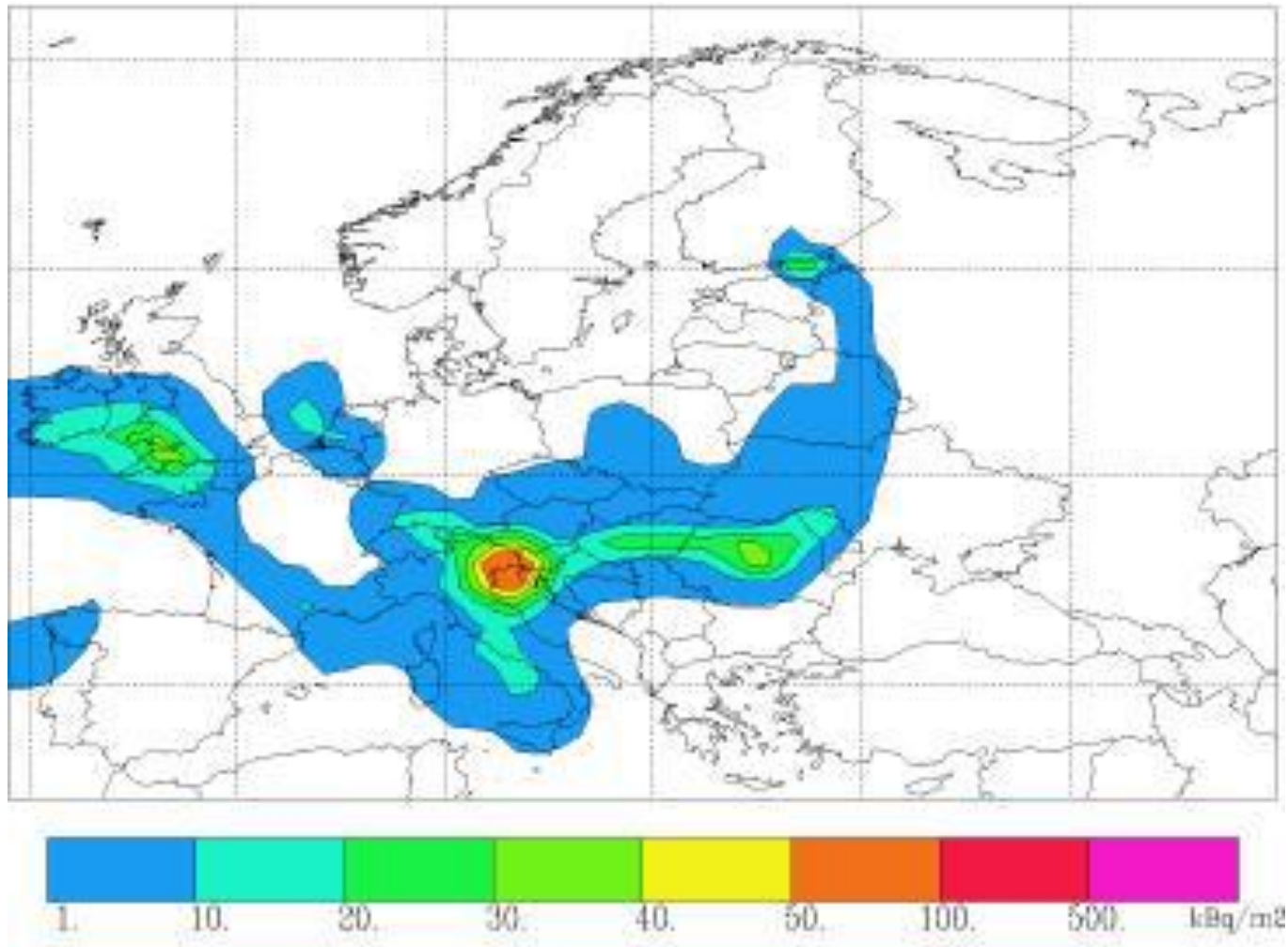
Conclusion for VVER-1200/V491

Taking into account:

- The open issues and challenges identified regarding the safety of this reactor type
- The lack of demonstration that accidents with large releases are extremely unlikely, with a high degree of confidence

It has to be concluded that **severe accidents with large releases cannot be excluded for the VVER-1200/V491, based on information available today.**

Possible Consequences of a Large Release



Budapest, 08.10.2014

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Safety of VVER-1200/V491 vs. EPR

Overall picture is roughly similar; many differences in detail:

- Very low re-criticality temperature for VVER
- Dedicated valves for de-pressurization in case of severe accident for EPR
- Different design of core catcher
- Containment heat removal in case of severe accidents passive for VVER / active for EPR
- Redundant trains are separated by distance for EPR
- Published PRA-results are very similar

Clear difference: Much more detailed technical information is available for EPR (e.g. Pre-Construction Safety Report for UK EPR).

Thank you for your attention!

Main basis for this presentation:

- KKW Paks II – Fachstellungnahme zum Entwurf einer Umweltverträglichkeitsprüfung (UVP-Scoping-Dokument) im Rahmen der UVP
A. Wallner, G. Mraz, H. Hirsch, A.Y. Indradiningrat, O. Becker, G. Pauritsch, M. Baumann, 2013
- NPP Fennovoima (Hanhikivi 1) – Expert Statement to the Environmental Impact Assessment Report
O. Becker, H. Hirsch, A.Y. Indradiningrat, A. Wallner, 2014

Expert Statements by Order of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, published at the Website of the Environment Agency Austria –

http://www.umweltbundesamt.at/umweltsituation/kernenergie/uvp_kernkraft/