BUNDESMINISTERIUM
FÜR KLIMASCHUTZ,
UMWELT, ENERGIE,
MOBILITÄT,
INNOVATION UND
TECHNOLOGIE

Safety Dialogue on EMO 3+4 Completion

Final Summary Report of the Slovakian-Austrian Consultations 2008 - 2021

Authors:

H. Hirsch, cervus nuclear consulting, Neustadt a. Rbge.
Co-ordinator of the Austrian Expert Team

M. Brettner, Physikerbüro Bremen
K. Decker, Department for Geodynamics and Sedimentology, University of Vienna

Compiled by Order of the Federal Ministry of Sustainability and Tourism
Project Supervision Division I/6 "Nuclear Co-ordination"
GZ: BMLFUW-UW.1.1.4/0001-I/6/2016

Neustadt a. Rbge., September 2021

Contents:

Summary

In 2016 the then Federal Ministry of Sustainability and Tourism of the Republic of Austria has commissioned this report, following the 24th bilateral meeting under the Agreement between the Government of the Slovak Republic and the Government of Austria on issues of common interest in the field of Nuclear Safety and Radiation Protection. Its content has been extensively discussed between Austrian and Slovak experts.

The Slovak electrical utility Slovenské Elektrárne, a.s. is completing the units 3 and 4 of the Mochovce NPP (EMO 3+4). SE submitted three applications (for construction permit, changes in safety relevant components and installations and changes in the Preliminary Safety Analysis Report) in May 2008, which were accepted by the regulatory authority (ÚJDSR) in August 2008. Construction is under way since then. As of August 2021, unit 3 was in commissioning (before fuel load).

Austria could potentially be affected by radioactive releases in case of a severe accident in one of those units. Hence, technical issues of the EMO 3+4 project are of interest from the Austrian viewpoint, if they are (directly or indirectly) relevant in the context of severe accidents.

Agreement was reached between the Slovak Republic and Austria to hold dedicated bilateral expert workshops on the following topics for EMO 3+4:

- Severe accidents
- Confinement and bubbler condenser
- Site seismicity and seismic design
- Reactor pressure vessel integrity
- Digital instrumentation and control

The workshops (two on severe accidents, one for each of the other topics) took place between late 2009 and mid-2016. Furthermore, Austrian experts had opportunity to consult the Preliminary Safety Analysis Report of EMO 3+4, and to visit the site. All in all, more than 200 experts from Slovakia and Austria participated in the safety dialogue.

As a result of the discussions at the workshops and additional information which was provided by the Slovak side, the following topics could be completely clarified, with all Austrian questions answered and full consensus achieved:

- Confinement and bubbler condenser
- Reactor pressure vessel integrity

For the other topics, most of the technical aspects addressed in the Austrian questions were concordantly resolved. However, there are, in the view of the Austrian experts, a few aspects of the topics listed below which could not be fully clarified to date, and for which it would be desirable and expedient to resume discussion:

- Site seismicity and seismic design – aspects of seismic hazard assessment, investigation of faults and peak ground acceleration.

- Digital instrumentation and control – software reliability (in particular, testing methods).

- Severe accident management –the experimental and analytical projects, which support the concept of the in-vessel retention of molten core.

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussions was exhaustive. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

In addition, differences of opinion between the Slovak experts and the Austrian experts remained for two topics:

- Digital instrumentation and control – possibility of common cause failures in PLD modules.
- Severe accident management – importance of full-scale tests of filling of the reactor cavity, and the appropriateness of ESFAS diversification.

At the 24th bilateral meeting under the Agreement between the Government of the Slovak Republic and the Government of Austria on issues of common interest in the field of Nuclear Safety and Radiation Protection held on June 20-21, 2016 in Vienna, it has been mutually acknowledged that the condition 3.2 of the conclusions of the Final Statement of the Ministry of Environment of the SR on EIA of EMO3&4 had been fulfilled.

At this meeting, it was also agreed that the executive summaries of the reports of the Austrian experts on the topics which were discussed might be published by Austria pending the approval of the Slovak side. Such approval would be provided via the exchange of Note Verbale once the text has been agreed on by the designated partners for this case – Mr. Mikuláš Turner (SK) and Mr. Andreas Molin (AT). In the spirit of this agreement the exchange of views and information continued after the meeting. This report reflects this agreement.

Furthermore, it was agreed that the exchange of information will be assured at the regular bilateral meetings held once a year.

Zusammenfassung

Im Jahr 2016 gab das damalige Bundesministerium für Nachhaltigkeit und Tourismus der Republik Österreich diesen Bericht in Auftrag, im Anschluss an das 24. Bilaterale Treffen gemäß dem Abkommen zwischen der Regierung der Slowakischen Republik und der Regierung von Österreich zur Regelung von Fragen gemeinsamen Interesses im Zusammenhang mit der nuklearen Sicherheit und dem Strahlenschutz. Sein Inhalt ist umfassend zwischen österreichischen und slowakischen Expert:innen diskutiert worden.

Das slowakische Elektrizitätsversorgungsunternehmen Slovenské elektrárne, a.s. (SE) arbeitet am Fertigbau der Blöcke 3 und 4 des KKW Mochovce (EMO 3+4). SE reichte im Mai 2008 drei Anträge ein (für die Baugenehmigung, für Änderungen an sicherheitsrelevanten Komponenten und Einrichtungen sowie für Änderungen im Vorläufigen Sicherheitsbericht (Preliminary Safety Analysis Report, PRESAR)), die von der Genehmigungsbehörde (ÚJDSR) im August 2008 angenommen wurden. Seit damals ist der Bau im Gange. Im August 2021 befand sich Block 3 in der Inbetriebnahme (vor der Beladung mit Brennstoff).

Österreich könnte potenziell von radioaktiven Freisetzungen bei schweren Unfällen in einem der dieser Blöcke betroffen sein. Daher sind technische Fragen des EMO 3+4 Projektes aus österreichischer Sicht von Interesse, soweit sie (direkt oder indirekt) im Zusammenhang mit schweren Unfällen relevant sind.

Die Slowakische Republik und Österreich kamen überein, zweckbestimmte bilaterale Expertenworkshops zu den folgenden Themen für EMO 3+4 abzuhalten:

- Schwere Unfälle
- Sicherheitseinschluss und Druckabbausystem („bubbler condenser“)
- Seismizität des Standortes und seismische Auslegung
- Integrität des Reaktordruckbehälters
- Digitale Leittechnik

Die Workshops (zwei für schwere Unfälle, je einer für die anderen Themen) fanden zwischen Ende 2009 und der Jahresmitte 2016 statt. Darüber hinaus hatten österreichische Expert:innen die Gelegenheit, den Vorläufigen Sicherheitsbericht von EMO 3+4 zu konsultieren sowie den Standort zu besuchen. Insgesamt nahmen mehr als 200 Expert:innen aus der Slowakei und aus Österreich an dem Sicherheitsdialog teil.

Als Ergebnis der Diskussionen bei den Workshops und zusätzlichen Informationen, die von der slowakischen Seite zur Verfügung gestellt wurden, konnten die folgenden Themen vollständig geklärt werden, mit Beantwortung sämtlicher österreichischer Fragen und Erzielen eines vollen Konsenses:

- Sicherheitseinschluss und Druckabbausystem („bubbler condenser“)
- Integrität des Reaktordruckbehälters

Bei den anderen Themen konnten die meisten technischen Aspekte, die von den österreichischen Fragen angesprochen wurden, einvernehmlich gelöst werden. Es gibt allerdings, aus der Sicht der österreichischen Expert:innen, einige Aspekte der unten aufgelisteten Themen, die bisher nicht vollständig geklärt werden konnten. Für diese wäre es wünschenswert und angebracht, die Diskussion wieder aufzunehmen:

- Seismizität des Standortes und seismische Auslegung – Aspekte der seismischen Gefahren-Bewertung, Untersuchung von Bruchlinien, maximale Bodenbeschleunigung.
- Digitale Leittechnik – Zuverlässigkeit der Software (insb. Methoden der Tests).
- Management schwerer Unfälle – die experimentellen und analytischen Projekte, die das Konzept der Rückhaltung des geschmolzenen Kerns im Reaktordruckbehälter (in-vessel retention) unterstützen.

Die slowakischen Expert:innen sind der Auffassung, dass sie ausreichende, evidenzbasierte Informationen zur Verfügung gestellt haben. Ihrer Ansicht nach war die Diskussion erschöpfend. Sie denken, dass, unter Berücksichtigung der zusätzlichen Informationen, die nach den Workshops zur Verfügung gestellt worden waren, diese Punkte umfassend und erschöpfend geklärt wurden und keine offenen Punkte verblieben sind.

Darüber hinaus sind bei zwei Themen Meinungsverschiedenheiten zwischen den slowakischen und österreichischen Expert:innen verblieben:

- Digitale Leittechnik – Möglichkeit von gemeinsam verursachten Ausfällen in PLD (programmable logic device – programierbare Logik-Schaltung) Modulen.
- Management schwerer Unfälle – Bedeutung von Tests in vollem Maßstab zum Auffüllen der Reaktorgrube sowie Angemessenheit der Diversifizierung des

ESFAS (Engineered safety systems actuation system – System zur Auslösung der technischen Sicherheitssysteme).

Auf dem 24. Bilateralen Treffen gemäß dem Abkommen zwischen der Regierung der Slowakischen Republik und der Regierung von Österreich zur Regelung von Fragen gemeinsamen Interesses im Zusammenhang mit der nuklearen Sicherheit und dem Strahlenschutz, das am 20./21. Juni 2016 in Wien stattfand, wurde von beiden Seiten anerkannt, dass die Bedingung 3.2 der Schlussfolgerungen der Endgültigen Stellungnahme des Umweltministeriums der Slowakischen Republik zur Umweltverträglichkeitsprüfung von EMO 3+4 erfüllt worden ist.

Bei diesem Treffen wurde auch übereingekommen, dass die Kurzzusammenfassungen der Berichte der österreichischen Expert:innen über die diskutierten Themen von Österreich veröffentlicht werden könnten, sofern die slowakische Seite zustimmt. Eine solche Zustimmung würde durch den Austausch einer Note Verbale erfolgen, sobald die für diesen Fall ausgewiesenen Partner – Herr Mikuláš Turner (SK) und Herr Andreas Molin (AT) – dem Text zugestimmt haben. Im Geiste dieses Abkommens dauerte der Austausch von Ansichten und Informationen nach dem Treffen an. Dieser Bericht reflektiert die Zustimmung.

Weiterhin wurde vereinbart, dass der Austausch von Informationen auf den regulären bilateralen Treffen, die einmal jährlich abgehalten werden, gewährleistet ist.

Introduction

The Slovak electrical utility Slovenské Elektrárne, a.s. is completing the units 3 and 4 of the Mochovce NPP (EMO 3+4). As of August 2021, unit 3 was in commissioning (before fuel load).

In May 2008, SE submitted three applications – one for a construction permit for the modified plant, the second for the implementation of changes in safety relevant components and installations, and the third for a permit to implement changes in the preliminary safety analysis report. The nuclear regulatory authority ÚJD SR accepted the applications and issued the corresponding three official decisions in August 2008.

The project to complete and operate the two units at EMO might cause adverse transboundary impacts. In particular, Austria could be affected by radioactive releases in case of a severe accident, which could occur during the entire operation of EMO 3+4. Hence, technical issues of this project are of interest from the Austrian viewpoint, if they are (directly or indirectly) relevant in the context of severe accidents.

At the 16th Bilateral Meeting under the Agreement between the Government of the Slovak Republic and the Government of Austria on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection, held in December 2008, the current state of the project was presented by the Slovak side and discussed as far as possible at this time and within the schedule of the meeting.

The Austrian side expressed interest to further discuss questions related to the following issues (including relevant safety standards):

- Severe Accidents including external events (e. g. plane crash)
- Confinement and Bubbler condenser
- Site Seismicity and Seismic Design
- Reactor Pressure Vessel (RPV) Integrity including pipe breaks
- Instrumentation and Control (I&C) and Human-Machine Interface

Organization and substance related to such discussions were to be agreed between the designated partners (Slovakia – Mr. M. Turner, Austria – Mr. A. Molin) in cooperation with the relevant institutions and organizations.

At the 17th Bilateral Meeting under the Agreement between the Government of the Slovak Republic and the Government of Austria on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection, held in June 2009, it was envisaged to begin the organization of expert meetings in the same year. “Severe accidents” and “reactor pressure vessel integrity” were considered as possible topics for the first meetings.

In November 2009, Slovak-Austrian Bilateral Consultations According to Art. 5 of the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo-Convention) took place, concerning the Environmental Impact Assessment Procedure on the Mochovce 3&4 Project. At this occasion, the planning for the expert meetings was further expedited. Due to the importance of the issues listed below, both delegations agreed to hold dedicated expert workshops:

- Severe accidents
- Confinement and bubbler condenser
- Site seismicity and seismic design
- Reactor pressure vessel integrity

The topic of instrumentation and control and human-machine interface had not been discussed at these Consultations. However, it was later confirmed (in particular, at the 20th Bilateral Meeting in October 2012) that a workshop should also be dedicated to this topic.

For each workshop, the Austrian side submitted a list of questions well in advance. This list served as the starting point for the presentations from the Slovak side, and the subsequent discussions.

The first workshop, concerning severe accidents, took place at the office of the Slovak regulatory authority ÚJD SR in Bratislava on December 15, 2009.

The second workshop, on confinement and bubbler condenser, took place in the same location on April 28, 2010, followed by a workshop on seismic issues on July 14, 2010.

To provide background information to the Austrian side, a small group of experts was given the opportunity to briefly consult the Preliminary Safety Analysis Report of EMO 3+4 on June 06/07, 2011, at the headquarters of Slovenské Elektrárne, a.s. in Bratislava.

Subsequently, a workshop on reactor pressure vessel integrity took place at the office of ÚJD SR in Bratislava on November 20, 2012.

There were no activities in 2013/2014 because the Fukushima accident led to urgent follow-up actions in Slovakia and Austria (as well as in the other countries of the EU, and worldwide) and there was no capacity to carry forward the Safety Dialogue.

At the 23rd Bilateral Meeting under the Agreement between the Government of the Slovak Republic and the Government of Austria on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection, in June 2015, it was envisaged to resume the activities and to hold the Workshop on instrumentation and control and human-machine interface in the near future.

The workshop on instrumentation and control and human-machine interface took place at ÚJD SR on December 11, 2015.

On April 27/28, 2016, the last dedicated expert workshop took place at ÚJD SR. This workshop dealt with Severe Accident Management and was also a follow-up of the first workshop held in 2009. At this workshop both sides confirmed that this workshop is considered as a conclusion of the expert consultation process agreed in 2008 and contained in the final statement of the Ministry of Environment of the SR on EIA of EMO3&4 (2010). Further exchange of information will be assured during regular bilateral meetings held once a year.

As closing event of the Safety Dialogue, an Austrian expert team visited the site of EMO 3+4 on June 28, 2016.

After each workshop, the Austrian experts summed up the information received and the resulting discussions in reports which were made available to the Slovak side. In reply, comments and explanations were provided by the Slovak experts. This Final Summary Report takes into account the presentations and discussions at the workshops as well as all the additional information and statements the Austrian experts received. Substantial comments provided by the Slovak side (concerning seismic issues, digital I&C and severe accident management) have been received in March 2019; further clarifications were conveyed in October 2019 and in March and June 2020.

In the view of the Austrian experts, there are a few aspects of some of the topics mentioned above which could not be fully clarified to date and for which it would be desirable and expedient to resume discussion.

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussions was exhaustive. They consider that together with the additional information provided after the workshops these aspects were comprehensively and exhaustively clarified and no open points remained.

In addition, some differences of opinion between the Slovak experts and the Austrian experts persist. These different opinions between the Slovak experts and the Austrian experts are identified and explained in the report at hand, at the respective sections.

At the 24th bilateral meeting under the Agreement between the Government of the Slovak Republic and the Government of Austria on issues of common interest in the field of Nuclear Safety and Radiation Protection held on June 20-21, 2016 in Vienna, it has been mutually acknowledged that the condition 3.2 of the conclusions of the Final Statement of the Ministry of Environment of the SR on EIA of EMO3&4 had been fulfilled.

At the 24th bilateral meeting it was also agreed that the exchange of information will be assured at the regular bilateral meetings held once a year.

Confinement and Bubbler Condenser

The workshop on confinement and bubbler condenser was held at the ÚJD SR offices in Bratislava on April 28, 2010.

Before entering the technical discussion, terminology was considered. It was agreed to henceforth use the terms “confinement” and “containment” – which are often used as synonyms in technical documents – strictly according to the IAEA definition [IAEA 2007, pp. 39 and 41]. Accordingly, confinement refers to the function of prevention or control of releases of radioactive material, containment to the means for achieving that function.

Regarding containment types, it was clarified that the bubbler condenser containment of EMO 3+4 and other reactors of the same type represents a type of containment which is different from the full pressure containments often found at PWRs of Western provenance, and which is more similar to BWR containments which are often equipped with pressure suppression.

Two types of full pressure containments as well as a containment type similar to the bubbler condenser containment are listed by the IAEA in the relevant safety guide [IAEA 2004, p. 144] among the examples of PWR containments.

As for every workshop, a list of questions provided by the Austrian side before the workshop constituted the basis for the further discussion.

New, relevant information and – in some cases – concrete references the Austrian experts had not been acquainted with before have been provided for the Austrian questions. For some questions, the Austrian experts have also evaluated additional information available to them.

As a result, all Austrian questions have been clarified; mostly at the workshop and in some cases by additional information which was provided later.

Design of Containment System of EMO 3+4 compared to EMO 1+2

All measures which have been implemented at EMO 1+2 will also be implemented at EMO 3+4, as well as some additional measures concerning hydrogen management, vacuum breakers and water reserves for severe accident management.

Tests of Bubbler Condenser

Concrete references concerning investigations of the bubbler condenser issue have been made available to the Austrian experts. From the results, the applicant concludes that the performance of the bubbler condenser is fully verified; the Slovak regulatory authority agrees.

The Austrian experts assert that the available information supports these positive conclusions, on the level of a plausibility check such as could be performed at the workshop.

Calculations for Bubbler Condenser

To some extent, this point had already been discussed under question above. Additional information was provided showing that the results of calculations performed were satisfactory.

Quality Control

The control methods being used for welded joints and the entire load bearing structure were presented.

Hydrogen Recombiners and Igniters

This issue was clarified as far as possible at the state of planning at the time of the workshop, which corresponded to an early phase of detail design. Information of the analyses which were performed during the basic design phase was provided. The positioning of recombiners and igniters was discussed in a general manner, as well as the different types which are available.

This issue had already been addressed at the workshop on severe accidents in December 2009 and the Slovak side expressed readiness for further discussion as new information became available. This discussion took place at the second workshop on severe accidents in April 2016. At this occasion, all questions from the Austrian side were answered and the issue was closed (see section on severe accident management).

DBA Scenario for Bubbler Condenser

The pressure load sequences acting on the bubbler condenser in case of relevant DBAs and the break time assumptions for LOCA were discussed.

Longer-term Management of Containment Pressure

The design of the spray system, which is crucial for the pressure management was presented, as well as the role of this system for pressure reduction in the course of different accident sequences. The provisions for water supply and the role of the vacuum breakers was explained.

Behavior of Bubbler Condenser in Case of BDBA

The role of the bubbler condenser in case of primary depressurization was explained, as well as the role in case of LOCA with various break sizes.

Air Flaps

The tests performed for full-scope verification of the functioning of the air flaps were described.

The Austrian experts noted that the questions concerning longer-term management of the containment pressure and the behavior of the bubbler condenser in case of BDBA should be reflected in the future discussion of beyond design basis accidents and accident management. This concerned, for example, the reliability of the power supply for the active spray system.

These points were subsequently discussed at the second workshop on severe accidents in April 2016. All questions from the Austrian side were answered and the issues closed (see section on severe accident management).

At the occasion of the site visit in June 2016, the Austrian expert had opportunity to see the bubble condenser air traps and the connecting corridor between the steam generator box room and the bubble condenser room (see section on visit of the EMO 3+4 site).

Taking into account all the relevant information available to them, the Austrian experts arrive at the following conclusion, regarding the standard of the containment of EMO 3+4:

The design of the containment of EMO3+4 is in accordance with current recognized general safety practices and requirements for design, for nuclear power plants operating today.

Furthermore, improved features have been implemented, with the goal to go beyond the safety standards for operating nuclear power plants. They consist of measures for control and mitigation of severe accidents (for example, hydrogen control, in-vessel retention of the molten core and the long-term management and limitation of containment pressure).

It has to be noted that there is, in the view of the Austrian experts, one aspect for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

This aspect belongs to the issue of severe accident management and is relevant for the confinement (concerning the scope of validation of in-vessel-retention of the molten core – see section on severe accident management).

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussions were exhaustive. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively explained and no open point remained.

Site Seismicity and Seismic Design

The workshop on site seismicity and seismic design was held at the ÚJD SR offices in Bratislava on July 14, 2010.

As for every workshop, a list of questions provided by the Austrian side before the workshop constituted the basis for presentations and discussions.

The questions were dealt with in a comprehensive manner. New, relevant information was provided and two IAEA Review Mission Reports (from missions in 1998 and 2003) concerning seismic safety were handed over by the Slovak side after the workshop. Furthermore, additional clarifications and information were provided by the Slovak experts in March 2019, October 2019 and March and June 2020.

As a result, a considerable part of the technical aspects addressed in the Austrian questions was concordantly resolved.

However, there are, in the view of the Austrian experts, some aspects for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussion was exhaustive. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

<u>Site Seismicity:</u>

The following question has been fully clarified:

State of Site Evaluation

The development of the horizontal peak ground acceleration assumed for the design basis earthquake (SL2 earthquake) was explained by the Slovak side. In 1992, a value of 0.1 g was recommended.

The most recent hazard evaluation, reviewed by an IAEA mission, changed this value to 0.143 g for the 10^{-4} annual probability PGA. The value was raised to 0.15 g for the seismic upgrade of EMO 3+4 by ÚJD SR in 2005. It was explained that the reason for this small increase of the PGA for the SL2 earthquake was the conservative assumption that some faults near the site were still active.

For the following questions, there are some aspects for which, in the view of the Austrian experts, it would be desirable and expedient to resume bilateral discussions as soon as viable.

However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

Hazard Assessment

Significant information has been provided for this issue. However, there are a number of points which were not sufficiently clarified at the workshop in the opinion of the Austrian experts. The Slovak side supplied additional information relevant for these points in March 2019 and October 2019.

- Methodological approaches which were used for hazard assessment: The methodology used in the hazard study completed in 2003 was a standard PSHA approach.
  The Slovak experts stated in March 2019 that the probabilistic seismic hazard assessment (PSHA) of 2003 corresponded to the knowledge and best practices at the time of the study, adding that in future analyses for the Mochovce site, more robust and up-to-date methods will be used.

- Earthquake catalogue: The possibility to use more robust estimation methods for the magnitude of historic earthquakes; homogenization of data base; reliability and completeness of instrumental data.
  The IAEA Review Missions also raised the issues of uncertainties in the magnitude of earthquakes, and the completeness of data.

- Seismic zoning: Use of a background zone and maximum magnitude selected for this zone; impact of a change of the zoning on hazard results; definition of zones Zn01 (including the seismicity near Komarno) and Zn05 (including the Certovica Shear Zone and the Central Slovakian earthquake of 1443).
  The IAEA Review Mission of 2003 also raised the issue of seismic zoning. According to the Slovak experts, the potential impact of changes in the zoning

on hazard results were investigated in a sensitivity study in 2014 by ENEL. The Slovak experts point out that the purpose of this sensitivity study was to identify relevant aspects which particularly affect the seismic hazard of the NPP site, as well as potential effects of changes in the input database on seismic hazard results. It is not a sensitivity study of the original PSHA for the NPP Mochovce of 2003 and thus cannot be interpreted as an indication for possible changes of the PGA value for the site. The sensitivity study was limited to a few examined factors, when taken individually. It did not include a full logic tree calculation (which had been used in the PSHA). The ENEL sensitivity study concluded that the PGA value for the site calculated in 2003 can be considered as a representative value for the site hazard.
According to the Slovak experts, the sensitivity study cannot be used to draw any conclusions on the uncertainty of the final PGA value because the ENEL sensitivity study was about what is the impact within a mathematical model of a singular examined factor when varied, while combination with other factors were not examined. The results of this study should be taken as indicators only for the future PSHA with regard to the set of relevant input parameters. The Austrian experts note that an assessment of the uncertainties of the PGA value is highly relevant and that the sensitivity study should at least provide an indication for the uncertainty of the PGA value. However, the sensitivity study has not been made available to the Austrian experts. Therefore, they cannot form their own definitive opinion concerning the significance of the ENEL study results. Hence, the Austrian experts cannot verify whether they agree with these considerations of the Slovak experts, or not.
However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

- Determination of maximum and minimum magnitudes: According to Austrian expert's opinion for some source zones the maximum magnitude should be increased to correspond to current European practice.
  The maximum magnitude for the source zone including the site was selected with M_s=5.5 (corresponding to M_W=5.65 according to the empirical correlation used by SCORDILIS [2006]). Such a low value for maximum magnitude is not in agreement with current European practice. The SHARE project uses maximum magnitudes between M_W=6.7 and 7.3 for the area under consideration [WOESSNER 2015].
  The IAEA Review Mission 2003 also raised the issue of the influence of uncertainties on source-zone maximum magnitudes.
  In the view of the Slovak experts, the determination of the maximum magnitude depends on the seismotectonic model and the seismic zonation (superzones/small zones). It follows that, in their view, it is not appropriate to

compare the maximum magnitude values determined by using different seismotectonic models and zonation approaches. The Austrian experts note that this explanation does not sufficiently explain the significant discrepancy between the M_{max} values used in the different studies. The Slovak experts, however, consider that they have provided sufficient information and exhaustive explanation.
Another issue in this context is the selection of the value M_w=5.0 for the lower-bound earthquake magnitude on seismic hazard and the SL2 level. Cutting out the events between 4.0 and 4.9 can drastically remove the seismicity.
As already mentioned above, the Slovak experts pointed out in March 2019 that the seismotectonic model used for the PSHA study 2003 corresponded to the knowledge and best practices at that time. In response to the 2010 workshop, two sensitivity studies of the PSHA were performed: A study by Rizzo in 2013 updated the seismotectonic model, while source zone geometries were maintained. A study by ENEL in 2014 (already mentioned above) varied the source zone model and investigated the choice of the maximum magnitude for the source zones.
Regarding the lower-bound magnitude, the Slovak experts stated that the sensitivity study showed that the choice of a lower value for it does not lead to significant changes of the seismic hazard. The Slovak side further conveyed that additional measures were taken to protect containers for liquids with free surfaces, including the emergency core cooling tanks, against low magnitude/high acceleration earthquakes.

- Attenuation models: Models from the 1990s which have been used. Their representativeness and conservativeness were questioned by the Austrian experts.
  The IAEA Review Mission 2003 also raised the issue of adequate knowledge concerning attenuation, and appropriate attenuation models.
  The sensitivity studies by Rizzo 2013 and ENEL 2014 investigated the impacts of new ground motion prediction equations (GMPEs) on hazard results. They concluded that the main contribution to uncertainty in the hazard calculations arises from the uncertainty of the GMPEs used, and that the results are not in contrast with the results of the PSHA study.

The Austrian side acknowledges that relevant work has been performed since the workshop in 2010; in particular, the two sensitivity studies. However, these studies have not been made available so far. Thus, the Austrian experts cannot evaluate the methodologies and the results of these studies, and they cannot check whether they in fact cover the relevant points completely.

The Slovak experts stated that the results of the sensitivity studies will be appropriately taken into account in future seismic hazard calculations for the Mochovce NPP.

In the view of the Austrian experts, these sensitivity studies as well as the above-mentioned future analyses for the Mochovce site which are expected to use up-to-date methods which were not available for the PSHA from 2003, are aspects for which it would be desirable and expedient to resume bilateral discussions as soon as viable.
However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

Investigation of Faults

For most questions which were raised, this question has been clarified. Comprehensive information on the geological background of the EMO seismic hazard assessment as well as the evaluation of faults close to the site was provided by the Slovak experts.

The PSHA study had considered five faults in the vicinity of the NPP site (within a 5 km radius). Although three of them were marked as most likely being erosional structures, they were nevertheless included in the seismic hazard computation at that time. At the workshop, the Austrian expert team had not received information on specific studies of the youngest tectonic history of faults in the EMO near-region (5 – 25 km from the site). The Austrian experts regarded such evaluations as highly important, particularly for the Kozárovce and Mojmirovice faults which apparently displace sediments as young as Pliocene[1] (5.4 – 1.8 million years, as shown by reflection seismic and geological profiles), as well as the Levice fault which appears to show significant microseismic activity possibly including two M>3 events (1991 and 2004).

In March 2019, the Slovak experts provided the information that according to a study of 2013, the Levice fault can be considered to be a tectonically and seismically inactive structure. Also, it was claimed that the Kozárovce structure does not represent a tectonic fault. The Slovak experts also mentioned that further research activities are planned in the near future to study the nature of one of the faults in the vicinity (the Tlmače fault).

Furthermore, according to additional information supplied in March 2019, several studies of the youngest tectonic history of faults in the EMO near-region were

[1] IAEA [2010, 2015] suggests that the period Plicoene-Quaternary may be appropriate for the assessment of capable (active) faults.

performed, including paleo-seismic investigations northwest of the Mochovce site. Subsequent research concluded that the Dobrica elevation fault has atectonic character.

Another microseismic identification of tectonic structures was performed in 2009 near the NPP. A study of faults followed in 2013. The identified structures will be further investigated using microseismic data from the local network of seismic stations around the NPP.

The Slovak side noted that the microseismic data acquired and analysed so far do not identify active faults in the Mochovce NPP near-region.

The Austrian side acknowledges that relevant work has been performed in this field. However, the studies mentioned above, on the youngest tectonic history as well as on the Levice, Kozárovce and other faults, have not been made available so far. Thus, the Austrian experts cannot evaluate the methodologies and the results of these studies.

The correct assessment of (active) faults is of utmost importance for reliable seismic hazard assessments, against the background of the seismotectonic site characteristics (intraplate setting with slow and very slow-moving faults) and short earthquake observation periods (few hundred years / decades for historical and instrumental observations, respectively).

Therefore, in the view of the Austrian experts, the studies mentioned above are among the aspects for which it would be desirable and expedient to resume bilateral discussions as soon as viable.
However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

Peak Ground Acceleration (PGA)

At the workshop, a discrepancy between the results of the probabilistic seismic hazard assessment performed for the EMO site on the one hand, and the values provided by published hazard maps (SESAME, GSHAP and MUSSON [2000]) for the Slovak territory on the other, was identified. These hazard maps show much higher hazard levels for Slovakia. The differences are important; they could not be explained at the workshop. A possible explanation could be different assumptions for the lower-bound magnitudes used in the PSHAs. The 2010 workshop showed that this topic requires clarification and the Slovak experts agreed with the Austrian team that it should be discussed further.

In a comment received in March 2019, the Slovak side pointed out that the main reason for the discrepancies arises from the fact that GSHAP and SESAME seismotectonic models are not site specific, in contrast to the model used for the PSHA. It was stated that in general, it is expected to obtain slightly different seismic hazard values based on using different sets of input data on different scales.

According to the Slovak experts, these GSHAP and SESAME projects are also outdated and do not represent the actual state-of-the-art. The reference pan-European project today is the SHARE project from 2013. The Slovak experts asserted that it indicates significantly lower values for the seismic hazard at the Mochovce site.

According to the Austrian experts' opinion, this comment does not sufficiently clarify the reasons for the discrepancies between different seismic hazard assessments for the Slovak territory and the PSHA performed for the Mochovce site. In particular, the statement that the SHARE project indicates seismic hazard values which are significantly lower than those derived for the site cannot be verified based on SHARE data that indicates a ground motion value of 0.195 g for a recurrence interval of 4975 years for the site [mean hazard value; EFEHR 2013]. The Austrian Experts, however, agree that SHARE indicates a lower hazard level for the recurrence period 475 years which applies to normal building codes.

In this regard, the Slovak experts noted that all three projects (SHARE, GSHAP and SESAME) are regional, i.e., not site-specific and their results for the EMO site are therefore only indicative, not absolute. There are intrinsic differences between these regional projects and the site-specific seismic hazard calculations. Moreover, the site-specific seismic hazard analysis for the EMO site is calculated for a recurrence interval of 10 000 years, whereas the SHARE project does not provide reasonably applicable seismic hazard results for such recurrence period and its hazard curves cannot be used for direct comparison due to its regional character.

The Austrian experts assume that the two sensitivity studies mentioned above also addressed some aspects relevant for the determination of the site-specific PGA. However, details concerning the methodologies and results of these studies have not been provided to the Austrian side so far.

Therefore, in the view of the Austrian experts, the issue is among the aspects for which it would be desirable and expedient to resume bilateral discussions as soon as viable

However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

Seismic Monitoring System

Comprehensive information was provided regarding the microseismic monitoring system, and the results of monitoring obtained so far. This has been completely clarified.

In the view of the Austrian experts, the microseismic observations have provided evidence for possible active faulting in the near-region of the EMO site. The data were collected after the completion of the seismic hazard assessment of 2003; hence, they could not be taken into account for this seismic hazard assessment.

At the workshop, the Austrian expert team agreed with the Slovak experts that the question of the use of the microseismic data for fault-related research is highly relevant and requires further attention. Microseismic data now cover a record length of 24 years which should be sufficient to highlight seismogenic structures and support tectonic interpretations by fault plane and/or moment tensor solutions.

In 2019, the Slovak experts commented that the local network of seismic station has been active since 1996. At present, the microseismic data acquired so far are being analysed by the Earth Science Institute of the Slovak Academy of Sciences and will be used in further investigations in the Mochovce near-region in the near future.

According to the Slovak side, the microseismic data acquired and analysed so far do not identify active faults in the Mochovce near-region. In the view of the Austrian experts, however, it appears that analyses have not led to a definite conclusion regarding the potential activity of faults as yet. Austria expressed interest in the outcomes of the analyses and investigations when relevant and available.

An Austrian question concerning lessons learned from recent earthquakes was not discussed at the workshop, upon mutual agreement.

<u>Seismic Design:</u>

All questions have been fully clarified:

Overview

The equipment of EMO 3+4 was originally qualified for PGA of 0.1 g. Now, 0.15 g is required. Therefore, equipment has to be qualified for this value, plus a safety margin. In most cases, it is expected that the tests of manufacturers already covers the higher loads. Re-testing is necessary for a small percentage.

There are no requirements for the monitoring of SSCs with respect to low-cycle fatigue effects from normal operation in Slovakia. These effects might impair seismic load bearing capabilities. According to ÚJD SR , there is no intention to implement such requirements in the foreseeable future.

Seismic Margin Analysis, Re-evaluation

Seismic re-evaluation of structures and equipment had already been performed for EMO 3+4 at the time of the workshop. Piping systems and ventilation ducts are included in the re-evaluation. It included a seismic margin analysis.

Therefore, a number of measures were taken: For example, some parts of the super-emergency feedwater system have been strengthened and the firefighting building was reinforced.

Seismic Load Impacts

A comprehensive seismic load impact assessment was performed for the main building including the bubbler condenser tower. (The cooling towers have not been qualified for seismic loads.) A safety factor of 1.5 is used for simple equipment and pipeline hangers. For larger structures, 3-dimensional testing is applied.

Problems with anchor bolts (as were discovered in Germany in several nuclear power plants around 2006) are not expected by the Slovak experts. They pointed out that there is a fixed procedure for checking the installation of such bolts[2].

Seismic Qualification and Tests

Equipment qualification follows the methodology required by US standards, as well as standard IEC 60980. The test response spectrum does envelope the whole required response spectrum over the critical frequency range.

[2] The anchor bolts were discussed at the regular bilateral meeting between the Slovak Republic and Austria in 2019.

General Safety Concept

Significant information has been provided for this issue, regarding the modeling of buildings, superposition of loads etc.

If new information would provide reason for selecting a higher value for the peak ground acceleration than currently assumed, further information would be welcomed by the Austrian experts concerning seismic margin analysis, seismic load impacts as well as seismic qualification and tests.

Reactor Pressure Vessel Integrity

The workshop on reactor pressure vessel integrity was held at the ÚJD SR offices in Bratislava on November 20, 2012.

As for every workshop, a list of questions provided by the Austrian side before the workshop constituted the basis for the further discussion.

The questions were dealt with in a comprehensive manner. Some of the additional questions which were raised in the discussion could not be clarified at the workshop. Written answers to these questions were provided afterwards by the Slovak side, with an additional clarification given at the occasion of the second workshop on severe accidents in April 2016.

As a result, all Austrian questions have been clarified; mostly at the workshop and in some cases by additional information which was provided later:

Differences in Design of RPV and PC between EMO 3+4 and EMO 1+2

Manufacturing drawings, technological procedures, quality management, testing and production processes are the same for all RPVs of reactors of the type VVER-440/213.

There are no differences in design between the RPVs of EMO 1+2 and of EMO 3+4. Regarding the primary circuit, there are only minor differences which cannot influence the reactor pressure vessel.

Materials Used, Production of the Reactor Pressure Vessels

For the reactor pressure vessels, the ferritic-bainitic carbon steel 15Ch2MFA was used; for the primary circuit, the austenitic stainless steel 08Ch18N10T.

For the production of the EMO 3+4 RPVs, the producer (Škoda) could draw upon their accumulated experience from earlier RPVs. There is low content of copper, phosphorus and other impurities which could favor embrittlement.

No embrittlement problems are expected for the assumed lifetime of 40 years. Long-term operation for 60 years was not further discussed because this was not a subject at the expert workshop.

Preservation and Mothballing of the EMO 3+4 RPVs

Preservation and protection work was performed based on a program, which had been approved by ÚJD SR. The RPVs were stored under low humidity and regularly checked. The entire outer and inner surfaces were coated to prevent corrosion effects. No significant deficiencies were identified during preservation.

Archive material (e.g. for RPV surveillance samples) was stored under similar conditions. Samples were tested during EMO 3+4 completion and the results showed that the long-term conservation and storage had no influence on the mechanical properties.

Deviations from the Design Requirements

There are small deviations from design requirements and small variations between the RPVs – mainly as tolerances in the dimensions. However, all specifications were met within acceptable tolerances.

Embrittlement Curves

Both units will use a state-of-the-art surveillance specimen program. This program is based on the experiences with the other VVER-440/213 in Slovakia; compared to earlier programs, the number of specimen has been increased and their specifications have been changed. Also, their irradiation temperature can be determined much more accurately than in the earlier program.

The program includes samples from the heat-affected zone.

Embrittlement trend curves for EMO 3+4 will only be obtained after start-up of operation, with the aid of the surveillance program results. No predictions are performed based on the chemical composition. The current methodology for embrittlement prediction is based solely on experimental data (sample results). Results from mechanical testing of samples will be evaluated, using the “Master Curve” approach.

For EMO 1, the embrittlement temperature is expected to rise to about 25° - 45° C; according to PTS-analyses, the critical temperature for brittle fracture is higher than 90° C.

After one year of operation of a unit, the first surveillance samples will be taken out of the RPV. The first results on radiation embrittlement will be available about one and a half year later.

Lead Factors of the Surveillance Program

The lead factors of the original surveillance program (dating back more than 30 years) were in the range of 5 – 15. For the new program, lead factors for the RPV material vary in the range of 3 – 5.

A possible dose rate effect is not considered as significant by the Slovak experts. Dose rate effects had been observed at very high fluences (with lead factor about 150). No dose rate effect became apparent when comparing samples with lead factors 5 and 15.

Load Cases for PTS Analyses

At the time of the workshop, PTS analyses for EMO 3+4 had not yet been performed. Information concerning the events which have been analyzed was given later by the Slovak side.

As for EMO 1+2, ten initiating scenarios have been calculated. A table of these scenarios including the cases considered for each scenario was provided at the workshop. The scenarios cover LOCA, primary-to-secondary leakage, inadvertent actuation of ECCS high pressure injection, single steam line breaks etc. Multiple steam line breaks are not included. According to the Slovak side, the results for all scenarios show that the required conditions are fulfilled and acceptance criteria will not be violated.

At the workshop, it was reported that generally, no operator action is required within 30 minutes; except in one case (leakage of primary collector head of steam generator) for which an intervention time of 20 minutes was reported. At the second workshop on severe accidents (April 2016), however, it was stated that this information has become obsolete and more recent analyses have shown that there are always 30 minutes or more available for operator intervention (see section on severe accident management).

Conservatism is to be applied by appropriate assumptions (e.g. maximum primary side cool-down and overpressure). The code RELAP 5 mod 3.3 was used for thermos-hydraulic calculations. For structural analyses, the codes ANSYS and ADINA were employed. The RELAP 5 model was validated with results from experiments at Paks NPP.

The crack size assumed for the PTS analyses is based on the reliability of crack detection, taking into account inaccuracies. For example, for an underclad crack a postulated depth of 15 mm is assumed. For each case considered in the PTS analysis, the maximum allowable critical temperature of embrittlement is determined for all points of the crack front; the minimum of these values is the maximum allowable temperature for this PTS case. The maximum allowable temperature for the RPV is equal to the minimum value of the maximum allowable temperatures for all analyzed PTS sequences.

External cooling of the reactor pressure vessel in case of a severe accident is among the PTS cases considered. Spurious activation has been practically eliminated on the basis of probabilistic analyses; nevertheless, analyses have been performed (this was discussed further at the second workshop on severe accidents in April 2016, see section on severe accident management). Flooding of the reactor cavity in case of LOCA has also been analyzed.

Application of VERLIFE Methodology

VERLIFE is to provide a concise and coherent methodology for the assessment of integrity of components of NPPs with WWER reactors. Inter alia, it also deals with assessment of RPV integrity. It covers inspection, monitoring, diagnostics and prediction of RPV ageing.

The latest version of VERLIFE at the time of the workshop (2008) has been adopted by the Slovakian regulatory authority. A new version is to be published as an IAEA guide in the near future.

Ultrasonic Testing Methods

The task of ultrasonic testing is to detect, localize and size defects. The inspection system used for EMO 3+4 has been qualified in accordance with an ÚJD SR guideline, based on European methodology. As already mentioned (see load cases for PTS analysis), the postulated crack depth for PTS analyses is 15 mm for underclad cracks. The target defect for ultrasonic testing which is to be detected with 100 % reliability is smaller (6.5 mm for underclad cracks).

The inspection period of the reactor pressure vessel is 8 years. All welds of the primary circuit are accessible for ultrasonic testing.

Low-leakage Strategy and Other Precautionary Measures

For fuel loadings after the initial one, profiled fuel will be used – the enrichment of the fuel assemblies will be highest in the central core region and lower in the peripheral regions. Thus, neutron fluence in the RPV wall will be reduced. There are no plans to use dummy elements.

Emergency core cooling water will be pre-heated to between 55° and 60° C in the hydro-accumulators and between 50° and 55° C in the ECCS tanks.

Regarding the development of the embrittlement, the Austrian experts would appreciate to be informed about the first and all further future results of the surveillance program for EMO 3+4, including a comparison with the results from EMO 1+2.

Digital Instrumentation and Control

The workshop on digital instrumentation and control was held on December 11, 2015 at the ÚJD SR offices in Bratislava.

A list of questions provided by the Austrian side constituted the basis for presentations and discussions at the workshop.

The questions were dealt with in a comprehensive manner. New and relevant information the Austrian experts had not been acquainted with before was provided. After the workshop, additional clarifications and information were provided by the Slovak side in March 2019 and October 2019.

As a result, most of the technical aspects addressed in the questions were concordantly resolved. For some other aspects, differences of opinion between Slovak experts and Austrian experts have remained.

Furthermore, there is, in the view of the Austrian experts, one point for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussions were exhaustive. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open points remained.

The following questions have been fully clarified:

Comparison of Digital I&C of EMO 3+4 with EMO 1+2

Information concerning the software systems used in EMO 1+2, and the updates performed as planned, was provided. Furthermore, the main similarities and differences regarding lifetime, customer requirements, architecture, function and hardware between EMO 1+2 and EMO 3+4 were explained.

Reference Standards and Norms, Classification

The international standards and norms to which the I&C platforms used at EMO 3+4 (TELEPERM XS and SPPA-T2000) had been developed were indicated. An overview of the categorization of the difference functional parts of the I&C was provided, as well as an assignment of different I&C systems to safety classes.

System Architecture

An explanation and description of the general architecture of the EMO 3+4 I&C systems was provided, as well as of different functional parts for operational control, reactor protection, prevention of core melt etc. Furthermore, the I&C coverage for outages and refueling was described.

A table with the assignment of the I&C systems to the levels of defence-in-depth was presented.

Power Supply

The connection of the power supply for I&C important to safety to the different redundancies of the emergency power systems was described and the independence of the available emergency power sources explained. Information regarding the time for which power supply to the I&C important to safety is guaranteed in case of total loss of AC power was provided.

Maintenance and Modification

The regime for changes during the systems' lifetimes was presented. The expected frequency of changes was discussed, information on the criteria for granting permission to change was provided.

Furthermore, the regime for re-assessment after a change was addressed, as well as the questions of availability of maintenance and replacement parts, and the handling of commodity software being used.

Testing and Quality Assurance at all Steps of Development, Use and Modification

The criteria for acceptance tests for digital I&C important to safety were presented, as well as information on how the tests were performed. The present status of the site acceptance tests was described. The performance of version tracking and update management was explained. The scope of the test cases was discussed, in particular the inclusion of "exotic" situations, as well as the extent of testing of complex combinations of scenarios.

Control Room, Operator Response

The annunciation of digital I&C failures in the control room was described. The coverage of such failures by EOPs was discussed, as well as the dependency of the emergency control room on digital I&C.

An overview of the implementation of human-system interfaces in the main and emergency control rooms was provided.

Some aspects of this topic were discussed in the context of design diversity (see below).

Interaction with Other Functions

The potential interactions of the digital I&C systems with access control systems, emergency lighting, fire and smoke alarms were discussed, as well as the interactions with local control stations and manual system actuation.

Internal and External Hazards, and I&C

Information about the analyses and tests which were performed regarding the impact of internal and external hazards on I&C was provided. Electromagnetic interference and lightning-strike received particular attention, as did the questions of possible impacts of an inadvertent actuation of the fire suppression system on digital I&C.

For the following questions, there are differences of opinion between Slovak and Austrian experts. Furthermore, there is in the view of the Austrian experts, one point for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussions during the workshop were exhaustive. They consider that together with the additional information provided after the workshops, all issues were comprehensively and exhaustively explained and no open point remained.

Design Diversity, Physical Separation and Independence

The levels of diversity between the redundancies of the reactor protection system, and between the channels of each redundancy were discussed, as well as the main elements of diversity and dissimilarity realized for the protection system and other I&C important to safety.

The extent of physical separation and functional independence of the different parts of the I&C systems was presented; reliability of gateways, galvanic separation and flow-control fairness in the networks were discussed.

All aspects of this issue were clarified, with one exception, concerning the use of manual (operator) actions as diverse back-up for an assumed complete failure of ESFAS. It was agreed that this matter should be discussed further at the second workshop on severe accidents in April 2016. After this further discussion, some differences of opinion between Slovak experts and Austrian experts remained (see section on severe accident management).

Software Reliability

Quantitative reliability goals for the I&C systems as well as reliability values for some systems (both of operating system software and application software) were presented. The analyses used for the demonstration that the goals are achieved were discussed. It was pointed out that values for probability of failure on demand (pfd) are based on engineering judgment of supplier specialists.

Information on the diversity between the two platforms Teleperm XS and SPPA-T2000 was provided, and the independence of failures between these platforms discussed. Furthermore, questions concerning an analogue backup, the simplicity of the software and the use of pre-existing software were addressed. The position of the regulatory authority UJD SR regarding software reliability issues was also presented in the discussion.

All questions of the Austrian experts were answered. However, an aspect to be discussed further remained concerning software reliability – in particular, concerning the reliability of some very low values provided for failure on demand.

The Austrian experts pointed out that statistical testing of software, with simulated demands, would be an advantageous method to determine pfd values. Failures both at operating system level and application level would automatically be taken into account, as well as the interplay between different systems. Statistical testing was required by the UK regulator ONR to support claims for the pfd of the I&C system of the EPR.

The Slovak side explained that the software in the safety I&C systems has been developed by application of the IEC 60880 standard, the relevant international norm which is also applied by UJD SR as basic requirement. According to the Slovak experts, the application of this standard will ensure the maximum attainable software reliability and therefore, the probability of a software failure will be sufficiently low. Therefore, the values provided for pfds, based on supplier engineering judgment, are acceptable for ÚJD SR.

The Slovak experts furthermore agree that statistical testing would be feasible; however, they emphasize that one has to keep in mind not only the advantages of this method, but also its drawbacks. They also point out that there are differences of opinion between international experts regarding the appropriate methodology for assessing the reliability of software. For EMO 3+4, "expert-controlled testing" (relying on calculation approaches and engineering estimates) has been selected as testing method: This includes experiences with on-going and completed licensing for systems based on TELEPERM XS in various countries operating NPPs. The Slovak experts further noted that the experience-based method combined with a strong verification and validation cycle for development of I&C systems provides high confidence of system robustness. On the contrary, usage of statistical method provides only indicative information that is most of time subject of different interpretations.

The Austrian experts expressed reservations about this approach. In their opinion, expert judgment can be questionable when estimating the chance of rare events. On the other hand, statistical tests as they can be performed today, with a sufficiently high number of test demands, permit to achieve high confidence in upper limits for pfd values.

The Austrian experts also note that although the Slovak experts state that the statistical method has drawbacks, they did not provide a comprehensive substantiation for this point. Consequently, this issue should be considered a topic for future bilateral discussions.

However, the Slovak experts consider that they have provided comprehensive substantiated explanations on the statistical method. They consider that together with the additional information and comments provided after the workshops this point was comprehensively and exhaustively clarified and no open points remained.

Failure Modes, in Particular Common Cause Failures

The overall concept to avoid or control CCF of important functions was presented. Specific information about the methods applied for CCF analysis was not discussed because detailed treatment of CCF analysis would be beyond the scope of the Safety Dialogue.

The failure modes assumed to occur in CCF analyses were discussed, in particular concerning the control of an active functional failure. Furthermore, the compensation of a CCF failure in the reactor protection system and the ESFAS was addressed.

Regarding potential CCF of the reactor trip breakers and the priority actuation and control system (PACS), which are both based on PLD technology, the Slovak experts pointed out that there is no network communication between individual PLD-based modules; they all perform their logic operations independently. Thus, potential fault propagation via networks (one of the main risks for CCF in complex systems) is excluded. ÚJD SR treats those PLD modules as pure hardware components and therefore does not impose special requirements related to CCF-risk.

The Austrian experts agree that internationally, there are considerations to treat PLDs as hardware components, i.e. as components without some of the specific drawbacks of software based systems. However, according to their knowledge, design diversity between the PACS modules is requested for the European EPR if PLDs are used, due to the high safety relevance of this system.

Thus, a difference of opinion remained for this issue.

Severe Accident Management

Two workshops on severe accident management were held: On December 15, 2009 and on April 27/28, 2016. Both took place at the ÚJD SR offices in Bratislava.

At the time of the first workshop, the basic design phase of EMO 3+4 had been concluded and the detail design phase had started. Technical questions as well as questions concerning safety targets for severe accidents were discussed.

At this first workshop for a number of issues, the information provided was sufficient to make clear the general approach and the underlying philosophy. However, differences of opinions remained on some subjects and some open questions remained. Furthermore, there were other issues which were discussed in a very summary manner only.

The Slovak and the Austrian side agreed that further discussion of these issues would only be possible as more information becomes available in the course of the licensing procedure – to the extent that the detail design proceeds.

Therefore, a second workshop on severe accident management was held in 2016 at a time when the detail design phase was already very far advanced.

For both workshops, a list of questions provided by the Austrian side constituted the basis for presentations and discussions. The following is focused on the second workshop which covered all questions dealt with in the first workshop in more detail, as well as additional points.

The questions were dealt with in a comprehensive manner. New and relevant information the Austrian experts had not been acquainted with before was provided. After the workshop, additional clarifications and information were provided by the Slovak side in March 2019, October 2019 and March 2020.

As a result, a considerable part of the technical aspects addressed in the Austrian questions was concordantly resolved; for some other questions, differences of opinion between Slovak experts and Austrian experts have remained.

Furthermore, there is, in the view of the Austrian experts, one point for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

The Slovak experts consider that they have provided sufficient evidence-based information. In their view, the discussions were exhaustive. They consider that together with the additional information provided after the workshops these points were comprehensively and exhaustively clarified and no open point remained.

At the beginning of the workshop, an overview of the legal framework for severe accidents was provided, covering the most important Decrees and Guides in this field. Current updating processes were mentioned. The application of regulations to existing and new reactors was discussed, as well as the use of the European Utility Requirements (EUR) by the applicant.

The following technical questions have been fully clarified:

Overview of relevant safety targets and approaches to safety

The current safety targets and the definitions of large and early releases were presented. The application of the European Utility Requirements (EUR) was discussed. An overview of severe accident scenarios was provided, as well as an overview of the hardware provisions dedicated to the mitigation of severe accidents, including the electric power supply. Also, a general overview of the SAMGs was given. The application of the "practical elimination" concept was discussed.

Regarding the mobile emergency power supply after earthquake loads exceeding the design basis earthquake (design extension conditions), the Slovak side asserted that mobile DGs are designed for DEC, including earthquake. It was also pointed out that the mobile DGs for all NPPs are interchangeable. The shelters for the mobile DGs are designed with safety margins to withstand at least the design basis external events. The availability and the accessibility of the connection points for the mobile DGs during DEC (including earthquakes) have been taken into account in the operation procedures.

Hydrogen Production, Release and Mitigation

An overview of the capabilities, capacities and positioning of recombiners and igniters was provided. Interactions between recombiners, igniters, containment spray and ventilation system were discussed, as well as the performed analyses of accident scenarios, regarding hydrogen release and recombination.

Furthermore, the possibility and consequences of deflagrations was discussed and the status of a project on hydrogen migration presented. An overview of the relevant SAMGs was provided.

Primary Depressurization

A description of the dedicated depressurization system for severe accidents was presented, as well as relevant accident scenarios. Frequency and consequences of failure of depressurization were discussed, as well as the relevant SAMGs.

Long-term Management of Containment Pressure

The containment spray system was described. Relevant accident scenarios with late pressurization of the containment were discussed, including the expected behavior of the bubbler condenser and the trap for non-condensable gases. Considerations concerning the containment failure pressure as well as an overview of the relevant SAMGs were provided.

Provisions for Multi-Unit Accidents

The current status of analyses and the implementation plan for additional measures in case of multi-unit accidents were discussed.

Source Terms for Different Accident Scenarios

An overview of estimated source terms and assumed conditions for different severe accident scenarios was provided. The treatment of uncertainties caused by different options for fuel/core configuration was discussed, as well as accident scenarios leading to cliff-edge effects.

Design Basis Accident Scenario Requiring Operator Intervention within < 30 Minutes

Variants of pressurized thermal shock (PTS) analyses in case of primary-to-secondary leakage were discussed.

At the workshop on reactor pressure vessel integrity (November 2012), it had been reported that in one case (leakage of primary collector head of steam generator) operator intervention was required within 20 minutes. This was noteworthy since guidelines and methodologies applied for evaluation of accidents (DBA and DEC-A) assume that operator intervention is not needed within less than 30 minutes.

However, it was explained that this information has become obsolete and more recent analyses have shown that there are always 30 minutes or more available for operator intervention (see also section on reactor pressure vessel integrity).

An overview of the results of the analyses was provided, as well as information on the model scenarios for simulator training.

External Events of Human Origin

An overview of the considerations regarding screening out of impacts on the plant from industrial, transportation and military activities was provided. Furthermore, the methodology for analyzing the impact of a small aircraft was briefly discussed.

For the following questions, differences of opinion between Slovak and Austrian experts remained. Also, there is, in the view of the Austrian experts, one point for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshops this point was comprehensively and exhaustively clarified and no open point remained.

In-Vessel Retention of Molten Core

The whole system for in-vessel retention including electric power supply and instrumentation was described. The required design modifications were presented. An overview of the relevant accident scenarios was provided.

The experimental and analytical confirmation of the functioning of the IVR strategy, including large-scale experiments, was presented and discussed at length, in particular concerning the so-called CERES experiments. An overview of the PTS analyses for IVR scenarios was provided, as well as an overview of the relevant SAMGs.

Furthermore, the analyses and considerations for the failure of the IVR strategy were discussed.

A significant amount of new information was provided and most aspects of this issue were sufficiently clarified. However, some differences of opinion remained. The Austrian expert team is not sure how representative the CERES-experiments are since the azimuthal section of the RPV which is reproduced in the experimental facility is small (a slice of 9 degrees). Also, less than 10 qualified experiments were performed. The Slovak experts, on the other hand, state that the experiments are in fact representative since the CERES facility represents a full-scale replica in height (although the scaling in azimuthal direction is only 1:40) and that the number of experiments is regarded as sufficient.

All in all, the information provided so far did not permit the Austrian experts to achieve a conclusive overview of the extent of the experimental and analytical projects mentioned by the Slovak experts, and how these projects have been utilized to support the EMO 3+4 IVR concept.

The Slovak experts consider that they have provided comprehensive information concerning the in-vessel retention of the molten core. The Slovak experts point out that various organizations (domestic and international) have been involved in the design of the IVR strategy and its review. In their view, the analyses and experiments confirm that the IVR strategy is effective and there is no evidence to the contrary.

Furthermore, the Austrian experts are of the opinion that a full-scale cold test of the filling up of the reactor cavity and flooding of the reactor pressure vessel is essential.

The Slovak experts agree that special attention should be paid to this issue. However, a difference of opinion remains: the Slovak experts do not agree that a full-scale cold test would help to increase confidence in the design solution since the conditions of the cold test would differ considerably from the reality. Thus, the conditions of the cold test would differ so much from reality that the efforts and potential difficulties associated with the test would outweigh the benefits. The confirmation that the flooding of the reactor cavity is effective is based on analyses which have been performed by different expert groups, with different computer codes and models. In the view of the Slovak experts, the analyses confirm that the flooding of the reactor cavity is effective and there is no evidence to the contrary. A difference of opinion remained here.

All in all, in the view of the Austrian experts, the issue of the scope of the experimental and analytical validation of the IVR concept of EMO 3+4 should be considered a topic of future bilateral discussions.

The Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshop this subject was comprehensively and exhaustively explained and no open point remained.

Accident Sequences Requiring Operator Intervention in Case of an assumed complete ESFAS Failure

The postulated initiating events which have been considered were presented and discussed. The time of needed operator intervention received special attention.

The Slovak side explained that the functions of ESFAS are assured in a redundant and diverse manner: In addition to the three redundant (identical) automatic sub-systems of the ESFAS, the operator also has the possibility to intervene and actuate the needed systems manually. Thus, manual action serves as diverse back-up.

The Austrian questions raised were answered and clarified. However, differences of opinion between Slovak experts and Austrian experts remain regarding the diverse means for the actuation of ESFAS functions.

The Austrian experts are of the opinion that a diverse automatic system for ESFAS would be advantageous and that diversity should not only be provided by operator action.

The Slovak experts consider that ESFAS diversification is not needed. They explained that no operator actions are required within the first 30 minutes after accident initiation, for all severe accident scenarios (DiD level 4). This is due to the high water inventory of VVER units. All operator actions are performed according to symptom based SAMGs, independent of the specific scenario.

The Austrian expert team noted that nevertheless a diverse system for ESFAS that would help to keep an accident at the third level of DiD (design basis accidents) would be favourable.

The Slovak side, on the other hand, stated that diversification of ESFAS at the third level of DiD is unusual for reactors with small thermal power like Mochovce, although ESFAS diversification can be seen in new reactor designs with large thermal power to suppress occurrence of some specific initiating events and their consequences not typical for VVER-440 reactors. Furthermore, according to the Slovak experts, the results of PSA confirm that the risk for EMO 3+4 NPP is low enough. The ESFAS is a very reliable system and its contribution to the overall risk is very small. (The issue of ESFAS diversification had already been addressed at the workshop on digital I&C in December 2015, and was assigned for further discussion to the second workshop on severe accidents – see section on digital information and control).

Consultation of the Preliminary Safety Analysis Report

A small group of Austrian experts was given the opportunity to consult the Preliminary Safety Analysis Report (PRESAR) of EMO 3+4 on June 06/07, 2011, at the headquarters of Slovenské Elektrárne, a.s., in Bratislava.

The PRESAR is a document of approx. 5,800 pages, dating from August 2008. It was prepared by the technical support organisation VÚJE.

The PRESAR is in Slovak language. It is structured according to the ÚJD SR safety guideline BNS I.1.2/2008, which on its part closely follows the IAEA Safety Guide "Format and Content of the Safety Analysis Report for Nuclear Power Plants", Safety Standards Series No. GS-G-4.1, 2004.

A table of contents was provided for the consultation. The Austrian experts could study the PRESAR with the aid of an interpreter; a representative of Slovenské Elektrárne provided some explanations and additional information going beyond the PRESAR sections which have been studied.

A number of sections were consulted, dealing with design requirements, design of various systems of the plant, as well as safety analyses.

Consulting the PRESAR was an exercise worthwhile to be undertaken, since the Austrian experts acquired a considerable scope of useful information. At the same time, an overall impression on structure and scope of the PRESAR could be gained.

When studying the PRESAR, it had to be kept in mind that this document is dated from August 2008 – it represents the state of considerations near the end of the basic design phase. It does not contain information on the detail design phase.

Visit of the EMO 3+4 Site

As part and closing activity of the Safety Dialogue, a visit to the construction site of EMO 3+4 was organized on June 28, 2016.

A delegation of Austrian experts had the possibility to visit the following parts on site:

- Inside the containment:
  - Reactor cavity
  - Corridor between bubbler condenser tower and steam generator boxes
  - Bubbler condenser tower floor and Air trap
- Intermediate building: dump-to-atmosphere valves (BRU-A)
- Turbine hall: dump-to-condenser valves (BRU-K) and turbine
- Reactor building:
  - Control room and emergency control room
  - I&C panel room
  - Emergency feed-water tanks and SAMG borated water tanks

The general impression was that the Slovak experts were very open to give detailed information and answer all questions asked by the members of the Austrian expert team during the site visit.

The site visit has provided the Austrian expert team with a better understanding of the systems which were discussed during the dedicated expert workshops. Many questions were answered and clarified. However, some issues remain in which the opinion of the Austrian expert team differs from the opinion of the Slovak experts, and some issues are considered not yet resolved by the Austrian expert team.

Regarding the IVR strategy, what was shown about the flooding process gave the impression that flooding of the cavity should be possible if the cavity is leak-tight (for further discussion of this issue, see section on severe accident management).

The distance between the main control room (MCR) and the emergency control room (ECR) appears to be rather small. No special provisions to protect the ECR could be observed by the Austrian expert team. The assumption that the ECR remains habitable when the MCR is not seems questionable.

However, according to additional information provided from the Slovak side in October 2019, the ECR is not primarily destined for cases involving a severe accident. Rather, it is meant for situations when the habitability of the MCR is decreased due to circumstances other than nuclear, and there is a need to shut down the reactor. It does not feature a dedicated severe accidents panel, but nevertheless management of severe accident systems is also possible from the ECR through the standard instrumentation and control interface, when accessed via special SAMG credentials.

Furthermore, the Slovak experts stated that the emergency response centre (ERC), which also can take over control of the unit, is equipped with a SA panel. The ERC is located in a protected shelter in a separate building on the territory of the Mochovce NPP.

Conclusions

Confinement and bubbler condenser:

All Austrian questions have been clarified.

The design of the containment of EMO 3+4 is in accordance with current recognized general safety practices and requirements for design, for nuclear power plants operating today.

Site Seismicity and Seismic Design:

A considerable part of the technical aspects addressed in the Austrian questions was concordantly resolved. This includes agreement that the question of the use of microseismic data for fault-related research is highly relevant and requires further attention.

There are, in the view of the Austrian experts, some aspects for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

The Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshop this subject was comprehensively and exhaustively explained and no open point remained.

For the hazard assessment, the aspects mentioned above concern the earthquake catalogue, seismic zoning, maximum and minimum magnitudes, and attenuation models. According to information provided by the Slovak side in 2019, two sensitivity studies have been performed since the workshop 2010 which are relevant for these issues. However, these studies have not been made available to the Austrian experts. It was emphasized by the Slovak experts that the sensitivity study is not a sensitivity study of the original PSHA for the NPP Mochovce of 2003 and thus cannot be interpreted as an indication for possible changes of the PGA value for the site. Nevertheless, the Austrian experts think that it should provide an indication for the uncertainty of the PGA. Differences of opinion remained.

The Slovak experts further stated that the results of the sensitivity studies will be appropriately taken into account in future seismic hazard calculations for the Mochovce NPP site.

In the view of the Austrian experts, these sensitivity studies as well as the above-mentioned future analyses for the Mochovce site which are expected to use up-to-date methods which were not available for the PSHA from 2003, are aspects for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

The Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshop this subject was comprehensively and exhaustively explained and no open point remained.

Another point concerns the investigation of faults. According to information provided by the Slovak side in 2019, studies on the youngest tectonic history in the EMO near region (including paleo-seismic investigations), as well as studies on the Levice, Kozárovce and other faults have been performed since the workshop. These studies have not been made available to the Austrian experts. The Slovak side noted that the identified structures will be further investigated using microseismic data from the local network of seismic stations around the NPP. Slovak experts further noted that the microseismic data acquired and analysed so far do not identify active faults in the Mochovce NPP near-region.

The Austrian experts expressed interest to discuss studies and data mentioned above.

Regarding the peak ground acceleration (PGA), a discrepancy between the results of the PSHA on the one hand and the values provided by published hazard maps (GSHAP, SESAME) on the other was identified. In 2019, the Slovak side stated that a pan-European project on seismic hazard (SHARE) indicated significantly lower hazard values than GSHAP and SESAME. In view of the Austrian experts, this statement cannot be verified for the EMO design basis based on published data.

In this regard the Slovak experts noted that all three projects (SHARE, GSAP and SASAME) are regional, i.e. not site specific and their results for the EMO site are therefore only indicative (e.g. hazard curves).

The Austrian experts assume that at least one of the sensitivity studies mentioned above is also relevant for the determination of PGA. This would be another reason to consider it as a topic for further discussion.

However, the Slovak experts consider that they have provided sufficient evidence-based information. They consider that together with the additional information provided after the workshop these points were comprehensively and exhaustively clarified and no open points remained. In particular, in their view the sensitivity study cannot be used to draw any conclusions on the uncertainty of the final PGA value because of its limited scope.

Reactor Pressure Vessel Integrity:

All Austrian questions have been clarified.

Regarding the development of the embrittlement, the Austrian experts would appreciate to be informed about the future results of the surveillance program for EMO 3+4, including a comparison with the results from EMO 1+2.

Digital Instrumentation and Control:

A considerable part of the technical aspects addressed in the Austrian questions was concordantly resolved.

There is, in the view of the Austrian experts, one aspect for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

This concerns software reliability. The Austrian experts consider statistical testing as an advantageous method to determine pfd values. The Slovak side, however, selected expert-controlled testing as testing method, pointing out that the statistical method has drawbacks.

The Slovak experts noted that the experience based method combined with strong verification and validation cycle for development of I&C systems provides high confidence of system robustness. On contrary, usage of statistical method provides only indicative information that are most of time subject of different interpretations.

However, in the view of the Austrian experts, the Slovak experts did not provide comprehensive substantiation for this aspect. Therefore, it should be considered as topic for future discussions.

However, the Slovak experts consider that they have provided comprehensive and substantiated information on this point. They consider that together with the additional information and comments provided after the workshops this point was comprehensively and exhaustively clarified and no open point remained.

Furthermore, differences of opinion remained for two issues. They concern aspects of design diversity (which was discussed further in the second workshop on severe accident management) as well the possibility of common cause failures in PLD modules.

Severe Accident Management:

A considerable part of the technical aspects addressed in the Austrian questions was concordantly resolved.

There is, in the view of the Austrian experts, one aspect for which it would be desirable and expedient to resume bilateral discussions as soon as viable.

This aspect concerns the experimental and analytical validation of the in-vessel retention of the molten core at Mochovce NPP. A significant amount of information was provided by the Slovak experts concerning this topic. However, the information did not permit the Austrian experts to achieve a conclusive overview of the extent of the experimental and analytical projects mentioned, and how they have been utilized to support the EMO 3+4 IVR concept. This issue is of pivotal importance in the context of severe accident management and should be considered as a topic for future bilateral discussions.

The Slovak experts consider that they have provided comprehensive information and emphasized that various organisations (domestic and international) have been involved in the design of the IVR strategy and its review. In the view of the Slovak experts, the analyses and experiments confirm that the IVR strategy is effective and there is no evidence to the contrary. They consider that together with the additional information and comments provided after the workshops this point was comprehensively and exhaustively clarified and no open points remained.

Furthermore, differences of opinion remained for two issues.

One point concerns the importance of a full-scale cold test of the filling up of the reactor cavity and flooding of the reactor pressure vessel. The site visit has provided the Austrian expert team with a better understanding of the systems involved. They regard such a test as essential. The Slovak experts, on the other hand, point out that analyses of the cavity flooding have been performed by different expert groups, with different codes and models. They confirmed that the flooding is effective. In the view of the Slovak experts, a full-scale test would not help to increase confidence in the design solution.

The second point concerns the diversification of ESFAS. The Austrian experts regard a diverse system for ESFAS that would help to keep an accident at the third level of DiD as favourable. The Slovak experts point out that that ESFAS is a very reliable system and that ESFAS diversification at the third level of DiD is unusual for small reactors like Mochovce. ESFAS diversification can be seen in designs of reactors with large thermal power to suppress occurrence of some specific initiating events and their consequences not typical for VVER-440 reactors.

At the second workshop on severe accidents both sides confirmed that this workshop is considered as a conclusion of the expert consultation process agreed in 2008 and contained in the final statement of the Ministry of Environment of the SR on EIA of EMO3&4 (2010.

References

EFEHR 2013	Seismic hazard map - shapefiles downloaded 03.04.2013 and 19.03.2020 http://www.efehr.org/en/hazard-data-access/hazard-maps/
IAEA 2004	International Atomic Energy Agency: Design of Reactor Containment Systems for Nuclear Power Plants; IAEA Safety Standards Series No. NS-G-1.10; Vienna 2004
IAEA 2007	International Atomic Energy Agency: IAEA Safety Glossary, Terminology Used in Nuclear Safety and Radiation Protection; Vienna 2007
IAEA 2010	International Atomic Energy Agency: Seismic Hazards in Site Evaluation; IAEA Specific Safety Guide No. SSG-9; Vienna 2010
IAEA 2015	International Atomic Energy Agency; The Contribution of Palaeoseismology to Seismic Hazard Assessment in Site Evaluation for Nuclear Installations; IAEA-TECDOC-1768; Vienna 2015
MUSSON 2000	Musson, R.: Generalised seismic hazard maps for the Pannonian Basin using probabilistic methods; Pure Applied Geophysics, vol. 157, 2000, 147-169
SCORDILIS 2006	Scordilis, E.M.: Empirical global relations converting MS and mb to moment magnitude; J. Seismology, vol. 10, 2006, 225-236
WOESSNER 2015	Woessner, J. et al.: Bulletin of Earthquake Engineering, vol. 13, 2015, 3553-3596

Abbreviations

AC	Alternate current
BDBA	Beyond design basis accident
BRU-A	Dump-to-atmosphere valves in secondary circuit
BRU-K	Dump-to-condenser valves in secondary circuit
BWR	Boiling water reactor
CCF	Common-cause failure
DBA	Design Basis Accidents
DEC(-A)	Design extension conditions (without severe fuel damage)
DG	Diesel generator
DiD	Defence-in-depth
ECCS	Emergency core cooling system
ECR	Emergency control room
EIA	Environmental Impact Assessment
EMO	Mochovce NPP
ENEL	Ente Nazionale per l'Energia Elettrica
EOPs	Emergency operational procedures
EPR	European Pressurized Water Reactor
ESFAS	Engineered safety systems actuation system
EUR	European utility requirements
GMPE	Ground motion prediction equation
GSHAP	Global Seismic Hazard Assessment Program (seismic research program)
I&C	Instrumentation and control
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
IVR	In-Vessel Retention
LOCA	Loss of coolant accident

M	Magnitude (of earthquake)
MCR	Main control room
NPP	Nuclear power plant
ONR	Office for Nuclear Regulation (UK nuclear regulatory authority)
PAC	Preliminary acceptance certificate
PACS	Priority actuation and control system
PC	Primary circuit
pfd	Probability of failure on demand
PGA	Peak ground acceleration
PLD	Programmable logic device
PRESAR	Preliminary Safety Analyses Report
PSA	Probabilistic safety assessment
PSHA	Probabilistic seismic hazard study
PTS	Pressurized thermal shock
PWR	Pressurized water reactor
RPV	Reactor pressure vessel
SA	Severe accident
SAMGs	Severe accident management guidelines
SE	Slovenské elektrárne
SESAME	Seismic Effects Assessment Using Ambient Excitations (seismic research program)
SHARE	Seismic Hazard Harmonization in Europe (collaborative European project)
SL2	Safety level 2 (for earthquakes, corresponds to design basis)
SSCs	Systems, structures and components
ÚJD	Úrad Jadrového Dozoru (Nuclear Regulatory Authority of the Slovak Republic)
VERLIFE	Guidelines for integrity and lifetime assessment of components and piping in WWER NPPs during operation
VVER	Vodo-vodyannoy energeticheskiy reactor (soviet-design reactor type)

Appendix: Alphabetical Listing of Participating Experts

In the following table, all experts who have taken part at least once in WS and/or PRESAR consultation and/or site visit as part of the Austrian delegation are listed alphabetically.

Name	Institution	Participation*)
H. Hirsch	Co-ordinator of the Austrian Expert Team cervus nuclear consulting, Neustadt a. Rbge.	All events
M. Brettner	Physikerbüro Bremen	WS-CBC (2010) WS-SSD (2010) PRESAR (2011) WS-RPV (2012) WS-DIC (2015)
S. Carena	Department of Earth and Environmental Sciences, Munich University	WS-SSD (2010)
K. Decker	Department for Geodynamics and Sedimentology, University of Vienna	WS-SSD (2010)
R. Donderer	Physikerbüro Bremen	WS-SAM-2 (2016)
E. Hintersberger	Department for Geodynamics and Sedimentology, University of Vienna	WS-SSD (2010) Site Visit (2016)
C. Hirsch	UmbriaLogic Perugia	WS-DIC (2015) Site Visit (2016)
A. Indradiningrat	cervus nuclear consulting, Neustadt a. Rbge.	WS-SAM-2 (2016) Site Visit (2016)

Name	Institution	Participation*)
B. Littlewood	Centre for Software Reliability, City University of London	WS-DIC (2015)
N. Müllner	Institute for Safety and Risk Sciences, University of Natural Resources and Applied Life Sciences, Vienna	WS-SAM-1 (2009) WS-CBC (2010) WS-RPV (2012) WS-DIC (2015) WS-SAM-2 (2016) Site Visit (2016)
R. M. W. Musson	British Geological Survey, Edinburgh	WS-SSD (2010)
B. Schwinges	Consultant, Cologne	WS-CBC (2010)
E. Seidelberger	Institute for Safety and Risk Sciences, University of Natural Resources and Applied Life Sciences, Vienna	WS-SAM-1 (2009) WS-CBC (2010) WS-SSD (2010) WS-RPV (2012) WS-DIC (2015) WS-SAM-2 (2016) Site Visit (2016)
A.Strupczewski	ENCONET Ges.m.b.H, Vienna	WS-SAM-1 (2009) WS-CBC (2010) WS-SSD (2010) PRESAR (2011) WS-RPV (2012) WS-SAM-2 (2016)
I. Tweer	Consultant, Buxtehude	WS-RPV (2012)
G. Weimann	Consultant, Vienna	WS-SAM-1 (2009) WS-CBC(2010) WS-SSD (2010) PRESAR (2011) WS-RPV (2012) WS-SAM-2 (2016)
A. Wenisch †	Austrian Institute for Ecology, Vienna	WS-SAM-1 (2009) WS-CBC(2010), WS-SSD (2010)

*) Abbreviations used:

- WS-SAM-1 (2009): (The first) workshop concerning Severe Accident Management on December 15, 2009.
- WS-CBC (2010): Workshop concerning Confinement and Bubbler Condenser Safety Issues on April 28, 2010.
- WS-SSD (2010): Workshop concerning Site Seismicity and Seismic Design on July 14, 2010.
- WS-RPV (2012): Workshop concerning Reactor Pressure Vessel Integrity on November 20, 2012.
- WS-DIC (2015): Workshop concerning Digital Instrumentation and Control on December 11, 2015.
- WS-SAM-2 (2016): (The second) workshop concerning Severe Accident Management on April 27/28, 2016.
- PRESAR (2011): Consultation of EMO3+4 PRESAR by Austrian experts on June 06/07, 2011.