Seminar 1b – Nuclear installation safety research – Session 1

Chaired by A. Wielenberg (GRS) / M. Adorni (NEA)

10:00 - 10:30 | Impulse speech

Nuclear installation safety research: a long-term challenge

V. Rouyer (NEA)

The membership of the Nuclear Energy Agency (NEA) is composed of 34 member countries and has close relationships with several strategic partners (e.g., China and India). The NEA programme of work is developed by 8 standing committees and more than 80 working parties and expert groups. In addition, the NEA Data Bank provides nuclear data, code, and verification services. The NEA also host three large multinational initiatives and 28 special projects. The NEA's framework allows for selected non-member countries to participate in the activities of some committees, especially those focused on safety issues.

A new NEA Strategic Plan has been recently approved by the Steering Committee for Nuclear Energy for the period 2023-2028. As envisioned by this plan, the NEA's future programme of work should be in the continuity of the current programme of work but should also focus more on developing education and public communication activities and interactions with industry, academia, civil society/NGOs. Moreover, additional NEA activities regarding the role of nuclear energy in future energy systems, SMRs, public perception, clean energy, economics of nuclear should be developed.

The new plan identifies Strategic Programme Areas including: Nuclear Safety Technology and Regulation, Human Aspects of Nuclear Safety, Nuclear Science, Development and Innovation in the Civil Use of Nuclear Energy, Radiological Protection of People and the Environment, Radioactive Waste and Spent Fuel Management, Nuclear Decommissioning and Legacy Management. Further, several vital areas are identified as vital Infrastructure and Enablers: Dissemination of Information to Build Understanding and Awareness of Nuclear Matters, Supporting the Development of a Next Generation of Nuclear Scientists and Technologists, Economics and Resources for Nuclear Development, Nuclear Law, Management, Preservation and Validation of Nuclear Data Assets and Codes.

The development of human capacities has become central to many NEA activities. The Nuclear Education, Skills and Technology (NEST) Framework has made good progress in facilitating the involvement of young researchers in several scientific and technological projects including the projects focused on nuclear safety topics. Another new initiative, the NEA Global Forum on Nuclear Education, Science, Technology and Policy, became a reality in 2021. It

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provides a first-of-a-kind international platform for sustained co-operation amongst academic institutions and provides this community with the ability to engage experts, policy makers and stakeholders around the world. Having separate scopes of work and missions, the Global Forum and the NEST Framework are co-ordinated to strengthen the role of the Agency in nuclear education and capacity building and provide support and policy advice to NEA member countries in addressing the nuclear education challenges.

Thanks to the motivation of many of NEA member country partners, the NEA hosts a range of joint projects which provide countries with a flexible platform to cooperate in addressing special research needs, especially in the area of nuclear installations safety research activities (currently, the NEA hosts 20 joint research project, mainly experimental projects and database projects, dedicated to cover a large scope of nuclear power plant safety issues). Most recently, the NEA successfully implemented a new, ground-breaking initiative, the post-Halden NEA Framework for Irradiation Experiments (FIDES). FIDES launched on 16 March 2021 with 27 participating organisations from 12 countries and the European Commission (EC). FIDES is designed to provide a stable, sustainable, reliable innovative platform for fuel and materials testing using nuclear research reactor facilities in NEA member countries.

Additionally, the NEA is supporting for more than 10 years several initiatives and projects to discuss research gaps identified after the Fukushima-Daiichi accident. The NEA was very gratified with work with Japanese organisations and many experts to complete and issue in March 2021 the report Fukushima Daiichi Nuclear Power Plant Accident, Ten Years On; progress lessons and challenges and the associated web-event launched in March 2021 where we had around 1400 registrations. (www.oecd-nea.org/jcms/pl_56777/ten-years-after-the-fukushima-daiichi-accident) providing general considerations but also summarizing activities, projects, publications developed as a long-term plan to support research activities.

NUCLEAR SAFETY RESEARCH AND TECHNOLOGY FOCUS AND RECENT ACHIEVEMENTS

The NEA working framework constitute a unique space to investigate a very large scope of research gaps, to fit the country member needs and share resources and research capabilities. The general objectives remain to identify significant generic issues and trends, assist member countries in the resolution of safety issues and strengthen confidence in the solutions and their implementation. Moreover, the activities help to maintaining an adequate level of capability, research facilities, tools and competence in member countries in close coordination with the new initiatives in the education area described above.

In addition to the current portfolio of work to address accident scenarios for fuel and reactor power plants, components behavior for current and long-term operation, external hazards

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impact and safety issues related to electrical systems, several initiatives of the Committee on the Safety of Nuclear Installations (CSNI) have been launched recently to address topical issues (e.g.):

- A new Senior Group on Preservation of Key Experimental safety datasets
- A new ad hoc expert group to advise the Committee on activities that should be undertaken to address safety of Small Modular Reactors
- A new ad hoc expert group to analyse how to improve the relevance and effectiveness of the CSNI's fire research activities
- Organisation of the Symposium on PSA for Reactors with a Singular Design (Joint NEA and IAEA Event) in February 2022

The key questions currently investigated can be summarized as follows:

- How to advance the understanding of accident phenomenology and address the safety-significant issues?
- How to better address fuel safety issues emerging from power plants operating experience and research?
- How to improve risk-informed regulation and safety management with uses of Probabilistic Safety Assessment (PSA)?
- How to improve the understanding and treatment of external hazards and to improve the effectiveness of regulatory practices?
- How to better understand the response of electrical systems and to further increase the reliability and safety performance?
- How to anticipate technical behaviour of commercial power plants components, especially in case of LTO?
- How to improve safety of Nuclear Fuel Cycle Facilities?
- Human and organisational factors in nuclear installations.

Examples of recent developments and achievements:

- a technical opinion paper that reviewed the applicability of current safety criteria to the deployment of advanced fuels designed to exhibit better behaviour under accidents, referred to accident tolerant fuels.
- a report comparing different approaches for modelling the risk associated with digital instrumentation and control systems.

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- a report that identifies the key organisational capabilities for decommissioning and how to provide effective regulatory oversight for organisations transitioning from operations to decommissioning
- a topical opinion paper on the use of Computational Fluid Dynamics (CFD) codes for nuclear safety evaluation
- a report on simulation capability of 3D System-Scale Thermal-Hydraulic (T/H) analysis codes
- Several NEA reports were published, including the "Long-Term Management and Actions for a Severe Accident in a Nuclear Power Plant" report.

The NEA develops also a rich scope of activities related to Safety Culture, Public Communication, Stakeholder Engagement and Trust as well as additional technical studies on Human and Organisational Factors.

Research activities have to be developed and implemented in a long-term plan and collaborative process to anticipate and address the needs for a safe operation of current and future nuclear installations.

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10:30 - 11:00 | No. 111

Results obtained within the H2020 IVMR project in support of investigating the feasibility of successfully achieving In-Vessel Melt Retention by ex-vessel

T. Van Rompuy (Bel V), M. Adorni (NEA), D. Gryffroy (Bel V) and A. Malkhasya (Bel V)

In support of the licensee's severe accident management improvement program, an update of the mitigation strategies for Belgian NPPs to cope with different containment failure modes has been presented in 2017 to Belgian safety authorities. For the Doel NPP, the approach proposed by the licensee to avoiding containment failure by BaseMat Melt Through (BMMT) involved (as before) the flooding of the reactor cavity prior to vessel failure, but, as a new element, aimed at addressing the associated ex-vessel steam explosion risk by demonstrating the feasibility of successfully achieving In-Vessel Melt Retention (IVMR) by ex-vessel cooling (EVC) by the timely filling of the reactor cavity.

In parallel with the licensee, Bel V investigated the issues to be adequately addressed in order to allow for convincingly demonstrating IVMR feasibility in Doel NPP. Results obtained within the H2020 IVMR project, combined with plant-specific data and simulation results, were found to be of primary relevance to this venture.

Issues identified as a result of this Bel V effort could be broadly divided into two categories: 1) issues for which the satisfactory resolution involves dealing with plant-specific practical and technical challenges and 2) issues for which the resolution mainly depends on the capability to sufficiently reliably model certain phenomena which are specific to severe accident conditions and for which considerable uncertainties exist. Consequently, Bel V recommended prioritizing efforts on those issues of the first category which were likely to turn out to be unresolvable either on the basis of an assessment using relatively simple, straightforward calculations applying well-established methods (i.e. not necessitating the application of advanced severe accident modelling capabilities related to the issues of the second category and for which the validity might be the subject of extensive debate and/or require further R&D) or for reasons unrelated to severe accident management.

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The licensee and its architect-engineer, having independently adopted a broadly comparable approach to Bel V's reasoning and benefitting from experience gained by actively contributing to the H2020 IVMR project, also identified a number of plant pre-requisites to the succesful demonstration of IVMR feasibility by ex-vessel cooling. Those pre-requisites covered all of the issues which were to be given priority according to Bel V and were thus promptly assessed by the licensee, resulting in the consensus shared by licensee and Bel V that the thermal insulation of the Doel NPP reactors makes IVMR by EVC impracticable.

Consequently, the licensee proposed to continue considering the IVMR strategy as an option to be further investigated, but primarily as IVMR by in-vessel instead of ex-vessel cooling. This investigation is currently ongoing.

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11:00 - 11:30 | No. 112

Analysis of Loss of Cooling Accident at a Generic CANDU Type Spent Fuel Pool

M. Constantin (RATEN ICN)

One of the many lessons learned from the Fukushima disaster is that analysts have to pay the same attention to the source term released both by the reactor core and the Spent Fuel Pool (SFP). Therefore in the last decade important efforts were devoted to investigate the complete spectrum of severe accidents including SFP accidents. The Loss of Cooling Accident at a SFP has a potential to evolve to a severe accident. In comparison with LWR plants CANDU SFP has the following peculiarities: lower burnup due to the use of natural uranium, daily discharging of spent fuel bundles, larger volumes of spent fuels, horizontal storage of bundles in trays placed in racks, complexity of the cooling paths due to the configuration of racks and cross-flows.

In the present paper an analysis of the loss of cooling accident at CANDU SFP is performed based on the existing capabilities of ASTEC V2.0 code. A full loss of the cooling is postulated due to the loss of the electricity. The accident is split into three phases: (1) boiling of water and uncovering of the top placed fuel bundles, (2) degradation of uncovered fuel bundles, (3) transport of the fission products in the atmosphere of SFP and release to the environment. The following modules of ASTEC are used: ICARE, CESAR, CPA, SOPHAEROS, and IODE.

The results of the analysis are connected with: the timing of the accidents and possible measures to mitigate it, the estimation of the source term at the level of the atmosphere of the SFP building, the source term at the level of the environment.

On the other hand the paper discuss the assumptions of the model and the used methodology in order to identify possible ways to reduce the uncertainties.

A part of the results was transferred into the database for the source teem of the relevant accidents built by H2020 FASTNET project, another one, dedicated to methodological construction and extension of ASTEC code applications, was supported by ASCOM project.

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11:30 - 12:00 | No. 113

Application and Qualification of MELCOR for Simulating VVER Technology in Severe Accident Scenarios

A. Flores y Flores (CV Rez), G. Mazzini (CV Rez), M. Ruscak (SURO) M. Hrehor (SURO) and A. Musa (SURO)

After Fukushima Daiichi accident, in Europe there was an intense activity to assess the current Nuclear Power Plants (NPPs) under Long Term Station Black Out scenarios. An intensive program of NPPs models preparation and assessment was performed with the goal to investigate the progression of these scenarios and to quantify their consequences. In Czech Republic, a consortium creating models and methodologies to support State Office for Nuclear Safety (SONS) was established and supported by the Czech Republic Ministry of Interior. In the actual stage, the models were improved updating the existing ones from MELCOR 1.8.5 and MELCOR 1.8.6 to MELCOR 2.2. In parallel, according to the project requirements, the Research Center Rez (RCR) was in charge to get a qualification of the methodology through the SONS Severe Accident expert commission with the support of the National Radiation Protection Institute.

The paper describes the general outcome of the qualification process based on THAI and PHEBUS programs. In addition, it introduces the VVER-1000 and VVER 440 NPPs nodalization used in the project to estimate the fission product transport into the containment dome.