NUGENIA/TA2 ACHIEVEMENTS IN SEVERE ACCIDENTS RESEARCH (2015-2020)

L.E. HERRANZ (CIEMAT), A. BENTAIB (IRSN), F. GABRIELLI (KIT), S. GUPTA (B-T), I. KLJENAK (JSI), S. PACI (UNIPI), P. PILUSO (CEA) & F. ROCCHI (ENEA)

INTRODUCTION

No matter how unlikely they are, severe accidents (SA) may happen and, then, the best management possible of an incredibly complex scenario is needed. Both preventive and mitigating actions are articulated in Severe Accident Management Guidelines (SAMGs), whose development requires an in-depth knowledge of both SA phenomena and management measures (i.e., efficiency, modes of implementation, side effects, etc.). As a consequence, investigation on SA has been ongoing for decades.

Even though SA research started with the development of nuclear power, it was after the Three Mile Island accident, in 1979, when it took off and drew major attention among nuclear technology scientists. However, in the 1990's such significant momentum faded away to some extent and most research focused on the international PHEBUS-FP project [Clement, 2013]. In the first years of this century (2004), the search for an efficient use of the still available technical and human resources ended up with the launch of a Severe Accident Research NETwork (SARNET) under the 6th and 7th FrameWork Programmes (FWP) of the European Commission (EC) from 2004 to 2013 [Van Dorsselaere, 2015]. It was coordinated by IRSN and mostly participated in by European institutions, although prominent Asian and American organizations in SA research also joined the network. SARNET self-sustainability was achieved through integration in the NUGENIA European association in 2013, which had been created two years before to foster R&D on fission technology of Generation II and III reactors. Since then, SARNET turned into what is known as NUGENIA Technical Area 2 (NUGENIA/TA2) of the Sustainable Nuclear Energy Technology Platform (SNETP).

The paper presents the major developments and achievements on SA research accomplished in the last five years by NUGENIA.

MAJOR ACHIEVEMENTS

The issues investigated have been inspired by periodic prioritization of SA research needs [Klein-Heßling, 2014; Manara, 2019], which aimed at reducing the uncertainties in current analytical tools and enhancing the capability of accident management. In all the cases, the projects enlarged the existing database and enhanced the modelling capability at the time.

In-vessel corium/debris coolability

The research activities have been focused on cooling the degraded in-vessel and corium behavior. The objective is to find out ways of retaining corium within the Reactor Pressure Vessel (RPV) or, at least, to minimize and/or delay its transfer to containment. The success of any of these strategies would heavily impact Severe Accident Management (SAM) for existing Nuclear Power Plants (NPPs) as well as for the design and safety assessment of future reactors.

Several projects have been launched within the EU and/or the NUGENIA framework. Two initiatives stood out as an optimization of the use of worldwide experimental facilities under the 7th FWP of EC: SAFEST (Severe Accident Facilities for European Safety Targets) [Miassoedov, A., 2015] and ALISA (Access to Large Infrastructures for Severe Accidents) [Miassoedov, 2018b] projects, both led by KIT. The SAFEST project (2014-2018) consisted of a pan-European laboratory of sixteen facilities focused on studying the corium behaviour. An example the LIVE2D test vessel at KIT for investigating the evolution of the in-vessel late phase of a SA is shown in Figure 1 [Gaus-Liu, 2010]. As a result, roadmaps on European SA experimental research for LWRs and for Gen IV technologies were developed. The ALISA project (2014-2018) allowed, for the first time, the mutual access to six European and to six Chinese large research infrastructures to perform large scale experiments under prototypical conditions for SAs in existing and future power plants. An

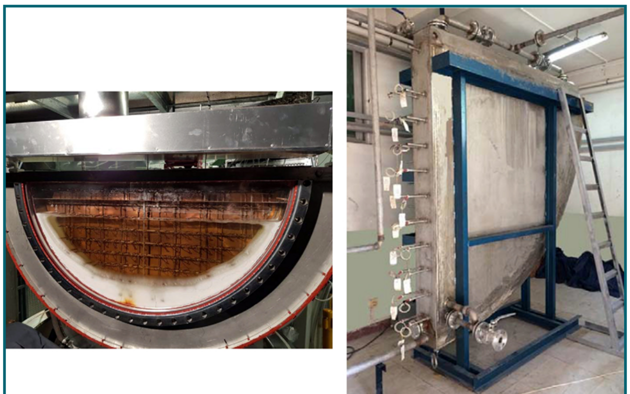


Figure 1. LIVE2D (left) [Gaus-Liu, 2010] and the COPRA (right) (@XJTU, 2016) test vessel facilities.

example the Chinese COPRA facility at the Xi'an Jiaotong University (XJTU) to simulate in the full scale the natural convection heat transfer in corium pools in an ACP-1000 lower head is shown in Figure 1 [Miassoedov, 2018].

The H2020 EC IVMR (In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs) project [Fichot, 2016], coordinated by IRSN, was launched in 2015. The project has provided new experimental data on the corium behaviour within the RPV lower head in different conditions. A new methodology based on the residual thickness of RPV as a safety criterion has been proposed for In-Vessel Retention (IVR), which might improve the SAM of large power reactors, as it was in mid-size (VVER 440) or large Gen. III reactors (AP1000).

The CoreSOAR in-kind project, coordinated by IRSN, complemented the other in-vessel activities by updating the previous state of the art on core degradation (2016-2018) [Haste, 2019]. The results of the major experimental programs in the last 20 years (Phébus FP, QUENCH, LIVE-2D/3D, HEVA/VERCORS, VERDON, PRELUDE/PEARL, and KROTOS) as well as updated material properties database and modelling have been included and priorities highlighted, such as the need for further data on debris coolability.

The QUESA (QUEnch experiment with Steam and Air) in-kind project (2016-2018), coordinated by GRS, focused on the effect of air ingress into RPV on the oxidation and degradation of the in-vessel materials [Hollands, 2018]. Several air ingress bundle experiments were carried out, e.g. AIT-1, AIT-2, QUENCH-10, PARAMETER SF4, QUENCH-16, and QUENCH-18. The results revealed a strong influence of nitrogen on the oxidation and degradation of Zr-based claddings, particularly at intermediate temperatures (~800 C°-1200 C°) in slow transients.

Under most of the above projects, the analytical tools and particularly the Accident Source Term Evaluation Code (ASTEC) have been significantly enhanced and the field of application has been extended, e.g. to Spent Fuel Pools (SFP) SAs. Specific projects have been conducted with this purpose, like AIR/SFP [Coindreau, 2018] and CESAM [Novak, 2018], which have also meant a huge validation effort. Such developments still continue under the frame of the ASCOM in-kind project (2018-2022), coordinated by IRSN, where major emphasis is being the development of generic input decks for Gen II and Gen III designs, as well as for SFPs and Small Modular Reactors (SMRs).

Ex-vessel corium /debris coolability

Research on ex-vessel corium and debris coolability during 2015-2020 has been split in three major topics: Fuel Coolant Interaction (FCI) and Steam Explosion, debris cooling during and after Molten Core Concrete Interaction (MCCI) and Fukushima Daiichi ex-vessel corium progression. Some of these activities were conducted within NUGENIA/TA2 in the frame of SAFEST and ALISA projects, but there have been remarkable projects in other frameworks too.

Ex-vessel steam explosions and their mechanical short-term consequences on the containment building are still an open issue [OECD/NEA, 2015]. Even though the phenomenon has been found to develop in stages (pre-mixing, triggering, propagation and explosion), the major challenge ahead is to accomplish a thorough understanding that allows scaling up models to reactor scale. After the SERENA-2 project, which stressed the importance of the corium composition and oxidation and of the local void fraction on the energetics of steam explosion, a number of national projects have been carried out to keep this research and to allow preservation of key experimental facilities (e.g., PLINIUS platform) [Piluso, 2015] that have been used later in international projects, like the already mentioned ALISA.

Under the frame of ALISA (7^{th} EC FWP), one test was conducted in the KROTOS facility (Figure 2) exploring the effect of shallow water pools on the impulse and possible mechanical consequences of a steam explosion. The melt fell down into the water phase and a dynamic view of the 3 phases (corium, steam, water) during the premixing/fragmentation step was achieved through a X-Ray Linatron, which enables possible modelling for these mechanisms.

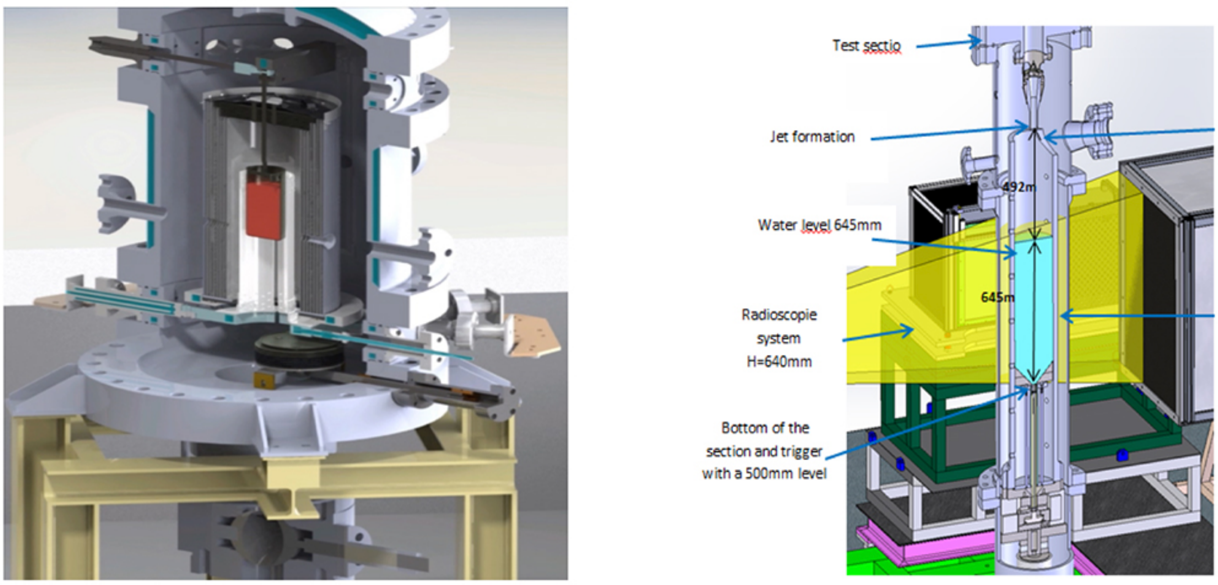


Figure 2. KROTOS facility-ALISA configuration Left: High Temperature furnace (T=3100K)- Right: Test section with High Energy (6 MeV) X-Ray Linatron Radioscopy.

In the frame of the SAFEST Project, a new and innovative methodology for corium post-test analysis has been developed. Knowledge of solid state for corium debris coolability and for corium decommissioning of severely damaged NPPs, like Units 1-3 of Fukushima is a key issue. The latter has been one of the goals of the OECD Pre-ADES project [Nakayaoshi, 2019]. As a consequence of these activities, it has been built the Intra-European Network for Corium Analysis (INCA), which is a consortium of European laboratories which collaborate in the thorough characterization of corium samples.

Containment phenomena

Specific activities, related to issues identified in [Kljenak, 2012], resumed within the in-kind project SAMHYCO-NET, started in 2017 and coordinated by IRSN. In the coming years, the AMHYCO H2020 project, coordinated by UPM, will bring the knowledge gained on hydrogen distribution and combustion into the practical arena of accident management.

Containment atmosphere behaviour

A Generic containment benchmark, coordinated by FZJ, was launched to discern the differences between lumped-parameter codes that might have a significant influence on simulations in safety analyses of actual NPPs [Kelm, 2014]. A generic scenario based on the German KONVOI containment (Figure 3), with uniquely defined modelling of containment geometrical characteristics and materials, as well as initial and boundary conditions, was proposed. The first step tracked down fluid flows and heat/mass transfer in the system, with particular attention to H_2 distribution, whereas the second step addressed the same scenario, but with added PARs (Passive Autocatalytic Recombiners). The results are much more similar to each other than at the start of the previous benchmark, organized during SARNET. However, as most simulations are based on existing models used previously, a benchmark with a new generic containment would be necessary to objectively assess the progress in lumped-parameter modelling.

Another benchmark exercise, focused on modelling PARs performance, is being coordinated by FZJ, with both CFD and lumped-parameter codes used for simulations. The exercise consists of three steps: a preparatory phase devoted to the assessment of removal models for H_2 in oxygen-rich and oxygen-lean atmospheres; a second phase, based on REKO-3 tests (Figure 4), aimed to analyse the PAR performance in steady conditions with H_2 and CO present in oxygen-rich atmospheres; and, finally, modelling PAR performance in transient conditions with both H_2 and CO present, in the THAI HR-51 test. Comparisons between submitted results are currently being done.

Hydrogen combustion in containment

A benchmark on hydrogen combustion, based on experiments performed in the ENACCEF II facility (Figure 5) at ICARE (Institut de Combustion, Aérothermique et Réactivité) is being organized by IRSN. Most simulations are being per-

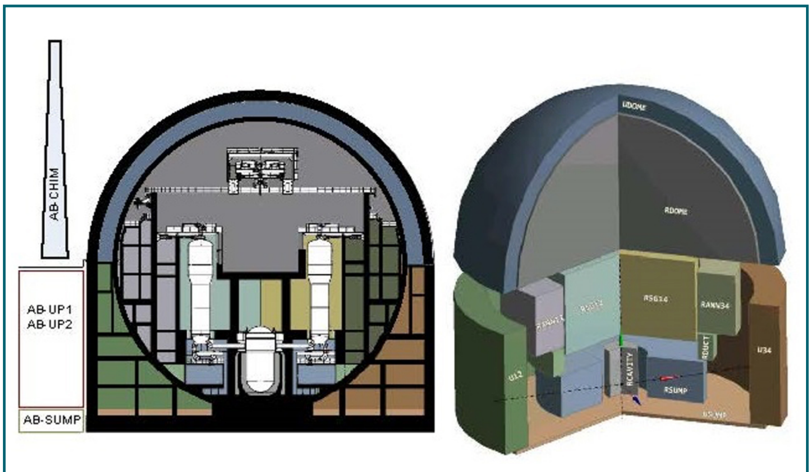


Figure 3. Schematic of generic containment.

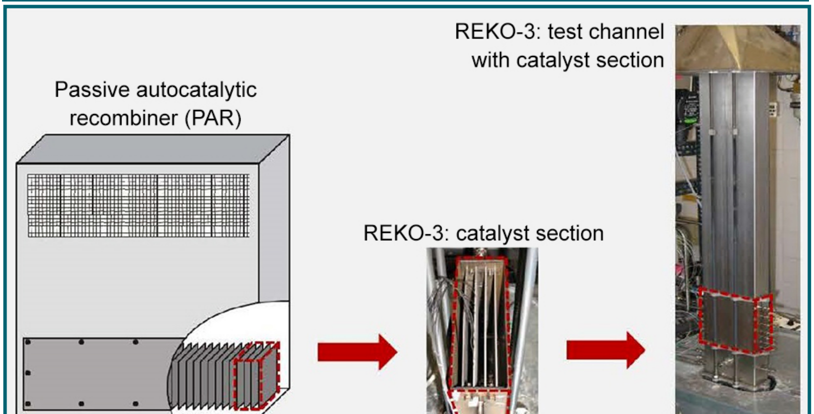


Figure 4. Principle of REKO-3 experiment.

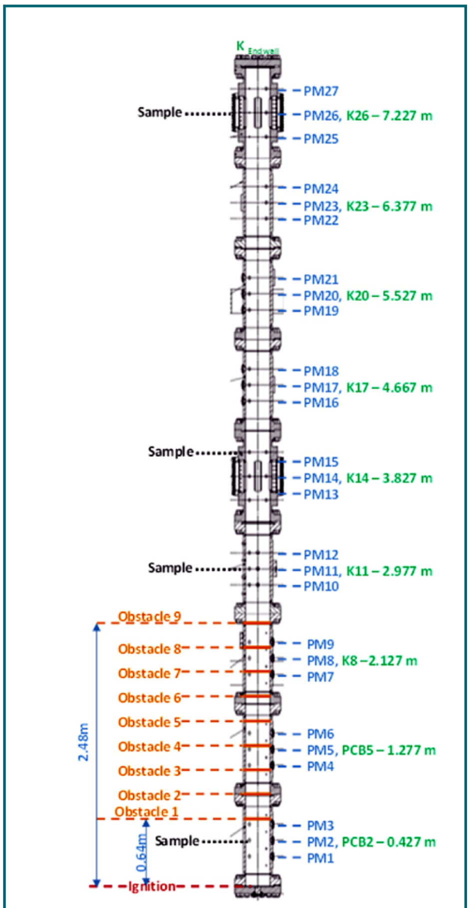


Figure 5. Schematic of ENACCEF II experimental facility.

formed using CFD codes, except one with a lumped-parameter code. An experiment on hydrogen deflagration in a homogeneous hydrogen-air atmosphere was simulated first. The comparison of blind and open simulations to experiments underlined the codes' ability to predict qualitatively the pressure evolution and highlighted their limitations to deal with flame deceleration. After that, a similar experiment, but with some air replaced with steam, was considered. The analysis of blind simulation results is currently ongoing.

Source Term

The main priority of source term research, particularly fostered since the Fukushima accident, has been the prevention and/or mitigation of SA consequences (i.e., radioactivity release to the environment). This has been articulated in a number of EC and NUGENIA projects: FP7/PASSAM (research on passive and active systems for source term mitigation) [Albiol et al. 2018], H2020/FASTNET (emergency preparedness and response) [Rocchi, 2019], and the ongoing projects H2020/MUSA (uncertainties in SA) [Herranz, 2020] and NUGENIA/IPRESCA (pool scrubbing) [Gupta, 2017]. The remaining research needs, though, were openly discussed under the frame of CSNI/WGAMA [NEA, 2020] and, as a consequence, in the coming months the OECD projects ESTER and THEMIS, coordinated by IRSN and Becker Technologies respectively, will be launched with the participation of a good number of TA2 members. In these experiments, a special emphasis will be placed on addressing realistic severe accident conditions.

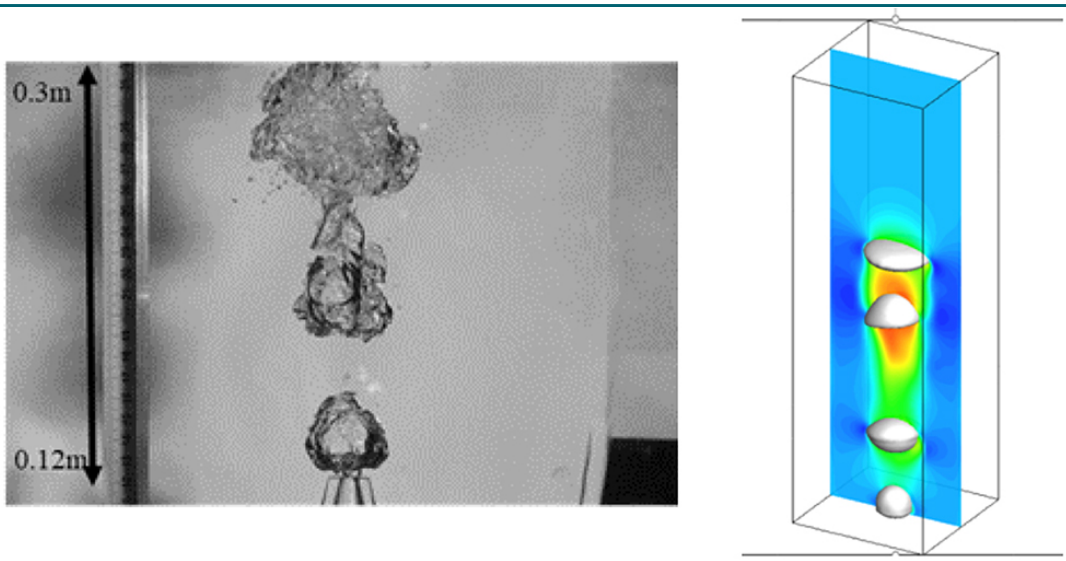
Started in January 2018 for the duration of three years and coordinated by B-T, the in-kind project IPRESCA has currently several pool-scrubbing related experimental and analytical activities in progress. The project has already produced a number of outcomes: a critical assessment of the pool scrubbing database, which discussed the tests qualification for model validation and identified further experimental needs; test matrices on hydrodynamics, aerosols and iodine experiments have been conducted based on the existing experimental database and new tests are being proposed; insights into bubble hydrodynamics have been gained by conducting benchmarks based on LP and CFD approaches. LP benchmark performed based on a RSE test (Figure 6) [Albiol, 2018], indicate that codes are far from describing the actual bubble morphology or swarm velocity. CFD benchmark revealed that modelling results are still too scattered as to be considered a reliable approach for bubble hydrodynamics analyses.

The future IPRESCA activities aim to cover potential application of CFD to support pool scrubbing analysis towards reactor application, and development of a PIRT.

Accident scenarios

Research activities in the area of accident scenarios have been carried out mainly in the framework of the H2020 Euratom project FASTNET (2015-2019), dedicated to the development of fast and reliable tools for source term prediction during emergencies [Rocchi, 2020]. In order to validate the tools and to provide the European emergency preparedness and response community with reference data, several accident scenarios were identified for the main NPP types installed in Europe (ideally including SFPs) (Table 1) and then analyzed with best-estimate codes like ASTEC, MELCOR or MAAP. The results were stored in a dedicated database, which was the basis of the verification done of fast deterministic and probabilistic (based on Bayesian Belief Networks) approaches intended in fast running tools. Such a database was finally transferred to the IAEA Incident and Emergency Center for future uses.

The NUGENIA AIR-SFP project [Coindreau, 2018) was an analytical exercise of severe accident codes application to Spent Fuel Pools (SFP) accident scenarios. The project highlighted that a straightforward application is not allowed and some approximations and/or even new developments were needed to apply the tools out of a non-radial topology, as the reactor one.



(a). LP benchmark: RSE-experiment, PASSAM project. Airflow rate = 5.7 kg/h – ambient temperature - Bubbly flow

(b). CFD benchmark: calculation domain 2 x 2 x 8 cm^3, Inlet section: 4 mm dia. orifice, inlet gas velocity: 0.2 m/s

Figure 6. Details from IPRESCA code benchmarks.

GENERIC DESIGNS	ATW	LFWSG	LBLOCA	IBLOCA	SBLOCA	SBO	SGTR	SFP
BWR-MARK1				*		*		
BWR-ABB	*		*			*		
CANDU			*		*	*	*	
French PWR 1300		*	*	*	*			
French PWR-900						*		
PWR-1000			*	*	*	*		*
VVER-440			*			*	*	
VVER- 1000					*	*		

Table 1. Table showing the SA scenarios analyzed in the FASTNET project.

Presently, the ASTEC COMmunity (ASCOM) project nucleates the ongoing activities to validate the ASTEC code [Chailan, 2019] and to extend its NPP models database, including SMRs.

Finally, the recently started H2020 Euratom projects with NUGENIA labels MUSA (Management and Uncertainties in Severe Accidents, led by CIEMAT, 2019-2023) and R2CA (Reduction of Radiological Consequences of Design Basis and Design Extended Accidents, led by IRSN, 2019-2023) are clustering most of efforts in severe accident modelling. The former aims at systematically apply the Best Estimate Plus Uncertainties (BEPU) approach in severe accident analysis [Herranz, 2020]. The latter focuses on reducing radiological consequences of Design Basis Accidents (DBAs) and Design Extended Conditions (DECa) by enhancing the current modelling capabilities in severe accident codes [Girault, 2020]

DISSEMINATION OF KNOWLEDGE

Severe Accident Phenomenology (SAP) Course

The Severe Accident Phenomenology (SAP) is a one-week course that was born as a part of the Excellence Spreading activities started in SARNET [Paci, 2012] and now maintained in NUGENIA/TA2. The purpose was disseminating the knowledge gained on SA in the last two decades to Masters-PhD students, engineers and scientists recently involved in Severe Accident. The SAP key-topics have evolved along years, although the core of the course is still kept today: SA phenomenology, progression and mitigation in current Light Water-cooled Gen. II and III NPPs. Recently, sessions concerning the Fukushima accidents and their associated analyses, have been included. To a good extent, the course material is based on the textbook published by SARNET in 2011 under the title "Nuclear Safety: Severe Accident Phenomenology" [Sehgal, 2012.].

A total of 9 editions of the SAP Course have been already held, with attendance ranging from 40 to 100 approximately. The last ones was hosted by CEA in Oct. 2019 at Cadarache. The next 10th edition of the SAP Course will be organized by ENEA in Bologna (I) from 21 to 25 June 2021.

ERMSAR conferences

The "ERMSAR - European Review Meeting on Severe Accident Research" is presently a well consolidated biennial conference. Started in 2005, it was not until its 5th edition in 2012 that ERMSAR was open beyond the SARNET community. In the period covered in this article (2015-2020), three more editions have been held. The 7th one (2015), hosted by CEA in Marseille (F) from 24 to 26 March 2015, was the first one to be organized under the auspices of NUGENIA. It gathered 165 participants from 54 organizations and 21 countries (including Japan, Russia, USA and Korea). It was considered the consolidation of ERMSAR as a worldwide reference event in the field of SA. The next two editions confirmed such a consolidation: the 8th one (2017), hosted by NCBJ in Warsaw (PL) from 16 to 18 May, was attended by 179 participants from 27 countries and 84 organizations (25% of participants from outside Europe); and the 9th one (2019), hosted by the ÚJV Řež in Prague (CZ) from 18 to 20 March, gathered 163 participants from 23 countries and 73 organizations (19% from outside Europe).

The next ERMSAR 10th edition will be organized by KIT in Karlsruhe (D) from 25 to 28 October 2021, in Karlsruhe (D).

In order to achieve a broader diffusion of the results presented in ERMSAR conferences, the proceedings are made freely available from the SNETP website in the NUGENIA pillar area (https://snetp.eu/technical-area-2-severe-accidents/). Furthermore, a selection of the most relevant papers has been published in refereed journals since 2010.

FINAL REMARKS

The firm belief in the need of further research on severe accidents has translated in the last five years into organizations' commitments within Europe and overseas to in-kind projects, like SAMHYCO-NET, QUESA, IPRESCA and ASCOM, all of them coordinated under NUGENIA/TA2. Moreover, NUGENIA/TA2 networking strengthens the ability to join in common ventures that manage official support from EC; this is the case of projects like FASTNET, MUSA, R2CA and AMHYCO. To complement this double project path, NUGENIA/TA2 is seeking for new ways for collaboration with subject-related international initiatives, like OECD projects and WGAMA (Working Group on Accident Management and Analysis) activities in the frame of Nuclear Energy Agency (NEA) and/or Coordinated Research Projects (CRPs) in the frame of International Atomic Energy Agency (IAEA).

NUGENIA/TA2 (previously SARNET) has always been sensitive to its top level objective: the enhancement of nuclear safety. Two supporting principles were coined to make its achievement feasible:

- To focus on missing knowledge that is safety relevant and has the potential to reduce efficiently the remaining uncertainties in SA analyses.
- To spread the word by open communication conferences (ERMSAR), courses (SAP), textbooks or any other instrument that gives access to a soundly based SA understanding.

Finally, it should be highlighted that NUGENIA/TA2 is intending to establish a bridge with the radiation protection Platforms (NERIS, EURADOS and ALLIANCE from MEENAS) to assess the impact of radioactivity releases from nuclear reactors to the environment during beyond design basis accidents.

REFERENCES

- [Albiol, 2018]. Albiol T. et al., Main results of the European PASSAM project on severe accident source term mitigation, Annals of Nuclear Energy, vol. 116, pp. 42-56, June 2018, https://doi.org/10.1016/j.anucene.2018.02.024.
- [Chailan, 2019]. Chailan L. et al., Overview of ASTEC integral code status and perspectives, Proceedings of the 9th European Review Meeting on Severe Accident Research (ERMSAR 2019), Prague, Czech Republic, March 18-20, 2019.
- [Clement, 2013]. Clement B., Zeyen R., The objectives of the Phébus FP experimental programme and main findings, Annals of Nuclear Energy, vol. 61, pp. 4–10, November 2013, https://doi.org/10.1016/j.anucene.2013.03.037.
- [Coindreau, 2018]. Coindreau O. et al., Severe accident code-to-code comparison for two accident scenarios in a spent fuel pool, Annals of Nuclear Energy, vol. 120, pp. 880-887, October 2018, https://doi.org/10.1016/j.anucene.2018.06.043.
- [Fichot, 2016] Fichot F., Carénini L., Bonnet J.M., Main physical questions raised by In-Vessel Melt Retention, Proceedings of the International Workshop on In-Vessel Retention, Aix-en-Provence, France, 2016.
- [Gaus-Liu, 2010]. Gaus-Liu X. et al., In-vessel melt pool coolability test - Description and results of LIVE experiments, Nuclear Engineering and Design, vol. 240, issue 11, pp. 3898-3903, November 2010, https://doi.org/10.1016/j.nucengdes.2010.09.001.
- [Girault, 2020]. Girault N., Minutes of the Kick-off Meeting, Ref. Ares(2020)279223. January 2020.
- [Gupta, 2017]. Gupta S., Herranz L. E., Van Dorsselaere J.P., Integration of pool scrubbing research to Enhance Source Term calculations, Proceedings of the 8th European Review Meeting of Severe Accident Research (ERMSAR 2017), Warsaw, Poland, May 16-18, 2017.
- [Haste, 2019]. Haste T. et al., CoreSOAR Core Degradation SOAR Update: Summary, Proceedings of the 9th European Review Meeting on Severe Accident Research (ERMSAR 2019), Prague, Czech Republic, March 18-20, 2019.
- [Herranz, 2020]. Herranz L.E. at al., First steps of the HORIZON 2020 MUSA Project on Management and Uncertainties of Severe Accidents, Proceedings of the Best Estimate Plus Uncertainty International Conference (BEPU 2020), Giardini Naxos, Italy, May 17-22, 2020.
- [Hollands, 2018]. Hollands T., First Results of the QUENCH-18 Post-Test Benchmark in the Frame of the NUGENIA QUESA Project, 24th International QUENCH Workshop, KIT Karlsruhe, Germany, November 12-15, 2018.
- [Kelm, 2014]. Kelm St. et al., Generic Containment: Detailed comparison of containment simulations performed on plant scale, Special number of Annals of Nuclear Energy on ERMSAR 2013 Conference, vol. 74, pp. 165-172, December 2014.
- [Klein-Heßling, 2014]. Klein-Heßling W. et al., Conclusions on severe accident research priorities, Special number of Annals of Nuclear Energy on ERMSAR 2013 Conference, vol. 74, pp. 4-11, December 2014.
- [Kljenak, 2012]. Kljenak I., Bentaib A., Jordan T., Hydrogen behavior and control in severe accidents, Nuclear Safety in Light Water Reactors, B.R. Sehgal (Ed.), Chapter 3.1, Elsevier, pp. 186-227, 2012.
- [Manara, 2019]. Manara D. et al., Severe accident research priority ranking: A new assessment eight years after the Fukushima Daiichi accident, Proceedings of the 9th European Review Meeting on Severe Accident Research (ERMSAR 2019), Prague, Czech Republic, March 18-20, 2019.
- [Miassoedov, 2015]. Miassoedov A. et al., Severe accident facilities for European safety targets - The SAFEST project, Proceedings of the 7th European Review Meeting on Severe Accident Research (ERMSAR 2015), Marseille, France, March 24-26, 2015.
- [Miassoedov, 2018a]. Miassoedov A. et al., SAFEST project on corium behavior in severe accidents, Proceedings of the 12th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics, Operation and Safety (Nuthos-12), Qingdao, China, October, 14-18, 2018.
- [Miassoedov, 2018b]. Miassoedov A., Gaus-Liu X, Liao Y, Chen P., ALISA Project: Access to large infrastructures for severe accidents in Europe and in China, Proceedings of NURETH-17 Conference, Qingdao, China, 2018.
- [Nakayaoshi, 2019]. Nakayaoshi A. et al., Current situation of OECD/NEA - Preparatory Study on Analysis of Fuel debris (PreADES) project, Proceedings of the International Workshop on Post-Fukushima Challenges on Severe Accident Mitigation and Research Collaboration, Daejeon, Korea, 2019.
- [NEA, 2020]. NEA, CSNI/WGAMA Source term workshop, Paris, France, January 2019, Draft 2020.
- [Nowack, 2018]. Nowack H. at al., CESAM – Code for European severe accident management, EURATOM project on ASTEC improvement, Annals of Nuclear Energy, vol. 116, June 2018, pp. 128-136. DOI: 10.1016/j.anucene.2018.02.021.
- [OECD/NEA, 2015]. OECD/SERENA Project Report – Summary and Conclusion, Nuclear Safety NEA/CSNI/R(2014)15, February 2015.
- [Paci, 2012]. Paci S., Van Dorsselaere J.P., Spreading of excellence in SARNET network on severe accidents: The education and training programme, Science and Technology of Nuclear Installation, vol. 2012, article ID 237371, 9 pages, https://doi.org/10.1155/2012/237371.
- [Piluso, 2015]. Piluso P. et al., ICE program: the CEA experimental program devoted to FCI studies with prototypical corium, Proceedings of the 7th European Review Meeting on Severe Accident Research (ERMSAR 2015), Marseille, France, March 24-26, 2015.
- [Rocchi, 2019]. Rocchi F., FASTNET: Final seminar of the project. Project deliverable FASTNET-DISSE-D5.6, September 2019.
- [Rocchi, 2020]. Rocchi F., Devol-Brown I., Raskob W., Nuclear and radiological emergency management and preparedness, EPJ Nuclear Sci. Technology, vol. 6, No. 37, May 2020. https://doi.org/10.1051/epjn/2019011.
- [Sehgal, 2012]. Sehgal B.R. (Ed.), Nuclear safety in light water reactors, Elsevier B.V., 2012 doi:10.1016/C2010-0-67817-5.
- [VanDorsselaere, 2015]. Van Dorsselaere et al., Recent severe accident research - Synthesis of the major outcomes from the SARNET network, Nuclear Engineering and Design, vol. 291, pp 19-34, September 2015. ■