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Editorial

R2CA H2020 project for Reduction of Radiological Consequences of design basis and design extension Accidents

The R2CA 4 ½-year project labelled within the NUGENIA Network and funded by the European Commission was initiated by the end of 2019. Dedicated to the Reduction of Radiological Consequences of Accidents, it mainly intended to improve the methodologies for assessing the environmental radiological sources terms of Design Basis Accidents (DBA) and accidents in the Design Extension Condition (DEC) domain without significant fuel melting (DEC-A). Coordinated by IRSN (France), it gathered 11 organizations (Universities, Research Centers, Technical Support Organisations, Industrials, SMEs) settled in 11 European countries. It focused on two main kinds of accidental scenarios (loss of Coolant Accident -LOCA- & Steam Generator Tube Rupture -SGTR- identified as the most penalizing ones in terms of consequences from PWR level 2 Probabilistic Safety Assessments) and covered a wide range of LWR concepts (PWRs, EPR, BWR & VVERs).

Three main reasons were behind the project idea:

- A continuous request worldwide for Nuclear Power Plant (NPP) safety improvements gradually implemented through more stringent safety objectives for DBA and the consideration at NPP design stages of accidental scenarios more severe than DBA. For these latter, also referred to as Design Extension Conditions accidents type A (or DEC-A), specific protection measures are requested to prevent from further evolution into severe accidents (or DEC-B).
- An enhanced predictability and risk evaluation of DEC-B accidents issued from the numerous R&D programmes initiated after the Fukushima-Daiichi accidents. All these substantial efforts, led to reduce their radiological consequences but, in turn, also highlighted the too high level of conservatisms often used in DBA studies.
- Conservative and decoupled approaches for Radiological Consequences (RC) evaluations often used in past DBA studies (covering uncertainties, unknown or poorly understood phenomena) prevent from anticipating NPP responses for other configurations, e.g., other types of fuel (Accident Tolerant Fuel - ATF, fuel with increased burn-up or Pu content). It also prevents from extending with confidence such evaluations to other NPP concepts such as Small Modular Reactor (SMRs) for which realistic radiological source term assessments will be even more crucial due to their potential proximity to homes and population.

R2CA main objectives were then:

- To provide more realistic evaluations of LWR RCs (then of NPP safety margins) of LOCA and SGTR accidents in DBA and DEC-A conditions by reducing the overly conservative assumptions and decoupling factors in calculation methodologies.
- To increase the NPP safety levels through optimizations of their emergency operating & accident management procedures and the use of innovative methods (based on Artificial Intelligence - AI) for their management.

The main technical activities addressed were:

- Review of existing knowledge (evaluation methodologies, experimental data, simulation tools) and identification of R&D gaps.
- Enhancement of models, simulation tools, calculation chains for most relevant LOCA/ SGTR phenomena and verification/validation upon the R2CA experimental database.
- Performance of LOCA/SGTR reactor calculations and evaluations of RCs.
- Development of optimized or innovative prevention/ management measures using events/symptoms-driven methods and AI.
- Organization of education and training courses and summer schools.

The project achieved its most important goals in providing an updated knowledge and upgraded validated numerical tools in support to the integration of DBA and DEC-A accident risk evaluations in the design phase of future NPP concepts. It led, in particular, to more realistic evaluations of the environmental source terms of numerous and various LOCA and SGTR transients within DBA and DEC-A conditions. Most of the time the updated evaluations resulted in lower radiological consequences than the initial ones. The updated calculated chains also helped to better evaluate the Pro and Cons of some near-term ATF concepts.

Various calculation methodologies were considered for the evaluations (i.e., for LOCA chaining thermal–hydraulic and fuel performance codes or using a more integral approach generally based on a severe accident code). Moreover, when addressing DEC-A scenarios either extended DBA methodology or severe accident codes were considered. Without stating what would be the right approach the goal of the project was, whatever the methodology used, to identify its inherent limitations and provide the necessary developments and implementations of new models, functions, or tools.

Considering this, R2CA, by bringing together experts in fuel and fission products, represented a major opportunity for improving models and simulation tools all along the calculation chain used when assessing the radiological source term. Several models and calculations chains were updated or newly developed during the project, covering a wide

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range of technical areas (from fuel thermo-mechanical to fission product behaviour). Not all were reflected in the updated evaluations because the simulation tools could not be upgraded in all the areas explored within the project in the limited time available. They will be however of benefits in future reactor calculations.

Based on all these evaluations, a compendium of recommendations for each transient considered was formulated (i.e. the need to better evaluate the fuel rod burst ratios in LOCA or the fission product transfer from primary-to-secondary circuit in SGTR) applicable to different kinds of operating and foreseen reactors in Europe that should further facilitate a harmonization of the radiological impact assessment methodologies at a European level.

Finally, the exploratory work carried out on Emergency Operating Procedures (EOP) and Accident Management Procedures (AMP) demonstrated that the increased capabilities of numerical tools and the use of expert methods based on AI can be advantageously used to further increase the NPP safety.

To encapsulate, preserve and disseminate all the gained expertise and knowledge, this special issue was initiated which contains a collection of papers in open access related to the main topics investigating during the project.

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