

ISSN 2052-4846



# **Radiation Regulator**

**Volume 1, Number 3**

**The International Journal  
Supporting Continuous  
Professional Development**

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# Research

## The NKS-R Programme for Nordic cooperation on nuclear reactor safety including organisational issues and decommissioning of nuclear installations



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This is the second of three articles describing NKS and its activities. The first article, which was published in the previous issue of *Radiation Regulator*, gave an overall introduction to the NKS organisation, whereas the third article, which will be published in the next issue of the journal, will focus on NKS activities in emergency preparedness.

### Abstract

The NKS platform for Nordic cooperation and competence maintenance in nuclear and radiological safety comprises two parallel programmes: the NKS-R programme on nuclear reactor safety and the NKS-B programme on emergency preparedness. This paper introduces the NKS-R programme and its current activities.

### General introduction to the NKS-R programme

Emerging on the background of decades of Nordic collaboration on nuclear energy, NKS started its first research programme in 1977, funding a series of four-year programmes covering the areas reactor safety, waste management, emergency preparedness and radioecology. The research programmes varied in each 4-year period depending on current interest, and were selected by the NKS board. However, nuclear safety and emergency preparedness remain major priority areas, as demonstrated in connection with an organisational change in 2002, when the owners of NKS decided to

revise the overall structure of NKS. The new NKS structure accommodated two parallel research programmes: NKS-R (reactor safety) and NKS-B (emergency preparedness), each coordinated by a programme manager. Activities were then restricted to one-year periods, with the possibility of continuation, subject to approval of a new application in connection with annual calls for proposals. The purpose of the organisational change was to improve the flexibility of NKS work, and at the same time enhance cost-effectiveness. A declared main objective of the NKS-R programme is to address current and emerging challenges that the nuclear industry and authorities are facing. These include safety aspects in



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modernisation of old plants, harmonisation of safety requirements and standards, power up-rates, ageing issues, decommissioning and dismantling, waste disposal and new nuclear facilities. The current structure of the NKS-R programme distinguishes between activity types in seven formal categories:

- Thermal hydraulics
- Severe accidents
- Reactor physics
- Risk analysis & probabilistic methods
- Organisational issues and safety culture
- Decommissioning, including decommissioning waste
- Plant life management and extension

Over the years, the NKS-R programme has produced hundreds of reports (all publicly available free of cost on the NKS website [www.nks.org](http://www.nks.org)) describing the outcome of research and development initiatives taken under the NKS-R framework to investigate and devise solutions to challenges in Nordic nuclear reactor safety. Many results from NKS activities have also been published in international peer-reviewed journals, thus disseminating results to a larger audience. Many of the developed solutions have been integrated, both on the Nordic utility and authority side, and are today important pillars in the Nordic reactor safety framework. At the same time, the many NKS-R activities have been valuable in maintaining useful dialogue between different Nordic nuclear power producing organisations, and in providing an informal network for communication also with and between Nordic authority organisations and other stakeholders in the field. This has resulted in a common understanding of important issues and a sound basis for Nordic collaboration far beyond the NKS-R framework.

The outcome of the activities has over the years several times undergone critical external review, which has generally been very positive. It should be noted that the funding for NKS research activities is limited: it corresponds to only roughly one percent of the total Nordic

funding in the area of reactor safety, phase-out and waste treatment. However, a recent review report states that 'considering the limited funding, the achievements of the NKS-R program have been remarkable'. Naturally, there have also been suggestions for improvements. It was pointed out in a review report that surprisingly no joint objectives or participation initiatives of NKS-R and NKS-B were launched in the four-year period up to 2005. It is clear that in some contexts there is a mutually beneficial perspective in cooperation across the two NKS programmes, as optimised emergency preparedness solutions should incorporate detailed information on reactor-specific processes for example in defining plausible accidental release source terms and accident time phases, and it would be in the industry's interest to secure that also solutions to low probability (but high potential adverse impact) events can be handled as well as possible. An extra effort has indeed subsequently been made by NKS to promote such activities. The NKS-R and NKS-B framework documents introducing the calls for proposals were revised to highlight the issue, and raise the awareness of what would be termed 'cross-over' aspects. An example from recent years (2012-13) of a NKS activity with clear elements relating to both the NKS-R and the NKS-B programme is the RASTEP activity, in which developments were made of a computerised tool for source term prediction and severe accident progression at a nuclear power plant using Bayesian belief networks.

In March 2009, the initiative was also taken to hold a two-day joint NKS-R and NKS-B seminar in Stockholm, specifically with the aim of furthering reciprocal awareness of ongoing research and issues under the respective NKS-R and NKS-B programmes. The goal was to promote new networking opportunities and generate new ideas and



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approaches to solving existing problems. The seminar proved, at least for the time being, to achieve its main objectives, as it was well attended and increased the number of proposals for new activities in the following autumn.

The Fukushima accident in 2011 logically prompted a decision to have a further look at the current state of development in Nordic nuclear safety and emergency preparedness. In January 2013, the NKS Seminar on the Fukushima Accident and Perspectives for Nordic Reactor Safety and Emergency Preparedness was held, again in Stockholm. The objective of the seminar was to provide an overview of the Fukushima accident, with emphasis on issues of relevance to the Nordic countries. This multifaceted accident prompted a series of internationally and nationally devised power plant tests, and both Nordic authority and utility organisations reported on their efforts to scrutinise the current safety systems. Issues that were highlighted in this context during the seminar included methods for evaluation of natural hazards (e.g., earthquakes, flooding and fire), reliability and robustness of electrical systems, possible needs for improvements of instrumentation to be used during accident scenarios, possible needs for revision of mitigation systems, and operator behaviour in stress situations and safety culture. The perspective of possibly having to deal with very long duration accident scenarios, compared with what had previously been assumed, was also a learning point, both for the reactor safety and emergency preparedness side. There are various ongoing programmes in the Finnish and Swedish utility organisations to improve reactor safety in case of extreme weather conditions and severe accidents, although the stress test reports concluded that there are no immediate needs for improvements at the Nordic nuclear power plants. It would be logical if this year's call for proposals for new NKS activities (submission deadline: 14<sup>th</sup> of October 2013) would address

topics of relevance to some of the problems that were discussed at this seminar.

### **Current NKS-R activities**

The total number of NKS-R activities has increased over the latest years, and is currently ten. Some of these are continuations of previous activities, which have demonstrated high quality and value in earlier phases, but this year also five entirely new activities were started. In connection with the annual call for proposals for new activities, a group of NKS board members evaluate all the applications to optimise the cost-benefit relationship in relation to declared goals of the organisation. The main aims of the NKS programmes are generally to maintain and strengthen Nordic competence, develop Nordic cooperation, and to support work, which is relevant to Nordic authorities, organisations, industries and university departments. The following activities are now running under the NKS-R programme.

#### *Thermal Hydraulics*

##### **ENPOOL**

NKS ENPOOL continues a series of steam blowdown experiment series. The work consists of experimental and numerical studies on suppression pool issues. In 2013, the experiments concentrate on the dynamic free water surface in a blowdown pipe to provide data on mixing of a thermally stratified pressure suppression pool and on direct contact condensation. The experiments carried out with the test facility provide a representative database for numerical studies and modeling, which are carried out under the ENPOOL activity.

##### **POOLFIRE**

The three year project focuses on development and validation of prediction models for pool fires in enclosures using



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pyrolysis models in a CFD model. Pool fire is one of the major fire accident types in nuclear power plants, together with cable and hydrogen fires. The model can be utilized in risk assessments for nuclear power plants.

#### *Severe Accidents and Reactor Physics*

##### **DECOSE**

The goal of the NKS DECOSE activity is to reduce uncertainties in assessment of debris bed properties and coolability by collaborative experimental and analytical studies. The experimental part of the project leads to investigation of key physical phenomena of the debris bed formation and coolability, and produces data for validation of simulation tools. The analytical approach will be utilized to improve prediction of coolability and to assess the uncertainties in modelling of steam explosion impact.

#### *Risk Analysis*

##### **DIGREL**

The activity develops practical guidelines for analysis and modeling of digital systems in probabilistic safety assessment for nuclear power plants. A compilation and analysis of failure modes taxonomies and a draft guidelines document on taxonomies for digital systems have been prepared. In a parallel task, a fictive digital I&C PSA-model has been developed for demonstration and testing of modeling approaches. In 2013, the main activities will be to finalize the guidelines and to work with software reliability modeling and quantification.

##### **DPSA**

NKS DPSA is a new three year activity on deterministic-probabilistic safety analysis methodology. The goals of the project are to develop DPSA modelling approaches for scenarios where timing of the events, including PSA Level 1 and recovery actions, has significant effect on the results, and to

develop methods for improving PSA using DPSA generated data.

##### **L3PSA**

A new activity, which aims to develop a guidance document for probabilistic consequence analysis, which is often referred to as Level 3 PSA. Level 3 PSA provides an assessment of off-site consequences from radioactive releases. Results from the site components and human factors (Level 1 PSA) and the severe accident and radioactive source term analysis (Level 2 PSA) are incorporated with meteorological data, radionuclide release data, population and agricultural data to estimate the risks to the public. The typical outputs of a Level 3 PSA can vary, but often include collective radiation doses, health effects, economic impacts, and agricultural effects.

##### **EXAM HRA**

A new NKS project on existing applications and guidance on methods for human reliability analysis (HRA). The project aims to provide guidance for a state of the art HRA. The guidance may be utilized in probabilistic safety assessments to ensure that plant specific properties are properly taken into consideration in the analysis.

#### *Organisational Issues and Safety Culture*

##### **HUMAX**

A new NKS-R activity, which studies the use of human performance tools by maintenance workers in Finnish and Swedish nuclear power plants. The project will look at the use of specific tools or lack thereof, and interview maintenance workers and those responsible for developing human performance programs at the plants on their opinions on the human performance tools. The two year project aims to provide recommendations on how to improve the effectiveness of human performances, and to assess which aspects

of maintenance work that could be better solved by other sociotechnical means.

#### SADE

The last year of a three-year project on safety culture in design and implementation of technological and organizational solutions. The objective of the NKS SADE activity is to identify the organizational challenges associated with design and implementation activities and contribute towards improved evaluation of the risks linked to new designs and their implementation. The study will also seek to provide guidelines to support and guide the design process and to anticipate emerging risks.

#### *Decommissioning*

##### DECOM-SEM

The NKS Seminar on decommissioning of nuclear facilities will be held on 6-7<sup>th</sup> November 2013 in Halden, Norway. The seminar will consist of presentations of completed, existing and planned decommissioning projects in the Nordic countries in addition to presentations of activities and developments that may support decommissioning processes. The last NKS seminar on decommissioning was held in September 2010. Since then the activities, research and developments in the field of decommissioning nuclear facilities have continuously developed. A new seminar provides a good opportunity to exchange experiences and discuss the future.

#### **Conclusions**

The NKS-R programme has only existed since 2002, but builds on a solid foundation of previous collaborative activities on nuclear reactor safety related issues within the NKS framework. Over the years the programme has generated numerous seminars, reports, conference presentations, journal papers and other NKS activity products, which have generally been well received by the designated user community.

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