



Nordisk kernesikkerhedsforskning
Norroenar kjarnöryggis rannsóknir
Pohjoismainen ydinturvallisuustutkimus
Nordisk kjernesikkerhetsforskning
Nordisk kärnsäkerhetsforskning
Nordic nuclear safety research

NKS-R Status Report

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STATUS SUMMARY

This report gives a short overview and summary of the current status regarding the NKS-R activities.

2011 years activities

For year 2011 seven activities received funding. Six of these activities are new and one is a continuing activity. All activities launched during 2011 are performing according to plan. All contracts are signed (in total 9 contracts). 12 of 18 of the expected first invoices have been received.

2010 years or earlier activities

Four of seven projects from 2010 are completed; Decom-sem, DIGREL, IACIP, MOSACA. Three final reports are being revised; INCOSE, NROI, POOL (VTI). There is one missing final report, POOL (KTH). It is expected to be delivered in May.

Seminars

No seminars have been held since the last board meeting. One upcoming seminar is announced; NOMAGE4 seminar 31.10 - 1.11.2011, Halden, Norway.

Published reports

Since the last board meeting in January 2011, eight new NKS-R reports have been published, see Table 1.

Table 1. Published report since the last board meeting.

NKS code	Date	Author(s) and title	NKS activity
NKS-241	March 2011	Markku Puustinen, Jani Laine, Antti Räsänen: <i>MULTIPLE BLOWDOWN PIPE EXPERIMENTS WITH THE PPOOLEX FACILITY</i>	NKS-R / POOL
NKS-240	March 2011	Jani Laine et al: <i>PPOOLEX EXPERIMENTS ON STRATIFICATION AND MIXING IN THE WET WELL POOL</i>	NKS-R / POOL
NKS-239	February 2011	Teemu Reiman et al: <i>Nuclear Safety Culture in Finland and Sweden - Developments and Challenges</i>	NKS-R / MOSACA
NKS-237	January 2011	Jonas Andersson: <i>Automation strategies in five domains - A comparison of levels of automation,</i>	NKS-R / AutoStrat

		<i>function allocation and visualisation of automatic functions</i>	
NKS-236	January 2011	Timo Pättikangas, Jarto Niemi, Antti Timperi: <i>CFD and FEM modeling of PPOOLEX experiments</i>	NKS-R / POOL
NKS-235	January 2011	Markku Puustinen, Jani Laine, Antti Räsänen: <i>PPOOLEX Experiments on Dynamic Loading with Pressure Feedback</i>	NKS-R / POOL
NKS-234	January 2011	Jani Laine, Markku Puustinen, Antti Räsänen: <i>PPOOLEX Experiments with Two Parallel Blowdown Pipes</i>	NKS-R / POOL
NKS-231	January 2011	Makoto Tsuiki and Steven Mullet: <i>Comparison of VNEM to Measured Data from Ringhals Unit 3 (Phase 3)</i>	NKS-R / IACIP

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ACTIVITIES INITIATED 2010 OR EARLIER

Three of the seven 2010 initiated projects are still uncompleted. The POOL (KTH) report is missing but is promised to be delivered in May. INCOSE, NROI and POOL (VTT) have delivered final reports which are being revised. The following table gives an overview of 2010 projects:

Table 2. Overview of 2010 projects.

Project	Status	Name	Running period	Funding NKS 2010 [kDKK]	Total NKS funding received (incl. 2011) [kDKK]	Project partners
Decom-sem	Completed	Decommissioning seminar	2010	100	100	Studsvik, SKB
DIGREL	Continuing	Guidelines for reliability analysis of digital systems in PSA context	2010 -	200	500	VTT, Risk Pilot
IACIP	Completed	Improving accuracy of the calculation of in-core power distributions for light water reactors	2008 - 2010	300	850	IFE, Vattenfall
INCOSE	Report under revision	In-vessel coolability and steam explosion in Nordic BWRs	2009 - 2010	300	600	KTH
MOSACA	Completed	Development model of safety culture applied in the nuclear industry & Subcontractors' role in the Nordic nuclear safety culture	2008 - 2010	500	1300	VTT, KTH, Risk Pilot
NROI	Report under revision	Nordic research on radiolytic oxidation of iodine	2008 - 2010	550	1450	Chalmers, VTT
POOL	Waiting for one final report	Condensation pool experiments	2007 - 2010	550	2000	VTT, KTH, LUT

ACTIVITIES INITIATED 2011

Status of the projects as reported by the project leaders in April 2011.

1.1 AIAS

Activity name	Adsorption of iodine oxide aerosols on surfaces		
Objectives	Analysis of the behaviour of IOx particles on different surfaces in the reactor containment during severe accident conditions.		
Organisations	Chalmers, VTT		
Initiated	2011	Year	1(1)
Funding [kDKK]	540	NKS-code	NKS_R_2011_98
Invoices received	1:st		

Status

The work is planned to start in May in Finland. Ph.D student Sabrina Tietze from Chalmers is going to VTT in May to perform experiments.

1.2 DIGREL

Activity name	Guidelines for reliability analysis of digital systems in PSA context		
Objectives	Development of practical guidelines for analysis and modelling of digital systems in PSA for nuclear power plants. Continuing the pre-study made in 2010, now the activity would focus on preparing the guidelines document.		
Organisations	VTT, Risk Pilot AB		
Initiated	2010	Year	2(4)
Funding [kDKK]	300	NKS-code	NKS_R_2010_86
Invoices received	1:st		

Status

Task

WGRISK activity (task group) focusing on the development of best practice guidelines on failure modes taxonomy for reliability assessment of digital I&C systems for PSA

Status

Several phone meetings
 One task group meeting in Paris March 28-29
 File repository created for the task group
 Collection of taxonomies
 Activity plan prepared for 2011
 Workshop planned in May 2011 in Washington D.C., USA
 25%

Development of the generic digital I&C system example and associated demonstration PSA-model	Draft outline prepared 10%
Nordic end user workshop (Fall 2011)	Not started 0%
Interim report (public NKS report)	Not started 0%
Overall progress 20%	

1.3 ENPOOL

Activity name	Experimental and numerical studies on suppression pool issues		
Objectives	Modelling of rapid steam condensation processes in a BWR pressure suppression pool, using computational methods and experiments. CFD methods are further developed. Experiments produce data for validation of the CFD computation and for the 3D computational code GOTHIC .		
Organisations	VTT, LUT, KTH		
Initiated	2011	Year	1(5)
Funding [kDKK]	650	NKS-code	NKS_R_2011_90
Invoices received	1:st		

Status

Work is progressing well. See Appendix 1 for detailed status report.

1.4 MOREMO

Activity name	Modelling resilience for maintenance and outage		
Objectives	Research in resilience engineering for maintenance and outage of nuclear power plants, using Ringhals and Loviisa as case studies.		
Organisations	IFE, VTT, RAB		
Initiated	2011	Year	1(2)
Funding [kDKK]	500	NKS-code	NKS_R_2011_95
Invoices received	1:st		

Status

The MOREMO project started with a kick-off workshop in March where the data collection plan was finalized and the methodology was refined. During an initial data collection in Ringhals on March 14, information about the organization of outage activities was collected

(planning process, scheduling, coordination of activities during the outage). An extended data collection will take place in Ringhals in week 15 and 16, when observations of maintenance activities will be conducted by researchers from VTT and IFE. Over the summer, the data will be analysed using the Functional Resonance model (FRAM) and the Organizational Core Task model (OCT). Another data collection is planned for October.

The project is progressing according to plan. My estimate is that around 12 person-days have been used so far.

1.5 NOMAGE4

Activity name	Nordic Nuclear Materials Forum for Generation IV Reactors network activities		
Objectives	Support of the "Nordic Nuclear Materials Forum for Generation IV Reactors" network by seminars, webpage, mobility support for students and by giving presentations.		
Organisations	Studsvik, VTT, IFE, Risø		
Initiated	2011	Year	1(2)
Funding [kDKK]	250	NKS-code	NKS_R_2008_63
Invoices received	1:st		

Status

A kick-off meeting was held in March. The NOMAGE4 seminar has been planned and announced. The seminar will be held in Halden, 31st October - 1st November 2011. Invitations have been sent to all NOMAGE4 members. The seminar is advertized on the NKS webpage: http://www.nks.org/en/seminars/future_seminars/

1.6 POOLFIRE

Activity name	Predictive analysis of pool fires in enclosures by means of CFD models for risk assessment of nuclear power plants		
Objectives	Development and validation of prediction models for pool fires in enclosures using pyrolysis models in a CFD model, which can be used in risk assessments of nuclear power plants.		
Organisations	Lund, VTT, Haugesund, RAB		
Initiated	2011	Year	1(3)
Funding [kDKK]	360	NKS-code	NKS_R_2011_96
Invoices received	1:st		

Status

VTT is running and investigating the actual models available in FDS for fire development of pool fires.

LTH is conducting the first literature review. Haugesund will only come into the project later this year. The project is running as scheduled.

1.7 SADE

Activity name	Safety culture in design and implementation of technological and organisational solutions		
Objectives	Research of safety culture in design and implementation activities in the nuclear industry. Preparation of guidelines to support the design process and giving development ideas for the management of design and implementation activities.		
Organisations	VTT, KTH, Risk Pilot AB		
Initiated	2011	Year	1(3)
Funding [kDKK]	450	NKS-code	NKS_R_2011_97
Invoices received	1:st		

Status

Project kick-off meeting has been arranged with VTT, KTH and RiskPilot. At the meeting the concrete project plans for 2011 were specified. A meeting has been held at STUK concerning their role in the project. A further meeting has been scheduled with Fennovoima for week 15.

Also, the next SADE project meeting has been scheduled to take place at Stockholm 14.4.

APPENDIX 1

STATUS REPORT OF ENPOOL-NKS and NORTHNET RM3 April 4th, 2011

Work at Lappeenranta University of Technology (LUT)

Markku Puustinen, Lappeenranta University of Technology

ENPOOL-NKS (Funding from NKS and VYR/SAFIR2014/EXCOP)

Deliverable 1: Improvement of PPOOLEX instrumentation at the vicinity of the blowdown pipe outlet with an addition of a PIV and/or other sophisticated measurement system.

The behaviour at the blowdown pipe outlet during air/steam discharge needs to be investigated experimentally in more detail in order to improve simulation models. To achieve this goal sophisticated measuring solutions are sought and installed to the PPOOLEX test facility. For example, with Particle Image Velocimetry (PIV) or Electrical Impedance Tomography systems the flow fields and the level of turbulence at the vicinity of the blowdown pipe outlet could be found out.

The basic operation principle of a PIV measurement system has been studied and different possibilities for installing the system to PPOOLEX have been reviewed. A trip to Paul Scherrer Institute (PSI) in Switzerland to learn how PIV is utilized in the PANDA facility has been made. Possible suppliers of PIV systems have been preliminary contacted.

Task completion: 20 %

Deliverable 2: Execution of the experiment series on DCC.

Direct contact condensation (DCC) at the blowdown pipe outlet with improved instrumentation for tracking the flow fields and the level of turbulence will be studied experimentally in the PPOOLEX facility. The overall goal of the experiments is to produce CFD grade measurement data of rapid steam condensation processes to be used in the development and validation of simulation tools by VTT and KTH. So far, the calculation exercises of the previous PPOOLEX experiments have indicated incomplete condensation in cases with air/steam mixtures. In addition, information on thermal stratification in the gas space of the wetwell will be gathered for the verification of improved turbulence modelling.

The experiments on DCC will start after the PIV measurement system has been purchased and installed.

Task completion: 0 %

Deliverable 3: Reporting of the DCC experiments.

The experiments on DCC will be analysed and reported after the experiment series has been carried out.

Task completion: 0 %

Deliverable 4: Delivery of relevant experiment data to the simulation partners.

Measurement data of several previous PPOOLEX experiment series have been added to the STRESA database of the research group at LUT. Data from thermal stratification and from some chugging experiments have been delivered to KTH and VTT (by granting access to the STRESA database).

Task completion: 40 %

NORTHNET RM3 (Funding from NORTHNET and VYR/SAFIR2014/EXCOP)**Deliverable: Execution and reporting of the experiments with a blowdown pipe sparger.**

The effect of a sparger at the outlet of a blowdown pipe on condensation related loads will be tested. The shape and geometry of the blowdown/vent pipe outlet designs are known to have a significant effect on structural loads experienced by submerged condensation pool structures. In a previous experiment series with the PPOOLEX facility, a collar design at the pipe outlet was tested but somewhat contradictory results compared to expectations were achieved. With improved instrumentation the phenomena and physics behind the effect of the collar (and other pipe outlet designs) could be explained.

A scaled sparger model will be manufactured and installed to the blowdown pipe outlet of the PPOOLEX facility. Additional pressure sensors will be installed to the pool volume in order to gain high resolution data of the movements of pressure waves during steam discharge through the sparger. The speed of the sound measurement system will be optimally positioned for the determination of the effect of the steam bubble distribution.

Funding decisions from VYR have been achieved but from NORTHNET they are still pending. Only some preliminary work has been done.

Task completion: 5 %

Work at VTT**POOL-NKS and SAFIR2010/NUMPOOL**

Timo Pättikangas, Jarto Niemi and Antti Timperi VTT

Deliverable 1. CFD simulation of direct-contact condensation of pure vapour in a PPOOLEX experiment.

Direct-contact condensation (DCC) model for a large vapour bubble in a water pool is being developed. The model is tested against PPOOLEX experiments, where condensation of bubbles with pure vapour occurs. Different alternatives for modelling the interfacial area of gas and liquid

water are studied. Currently, the interfacial area density is estimated from the gradient of the void fraction at the bubble surface. This method has been found out to lead to underestimation of vapour condensation in the water pool. In addition, the effect of turbulence on condensation is studied. The turbulence level in liquid water near the bubble surface is known to strongly affect condensation.

Comparison of simulations performed so far suggest that turbulent mixing near the outlet of the vent pipe is underestimated. Alternative methods for modelling the turbulent heat transfer in this area are studied. CFD simulation of one PPOOLEX experiment with almost pure vapour will be done.

Task completion: 20 %

Deliverable 2. FSI calculation of a PPOOLEX experiment with a large condensing steam bubble.

The work on modeling large, rapidly condensing steam bubbles with the Volume Of Fluid (VOF) model is continued. The work aims at finding approximations for water-hammer loads on the pool walls by using numerical simulations as well as available experimental and literature data. As the Star-CD code showed anomalous results on the gas-phase temperature in the earlier calculations, Star-CCM+ and/or Fluent will be tested for this purpose. Also, new versions of Star-CD could be tested. An FSI calculation is performed by two-way coupling of the CFD and structural codes with MpCCI. The calculations are compared with the PPOOLEX experiments, where high-speed camera recordings of bubble collapse as well as measured pressures and displacements are available.

Task completion: 0 %

Deliverable 3. FSI calculation of blowdown with a sector model of a BWR.

The model for the BWR sector is further developed, so that interaction of multiple blowdown pipes can be studied. The early phase of the discharge is calculated, when the discharge consists of non-condensable gas. The VOF model is used for modelling the large gas bubbles. Both gas and water are modelled as compressible, so that the interaction of sound waves especially in the pipes and in the drywell can be studied.

Task completion: 0 %

Deliverable 4. Report on the CFD and FEM calculations.

Subtask has not yet been started. Task completion: 0 %

Work at Royal Institute of Technology (KTH), Division of Nuclear Power Safety

POOL-NKS and NORTHNET-RM3

Deliverable 1. Development of new effective models for prediction of stratification and mixing in a pressure suppression pool.

Review of existing experimental data, models and approaches to prediction of effective momentum and mixing induced by steam injection into a pool has been performed. No model which takes into account flow regime (quasi-steady or chugging) of steam injection into a subcooled has been found. Models for the Effective Momentum Source (EMS) and Effective Heat Source (EHS) are under development. Available experimental data and previously developed models for steam condensation oscillations in different regimes are used to develop EMS.

Task completion: 50 %

Deliverable 2. Validation of new models against available experimental data including tests in the POOLEX and PPOOLEX facilities.

Data from the previous POOLEX and PPOOLEX tests about dynamics of the free surface motion in the blowdown pipe is used for assessment of the EMS in chugging regime.

Task completion: 20 %

Deliverable 3. Simulations of plant scale phenomena.

Preliminary results for 3D simulation of plant scale phenomena with direct steam injection modelling are obtained. Effect of different boundary conditions was investigated and results were compared to available measured data. Reasonably good agreement achieved between predicted and experimental. An input for more complicated transients with switch on and switch off of the different cooling and mixing systems is under development.

Task completion: 35 %

Deliverable 4. Simulations of direct contact condensation phenomena with GOTHIC and comparison with CFD approach (VTI).

Wall condensation tests in PPOOLEX facility have been simulated with lumped parameter GOTHIC models. The GOTHIC models for the PPOOLEX facility have been developed. The LP and 2D simulations against STR-01 and STR-04 have been performed. The energy balance can be predicted well with LP modelling by GOTHIC. For test STR-04 where the thermal stratification is observed, mixing is obtained with 2D modelling by GOTHIC. The implementation of EHS/EMS model is under development for 2D simulation.

Task completion: 40 %

Deliverable 5. Report on model development and validation.

Draft report on basic EMS model development is under preparation.

Task completion: 10 %