NKS-R STATUS REPORT

Kaisu Leino
NKS-R Programme Manager
December 2012
Fortum Power and Heat

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1 Status summary

This report provides a short overview of current status regarding NKS-R activities and summary of NKS-R events during the year 2012. All the NKS-R activities are mainly on schedule, only minor delays are expected. This year young scientist travel support was granted for three PhD students. Three new reports are published after last board meeting in May 2012. Detailed status reports of the current NKS-R activities are attached in the end of this report.

1.1 Activities initiated in 2012

Nine activities were started in January 2012. Two of these are classified as new activities even thought Nordic-Gen4 continues working in the same field with earlier activity called NOMAGE4. Seven of CfP 2012 proposals are continuing activities started mainly in 2011. DIGREL project was started already in 2010.

In 2012 RASTEP was the only R/B cross-over activity.

Contracts have been issued with all activities and the first invoices have been received from all parties.

Final report has been received from one activity, Nordic-Gen4.

1.2 Earlier activities

There are not any unfinished activities from earlier years. All earlier activities are also reported and invoiced.

1.3 Seminars

Two NKS-R seminars have been held in 2012.

NKS-R DIGREL
Seminar on failure modes taxonomies for the reliability analysis of digital I&C systems
6th November 2012, Stockholm, Sweden

The seminar included presentations of the WGRisk (Working Group on Risk assessment) Task Group, DIGREL, which develops best practice guidelines on failure modes taxonomy for reliability assessment of DIC (digital instrumentation and control) systems for PSA. The seminar was continued with a 3-day meeting of the task group members working with the guidelines documents. Link to seminar proceedings.

NKS-R Nordic-Gen4
4th Nordic Seminar on Generation IV Nuclear Reactors
29-31 of October 2012, Risø, Denmark

The seminar brought together researches from academia and industry working within the different disciplines of nuclear technologies, related to the development of the next generation of nuclear power reactors.

Link to the seminar website for program and presentations: http://nordic-gen4.org/

1.4 Young scientist travel support

Four applications for young scientist travel support have been received. Three applications fulfilled the criteria for the support, one came after the seminar and costs were already covered by university. All eligible applicants had attended and given presentations at the Nordic-Gen4 seminar in Risø. Applicants granted for travel support:

- Lauri Rintala, PhD student, Aalto University, Fission and Radiation group
- Marti Jeltsov, PhD student, KTH, Nuclear Power Safety division
- Karen Atabekjan, PhD student, KTH, Nuclear Energy Engineering

1.5 Published reports

Since the last board meeting in May 2012, 3 new reports have been published. See Table 1.

Table 1. Published reports since May 2012.

NKS-266	June 2012	Hua Li, Walter Villanueva, Pavel Kudinov: *Effective Momentum and Heat Flux Models for Simulation of Stratification and Mixing in a Large Pool of Water*	ENPOOL
NKS-267	September 2012	Michael Knochenhauer, Vidar Hedtjärn Swaling, Per Alfheim: *Using Bayesian Belief Network (BBN) Modelling for Rapid Source Term Prediction - RASTEP Phase 1*	RASTEP
NKS-270	December 2012	Rudi Van Nieuwenhove, Bent Lauritzen, Erik Nonbøl: *Nordic Forum for Generation IV Reactors, Status and activities in 2012*	Nordic-Gen4

2 Status of activities initiated in 2012

This chapter describes shortly the status of nine current NKS-R activities. One activity, Nordic-Gen4, is already accomplished and reported.

2.1 AIAS

Activity name	Ad-/absorption and desorption/revaporisation behaviour of iodine aerosols on containment surface materials		
Objectives	Analysis of the ad-/absorption and desorption/revaporisation behaviour of different iodine aerosols (IOx and CsI) on different surface materials in the reactor containment during hyphothetical severe accident conditions.		
Organisations	Chalmers, VTT		
Initiated	2011	**Year**	2(2)
Funding [kDKK]	500	**NKS-code**	NKS_R_2011_98
Invoices received	1:st		

The project is on schedule. Desorption studies of the metal surfaces under different conditions are performed at Chalmers in 2012 and equivalent studies with painted samples will be

performed on February. See Attachment 1 for more detailed description of the work and experiments done so far.

2.2 DECOSE

Activity name	Debris Coolability and Steam Explosion		
Objectives	Assessment of debris properties and coolability, steam explosion impact. Experimental part of the project is responsible for investigation of key physical phenomena of the debris bed formation and coolability, and producing data for validation of simulation tools.		
Organisations	KTH, VTT		
Initiated	2012	**Year**	1(5)
Funding [kDKK]	500	**NKS-code**	NKS_R_2012_100
Invoices received	1:st		

The DECOSE project is divided to work to be done at KTH and work to be done at VTT. All the deliverables are mainly on schedule. The project is described more detailed in the attachment 2.

2.3 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**	3(4)
Funding [kDKK]	300	**NKS-code**	NKS_R_2010_86
Invoices received	1:st		

The DIGREL seminar was held and the first draft of final report has been made. See Attachment 3 for a detailed status of project.

2.4 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**	2(5)
Funding [kDKK]	590	**NKS-code**	NKS_R_2011_90

Invoices received	1:st

As in year 2011, three separate contracts have been made regarding the ENPOOL activity. Status of activity has reported in three separate sections.

LUT: The work has encountered problems with the PC used for running the control and measurements programs of the PV system. Delays are expected.

VTT: Performing the subtask 1 is delayed due to resource problems but it will be finished by the end of January.

KTH: The project is on schedule.

See Attachment 3 for more detailed description of the work and experiments done so far.

2.5 MOREMO

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

The summary of the findings on resilient work practise for maintenance and outage in the Nordic NPP's is being processed. The project is on schedule. See Attachment 4 for more detailed description of the work done so far.

2.6 NORDIC-GEN4

Activity name	Nordic Nuclear Forum for Generation IV Reactors		
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	IFE, Studsvik, Risø DTU, VTT		
Initiated	2012	**Year**	1(2)
Funding [kDKK]	250	**NKS-code**	NKS_R_2012_103
Invoices received	1:st, 2:nd		

The Nordic-Gen4 seminar was held and reported. All the invoices have been received and approved by PC.

2.7 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**	2(3)
Funding [kDKK]	360	**NKS-code**	NKS_R_2011_96
Invoices received	1:st		

The activity is on schedule. See Attachment 6 for more detailed description of the work and experiments done so far.

2.8 RASTEP

Activity name	Using Bayesian Belief Network Modelling for Rapid Source Term Prediction after a Severe Accident		
Objectives	The proposed activity aims at providing a basis for improving off-site emergency management by developing a computerized source term prediction tool. The name of the tool will be RASTEP (Rapid Source Term Prediction). RASTEP will use Bayesian belief networks (BBN) to model severe accident progression in a nuclear power plant. The output will be a set of possible source terms with associated probabilities. RASTEP consists of two fundamentally different parts, i.e., a BBN model used to model accident progression, predict plant states, and release paths, and a source term definition part used to characterise the source term (height, composition, amount, timing).		
Organisations	Scandpower AB, IFE		
Initiated	2011	**Year**	2(2)
Funding [kDKK]	400	**NKS-code**	NKS_R_2010_87
Invoices received	1:st		

The RASTEP activity follows a different schedule from the other activities. The final report was agreed to be completed by 30 June 2013. Initial activities of work have been finalised according to plan. See Attachment 7 for more detailed description of the work.

2.9 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**	2(3)
Funding [kDKK]	500	**NKS-code**	NKS_R_2011_97
Invoices received	1:st		

The activity is on schedule. Minor delays may occur due to the Safir2014 steering group wanting to revise the final report before submitting it to NKS.

Attachments

Attachment 1. AIAS detailed status report

NKS status report December 2012
AIAS-2 project = Adsorption of Iodine oxide Aerosols on Surfaces – part 2
Experimental work on the ad-/absorption and desorption/revaporisation behaviour of iodine oxides and CsI aerosols on surfaces in the containment during a severe nuclear accident

Author: Sabrina Tietze

1. Project-summary of AIAS-2:

The AIAS-2 (Adsorption of Iodine oxide Aerosols on Surfaces - 2) project is a continuation of the project AIAS-1 started and performed during 2011. Like AIAS-1, is AIAS-2 an experimental co-operation between the Scandinavian research institutions: Chalmers Technical University of Technology (Göteborg, Sweden) and VTT Technical Research Centre of Finland (Espoo, Finland). The goal of the co-operation is a continued investigation of the behaviour of iodine oxide aerosol particles (IOx) in the containment during a hypothetical severe nuclear accident. Within AIAS-2 a further iodine aerosol formed during a severe nuclear accident, cesium iodide (CsI), is studied in comparison to iodine oxide aerosols.

2. Goal

The goal of the project is to investigate the ad-/absorption and desorption/revaporisation behaviour of different iodine aerosols, IOx and CsI, in the containment. The project focuses on their interactions with the dominating containment materials in light water reactors, such as epoxy paint films (Teknopox Aqua VA) and various reactive metal surfaces (Cu, Al, Zn, SS).

3. Status of the project

The production of non-radioactive IOx aerosols at 50, 100 and 120 °C from AIAS-1 was repeated at VTT to study eventual differences of the composition of the produced IOx aerosols. Within AIAS-1 a mixture of I_2O_5 and IO_4. Longer time stored samples showed a film of HIO caused by humidity.

Both non-radioactive and I-131 radiolabeled IOx and CsI aerosols were produced and exposure to the studied surfaces at VTT. For the production of IOx aerosols within AIAS-1 and

AIAS-2 a modified version of the existing EXCI CONT facility had been used. For the production of CsI aerosols another facility, the EXCI PC (EXperimental Study on Iodine Chemistry in Primary Circuit) is used.
In November 2012 Cu, Zn, Al and SS surfaces were exposed to IOx aerosols and CsI aerosols. Furthermore a glassfibre filter sample was exposed to radioactive IOx particles produced at 120 °C to study the decomposition behavior under CO gas flow.

The exposure of Teknopox Aqua VA paint samples (non-aged and aged ones) will be performed in February 2013.Paint films of different age (exposed to heat and pre-irradiated ones {gamma radiation, dose rate = 14 kGy/h}) were prepared using Teknopox Aqua VA epoxy paint at Chalmers University of Technology.

Contrary to the experiments within AIAS-1 within AIAS-2 a much thinner aerosol deposition was established to study the actual surface effects and avoid thick layer deposition effects.

Metals exposed to the non-radioactive iodine aerosols are analysed by SEM-EDX and XPS at VTT to identify possibly formed metal iodides. Within AIAS-1 zinc and copper was found to formed metal iodides with IOx aerosols. No further results have been reported from VTT until now.

Samples which had been treated within the revaporisation studies at Chalmers in November/December 2012 will be characterized at VTT in 2013 to determine the changes on the surfaces using XPS and SEM-EDX.

Desorption studies of the metal surfaces under different conditions (heat, gamma irradiation, humidity: FOMICAG facility) were performed at Chalmers in November/December 2012 by Sabrina Tietze. Equivalent studies will be performed on the paint samples in February 2013.
The desorption studies showed that IOx aerosols desorb faster under the studied conditions (room temperature, 50 °C, 150 °C, gamma irradiation) than CsI. IOx aerosols wash as well easier off from the metal surfaces when immersed in water. Cu samples exposed to both IOx and CsI retained longest and most I-131. In case of CsI it didn`t wash off after irradiation and heat treatment followed by heating the samples 24 h in hot water indicating and confirming the findings from AIAS-1 that cupper iodide is formed.
The glass fiber filter exposed with IOx aerosols showed that the CO accelerates the revaporisation in comparison to air or nitrogen.
The quantitative analysis of the studies is undergoing.

Attachment 2. DECOSE detailed status report

STATUS REPORT OF DECOSE-NKS
December 19, 2012

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

DECOSE-NKS and APRI-8

Pavel Kudinov, Simone Basso, Alexander Konovalenko, Sachin Thakre, Liangxing Li, Weimin Ma, Aram Karbojian.

Deliverables of KTH in 2012:

Deliverable 1: The effect of the heaters geometry on the DHF. Comparison of data from POMECO-HT and COOLOCE. POMECO-FL tests for effective particle diameter.
The goals of the tests are (i) to provide comparison of DHF data with the same particles in COOLOCE and POMECO-HT which use different test sections and heater geometries, and (ii) provide measurements of pressure drop and effective particle size in POMECO-FL facility. The experiments with gravel particles have been carried out. We found that DHF is smaller in POMECO facility. However, measured porosity was lower and particle size distribution slightly deviates from those reported in COOLOCE experiment. More tests will be done with ceramic beads in order to clarify the findings.
Task completion: 75 %

Deliverable 2: DECOSIM code development and validation against the experimental results produced in COOLOCE and POMECO-HT facilities.
Validation of the DECOSIM code has been started against existing COOLOCE data. Results show reasonably good agreement between experiment and prediction. Validation to be continued as new data will become available from POMECO-HT and POMECO-FL facilities.
Task completion: 50 %

Deliverable 3: Investigation of particulate debris spreading and possible effect of heaters in COOLOCE facility (Task 4).
Exploratory tests in PDS-C facility (which stands for particulate debris spreading – closures) have been started A mock-up of the COOLOCE heaters and thermocouples have been designed and is currently under manufacturing. Other necessary preparations for the tests are ongoing.
Task completion: 30 %

Deliverable 4: DEFOR-A confirmatory series of tests with melt simulant material (Task 2).
Four confirmatory DEFOR-A tests have been carried out with new corium simulant material ZrO_2-WO_3. The effects of jet free fall height and melt superheat were investigated. We found similar dependencies for the melt agglomeration fractions as function of water pool depth as in the previous DEFOR-A tests with another simulant material. The effect of the jet free fall height seems insignificant with respect to the particle size distribution.
Task completion: 80 %

Deliverable 5: Application of MC3D to analysis of steam explosion in a BWR containment (Task 8).

Molten fuel-coolant interaction (FCI) scenarios are considered for a Nordic BWR design with different jet diameters, initial melt mass and fragmentation models. The effect of the melt release conditions on the maximum pressure and impulse on the walls have been assessed.
Task completion: 80 %

Deliverable 6: Reporting of the POMECO-FL, POMECO-HT and PDS experiments.
Reporting of PDS and DEFOR-A tests have been started.
Task completion: 50 %

Deliverable 7: Delivery of relevant experimental data to the simulation partners.
Draft report on the POMECO-FL and POMECO-HT tests has been submitted to VTT.
Task completion: 30 %

Work at VTT
DECOSE-NKS and SAFIR2014

Eveliina Takasuo, Ville Hovi, Niina Könönen, Mikko Ilvonen, Ilona Lindholm, Stefan Holmström, Tuomo Kinnunen

Deliverables of VTT in 2012:

Deliverable 1: The effect of the heater geometry on the DHF. Comparison of data from STYX with COOLOCE.
The experiments with STYX gravel in the COOLOCE facility have been run for 1-7 bar pressures. It was found that the dryout heat flux was somewhat smaller than in the original STYX experiments.
Task completion: 100 %

Deliverable 2: Experiment with cylindrical geometry with water ingress through the sidewall.

The experiments have been performed for 1.3 – 3 bar pressures (as high as possible with the available power) using a cylinder with open top and sidewalls, facilitating lateral water ingress through these surfaces. The dryout power was greater for the laterally flooded cylinder than for the top-flooded cylinder (roughly by 50%).
Task completion: 100 %

Deliverable 3: Experiment on the effect of initial pool subcooling with cylindrical debris bed geometry.

Experiments with no initial heating of the test facility to saturation temperature were done with several power levels. The results suggest that the cooler pool increases coolability compared to initially saturated conditions.
Task completion: 100 %

Deliverable 4: PORFLO code development and validation calculations against the experiments.
Test calculations have been done with 3D models of the conical and cylindrical debris beds. However, rather than validating the results against the experiments, the focus of the work has been on verifying the implementation of the porous media models into PORFLO and examining the fundamental differences between the CFD approach and the simpler porous media models (such as MEWA). This has been done by comparisons of MEWA, PORFLO and FLUENT results. In addition, the modeling of the experiments with the MEWA code, aiming to validate the results and to investigate the effect of model parameters, has been continued (from previous years).

Task completion: 75 %

Deliverable 5: Application of MC3D to analysis of steam explosion in a BWR containment.

Calculations for a Nordic BWR have been made using TEXAS V code. In November 2012 a training course was organized in collaboration with KTH at the KTH facility. During the course the participants learned the use of TEXAS V and specified a reference case for Nordic

BWR for further studies. Other issues during the meeting were the coupling of TEXAS V and DAKOTA and solving the TNT method for pressure calculations.
Task completion: 70 %

Deliverable 6: Feasibility study for advanced instrumentation.

A preliminary cost calculation of a double-tip conductivity needle probe has been received from Dresden-Rossendorf research center. Basic technical issues concerning the installation and positioning of the probe were resolved. However, it was decided that the procurement of such a system is not currently feasible because taking the new probe into use, processing the "additional" data and costs associated with the equipment would require a significant increase in the personnel and financial resources of the project (not realistic in the on-going SAFIR programme).
Task completion: 100 %

Deliverable 7: Reporting of the COOLOCE experiments.

A report of the COOLOCE-8 and 9 experiments has been written. Reports of the COOLOCE-10 experiment and the modeling work will be written in January 2013.
Task completion: 50 %

Deliverable 8: Delivery of relevant experimental data to the simulation partners.

The COOLOCE-8 and 9 report has been sent to KTH. Reports of the remaining experiments will be distributed after their completion. Distribution of experimental data in numerical format requires a written agreement according to VTT policies. Such an agreement is under preparation.
Task completion: 70 %

Attachment 3. DIGREL detailed status report

Task	Status
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	One Task Group meeting in Paris Febr 16-17 Status reported to OECD/NEA WGRISK Paris March 7-9, 2012 Draft guidelines compiled based on inputs from the Task Group, last version November 2012 Two papers presented in PSAM11/ESREL2012 conference in Helsinki June 2012 One paper presented in ANS NPIC & HMIT 2012 conference in San Diego in July 2012 A paper submitted and accepted in the International Journal of Nuclear Safety and Simulation (to be probably published in IJNS Vol.3, No.4, December 2012) 100%
Development of the generic digital I&C system example and associated demonstration PSA-model	One paper written to ANS NPIC & HMIT 2012 conference in San Diego in July 2012 A paper published *Nuclear Engineering and Technology*, Vol. 44, No. 5, June 2012. 471–482. An updated version of the example prepared (a four-redundant nuclear power plant) 100%
Nordic end user workshop (Fall 2012)	Seminar Nov 6 and task group meeting Nov 7-8 in Stockholm Proceedings prepared (Report VTT-M-07735-12) and published (http://www.nks.org/en/seminars/presentations/nks-r_digrel_6_november_2012.htm) 100%
Interim report (public NKS report)	First draft prepared. Expected to be ready and accepted by Nordic PSA Group in January 2013 60%

Overall progress 90%

Attachment 4. ENPOOL detailed status report

STATUS REPORT OF ENPOOL-NKS and NORTHNET RM3 December 10th, 2012

Work at Lappeenranta University of Technology (LUT) ENPOOL-NKS, NORTHNET RM3 and SAFIR2014/EXCOP

Markku Puustinen, LUT

Deliverable 1: Execution of the experiment series on DCC.

Behavior 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 devices (for example a Particle Image Velocimetry system and a modern high speed camera) have been installed to the PPOOLEX test facility in 2011.

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 high grade measurement data of rapid steam condensation processes to be used in the development of simulation tools by VTT and KTH.

The PC used for running the control and measurement programs of the PIV system was sent to Germany for fault detection and repair. Despite of numerous efforts to find the possible fault causing the problems and despite of reinstalling the operating system and measurements programs no solution for the situation has been found yet. The experiments will start when the PIV measurement system is operational again.

Task completion: 10 %

Deliverable 2: Reporting of the DCC experiments.

Task completion: 0 %

Deliverable 3: Execution of the experiment series on the dynamics of free water surface in the blowdown pipe.

PPOOLEX experiments in 2012 will provide necessary data for the development of the effective momentum source (EMS) and effective heat source (EHS) models at KTH. Dynamics and movement of the free water surface in the blowdown pipe will be detected with a fine net of measurements.

Details of the experiment parameters, test procedure and pre-test calculations with GOTHIC code were discussed on 24th of May in a meeting with the personnel of KTH at LUT and an updated test plan was received after the meeting from KTH. An extensive net of temperature measurements was added to the lower half of the blowdown pipe for tracking the movement of the steam/water interface.

Six experiments were carried out according to the test plan during the summer and autumn. The experiments focused on the development of thermal stratification during a low mass flow rate period and on complete mixing due to chugging regime.

Thermal stratification developed in all experiments in an expected way. Complete mixing of the pool volume was achieved during the chugging mode with the mass flow rates selected on the basis of the pre-test calculations. Re-stratification (during the high flow period) developed in those experiments which were continued so long that the pool water temperature had significantly increased. The movement of the steam/water interface inside the blowdown pipe was tracked in more detail than in the previous experiments due to the increased number of thermocouples in the pipe.

Task completion: 100 %

Deliverable 4: Reporting of the free water surface experiments.

A report on the experiments has been written and it is under internal review at the moment.

Task completion: 90 %

Deliverable 5: Delivery of relevant experiment data to the simulation partners.

Most of the data of the experiment series on the dynamics of free water surface in the blowdown pipe was delivered to KTH to be used in the development and validation of the EMS and EHS models of GOTHIC code. Some selected data of the test series has been delivered also to VTT to be used as a comparison material in chugging simulations.

Task completion: 90 %

Comment

The work on the deliverables 1 and 2 is delayed due to the problems with the PC, where the PIV measurement programs are running.

Work at VTT
ENPOOL-NKS and SAFIR2014/NUMPOOL

Timo Pättikangas, Jarto Niemi, Antti Timperi and Michael Chauhan, VTT

Deliverable 1: CFD simulation of chugging in a PPOOLEX experiment.

The CFD model for chugging is further developed. The models for heat transfer and the interfacial area of liquid water and vapor are improved. In CFD modeling, the goal is to obtain correct collapse speeds of vapor bubbles and correct penetration of liquid water in the vent pipes. The PIV measurements are used for detailed comparison of the calculations to the experiments, when they become available. Simulations of the chugging phase of a PPOOLEX experiment are performed with a fine mesh and a short time step in order to achieve improved resolution in the simulations.

Modifications of the direct-contact condensation model have been started. The present condensation model is compared to Japanese observations on the heat transfer coefficients in the liquid and vapor phases. The condensation model is modified to obtain higher condensation rates at the outlets of the vent pipes and to obtain lower frequency of the chugging oscillations. Test simulations with have been performed. Problems found in the direct-contact condensation model have been fixed.

Test simulations of the PPOOLEX experiment MIX-03 have been started because PIV data is not yet available. The simulations will be finished by the end of January.

Task completion: 60 %

Deliverable 2: FSI calculation of collapsing vapor bubble in a PPOOLEX experiment.

Modeling of the rapid bubble collapse is refined by taking into account the effect of the finite condensation rate. This is done by fitting the calculated collapse time and pressure load with the experiments. Proper approximations for the condensation rate are searched by co-operation with the CFD part of the project. The simulations are compared to the high-speed video images and pressure measurements from the experiments. The scaling of the pressure load amplitude and duration from the laboratory experiment to the BWR are also studied.

A short Fortran program has been written, which solves the one-dimensional dynamics of a spherical, collapsing steam bubble. The code was first validated against earlier analytical and numerical calculations for the simplified case of infinite steam condensation rate. So far, constant condensation rates have also been tested. The condensation rate has been adjusted so that the bubble collapse time observed in PPOOLEX experiment COL-01 results. The aim is to test different approximations for the condensation rate and to compare the collapse times and pressure loads near the bubble with the experiments.

Scaling of the pressure load by dimensional analysis is underway. An article by Sonin (1981) “Scaling laws for small-scale modeling of steam relief into water pools” is being studied. Dimensional analyses have also been performed separately for different phenomenon during

the LOCA: mass and energy flow scaling, pressure loss in the vent pipe, initial vent clearing transient and bubble rise in the pool.

Task completion: 70 %

Deliverable 3: FSI calculation of chugging with a BWR model with multiple vent pipes.

The loads in a BWR are considered with an acoustic model of half or full containment, i.e., 8 or 16 vent pipes. Stochastic analysis of the loads originating from multiple vent pipes is used to analyze the loads in the chugging phase. The pressure source statistics, such as load amplitude and delay between the vent pipes, is determined from experiments and data available in literature. Simulation of the loads and structural response in the BWR geometry is performed.

Previously used detailed model geometry has been simplified and the number of elements in the FEA-model reduced. This will enable the computation of longer time periods, i.e., the number of chugging events experienced per pipe will be increased. The statistics of the loading is studied with the help of simplified model geometry.

It has also been studied whether the modal dynamics procedure can be used to compute the structural response instead of time consuming implicit time integration.

Abaqus explicit dynamics has been applied to compute the structural response of containment. The behavior corresponds to that observed with implicit solver, but with less computation time. The structural response of containment during multiple (100) chugging events is computed using Abaqus explicit and simplified model geometry. The desynchronization time is varied within a given distribution. Time between chugging events and duration of an individual chugging event are taken to correspond to values found from literature.

Task completion: 60 %

Deliverable 4: Report on the CFD and FEM calculations.

A report on the CFD and FEM calculations will be written.

Task completion: 0 %

Comment

The work on the deliverables 2 and 3 has been started in June and August. Resources for finishing these Subtasks by the end of January 2013 are available. Performing the Subtask 1 has also been delayed because of resource problems but it will be finished by the end of January.

Work at Royal Institute of Technology (KTH), Division of Nuclear Power Safety
ENPOOL-NKS and NORTHNET-RM3

Hua Li, Walter Villanueva, and Pavel Kudinov, KTH

Deliverable 1: Development of the new Effective Heat Source and Effective Momentum Source models.

Basic versions of the Effective Heat Source (EHS) and Effective Momentum Source (EMS) models have been developed at KTH for steam injection through the blowdown pipes for prediction of development of thermal stratification and mixing in a pool. The EMS model is developed based on two sub-models: (i) the concept of so called “synthetic jet”, which establishes a connection between frequency and amplitude of steam-water interface oscillations with the resulting momentum influx to the pool; (ii) a model (based on the model originally proposed by Nariai and Aya) which predicts the frequency and amplitude of the interface oscillation in the pipe for given pool temperature and steam flow rate. Different approaches to the implementation of the EHS model have been proposed (e.g. uniform heat fluxes on the walls of the blowdown pipe and at the pipe’s outlet), which take into account the dynamics of steam condensation inside a blowdown pipe and pool conditions. These approaches can result in different thermal stratification behavior in the pool. The details can be found from recent research reports (NKS and NORTHNET). The EMS model has been developed further by taking into account the varying nature of the steam mass flux (with respect to time) from the steam source.

Since more thermocouples are installed in the blowdown pipe and the acquisition rate is also enhanced in the new series of PPOOLEX tests, the calculation of the effective momentum has greatly improved. With the new data it was possible to determine that the analytical model, specifically, the Nariai and Aya model, has a tendency to over-predict the frequency and amplitude of oscillations when applied to the (larger scale) PPOOLEX experiment. Necessary modifications of the above models are currently under investigation.

Task completion: 70%

Deliverable 2: Validation of the current version and modified GOTHIC code models against latest available data.

Validation of the models against available experimental data from POOLEX STB-20, STB21, PPOOLEX tests STR-03, STR-04, STR-06, STR-09, STR-10 has been performed. Validation against the tests STR-02, STR-05, STR-07, STR-08 and STR-11 is on-going. In general, results of validation suggest that EHS and EMS models can reasonably well predict characteristic time scales for development of stratification and mixing in a large scale pool. We are quite confident now that if we provide correct frequency and amplitude of oscillations, the synthetic jet model provides correct value of the effective momentum. We found that the model for prediction of the frequency and amplitude of oscillations can still be further improved.

Task completion: 60%

Deliverable 3: Pre- and post- test simulations of the new series PPOOLEX tests.

The pre-test simulation of the new series PPOOLEX tests has been performed with the aim to guide the choice of experimental test conditions. Preliminary analysis of the recently completed PPOOLEX-MIX tests indicates that the time scale for clearing phase predicted by the pre-test simulation matches the experimental data well. In addition, the 2D pre-test simulations also predicted well the temperature behavior observed in the experiments, from development of stratification, to mixing, and then development of stratification again. Post-test simulations of the tests are ongoing. At first, an over-predicted average pool temperature is obtained in the post-test simulation. The experimental data analysis shows that the water level increment of the pool is not consistent with the injected steam mass flow rate during the post-test simulations. To address this, the steam mass flow rate is estimated according to the measured water level and averaged pool temperature. A lumped simulation with estimated steam mass flow rate is then performed which shows a good agreement with the experimental data on the averaged pool temperature and water level. The corresponding 2D simulations will be performed soon.

Task completion: 70 %

Deliverable 4: Report on the model development and validation.

A report on the model development and validation is under preparation.

Task completion: 30 %

Comment

Note that the percentage of tasks accomplishment is according to the NKS work plan (which will continue in 2014), not NORTHNET work plan which has ended in 2012.

Attachment 5. MOREMO detailed status report

Status report May - December 2012:
Modeling Resilience for Maintenance and Outage (MoReMO)

Presentation of paper to ECCE 2012

A paper on "Understanding maintenance activities in a macrocognitive work system" was presented at the European Conference of Cognitive Ergonomics (ECCE) in August, 2012.

Data collection

This autumn, we have collected data in Swedish and Finnish nuclear power plants (NPPs):

- Observations and analysis of process operators' work during outage at Ringhals, Sweden
- Interviews, observations and data analysis of maintenance work at Loviisa and TVO, Finland

Data analysis and project group meeting

The data collected at the Nordic NPPs during 2011 and 2012 were discussed in a two-days project group meeting in Espoo, October 2012.

Dissemination seminar

A seminar with practitioners, regulators and researchers from Finland, Sweden and Norway will be held in Espoo, Finland on the 10/01/2013. The one day seminar will be held in in association with the Safir2014 MANSCU seminar.

Final report

We're currently summarizing the findings on resilient work practices for maintenance and outage in the Nordic nuclear power plants. The core task modelling of maintenance will be integrated with safety culture criteria and linked to resilient work practices. The observations of process operators during outage will be integrated with interview data to describe their main tasks, perceived boundaries and adaptive capacities.

Attachment 6. Nordic-Gen4 detailed status report

Status report on Nordic-Gen4 – December 2012

The preparation of the Nordic-Gen4 seminar at Risø DTU (29-31 October) went fine and the seminar can be considered to be succesfull. All the presentations are made available on the website http://nordic-gen4.org/seminars/nordic-gen4-riso-2012-2/ and a report has been sent to NKS.
It was not so easy this time to attract enough participants and a strong advertising effort was required. However, in the end 49 participants from 11 countries have participated.
The network created fruitfull interactions between the members but also improved the interaction with European programs on material research.
The objectives set forth in the beginning can be considered to be fulfilled.
It was investigated whether a network based on a membership fee was feasible, but unfortunately, this turned out not to be the case (only 10 members were prepared to pay such a yearly fee). Therefore, this approach was abandoned.
For next year, the coordination of the network will be taken over by Chalmers University of Technology (coordinator Prof. Imre Pazsit).

Rudi Van Nieuwenhove
Coordinator of the Nordic-Gen4 network

Attachment 7. POOLFIRE detailed status report

Status of the project and Achievements during period May 2012 - December 2012

The first year report comprised an overview of the current and new pyrolysis models as well as a first set of validation [1]. In 2012 the FDS liquid pyrolysis model was overhauled. The new liquid pyrolysis model, based on mass transfer calculation, was made the default, and only, liquid pyrolysis model in FDS. Numerical issues with the model were addressed. The first set of validation cases from 2011 was carefully reviewed, making sure that correct thermodynamic properties were used for fuel gases. One major source of error, namely the use of an erroneous specific heat for evaporated gas, was fixed, which significantly improved the model accuracy. Figure 1 shows some results from the above mentioned simulations. Some of the results pointed to a need to account for convection within the fuel. Further work is needed in reducing the grid dependence of the results, which will be performed in 2013. Correct heat transfer within the fuel also requires more attention. The results also highlight the importance of using correct input parameters for the models.

Data from the OECD PRISME project are still used at this moment [2]. Lund University has furthermore under 2012 validated the HVAC module in FDS and this validation work will be continued by adding the pyrolysis model into these run. Additionally data from the PRISME 2 project will be used. Data from real fires were gathered by Ringhals [3] and they formulated the basis for the first real case simulation and indicated a possible industrial fuel. This fuel has been examined by Lund University. A MSc student from the Erasmus Mundus programme will work with the topic on fire properties of liquid fuels. Haugesund and Lund conducted a second set of tests in the Lund lab during May 2012, which were reported as a MSc work [4]. A small pool fire (0,3m x 0,3m) with methanol was used as well as PIV measurements in the plume [3]. The PIV measurements were however difficult to interpret and need further analysis. Furthermore Lund conducted a series of pool fires (0,1x0,1 m, 0,2x0,2 m and 0,3x0,3 m) during July and August with methanol and heptane at different starting temperatures and with measurements in the liquid. This setup will be used to study a practical transformer liquid and it will also be investigated how other measurements can be included in order to obtain data for the validation work as well as data for the real case study. This part will continue partially in 2013. The project group gets also input from the safety engineer of the ESSS facility, which is under project development. They have indicated another type of transformer oil.

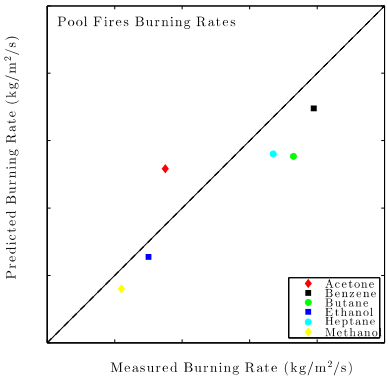

Figure 1. Comparison of FDS predictions of burning rates of 1 m²pool fires with data from SFPE handbook of fire protection engineering, Chapter 2.

References

1. Patrick van Hees, Jonathan Wahlqvist , Simo Hostikka, Topi Sikanen, Bjarne Husted, Tommy Magnusson, Fredrik Jörud, Prediction and validation of pool fire development in enclosures by means of CFD (Poolfire) Report – Year 1, Lund report 3163, ISRN: LUTVDG/TVBB--3163—SE, 2012.
2. http://www.nea.fr/jointproj/prisme.html (downloaded 2010-10-15)
3. Patrick van Hees, Board report May 2012.
4. D. Johansson, Implementation of improved EDC combustion model in the LES CFD code FDS, Master thesis Haugesund College.

Attachment 8. RASTEP detailed status report

SCANDPOWER Risk Management

Lloyd's Register

M E M O

To: Kaisu Leino (NKS)	
From: Michael Knochenhauer	**Copy:** Vidar Hedtjärn, Wiktor Frid (SSM)
Project No.: 210829	**Date:** 2012-12-20
Subject: **Status Report 2012-12-20 for NKS project RASTEP "Using Bayesian Belief Network Modelling for Rapid Source Term Prediction after a Severe Accident"**	

1 Background

The funding from NKS was granted in 16 January 2012, meaning that the present project phase covers July 2012-June 2013.

This memo presents the project as of 2012-12-19.

2 Project Overview

The project aims at providing a basis for improving off-site emergency response by developing a computerized source term prediction tool, RASTEP (Rapid Source Term Prediction). RASTEP uses Bayesian belief networks (BBN) to model severe accident progression in a nuclear power plant. The output is a set of possible source terms with associated probabilities. The approach chosen aims at facilitating decision making in a situation with incomplete or partly contradictive information.

RASTEP consists of two fundamentally different parts, i.e., a BBN model used to model accident progression, predict plant states, and release paths, and a source term definition part used to characterise the source term (height, composition, amount, and timing). The BBN model uses prior information from the plant Probabilistic Safety Assessment (PSA) level 1 and 2 model which is iteratively updated based on input related to plant observables.

Source term definition and modelling of severe accident progression uses information from deterministic severe accident analysis tools, e.g., MAAP. As the source term prediction part of the tool is crucial and separate from the BBN part, the possibility to integrate a deterministic

source term prediction code is being explored, including an M.Sc. diploma thesis at Chalmers Institute of Technology. In this connection, a comparison between MAAP and MELCOR will be performed. The last topic concerns a semi-quantitative approach to defining conditional probabilities based on expert judgement, and relating the performance of this method to the sensitivity of the BBN in terms of "result driving nodes".

The content of the tasks stated above is outlined in the phase 1 report (NKS-267).

3 Status Report

The main sub-activities and indicative time plan for the activity are presented below:

Sub-activities	Start	End
A. Initial activities	Aug 2012	Aug 2012
B. Linking RASTEP to a fast running deterministic code (M.Sc. Diploma thesis project)	Sep 2012	Jan 2013
C. Semi-quantitative method for CTP development	Jan 2013	June 2013
D. Gauging the sensitivity of RASTEP BBN	Jan 2013	June 2013
E. MAAP vs. MELCOR	Aug 2012	June 2013
F. Dissemination of results	July 2012	June 2013
G. Project report	June 2013	Aug 2013

3.1 Initial activities (A)

Initial activities, work planning, etc., have been finalised according to plan.

3.2 In-depth treatment of specific issues (B-D)

This is the most important part of the NKS project, as it addresses a number of research challenges in the practical application of BBN techniques. This part of the project is carried out through three M.Sc. Diploma thesis projects (two of them integrated) to be carried out in 2012 and 2013. The assignments of these projects are presented in the following sections, respectively.

3.2.1 Linking RASTEP to a fast running deterministic code (B)

This part of the project is carried out as an M.Sc. Diploma thesis project by Francesco di Dedda from Chalmers Institute of Technology. The work is a step forward in the process of making the source term module of RASTEP more dynamic and giving more realistic predictions. A review of state-of-the-art methods and approaches, and a feasibility study on linking RASTEP to a fast-running deterministic code was carried out in phase 1 of the NKS project. The MARS code was chosen as a best candidate for the linking. Now the aim is to define the conceptual and, to some extent, the technical integration of the MARS code into RASTEP. This means connecting two different worlds – a probabilistic one with a deterministic one.

The project is anticipated to be finished late January 2013. A detailed status report is found in Appendix A.

3.2.2 Semi-quantitative method for CTP development (C)

The BBN in RASTEP consists of nodes that are categorized based on what kind of information it is dealing with, which in turn determines how the Conditional Probability Tables (CPTs) are developed. In some cases the values are based on the PSA for the analysed NPP. In other cases qualitative information in terms of, e.g., expert judgments is used. In the latter cases, this process is both demanding on resources and difficult to validate and verify. In the thesis project a systematic semi-quantitative method will be developed for determining probabilities of a BBN in cases when the information available is mainly qualitative. The method will deal with prioritisation of information, as well as with uncertainty and applicability.

Two M.Sc. students (Technical Mathematics, Lund's Institute of Technology) have been appointed for this assignment (which is integrated with the one presented below). The project will be carried out at Scandpower's offices in Malmö and Stockholm, and will be supervised by Vidar H. Swaling.

3.2.3 Gauging the sensitivity of RASTEP BBN (D)

This work will be integrated in the previous one, i.e., the performance of the developed approach will be related to the sensitivity of the BBN in terms nodes driving the results, and optimization of the BBN. Important issues are how uncertainties in these CPTs, as well as their relative importance, should be taken into account in the development, as well as in supervising the execution of the RASTEP BBN.

3.3 MAAP vs. MELCOR (E)

In connection with the linking of fast running codes to RASTEP further comparisons between MAAP and MELCOR will be carried out, based on the need for understanding the problem complexity associated with connecting a dynamic source term predictor to RASTEP as well as the possibility of combining different codes serving different purposes. As an example, it might be that MAAP could be the best alternative for the purposes of developing a robust and general source term (calculation run-time not being an issue), but that MAAP wouldn’t serve the purpose of online calculations. The study will primarily be carried out using MAAP and MELCOR, mainly because these codes are widely used internationally for severe accident analyses, and because both are currently at the disposal of the project.

Scandpower has received a MELCOR model of Oskarshamn 3 developed by KTH. Curently one sequence (station blackout) has been analyzed with MELCOR. The remaining work is to continue to evaluate the MELCOR results and explain the differences between MAAP and MELCOR.

3.4 Dissemination of Results (F)

The project is presented to various organisations and at conferences/seminars when suitable occasions arise. Thus, presentations have been made both at the PSAM conference (Helsinki 2011) and at the latest Nordic PSA Conference (Slottsmöte 2011). The project has also been presented to, e.g., the IAEA.

It is currently discussed to include RASTEP in a benchmark exercise arranged within the OECD/NEA WGAMA (Working Group Accident Management); start-up meeting to be held in January 2013. The task name is “International benchmarking project on fast-running software tools used to model fission product releases during accidents at nuclear power plants”.

3.5 Finalisation of project report (G)

Considering that the deadline of the two M.Sc. diploma thesis projects performed spring 2013 (C-D) is June 30, the end of August 2013 is a reasonable date for submitting the final project report.

Attachment 9. SADE detailed status report

Status report for the "Safety culture in design and implementation of technological and organisational solutions - improving resilience of the sociotechnical system throughout the life-cycle" (SADE) NKS_R_2011_97 Project – December 2012

Work status

The main objective of **SADE** project is to identify the organizational challenges associated with design and implementation activities and contribute toward better evaluation of the risks linked to new designs and their implementation.

The following activities were planned for the year 2012:

1. In-depth analysis of the interviews conducted in 2011
2. Workshops with the power companies and the regulators in Finland and Sweden
3. Additional data gathering concerning the interface and collaboration between design organizations and end users / operators
4. Preliminary model of human and organizational factors affecting the design process.
5. Internal workshops with the research parties
6. Final report of the second phase of the SADE project

During the second reporting period of 2012 the following activities were performed:

1. In-depth analysis of the interviews conducted in 2011 and 2012 is in its finalisation stage. The analysis is focused on the identification of factors affecting the design process and in particular on the factors emerging from the interactions of different actors involved in the design process. Both challenges and opportunities have been identified.
2. Two internal workshops with the research parties took place in May and June 2012
3. The development of the preliminary model is on-going. The work is contributing to a scientific publication on Safety Science currently in preparation.
4. The production of the final deliverable is on-going. Structure of the report has been defined and responsibilities to the different research parties have been allocated.
5. A one day seminar with power companies and regulators from Finland and Sweden has been organised for the 11th of January 2013. The one day seminar will be held in Espoo (Finland) in association with the Safir2014 MANSCU seminar. The agenda of the seminar is in Annex.

Annex – MANSCU Project seminar agenda

Business from technology

SAFIR2014 MANSCU-project seminar

Date: 10-11 January 2013

Location: Metallimiehenkuja 2, Espoo, Otaniemi (seminar room Valimo)

Thursday, January 10, 2013

MOREMO – Modelling Resilience for Maintenance and Outages

Goal	To get new insights on how to deal with the complexity and variability of maintenance activities in a safe manner	
09:30 - 10:00	Welcome coffee	
10:00	Opening and goals of the seminar	Pia Oedewald - VTT
10:15	Is the current approach for safe management of maintenance activities enough? Power company perspective	Christer Axelsson - Ringhals AB
10:45	Complexity and variability in maintenance activity. Research perspective	Teemu Reiman - VTT
11:15	Resilience engineering as framework for dealing with complexity and variability	Luigi Macchi - VTT
12:00 - 13:00	Lunch	
13:00	Putting resilience into practice: How can we evaluate resilience of maintenance activities?	Nadezhda Gotcheva; Pia Oedewald - VTT
13:45	Putting resilience into practice: How can we expand the adaptive capacities of process operators during outage?	Maren H. Ro Eitrheim - IFE
14:30 - 15:00	Coffee break	
15:00	Putting resilience into practice: other potential solutions and contributions from participants	Elina Pietikäinen - VTT
15:30	Wrap up of the day	Pia Oedewald - VTT
16:00	End of the day	

Friday, January 11, 2013
DESIGN – Safety culture in the design process

GOAL	To get new insights on challenges and opportunities related to design activities in nuclear industry	
09:00 - 09:15	Coffee break	
9:15	Opening and goals of the day	Luigi Macchi - VTT
9:30	Challenges in design: Human factors and safety culture perspective	Eliina Pietikäinen - VTT
10:15	Opportunities in design: Human factors and safety culture perspective	Marja Liinasuo - VTT
11:00	Group work: analyzing human factors and safety culture in design	Luigi Macchi - VTT
11:45 -12:45	Lunch	
12:45	Group work: analyzing human factors and safety culture in design	Luigi Macchi - VTT
13:45	IAEA's approach to safety culture in pre-operational phases	Pia Oedewald - VTT
14:15	NUREG HFE process approach to design	Paula Savioja - VTT
14:15 - 14:45	Coffee break	
14:45	Strategies for HFE-related work in Swedish modernization projects	Ulf Kahlbom - Risk Pilot
15:30	Wrap up of the day	Luigi Macchi - VTT
16:00	End of the day	

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