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Nordisk kjernesikkerhetsforskning
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Nordic nuclear safety research

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Nordic Nuclear Materials Forum for Generation IV Reactors

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March 2010

Abstract

A network for material issues for Generation IV nuclear power has been initiated within the Nordic countries. The objectives of the Generation IV Nordic Nuclear Materials Forum (NOMAGE4) are to put the basis of a sustainable forum for Gen IV issues, especially focussing on fuels, cladding, structural materials and coolant interaction. Other issues include reactor physics, dynamics and diagnostics, core and fuel design. The present report summarizes the work performed during the year 2009. The efforts made include identification of organisations involved in Gen IV issues in the Nordic countries, update of the forum website, http://www.studsvik.se/GenerationIV, and investigation of capabilities for research within the area of Gen IV.
Within the NOMAGE4 project a seminar on Generation IV Nuclear Energy Systems has been organized during 15-16th of October 2009. The aim of the seminar was to provide a forum for exchange of information, discussion on future research needs and networking of experts on Generation IV reactor concepts. As an outcome of the NOMAGE4, a few collaboration project proposals have been prepared/planned in 2009. The network was welcomed by the European Commission and was mentioned as an exemplary network with representatives from industries, universities, power companies and research institutes. NOMAGE4 has been invited to participate to the "European Energy Research Alliance, EERA, workshop for nuclear structural materials" http://www.eera-set.eu/index.php?index=41 as external observers. Future plans include a new Nordic application for continuation of NOMAGE4 network.

Key words

Generation IV nuclear reactors, Nordic Nuclear Materials Forum, NOMAGE4

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Nordic Nuclear Materials Forum for Generation IV Reactors

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Studsvik Report

Studsvik VTT

STUDSVIK/N-10-12

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Generation IV Nordic Nuclear Materials Forum

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Reviewed by

Jonas Eskhult

Jonas Eskhult Date 2010-03-02

Approved by

Anders Molander Date 2010-03-02

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1 Introduction

Nuclear reactor systems of the future have been given the name Generation IV (Gen IV) since the prospects in technology goes beyond the advanced reactors (Gen III) currently under construction. The Gen III technology is based on systems of today's commercial reactors (Gen II). Gen IV reactor systems use the fuel much more efficiently and most systems will operate with a closed fuel cycle. The Gen IV nuclear reactors have high demands on safety, sustainability and economics [1]. Six reactor systems are referred to as belonging to Gen IV:

- Very High Temperature Reactor (VHTR)
- Sodium Fast Reactor (SFR)
- Gas-Cooled Fast Reactor (GFR)
- Lead-Cooled Fast Reactor (LFR)
- Molten Salt Reactor (MSR)
- Supercritical-Water-Cooled Reactor (SCWR)

Challenges for materials selection for Gen IV nuclear reactors are related to maximization of the nuclear fuel efficiency and minimization of the disposed waste. Furthermore, the challenges are identification and development of materials and alloys that can safely operate under the corresponding environmental conditions present in Gen IV reactors. Other issues include reactor physics, dynamics and diagnostics, core and fuel design. The thermal-hydraulic design is also important, as well as questions of reactor safety, waste disposal and infrastructure in the form of experimental facilities and in the form of personnel competence. R&D in direction of long-term goals requires building of knowledge, prepared scientists and nuclear professionals, as is illustrated in Figure 1.

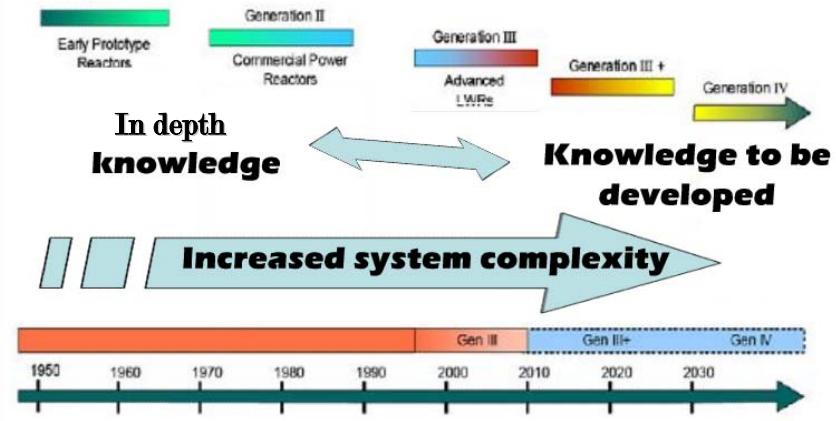

Figure 1
Time evolution for knowledge development and system complexity for nuclear reactor systems.

Potential cladding and structure materials for the different GenIV systems are presented in Table 1.

Table 1
Potential cladding and structural materials for the different GenIV systems [3-6].

System	Materials		
	Cladding	Core regions	Out of core regions
Gas-Cooled Fast Reactor System (GFR)	Ceramics Matrices of SiC, ZrC & TiN, ODS (Oxide Dispersion-Strengthened)	Ceramics Carbides SiC, ZrC Nitrides ZrN, TiN Oxides MgO $ZrYO_2$ Zr_3Si_2 ODS	Coated or non coated ferritic-martensitic or austenitic steels Nickel based super alloys ODS steels
Lead-Cooled Fast Reactor System (LFR)	Austenitic, ferritic-martensitic steel Coated cladding e.g. FeAl		
Molten Salt Reactor System (MSR)	-	Graphite Nickel-based alloys Ceramics	
Sodium-Cooled Fast Reactor System (SFR)	ODS (Metallic fuel) Ferritic-Martensitic steels (MOX-fuel)	Advanced austenitic steels	
Supercritical – Water-Cooled System (SCWR)	Austenitic, Ferritic-Martensitic steels ODS		Ferritic- Martensitic steels
Very-High-Temperature Reactor System (VHTR)	ZrC	Graphite Ceramics	Ni-Cr-W super alloys High temperature metal alloys

There is a strong link between the materials integrity and nuclear safety for all nuclear reactors. The operation conditions in new generation reactors will be more demanding and thus knowledge about materials behaviour and integrity under operation are critical. To evaluate and choose proper materials to be used for GenIV reactors, it is important to know the boundary limits for use of the materials under these specific operation conditions. Safety analysis is based on technological assessment where the materials integrity has a decisive role [1].

2 Objectives of the work

The aim of the project was to build a network for material issues related to Gen IV nuclear reactor systems. The idea of the network is to combine the resources of different research teams in order to carry out more ambitious and extensive research programs than would be possible for the individual teams. The network is focusing on the following aspects:

- Building of a sustainable Nordic network on GenIV issues, especially focussing on nuclear materials integrity and safety: fuels, cladding, structural materials and coolant interaction.
- Spreading knowledge on GenIV issues and ongoing research to different parties involved in the nuclear field, such as LWR licensees universities.
- Inspiring young people to GenIV related R&D.
- Building a strong Nordic forum for GenIV collaboration.
- The results will be used to enhance new project ideas for international programs, e.g., Euratom FP7, calls with a strong Nordic partnership.

3 Milestones, deliverables for 2009

	Date	Status
List of Nordic organisations involved in GenIV and other interested organisations	2009-08-15 2009-12-31	Done
Organising a workshop to which also young generation societies are invited • List of ongoing projects and responsible partners • List of reports etc shared within the pre-network • List of existing plans for future research	2009-10-15 – 2009-10-16	Done
Proposal for network structure, work plan and tool for information sharing	2009-12-31	Done
Final Report	2010-02-28	Draft

4 Organisations involved in Gen IV research

On our GenIV website www.studsvik.se/GenerationIV , our NOMAGE4 partners and members are listed together with contact names and is also presented in this report. Links to other organisations involved in research and development of Generation IV issues are also given.

4.1 Partners

- VTT
- NKS
- Vattenfall
- Fortum

4.2 Members

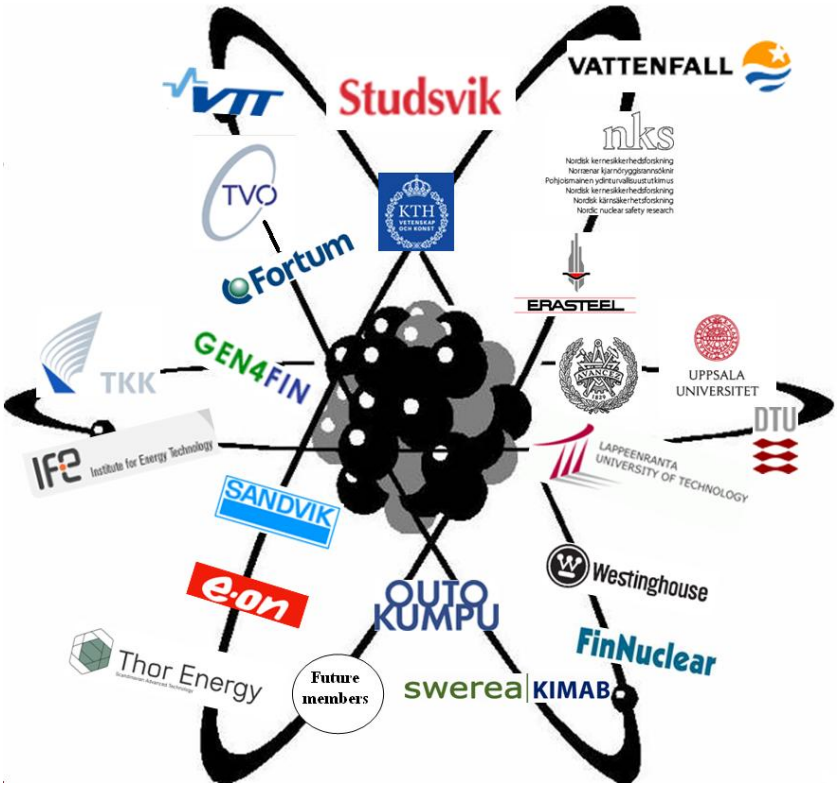

Figure 2
Members of NOMAGE4 network (December 2009).

List of members and the contact person from each organization is presented below:

- Vattenfall Pål Efsing
- EON Camilla Söderqvist
- Westinghouse Anders Andrén
- Sandvik Sofia Åkesson
- NKS Patrick Isaksson
- VTT Advanced nuclear fission technologies Sami Penttilä
- TVO Liisa Heikinheimo
- Finnish research network for generation four nuclear energy systems GEN4FIN (this is also in chapter 4.3?)
- Institutt for energiteknikk The Halden Reactor Project Rudi van Nieuwenhove
- KTH
  - Nuclear Power Safety Tomas Lefvert
  - Reactor Physics Janne Wallenius
  - Nuclear Reactor Technology Henryk Anglart
  - Nuclear Chemistry Mats Jonsson
  - Corrosion Science Christofer Leygraf
- Chalmers tekniska högskola
  - Nuclear Engineering Imre Pazsit
  - Nuclear Chemistry Gunnar Skarnemark
- Uppsala Universitet Institutionen för fysik och astronomi, tillämpad kärnfysik Ane Håkansson
- Svenskt kärntekniskt centrum SKC Jan Blomgren
- Outokumpu Gabriella Brorson
- Erasteel Daniel Petrini
- Thor energy Valentin Fhager
- Risø DTU National Laboratory for Sustainable Energy Bent Lauritzen
- Aalto University School of Science and Technology (Aalto) Rainer Salomaa

- University of Lappeenranta Riitta Kyrki-Rajamäki
- University of Oslo Truls Norby
- SWEREAKIMAB Baohua Zhu
- FinNuclear Prizztech Oy Jouko Koivula

4.3 Links to other organisations

Organisations

- GIF The Generation IV International Forum
- GEN4FIN Finnish Research Network for Generation Four Nuclear Energy Systems
- SNE-TP Sustainable Nuclear Energy Technology Platform

5 Gen IV questionnaire

A questionnaire was sent to the NOMAGE members to investigate current activities on R&D projects related to generation IV nuclear power at companies, research units and university institutions. The answers can be viewed at the activities link at the forum website (open only for the network members).

The following questions were asked for:

1	Is your organisation interested in R&D related to Generation IV nuclear power?
2	Does your organisation/institution/company perform R&D or participate in work on projects relevant for Generation IV nuclear power?
3	Are the projects parts of EU or other international/national programmes? Which?
4	Please describe the projects (volume, duration, partners, focus etc.) and your R&D area in it.
5	How much resources are spent in your organisation on projects relevant to Generation IV, in Euro/year or employees/year?
6	What kind of experimental equipment do you have relevant to Generation IV developments? Equipment for mechanical testing, simulation of reactor environment, etc (use attachments if needed)?
7	Do you have open references related to the Generation IV R&D (www-site, publications etc).
8	Do you know other contacts within your organisation that work on these issues? Please give names and e-mail addresses.
9	Free comments or other information of interest to R&D of Generation IV?
10	What would you expect to gain from a Nordic Network on Generation IV – free comments?

6 Forum website

The internet link to the forum website is http://www.studsvik.se/GenerationIV.

7 EU contacts

Studsvik started its membership in the Sustainable Nuclear Energy Technology Platform, SNETP, in 2008. Key EU contacts for each reactor concepts have been identified. We have developed good contacts with Commissariat à l'énergie atomique, CEA, corrosion laboratory with facilities for most of the Gen IV concepts and additional concepts as well as with Forschungszentrum Karlsruhe, FZK.

8 NOMAGE4 workshop in Studsvik

Two organizations, Studsvik from Sweden and VTT from Finland jointly organized a common NKS and Vattenfall seminar on Generation IV Nuclear Energy Systems. The aim of the seminar was to provide a forum for exchange of information, discussion on future research needs and networking of experts on Generation IV reactor concepts.

During the two seminar days, there was an active presence of all nuclear fission stakeholders in the audience:

- nuclear research organizations (public and private)
- systems suppliers (e.g. vendors, engineering companies, etc)
- energy providers (e.g. electric utilities, heat vendors, etc)
- education and training institutions, and, in particular, the universities
- the international institutional framework (Euratom).

The participation of the non-nuclear industry (in particular, 3 steel makers) was very important as there are clear needs for future materials that can resist to these special environmental conditions present in the GenIV reactor systems.

The presentations can be downloaded by the forum members from our website www.studsvik.se/GenerationIV by clicking on the NOMAGE4 atom picture (or by opening the headline Activities).

The next NOMAGE4 seminar will be held in 2010 in Lappeenranta (Finland). Further information will be present soon on our website: www.studsvik.se/GenerationIV

8.1 Summary of the oral and poster presentations

October 15th 2009

Magnus Arbell, the president of Studsvik welcomed the participants to Studsvik and to our seminar.

Daniel Westlén introduced Vattenfall's interests for Gen IV activities and research. Daniel mentioned that:

- Nuclear is an important part of Vattenfall's strategy.
- Sustainability is a fundamental driver.

- Interest in solutions for nuclear sustainability is a matter of credibility.
- The future is now!

Georges Van Goethem, the representative of the European Commission, presented Euratom RTD activities with emphasis on innovative materials entitled "Technological breakthroughs in nuclear fission (with emphasis on materials)". Georges also introduced the on-going Gen IV-related EU projects.

Link to more detailed information about Euratom for Nuclear Research and Training Activities:
ftp://ftp.cordis.europa.eu/pub/fp7/docs/wp/euratom/v_wp_201001_en.pdf

A new call for project proposals will be opened in November and this will be a good opportunity of our network to start collaborations:

Topic: Fission-2010-2.3.3: Materials research. The European Energy Research Alliance (EERA), set up under the Community Strategic Energy Technology Plan (SET-Plan) intends to launch a Joint Programming Action on (nuclear) materials. Support will be provided to coordinate this activity in order to optimise its effectiveness and efficiency. Participation of involved EERA institutions is essential, together with any other key stakeholders in the development/qualification of materials for nuclear energy applications. In the event that, by the time the present call is opened, the EERA initiative is advanced enough and areas where European action necessary to assure critical mass have already been identified, then proposals would be welcome that include support for actual R&D activities in these areas providing that the coordinating function is maintained.

Funding scheme: Maximum one Coordination and Support Action (coordinating) or one Collaborative Project (either small or medium-scale, or large-scale) with a significant networking component.

Janne Wallenius, Professor at the Royal Institute of Technology, KTH, Reactor Physics department in Stockholm, presented an overview of the Gen IV reactor systems. Janne pointed out that the new reactor systems need challenging materials as they will have more demanding operating conditions. "Gen IV reactors ought to:

- Increase fuel resources.
- Reduce long term radio-toxic inventory in waste streams.
- Operate at higher temperature.

Janne has identified some common corrosion issues for the fast spectrum systems and introduced the thermal spectrum systems. Janne concluded that the development of materials permitting to increase the life-time while maintaining safety margins is crucial.

The Nordic Gen IV network activities have been introduced by both ***Clara Anghel*** from Studsvik (NOMAGE4) and ***Liisa Heikinheimo*** from TVO (Gen4FIN).

Clara has introduced the objectives of the NOMAGE4 network, the network organization and the members (see Figure 2). Norway and Denmark are also represented in our Nordic network.

A schematic illustration of the activity organization for the NOMAGE4 project is shown in Figure 3.

The website address of our NOMAGE4 network is www.studsvik.se/GenerationIV and soon a new address www.GenerationIV.se will be provided for the network.

Liisa Heikinheimo introduced the activities of GEN4FIN, which is the model that we follow in Sweden to build our national network. Liisa presented the participants, goals and achievements of GEN4FIN. The on-going projects of the network members were mentioned. Liisa has identified future challenges for GEN4FIN.

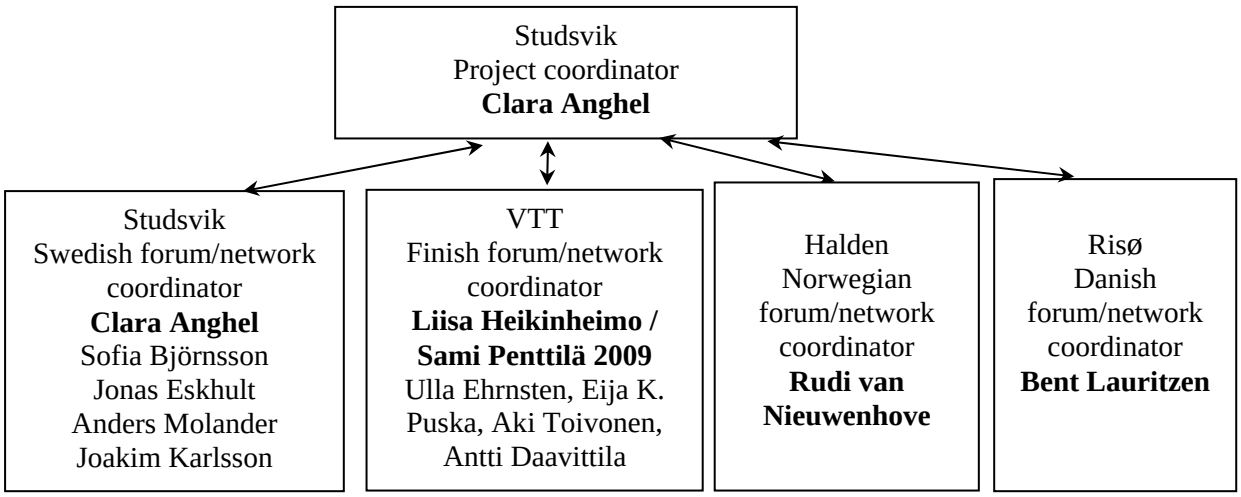

Figure 3
Schematic presentation of the activity organisation for the project NOMAGE4.The coordinators for each national network are written with bold letters.

Under the generic topic of ***Materials for GenIV nuclear systems***, the different reactor concepts were presented together with the latest cross cutting materials research results.

Daniel Westlén, Vattenfall, introduced "The Jules Horowitz Reactor – capabilities and planned activities". The situation of the European materials testing reactors was highlighted. There is an obvious need for new test reactors!

Main areas of use for the JHR:

- Materials testing
  - Accelerated radiation damage
- Fuels research
  - Increased burnup
  - Gen-IV fuels
- Medical isotope production
- Fundamental neutron research

The supercritical water cooled reactor, SCWR, system was described in detail by ***Jörg Starflinger*** from Karlsruhe Institute of Technology. The European and international projects that include research activities for this reactor concept have been identified.

The main conclusion related to materials for SCWR: There is a need for high strength and high corrosion resistance materials for this type of reactor concept. This conclusion has been supported by the research results presented by ***Sami Penttilä*** from the Technical Research Center of Finland VTT. Sami presented the "Materials Performance at SCW conditions and the GenIV materials activity at VTT". The presentation was a survey on the applicability of candidate materials to SCW environment by means of general corrosion, SCC and creep tests. The need for **new ODS steels** were highlighted! ***Henryk Anglart*** from the Royal Institute of Technology, in Stockholm, presented the "Thermal Design Issues in GEN-IV Supercritical Water Cooled Reactors". Henryk concluded that the thermal design of a nuclear reactor will require:

- Improved correlations for prediction of heat transfer coefficient.
- Criterion to predict the onset of heat transfer deterioration.
- A validation of CFD models for predictions in fuel assemblies with spacers.
- Evaluation of thermal-hydraulic stability of supercritical-water flow in the core.

The Sodium Cooled Fast Reactor, SFR, system was described in detail by ***Damien Féron*** from Commissariat à l'énergie atomique, CEA, France. The materials selection for the main SFR components was presented.

Important issues related to corrosion of structural materials in liquid sodium environment include:

- Liquid metal embrittlement
- Stress corrosion cracking (SCC)
- General corrosion (GC)

An important parameter that controls the corrosion behaviour of the structural materials in liquid sodium is related to the impurities present in the liquid sodium. Damien concluded that it is a necessity to increase the efforts on the development of phenomenological models, particularly at high temperature (above 600°C) and for long term (60 years) operation, including phenomena like (de)carburization and /or (de)nitrurization.

- Ferritic martensitic ODS nano-structured steels have been indicated as a good choice as cladding materials.

The “Experimental facilities at KTH relevant for Lead Cooled Fast Reactor, LFR, development” was presented by ***Janne Wallenius*** from KTH. A unique facility in Europe called ***TALL lead-bismuth loop*** has been constructed in KTH for TECLA project in 2004. Fabrication of a new (Pu,Zr)N fuel by carbo-thermic nitridation of oxides was accomplished at PSI in 2003, using a process modified by KTH. During irradiation of these pellets, the fission gas release was very low, which make this fuel material a very attractive competitor for the fuels used today. The idea to build a European Lead Cooled Training Reactor, ELECTRA project was also presented.

The Gas Cooled Fast Reactor, GFR, system was described in detail by ***Fanny Balbaud –Célérier*** from Commissariat à l'énergie atomique, CEA, France. The materials selection for the main GFR components was also presented. Fanny presented a thorough investigation of the corrosion behaviour of SiC material in inert gas in the presence of low and high oxygen partial pressures. The need for long term exposure results was pointed out.

- SiC-fiber/SiC-matrix composites have been indicated to be a good choice for GFR fuel design.

Petty Bernitt Cartemo from Chalmers University, Göteborg, presented the “Pulsed positron beam measurements at Chalmers”. Petty described the principles of Positron Lifetime Measurements, the complex data analysis and also has introduced some experimental results from the GETMAT project.

Pascale Vangeli, Outokumpu, presented the stainless steel materials for nuclear applications. Various examples of structural materials built using Outokumpu materials were presented.

The seminar continued with the **poster session**. A number of 6 posters were presented:

ELECTRA – European Lead Cooled Training Reactor
Andrei Fokau, KTH

Neutron Cross-Section Measurement and Simulation at 175 MeV
Milan Tesinsky, KTH

Transmute Americium in Medium Size Sodium Cooled Fast Reactor
Youpeng Zhang, KTH

Uranium-zirconium nitride: a nuclear fuel with interesting properties
Pertti Malkki, KTH

Erasteel - your source of metallic powder!
Daniel Petrini, Erasteel FoU – Söderfors

Generation IV Activities at TKK
Aarno Isotalo, Helsinki University of Technology

Best poster award was given to Pertti Malkki from KTH.

October 16th 2009

Tuomas Viitanen from Helsinki University of Technology (TKK), Finland, presented the "Reactor Core Calculations with Serpent". The Monte Carlo Reactor Physics Code Serpent has been developed by J. Leppänen at the Technical Research Center of Finland VTT. The methodology behind Monte Carlo and burn-up codes is being developed at Helsinki University of Technology and the results are implemented in Serpent code. Visit http://montecarlo.vtt.fi for more information.

Valentin Fhager, Thor Energy, Norway presented the "Development of thorium-based fuels for LWRs - a Scandinavian thrust for a superior fuel material for existing and future reactor types". Valentin concluded that:

- Thorium fuel can play a role in future energy systems and Gen IV technologies would support Thorium utilization.
- Thorium-plutonium oxide fuel in existing LWRs is a viable route for introducing a thorium fuel cycle.
- Thor Energy is taking the lead in the development of commercial Th-Pu fuels.

Imre Pázsit, Chalmers University, Göteborg, presented a detailed description of the Molten salt reactor system in the presentation entitled "Thorium research at Chalmers and physics of the Molten Salt Reactor".

Jouko Koivula, Prizztech, introduced the GenIV activities of Prizztech, Finland.

The Federation of Technology Industries and FinNuclear –programme has established together the ”Finnish Nuclear Suppliers’ Group” in March 2009. Prizztech Oy formed the FinNuclear unit to support FinNuclear steering board members and Finnish Nuclear Suppliers´ Group and run the activities for them. Jouko pointed out that it is important to join efforts/forces in order to pursue larger bids; larger entities, combined technologies.

Axel Steuwer from the ESS Scandinavia, Lund University presented a very interesting project “The European Spallation Source ESS”. This project is an example of what a good planning and project management as well as excellent marketing could produce!

Axel concluded that there is a world leading materials research laboratory to be built in Sweden:

- Alongside smallest emittance synchrotron X-ray source (MaxIV)
- Opportunities for fundamental and applied research
- Numerous benefits from GenIV involvement

Rudi Van Nieuwenhove from Halden presented a detailed study for the “Feasibility study for an in-pile SCW loop in the Halden reactor – Instrumentation development for SCW”.

Result of feasibility study:

- It is possible to realize an SCW loop in the Halden reactor (fuel or materials studies)
- Safety evaluations show no obstacles
- Cost (in-pile + out-of-pile)
  - Materials loop : 0.6 M Euro
  - Fuel loop : 1 M Euro

Instrument development for SCW:

- Linear Variable displacement transducer (LVDT) needed for materials and fuel studies.
  - stress relaxation, creep
  - cladding elongation, fuel elongation, fission gas release
- Electrochemical sensors, related to corrosion research.

Catharina Nästrén from Studsvik introduced her Ph.D. work performed at Chalmers University in collaboration with ITU, on "Fabrication and Characterization of Fuels and Targets for the Transmutation of Actinides".

Main developments in the project:

Fuel/target fabrication	Fabrication process Fuel specifications
Fuel properties	Vaporisation behaviour Self irradiation damage Coolant-fuel interactions
Reprocessing	Leaching tests of the An phase Matrix material recovery
Synthesis of new materials	Fabrication process Basic properties Self irradiation

Jan Blomgren from the Swedish Nuclear Technology Center, SKC, concluded the series of presentations from our seminar with an interesting presentation concerning the "Gen IV – SKC research strategy – Roadmap for structure and funding".

Jan has shown the three-stage funding plan:

1	VR spring 2009 academies only (done)
2	SSF late 2009 academies+ industry (NOW!)
3	Vinnova 2010 academies+ industry (time to prepare this application together!)

The strategy analysis (Fig. 4) generated lively discussions.

Concept	Plus	Minus
Follow the leader Join France on SFR	Small risk Closest to deployment "Better to be in than out" Sustainable electricity	No chance to win
Runner-up Take lead on LFR	Chance to take initiative Less competition Good Swedish competence Sustainable electricity	Tougher than LFR Risk to be out of the game Political support needed
High stake Develop HTR	Combat fossils in transport Most visionary Best non-nuclear spin-offs?	Less sustainable Most difficult (maybe plus?) Political support needed

Figure 4
Strategy analysis.

There were pro and cons for all these 3 concepts. The decision which one to follow has not been made but Jan is open for all the suggestions and comments.

8.2 Outcome of the panel discussion

A panel discussion was organized at the end of the seminar to summarize the questions that occurred during the seminar and to get feed-back from the members.

Panel members:

University representatives	Country
Prof. Janne Wallenius (KTH)	Sweden
Prof. Rainer Salomaa (Aalto)	Finland
Utilities	
Vattenfall AB, Daniel Westlén	Sweden
Steel producers	
Outokumpu, Pascale Vangeli	Sweden-Finland
NOMAGE4	
Studsvik AB, Clara Anghel	Sweden

The following questions were raised:

1. How can we enhance the Nordic and national Gen IV collaborations? How can this community exchange easier information and make the initiated Gen IV network sustainable.

Feed-back from different members have shown that the network is important:

a	Create “demonstration trips” for interested people to visit the different facilities.
b	Focus on cross-cutting issues, including reactor physics, thermal-hydraulics and materials. Support MSc and PhD within Gen IV.
c	We need to find research projects.
d	More work, less management!
e	We need to have regular (yearly) network meetings to keep up interest.
f	Keep information exchange by regular seminars perhaps yearly at least.
g	Courses in Gen IV, textbooks in Gen IV, Projects on fundamental research on Gen IV. Databases, seminars, conferences. A Nordic centre developing policy on Gen IV. Attract China and Russia for collaboration.
h	EFR - Scandinavia.
i	Concrete projects witch supports GIF is fundamental.
j	Include/Invite M.Sc. students!
k	Enhance cooperation: PhD students move around the different labs within one big common project. Included in their programs – support. Post Docs.
l	Financing at central level can keep the network active. Gather projects and apply to financing at a central level. Active coordinator!
m	Courses/textbooks on Gen IV materials needed. Thorium common factor.
n	The network must enhance real work and project coordination, not just annual meetings. The network should open for regular meetings for planning new and ongoing projects.
o	Network? Speciality?

2. NOMAGE4 – Generation IV website: how to improve it, ideas, what would you like to have on this website, it could be a good place to join Gen IV-related articles from different conferences and meetings.

a	Does the website even have any purpose? (other than "everyone must have one")
b	The website is a very useful idea. In its present form it is too crowded. It should be better structured.
c	Technical details. Minutes of this event.
d	Keep the website for information about meetings etc.
e	Present the members and their equipment and skills. That might attract new members reading the website.
f	Focus on image and data bank.
g	The website is a non-question given 1.
h	Database for advanced nuclear material and also references related to GenIV research.

3. Is there an interest to build a Nordic Gen IV Facility and Training Center?

a	Yes, it could enhance networking and collaboration
b	Materials testing facility is necessary to keep our activities.
c	New demo-reactor! OKG has got money. Build a reactor there. Yes, for low power LFR.
d	The needs from question 1 come first.

4. Development of ODS steels for Generation IV applications

a	ODS or F/M steels?
b	Unique opportunity for Sweden to lead.
c	ODS – why not?

During the discussions, ***Daniel Westlén***, Vattenfall mentioned that there is no other realistic fast reactor alternative than Sodium Cooled Fast Reactors. He said that fast reactors failed once and there will be only one second chance and sodium is the way to go.

9 Gen IV activities in the Nordic Countries

The network structure is presented in Figure 3. Each national coordinator has as task to identify and present the information about their national GenIV activities, evaluate and report the infrastructure facilities, measurement techniques, modeling capabilities. A national GenIV activity report has been prepared by the coordinators and presented as a summary in this report.

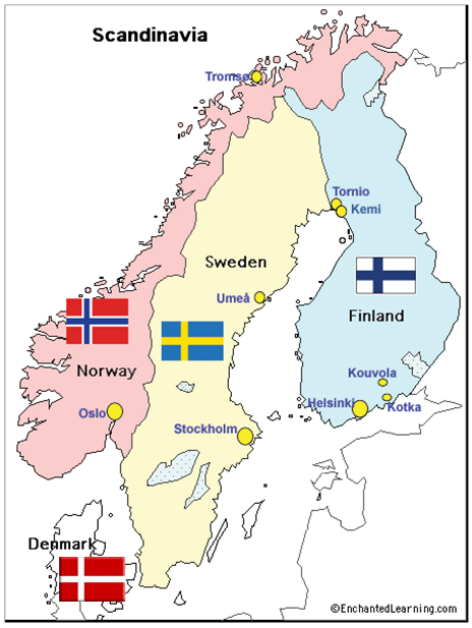

Figure 5
Map with the Nordic countries represented in our NOMAGE4 network.

9.1 Summary of Gen IV activities in Sweden

In Sweden, **Studsvik Nuclear AB** is the national coordinator for the Gen IV network and the project manager for the NOMAGE4 project is Clara Anghel (see Fig. 3).

Studsvik's expertise
The expertise, infrastructure and experience at Studsvik for corrosion and reactor chemistry issues for LWR today provide a solid ground for developing competence within corrosion, reactor chemistry and activity build-up issues for Gen IV reactors. The key to demonstrating the viability of the different nuclear reactor types belonging to Gen IV is to identify and develop materials and alloys that can safely operate at the temperature and pressures in a specified environment. In this process,

characterisation of the corrosion properties for the materials, is a crucial part. The development and the choice of materials to the different reactor types are strongly connected to the corrosion properties of the specific material. Studsvik has more than 40 years of experience related to materials research in the corrosion and water chemistry area and is equipped with the largest autoclave test laboratory in Sweden for corrosion tests. Different kind of corrosion tests to the nuclear industry world wide are performed in the laboratory. Therefore, there is of highest interest to make a contribution to the international collaboration of developing the Gen IV reactors. Our Materials and Water Chemistry Laboratory is shown in Figure 6. Studsvik's activity includes both materials integrity issues such as crack growth rate measurements and also corrosion issues which do not affect the materials integrity but affects the activity build up in the plant. Both aspects of corrosion are equally important for Gen IV reactors.

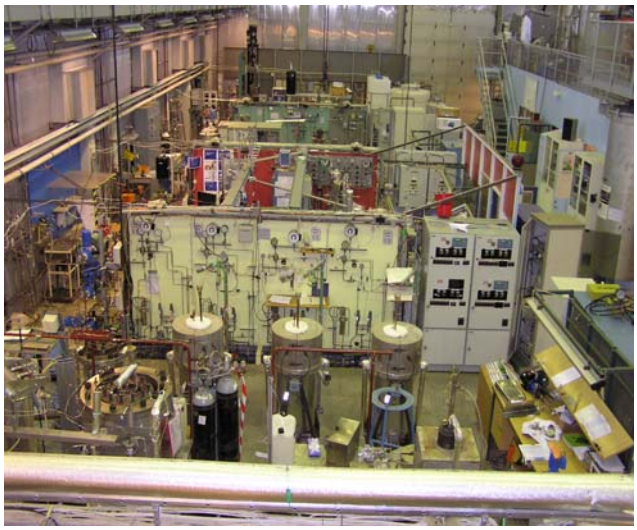

Figure 6
Studsvik Corrosion Laboratory.

In our hot cell laboratory, post irradiation evaluation, PIE, of fuel and structural materials can be performed. Through our cooperation agreement with the Halden reactor, irradiations and test reactor experiments can be performed.

A design study for building a sodium loop in Studsvik has started and will be finished during spring 2010. The experimental setup will be used for corrosion studies in sodium environment.

Studsvik's international and national collaborations

Studsvik is in collaboration with a number of partners in different projects. To mention some of the projects:

- Studsvik collaborate with VTT in this NOMAGE4 project
- *ECG-COMON*, European Cooperative Group on Corrosion Monitoring of Nuclear Materials (Anders Molander at Studsvik was Chairman 2004-2007).
- *MTR-I3*, Integrated Infrastructure Initiatives for Material Testing Reactor Innovations, within the European Framework programme. The project will define, develop and construct a new material testing reactor in Europe: "The Jules Horowitz Reactor Project". 18 partners participate in the project.
- *NULIFE*, Nuclear plant life prediction, within the 6th European Framework programme. Area: Other activities in the field of nuclear technology and safety, 36 collaboration partners.
- *ICG-EAC*, International Cooperative Group on Environmentally Assisted Cracking (Anders Jensen at Studsvik is vice Chairman)

In Sweden there are on-going or planned GenIV activities connected to all the reactor concepts and the network members have representatives from industries (steel producers: Sandvik, Erasteel and Outokumpu, nuclear fuel producer: Westinghouse), universities (KTH, Chalmers, Uppsala University and Lund University), power companies (Vattenfall, E.ON) and research institutes (SWEREAKIMAB, Studsvik Nuclear and Elforsk AB) and other interested parties such as SKC, NKS, as shown above in figure 2.

Expertise of the Swedish universities

The Swedish universities are actively involved in GenIV research.

KTH's expertise

KTH has been working in several areas which concern physics, thermal-hydraulics and safety of current and future nuclear rector systems. Both theoretical and experimental researches have been performed. Topics of particular interest, related to Gen-IV reactors, include:

- fuels for nuclear waste transmutation
- Accelerator Driven Systems (ADS) including development of material technology
- thermal-hydraulic and safety issues of lead-cooled reactors
- burning plutonium and minor actinides in high temperature reactors
- thermal-hydraulic and safety issues of supercritical-water-cooled reactors
- impact of the partitioning and transmutation on geological disposal and waste management.

High international reputation of KTH's research is - to a large extent - due to the experimental infrastructure, which has been developed by the three research groups over recent years. This includes such facilities as:

- *TALL loop*, which is constructed to study steady-state and transient thermal-hydraulics performance of lead-bismuth-cooled reactors, with the primary purpose of supporting the development of lead-bismuth-cooled ADS.
- *MISTEE facility*, which was developed to study steam explosions, a phenomenon observed when high temperature liquid comes into contact with relatively cold and volatile liquid.
- *HWAT loop*, which was designed to perform thermal-hydraulics tests for water-cooled reactors. The loop can withstand high pressures (up to 25 MPa), making it suitable for thermal-hydraulic tests relevant for supercritical-water-cooled reactors.

KTH's international and national collaborations

KTH participates in several international research projects aiming at development of new nuclear technologies of the Gen-IV type.

In particular, the *Nuclear Power Safety (NPS)* group of KTH is involved into the ELSY (European Lead Cooled System) project which aims at demonstrating the feasibility of designing a safe and economic fast reactor, using lead as coolant. NPS's contribution is focused on safety-related thermal-hydraulic experiments using the TALL facility, as well as on modelling of nitride fuel safety.

The *Nuclear Reactor Technology (NRT)* group contributes to the HPLWR (High-Performance Light Water Reactor) project of 6th Framework Programme, which has as a goal to demonstrate the feasibility of designing a thermal, supercritical-water-cooled reactor. NRT performs theoretical analysis of thermal safety margins in such systems, and in particular, of the conditions of heat transfer deterioration. For that purpose Direct Numerical Simulations (DNS) of turbulent supercritical-water flow and heat transfer is performed.

The *Reactor Physics (RP)* group is involved in the PUMA (Plutonium and Minor Actinides Management by Gas-Cooled Reactors) project, which has as the main objectives to exploit the potential of coated-particle nuclear fuel technology, so called TRISO particle fuel, for the purpose of burning plutonium and minor actinides in high temperature reactors. RP of KTH is one of the major partners in this project. In addition, the group is coordinating the 23 partner strong Red-Impact (Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal) project, which has as the main objectives to assess the impact of Partitioning and Transmutation (P&T) on geological disposal and waste management, as well as improvement of the economical, environmental and societal benefits resulting from the technology.

Chalmers' expertise

The *Department of Nuclear Engineering* is conducting research in several areas, covering basic neutron physics and neutron transport theory, thermal-hydraulics, reactor safety analysis and plant dynamics, nuclear fuel and core design, neutron detection and diagnostics, material analysis, safeguard and non-proliferation, radiation protection.

In the field of neutron detection and diagnostics, the group has developed advanced methods for simulation and analysis of neutron noise in LWRs. Modified versions of this technique has the potential to be useful for application in Gen IV systems as well. Plans are underway to explore this.

The department is planning to start-up neutron diagnostics research on future reactor systems (pebble bed, molten salt, gas or sodium-cooled fast

reactor etc). Especially, one intends to investigate the applicability and performance of the various neutron kinetic approximations.

Moreover, the department has initiated discussions for collaboration with CEA on the design and analysis of GFRs, both via participation in experimental studies and through computer simulations. CEA in Cadarache, France has provided codes to Chalmers which are particularly suitable for neutronic modelling of fast reactors such as GFR, SFR, LFR.

Two M.Sc. thesis projects on MSRs are currently running. One is to make a survey of the basic reactor physical principles in reactors with a fluent fissile medium and to investigate the neutron noise induced by temperature fluctuations. The other M.Sc. thesis project is a neutronic study of a conceptual MSR design with heavy-water moderation. For this work, collaboration with a research group at LPSC in Grénoble, France has been established, which has given Chalmers access to valuable codes and models.

The *Department of Nuclear Engineering* operates a pulsed positron beam which is used for the analysis of defects in materials by positron annihilation techniques. Useful experience has been gained through the participation in the EC funded project PERFECT and ADMAT.

The *Department of Nuclear Chemistry* is active in the fields of solution chemistry of actinides and fission products, separation processes for these elements and detection and measurements. Today, the department plays a leading role in the running EC FP7 project ACSEPT which deals with chemical reprocessing and actinide separation in advanced nuclear fuels of the type that is intended for use in Gen IV reactors.

Chalmers international and national collaboration partners
Kyoto University Research Reactor Institute, Japan (operates the only spallation-driven ADS worldwide)
CEA Cadarache, France (co-ordinator of many EU projects)
BARC, Mumbay, India (thorium-fuelled reactors)
Delft University of Technology, The Netherlands

Gen IV activities of other interested parties

The power companies have a great interest for Gen IV research and support the Gen IV activities in Sweden. The steel industry have shown also great interest in new materials development such as ODS steels.

9.2 Summary of Gen IV activities in Finland

In Finland, **Technical Research Centre of Finland, VTT** is the national coordinator for the NOMAGE4 network and our partner in the NOMAGE4 project is Sami Penttilä (see Fig. 3).

Increased international attention has recently been focused to Gen IV reactor concepts that differ essentially from the existing light water reactors. Basic processes of these new concepts are fundamentally different from those used today. Some new features may create new type safety challenges. They also aim to push nuclear reactor technology to completely new regimes of performance parameters, thus raising engineering challenges.

In order to allow Finland to benefit from new technologies and influence their development, it is necessary to join relevant international projects, develop domestic expertise on critical technologies involved, and participate in ongoing international efforts to develop safety requirements for them. The technical potential of Gen IV will be shown in a time span of 15 - 20 years as the first demonstration plants are to be built.

The Finnish Generation IV research project (GEN4FIN) is a network consortium of national partners (Fennovoima, FinNuclear, Fortum, Aalto University, LUT, STUK, TVO and VTT) to spread scientific knowledge and information about the Gen IV research for scientists in the field. The project is closely connected with the EU projects HPLWR Phase2 and GETMAT as well as JHR MTR and Academy of Finland project NETNUC (New Type Nuclear Reactors). The NETNUC project is a multidisciplinary consortium of national and international partners to carry out basic research to generate scientific knowledge needed for Gen IV reactors and to educate a new generation of research scientists in the field. In 2009, the GEN4FIN working group took part in first Nordic Gen IV field seminar hosted by Studsvik Nuclear AB. The Gen IV seminar was part of the NOMAGE4 activities in the Nordic cooperation. The development of new type nuclear reactors is an international effort and therefore international networking is an essential part of the Finnish network project and especially Nordic cooperation has been observed to be important in the near future.

The primary mission of the Finnish GEN4FIN is to improve scientific and technologic expertise in the field of nuclear energy technologies and related processes through collaboration with GIF and other global forums. The longer term mission is to create new business activities for the Finnish industry through enhanced technology transfer, innovative

process development, and materials engineering. The aim of the research network is to further support maintaining and developing national expertise and international co-operation. The activities in the research network will cover scientific, technological and industrial goals. Research & education, safety authority, manufacturing industry and power companies as well as ministries and other associated organizations are participating in the research network.

VTT together with the universities has organised an international seminar every other year in Lappeenranta (last seminar was on October 2008) on Generation IV systems and technologies. Invited lecturers have come from both Finland and from other European countries. Presentations on different Gen IV systems (SCWR, SFR, GFR, and HTR) have been made, as well as on fuel cycle, thermal-hydraulics, reactor physics and materials. In upcoming year 2010 a traditional two day Gen IV seminar will be organized again in Lappeenranta. The GEN4FIN working group has also arranged every year 1-2 national seminars at VTT on Generation IV issues having around 30-50 participants. Also less formal Gen IV researchers meetings have been held in Otaniemi together with the universities

VTT's expertise

Understanding of corrosion phenomena of candidate materials under SCWR (Supercritical Water Reactor) conditions necessitates a reliable experimental testing of materials and therefore also a development of monitoring techniques for the relevant conditions. In the field of materials research, VTT's competences are in the corrosion and water chemistry research and mechanical characterisation of non-irradiated and irradiated materials. VTT has two supercritical water autoclaves where the oxidation behaviour of candidate materials has been studied using both in-situ and ex-situ methods. The contact electric impedance (CEI) technique has been successfully used for in situ characterization of the electrical and transport properties of the corrosion layers both in LWR and SCWR conditions. Different kinds of mechanical testing methods are also available including SSRT, creep and CGR tests using a step motor controlled loading device and/or servo controlled pneumatic bellows system. In 2010, first steps towards developing a pneumatic servo-controlled bellows system for the candidate material studies under Pb-loop (in cooperation with JRC-IE) conditions will be performed.

VTT has several code systems available for the analysis of reactor physics, thermal hydraulics, and nuclear power plant systems. The SERPENT code, which has been developed completely in-house by VTT, is a Monte Carlo transport code that can be utilized for all kinds of nuclear reactor fuels and cores. Recently the SERPENT code was successfully applied in the OECD/NEA High-temperature gas-cooled reactor (HTGR) fuel depletion benchmark, where SERPENT was the only computer code capable of modelling randomly distributed fuel particles. As another option, the widely used Monte Carlo transport code MCNP is also available. VTT has also the tools necessary for processing nuclear data libraries, generating few-group cross-section data, burnup calculation etc.

For fast reactor physics VTT has recently developed a multi-group neutron diffusion model for VTT's APROS process simulation code, as well as acquired the ERANOS package for fast reactor analysis developed by CEA.

The APROS code has capabilities of simulating various coolant materials (gas, liquid) and plant control and automation systems, with applications in simulating nuclear power plant and non-nuclear industrial processes. APROS, as well as the coupled neutronics/thermal hydraulics code TRAB-3D/SMABRE, was successfully applied in the EU HPLWR2 project for the analysis of a super-critical water cooled nuclear reactor concept.

Expertise of the Finnish universities

Two Finnish universities are actively involved in Gen IV research: Aalto University School of Science and Technology (abbreviated Aalto, formerly Helsinki University of Technology, TKK) and Lappeenranta University of Technology (LUT).

Aalto's expertise

The Fission and radiation physics group of Aalto University is one of the partners of the NETNUC project, focused on the safety of Gen IV reactors and financed by the Academy of Finland. The main research emphasis of the group is on reactor physics and alternative thorium-based fuel cycles.

The Serpent code (http://montecarlo.vtt.fi) is being further developed in collaboration with VTT, focusing on e.g. Doppler-broadening of cross section data and different methods for burnup calculation, and the code is also applied in specific problems. Serpent is a general-purpose neutronics code, so it is applicable for all reactor concepts, including the Gen IV alternatives.

The thorium fuel cycle is under scrutiny from several perspectives, including the economics, physical fuel behaviour and proliferation issues. Various computer codes are applied in the studies. The APROS process simulator developed by Fortum and VTT is applied in studies of super-critical water. SCWR-related collaboration with VTT is close and some international contacts have also been established.

The group has also a strong background in gamma-ray spectrometry. General methodology has been developed and the main application has been treaty verification, i.e., applying gamma-ray spectrometry in international surveillance of airborne radionuclides.

The research of the Fission and radiation physics group is very computation-intensive. As an experimental facility we have access to the Triga research reactor operated by VTT and located in the same campus area in Otaniemi.

LUT's expertise

The *Laboratory of Nuclear Engineering* is conducting research on gas-cooled reactors, mainly the pebble-bed reactor. The research work so far consists of three topics. Coolant flow and heat transfer inside the reactor core is calculated with CFD codes. Reactor physics analyses are performed using the Monte Carlo reactor physics code Serpent. The packing and flow of the fuel spheres are studied with an in-house developed code. Combined thermal hydraulics, reactor physics and fuel element packing and flow analyses are expected to give a highly detailed and extensive understanding of the pebble-bed type reactor core.

LUT has the largest thermal-hydraulic experimental facilities in Finland. The facilities are operated by the *Nuclear Safety Research Unit*. The experiments are supported by calculation activities utilizing a range of system and CFD codes, such as APROS, TRACE, ANSYS FLUENT and TransAT. The current experimental and numerical work based on the LWR experimental facilities, such as the condensation pool PPOOLEX is easily linked to the research on SCWR.

LUT participates in the national research network GEN4FIN and leads the research project NETNUC funded by the Academy of Finland. In addition to national research efforts, LUT takes part in the EU projects NURISP and THINS as well as the ENEN-III education network. In the NURISP project, LUT develops condensation models for CFD codes. In THINS, CFD calculations are performed based on experiments with a gas-cooled heated rod with textured surfaces.

Additional information about the Gen IV activities in Finland is available for the network members on our website.

9.3 Summary of Gen IV activities in Norway

In Norway, there are three organizations interested in GenIV-related research: Halden – Institutt for energiteknikk, IFE, Thor Energy and University of Oslo. The Norwegian national coordinator is Rudi van Nieuwenhove from Halden.

IFE – HALDEN

The Halden reactor is a natural circulation boiling heavy water reactor. The maximum power is 25 MW (thermal), and the water temperature is 240°C, corresponding to an operating pressure of 33.3 bar. Pressurization tests are performed at regular intervals using a pressure of 40 bars.

A feasibility study has shown that it is possible to install also instrumented supercritical water loops into the Halden reactor (up to 250 bar, 600 °C) for materials and fuel studies. The external loop system will be similar to a PWR-loop system (max temperature 300 °C) and with possibility for hydrogen addition. For materials studies, a flow rate of 0.1 kg/s is sufficient, while for fuel irradiations a flow rate of 1 kg/s is required. The useable inner diameter of the in-pile section will be 35 mm (FFA flask) or 43 mm (ILS flask). Instruments, such as electrodes for potential monitoring and Linear Voltage Differential Transducers (LVDT) for supercritical water conditions, are presently under development.

Modeling Codes
Two thermal-hydraulic calculation codes (NATBU and VISTA) are used for safety analyses and for definition of experimental conditions. Detailed temperature distributions within test rigs are calculated using the finite element method / finite element analysis (FEM/FEA) codes QuickField and ANSYS.

The Reactor Physics Section makes use of several commercially-available code systems for performing neutronics calculations. Whole core calculations for normal operation are carried out using the REBUS/HETERO code system. The HELIOS code is used primarily for design evaluations and support calculations for test assemblies. Detailed information about gamma and neutron flux distributions within complicated test rig geometries is obtained using the Monte Carlo N-Particle transport code (MCNP). The WIMS code system is used for HBWR reactivity characteristics assessments. The data from the WIMS code can be assembled for a whole core calculation using the SNAP module.

In Halden there are post irradiation possibilities also, hot cells are available at the Kjeller Research Centre.

More detailed information about Halden capabilities is presented on our website.

Thor Energy has focused activities on the development of thorium-based superior fuel materials for existing and future reactor types. Additional information about the activities of Thor Energy can be found on our website.

The research group for solid-state electrochemistry at **Oslo University** http://folk.uio.no/trulsn/index.htm is working within fundamental research issues such as defects and defect-related properties in functional ceramic materials at high temperatures. This comprises defect chemistry and its thermodynamics, diffusion and mobility of defects, conductivity and permeability. A specialty is protons in oxides and a current interest is also the neutral hydrogen species and hydride ions in oxidic environments. The group study and develop proton conductors, oxygen ion conductors, electronic conductors, and mixed conductors for high temperature fuel cells and electrolysers, sensors, and dense, inorganic gas separation membranes. They are engaged in studies of fundamental processes involved in the degradation of such materials. The group has started to approach the emerging field of nano-ionics, taking tools and

concepts from nano-technology into use to understand and develop the properties of nano-dimensional structures; surfaces, electrodes, interfaces (phase, grain, and domain boundaries), nano-cages, and nano-particles. The group combine experimental studies with DFT-based and other theoretical modeling. Current focus comprises solid-state photoelectron-chemistry, thermoelectric oxides, nitrogen defects, surface kinetics, grain boundary transport properties.

9.4 Summary of GenIV activities in Denmark

In Denmark, **Risø DTU** is the national coordinator. The Danish network coordinator is Bent Lauritzen.

At **Risø DTU**, there are two divisions that can be involved in GenIV materials research: the Radiation Research Division (NUK), and the Material Science Division (AFM). As follows, there is a description of the facilities at Risø DTU.

NUK's focus is on radiation physics, radioecology and medical isotopes. Within the radiation physics programme, the MCNP (a general Monte Carlo N-Particle Transport Code) has been used in the past to perform neutronics calculations for the Danish research reactors, which are now being decommissioned. Today Risø NUK's is using the code to perform neutron and photon transport calculations for the Swedish utilities, in particular for the Forsmark NPP, and in calculations of radiation levels and nuclear heating for proposed diagnostics for the ITER fusion reactor. Neutron activation in structural materials calculations are performed with the Risø-developed code ACTIVA.

Medical isotopes are produced at the Hevesy laboratories cyclotron facility, equipped with a GE PETtrace cyclotron. These isotopes are mainly used for radiopharmaceuticals, which are distributed to different hospitals in Denmark. The radioactive isotopes are produced by bombarding different targets with 15 MeV protons or 7 MeV deuterons provided by the cyclotron. The typical beam current is between 20 and 120 micro Amps, lowest for the deuterons and up to even 180 micro Amps for the protons. Both liquid and solid target systems are used for the production of the radioactive isotopes. The laboratory is also equipped with a beamline facility for the irradiation of solid targets and other samples for different research purposes.

At Risø DTU there is a strong interest to start Gen IV-related activities.

10 Plans for future of our network

As an outcome of the NOMAGE4, a few collaboration project proposals have been prepared/planned in 2009, and just to mention a few: a common VR application of the Swedish universities, called “GENIUS”; participation in EU projects: KTH – Thermal-Hydraulics of Innovative Nuclear Systems (THINS) project and HPLWR project phase 2, Chalmers - Actinide reCycling by SEParation and Transmutation (ACSEPT) project, VTT - HPLWR project phase 2 and Gen IV and transmutation materials (GETMAT) and Studsvik (fusion); the continuation of the collaboration between Studsvik and VTT in the NKS NOMAGE4 project; Finnish projects: Academy of Finland project NETNUC (as a part of Finnish Sustainable Energy (SusEn) research programme) and GEN4FIN, planning of a project coordinated by Halden for the build up of a supercritical water loop to be used in the Halden reactor.

The first stage of our project has been successfully completed. We have to make the network sustainable and this is our long term vision.

At the ”2nd EERA workshop on Structural Materials for Innovative Nuclear Systems” held in Rome, 16-17th of November 2009, the EC representative has named NOMAGE4 as a very good forum were good collaborations possibilities are foreseen for future Gen IV projects.

11 Planned activities for 2010

Activities planned for NOMAGE4 during 2010 are:

- A Seminar for Generation IV Nuclear Energy Systems will be held in Lappeenranta organized by GEN4FIN and VTT
- New Nordic project proposal for continuation of the NOMAGE4 project. Four Nordic countries will be represented in a common application, and each national coordinator will bring together the Gen IV interested parties from his country. Next step is to define a strategy for continuation and planning a road map for future Gen IV-related collaborative project proposals.

12 Acknowledgements

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Great thanks to Liisa Heikinheimo for starting our collaboration and initiation of NOMAGE4 together with us and also for interesting discussions and great suggestions.

Great thanks to Pål Efsing and Daniel Westlén for the interest in the project and for active involvement in the development of GenIV community in Sweden.

Jonas Eskhult is gratefully acknowledged for the great work on organizing the GenIV seminar in Studsvik, for great discussions and suggestions and for designing and structuring our GenIV website.

Great thanks also to Joakim Karlsson, Anders Molander and Sofia Björnsson for interesting discussions, technical support and for the active involvement in the project.

Thanks also to Ulla Ehrnsten for the great collaboration.

All the participants to the first NOMAGE4 workshop are gratefully acknowledged for their contribution to the success of our first GenIV activity together.

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Abstract

A network for material issues for Generation IV nuclear power has been initiated within the Nordic countries. The objectives of the Generation IV Nordic Nuclear Materials Forum (NOMAGE4) are to put the basis of a sustainable forum for Gen IV issues, especially focussing on fuels, cladding, structural materials and coolant interaction. Other issues include reactor physics, dynamics and diagnostics, core and fuel design. The present report summarizes the work performed during the year 2009. The efforts made include identification of organisations involved in Gen IV issues in the Nordic countries, update of the forum website, http://www.studsvik.se/GenerationIV, and investigation of capabilities for research within the area of Gen IV.

Within the NOMAGE4 project a seminar on Generation IV Nuclear Energy Systems has been organized during 15-16th of October 2009. The aim of the seminar was to provide a forum for exchange of information, discussion on future research needs and networking of experts on Generation IV reactor concepts. As an outcome of the NOMAGE4, a few collaboration project proposals have been prepared/planned in 2009. The network was welcomed by the European Commission and was mentioned as an exemplary network with representatives from industries, universities, power companies and research institutes. NOMAGE4 has been invited to participate to the "European Energy Research Alliance, EERA, workshop for nuclear structural materials" http://www.eera-set.eu/index.php?index=41 as external observers. Future plans include a new Nordic application for continuation of NOMAGE4 network.

Key words Generation IV nuclear reactors, Nordic Nuclear Materials Forum, NOMAGE4