Nordic Nuclear Materials Forum for Generation IV Reactors and Hot Cell facilities at Studsvik

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Outline

- GenIV longterm vision
- Objectives NOMAGE4
- GenIV activities in Sweden
- Hot cell facilities at Studsvik
- Acknowledgements
Generation IV systems development

R&D in direction of long-term goals requires building of knowledge, prepared scientists and nuclear professionals

HOTLAB meeting, Prague, 20-23 September 2009
GenIV reactor concepts

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

The development of Accelerator Driven System technology shows large synergetic R&D with fast reactors and in particular the Lead Fast Reactor.
GenIV: Materials selection

**Low temperature (300-600°C) range:**
- austenitic steels, ferritic / martensitic steels, and Oxide Dispersion Strengthened (ODS) alloys

**Intermediate temperature range (600 - 800°C):**
- traditional and modified austenitic steels, ODS F/M steels, iron – or nickel-based super-alloys, refractory alloys

**High temperature (> 800°C) range:**
- Ni-based alloys, ferritic - ODS and refractory based systems, ceramics (silicon carbide composites), graphite and carbon-carbon composite

*Figure X. Operating temperature ranges and irradiation damage for different reactor concepts*
Material issues

- **Fuel**: “The waste of today is the fuel of tomorrow”

  - The recycling of valuable materials, called the “closed cycle”, as illustrated below.
Closed fuel cycle

- Plutonium is the fissile species
- All the actinides (U, Pu, Np, Am, Cm) are recycled together and not separated (integral actinide recycling)
- The use of fertile sub-assemblies is minimized: search for self-sustaining cores with a breeding gain close to zero
- The fuel cycle is only fed by natural or depleted U
- On site integration of fuel treatment and re-fabrication

Final Wastes
Fission Products
Self-sustainability
Grouped extraction
Proliferation resistance

Natural or depleted U
Used fuel
Fuel treatment and Re-fabrication
Actinides

GEN IV Reactor
Fast Spectrum
Nordic Nuclear Materials Forum for Generation IV Reactors

NOMAGE4

Potential members

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OBJECTIVES

- Building of a sustainable forum for GenIV issues, especially focusing on fuels, cladding, structural materials and coolant interaction.

- To develop an understanding of materials issues and their implications for design, operation & safety of generation IV reactors.

- Spreading knowledge on GenIV issues and ongoing research to different parties involved in the nuclear field, such as LWR licensees universities.
OBJECTIVES

- Inspiring young people for GenIV related R&D.
- Building a strong GenIV collaboration between Sweden and Finland.
- Identify possible collaborations with other Nordic countries
- To enhance new project ideas for international programs, e.g., Euratom FP7, calls with a strong Nordic partnership.
Activity organisation

Studsvik Nuclear, Swedish forum/network coordinator and NKS project manager:
Clara Anghel, Jonas Eskhult, Joakim Karlsson, Anders Molander

VTT, Finnish forum/network coordinator:
Sami Penttilä, Ulla Ehrnsten, Eija K. Puska, Aki Toivonen

Work will be performed also to identify the interest of Norwegian, Danish and Icelandic organisations to be part of a Nordic network for research on GenIV.
Generation IV Sweden

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

- HPLWR (High-Performance Light Water Reactor)
- ELSY (European Lead Cooled System)
- PUMA (Plutonium and Minor Actinides Management by Gas-Cooled Reactors)
GenIV activities in Chalmers University, Göteborg

Department of Nuclear Engineering

Prof. Anders Nordlund
and Prof. Imre Pázsit

Department of Nuclear Chemistry

Prof. Gunnar Skarnemark

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

- ACSEPT which deals with chemical reprocessing and actinide separation in advanced nuclear fuels of the type that is intended for use in GenIV reactors
- EU projects PERFECT and ADMAT.
- 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.).
GenIV activities at Studsvik

The first Studsvik GenIV report is available for the GenIV network members on the website:


We continue our international collaboration with VTT as well as our national collaboration with Swedish Universities and industry partners.

A few words about our hot cell facilities....
Facilities at Studsvik

Both unirradiated and irradiated materials

Materials and water chemistry laboratory

Active metals laboratory

Hot cell laboratory
Infra structure and competence for advanced experimental studies for nuclear applications

Corrosion, mechanical and chemical tests including irradiated materials/conditions.

Work with fuel, fuel cladding and reactor materials:
- System integrity
- Activity build-up

Established test and PIE techniques.

UPS systems for all laboratories.

Stand-by personnel 24 hours.

Materials and water chemistry laboratory
Studsvik Facilities

- Alfa cells (under installation) (Active metals laboratory)
  - 2
- Fresh fuel controlled atmosphere cells
  - 3 (Ar gas)
- Lead cells (Active metals laboratory)
  - 9
  - No fissile material
- Stainless steels cells (Active metals laboratory)
  - 8
- Crack growth rate cells for active materials
  - 4 lead cells
- Concrete cells (Hot Cell lab)
  - 7
  - Cell 2 (6 m²) specifically for chemical experiments
    • Mainly fuel final storage experiments for Swedish & foreign org’s
Hot cell PIE experience

- **PWR**
  - fuel
  - skeleton
  - control rodlets
  - guide tubes
- **BWR**
  - fuel
  - control rods
  - water rods
  - spacers
  - neutron detectors
- **VVER**
  - fuel
- **RBMK**
  - pressure tubes

Materials:
- Zr-Sn, Zr-Nb, Zr-Nb-Sn
- Zr-based alloys
- Stainless steel
- Ni base alloys

Fuel transports from/to:
- US, Spain, France, Germany, Finland, Switzerland, Japan
Non-Destructive Examination

• Visual Inspection
  – High magnification
  – Now with video recording (20x magnification)

• Length Measurements
• Eddy Current (EC) Lift-Off (“Oxide”)
  – Lateral mapping possible with mm resolution
• Eddy Current (EC) Defect Determination
• Profilometry
  – Several orientations
Non-Destructive Examination, cont’d

- Gamma scanning
  - High axial resolution (<< mm)
  - Dimensions
  - Burn-up assessment
- Neutron radiography
  - Hydrogen, uranium loss, pellet chipping
  - Several orientations
- Pellet-Cladding Gap Measurements
Destructive Examination

- Puncturing of fuel and control rods/blades
  - Fission gas pressure
  - Fission gas determination
- He Leak Test
- Fuel Density Determination
- Fuel Chemical Assessment
  - Nuclide composition
  - Uranium oxidation
- Hydrogen Determination
Destructive Examination, Microscopy

- Metallography
  - Oxide
  - Microstructure
  - Micro hardness
- Ceramography
  - Porosity
  - Grain size
- SEM
  - Fractography
  - EDS, WDS, mapping
  - EPMA (Pellet, oxide and crud)
Microscopy, cont.

Co-laboration Studsvik - KTH

- FEG-SEM (EDS, WDS, EBSD)
- FEG-TEM
  - Elemental analysis (EDS, HAADF, EELS)
  - Dislocation density
  - Grain boundary segregation
  - Precipitation density

Secondary electron image
Different materials will be seen
Fuel Chemistry

Analytical techniques includes:

• Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
• High Performance Liquid Chromatography – HPLC (in connection with ICP-MS)
• Atomic Absorption Spectroscopy – AAS
• Gas-Mass Spectrometry
• Chemical separation for nuclide specific analysis by α-, β- and γ-spectrometry
• Laser Fluorescence Spectrometry
• Phosphorescence Spectrometry
• Ion Exchange Chromatography (inorganic and organic anions)
New Pellet study technologies

Pellets: need to improve understanding and to model their behavior

• A new Laser ablation technique combined with ICP-MS and GS-MS has been newly developed for analysis of irradiated samples.
Test Reactor Experiments

Cooperation agreement including irradiation services with Halden reactor
Services and facilities for irradiated materials at Studsvik

• Shipment of irradiated materials.
• Wire cut EDM and various other conventional pieces of equipment for machining specimens of irradiated materials.
• Corrosion and mechanical testing equipment and various PIE methods.
• Waste disposal including irradiated test materials.
Future activities

✓ A Generation IV seminar will be held in Studsvik, Sweden in 15-16 October. Information about the seminar can be found on our website [www.studsvik.se/GenerationIV](http://www.studsvik.se/GenerationIV)

✓ Continue with the development of the nordic forum NOMAGE4 and strengthen the Finnish-Swedish collaboration as well as initiate new international collaborations on GenIV issues.
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