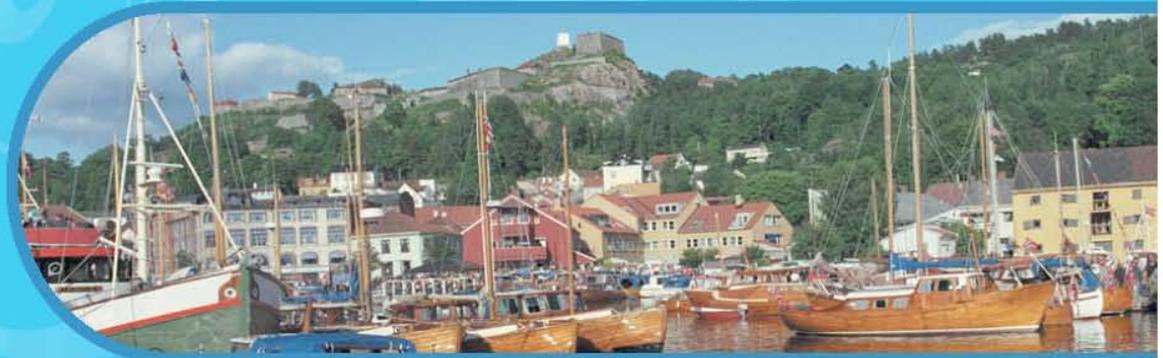




Institutt for energiteknikk  
OECD HALDEN REACTOR PROJECT



Plenary Meeting 2004



## HOTLAB: European Hot Laboratories Research Capacities and Needs

*6th-8th September 2004 Halden, Norway*



# **HOTLAB: European Hot Laboratories Research Capabilities and Needs**

**Plenary Meeting 2004**  
6<sup>th</sup> – 8<sup>th</sup> September, Halden, Norway

Editors:  
**B.C. Oberländer and H.K. Jenssen**  
January 2005

**Institute for Energy Technology**  
P.O.Box 40 2027 Kjeller, Norway  
[www.ife.no](http://www.ife.no)

## **Organising Committee**

Dr. B.C. Oberländer	Chairman, IFE Kjeller
Dr. L. Sannen	Co-chairman, SCK-CEN, MOI
Mr. H.K. Jenssen	Member, IFE Kjeller
Mr. R.K. Lund	Secretary, IFE Kjeller
Ms. T. Danielsen	Secretary, IFE Halden

ISBN 82 – 7017 – 505 – 6

## Contents

<b>Summary .....</b>	<b>5</b>
<b>Session 1: HOTLAB – WP leaders report and special papers .....</b>	<b>10</b>
<b>IAEA Post Irradiation Examination Facilities Database .....</b>	<b>11</b>
<b>Web portal for HOTLAB database (presentation slides) .....</b>	<b>19</b>
<b>Proposed Experiments to Characterize Fresh and Spent Fuel Fragmentation and Aerosol Formation after Mechanical Impact (presentation slides) .....</b>	<b>34</b>
<b>Session 2: Refabrication and instrumentation .....</b>	<b>44</b>
<b>Instrumentation of experimental fuel and future needs for PIE and hot-cell work (abstract &amp; presentation slides) .....</b>	<b>45</b>
<b>Refabrication of Fuel Rods – Qualification of the End Plug Welds.....</b>	<b>52</b>
<b>Refabricated and Instrumented Fuel Rods.....</b>	<b>59</b>
<b>Summary Design and Installations of a Circumferential Tig and Laser Welding at the Leci Laboratory .....</b>	<b>65</b>
<b>Re-fabrication and Instrumentation - résumé and outlook .....</b>	<b>73</b>
<b>Session 3: Post irradiation examination techniques.....</b>	<b>80</b>
<b>Available Post-Irradiation Examination Techniques at Romanian Institute for Nuclear Research .....</b>	<b>81</b>
<b>Post Irradiation Examination Techniques for Fuel Performance Evaluation .....</b>	<b>89</b>
<b>Indentation Techniques in Nuclear Applications: A review paper .....</b>	<b>95</b>
<b>Quantitative Burnup Determination: A Comparison of Different Experimental Methods.....</b>	<b>106</b>
<b>Scanning Electron Microscopy Analysis of CRUD-material in the PSI-Hotlab .....</b>	<b>114</b>
<b>Possibilities and Prospects of Investigation of Irradiated Structural and Fuel Materials Using Scanning Electron Microscope PHILLIPS XL 30 ESEM-TMP installed in the Hot Cell.....</b>	<b>121</b>
<b>New Possibilities of the Isotope Distribution Examination in Irradiated Absorbing Materials Using Secondary Ion Mass Spectrometry Method.....</b>	<b>127</b>
<b>Versatile Equipment for Mechanical Testing of Active Materials.....</b>	<b>132</b>
<b>Design and Fabrication of a Dead Weight Equipment to Perform Creep Measurements on Highly Irradiated Beryllium Specimens.....</b>	<b>137</b>
<b>Post-irradiation characterization of zirconia- and spinel-based inert matrix fuels – the OTTO experiment (abstract &amp; presentation slides).....</b>	<b>143</b>
<b>Session 4: Refurbishment and decommissioning.....</b>	<b>162</b>
<b>LECA Refurbishment Project or How to Get Ready for the Next Ten Years .....</b>	<b>163</b>

<b>Cleaning and dismantling of a high activity laboratory (abstract &amp; presentation slides) .....</b>	<b>169</b>
<b>The new Shielded Metallography Box in Paul Scherrer Institut Hot Laboratory ...</b>	<b>177</b>
<b>The molybdenum production facility and its relationship with NRG .....</b>	<b>183</b>
<b>Roadmap and Performance carried out during Ciemat Site Decommissioning ....</b>	<b>187</b>
<b>Taking into account seismic risk on glove boxes .....</b>	<b>192</b>
<b>BTC the UK Focus for Nuclear Fission R&amp;D in the post NDA era .....</b>	<b>198</b>
<b>Session 5: Waste and transport .....</b>	<b>206</b>
<b>Pyrometallurgical Separation Processes of Radionuclides contained in the Irradiated Nuclear Fuel.....</b>	<b>207</b>
<b>Scope and dissolution studies and characterization of irradiated nuclear fuel in Atalante Hot Cell Facilities (abstract &amp; presentation slides) .....</b>	<b>213</b>
<b>Management of Hot Cell Waste in Atalante Facilities (abstract &amp; presentation slides) .....</b>	<b>222</b>
<b>Recovery of Spent High Intensity Neutron Sources in Atalante Facility .....</b>	<b>230</b>
<b>Handling and behaviour of AVR fuel elements for interim storage .....</b>	<b>235</b>
<b>Programme, plenary meeting .....</b>	<b>242</b>



"HOTLAB" Plenary Meeting 2004, Halden

## Summary

IFE organized from 6<sup>th</sup> to 8<sup>th</sup> of September 2004 the annual HOTLAB plenary meeting at Halden and Kjeller, Norway. It was the 42<sup>nd</sup> annual plenary meeting in the "European Hot Laboratories Research Capabilities and Needs" series (former Hot Laboratories and Remote Handling). With a tradition of almost four decades, the European Working Group on "European Hot Laboratories Research Capabilities and Needs", at present formalized within the EC 6<sup>th</sup> Framework Programme HOTLAB, is firmly established as the major contact forum for the nuclear R&D facilities at the European scale.

During three days the meeting brought together more than 60 specialists from Hot laboratories and nuclear transport companies from 14 European countries, such as Belgium, Czech Republic, France, Germany, Greece, Hungary, Netherlands, Romania, Russia, Spain, Switzerland, Sweden, United Kingdom, and Norway at Park Hotel in Halden for technical sessions. 42 persons attended a technical visit to the nuclear facilities at IFE Kjeller.

The goal of the yearly plenary meeting was to:

- Exchange experience on analytical methods, their implementation in hot cells, the methodologies used and their application in nuclear research.
- Share experience on common infrastructure exploitation matters such as remote handling techniques, safety features, QA-certification, waste handling, etc.
- Promote normalisation and co-operation, e.g. by looking at mutual complementarities.
- Prospect present and future demands from the nuclear industry and to draw strategic conclusions regarding further needs.

The main themes of the five topical oral sessions of the Halden plenary meeting cover:

- **Work package (WP) leaders report (3) and specific paper (9):** presentation (WP1) of PIE facility databases, i.e. one worldwide (IAEA) and one inside the European communities. Reports from present & future needs (WP2) and on nuclear transports (WP3) (restricted).
- **Refabrication and instrumentation:** available equipments, technical characteristics such as fabrication procedures, hot-cell compatibility, and practical experiences (5 papers).
- **Post irradiation examination:** updated and new remote techniques and methodologies, new materials such as inert matrix fuels, spallation sources and neutron absorber materials (9 papers).
- **Refurbishment and decommissioning:** reports on refurbishment and decommissioning of PIE facilities (7 papers).
- **Waste and transport:** hot laboratory waste characteristics and handling, spent fuel research (5 papers).

The proceedings of the meetings will be published on the "HOTLAB" project web site hosted by SCK-CEN (<http://www.sckcen.be/hotlab/>). The next plenary meeting will be hosted by NRG, Petten, The Netherlands, May 23<sup>rd</sup> – May 25<sup>th</sup>, 2005.

### ***Session 1 "Work package (WP) leaders report and specific papers" chaired by Leo Sannen (SCKCEN- BE) and co-chaired by Jean Y. Blanc (CEA Saclay, FR)***

The HOTLAB Project is currently divided into 3 work packages (WP). WP1 consists in implementing a database on available European hot laboratories and examinations that can be performed in hot cells, on a dedicated website hosted by SCK-CEN at Mol, Belgium (<http://www.sckcen.be/hotlab/>). WP2 should provide a status of present and future needs for the European hot laboratories. WP3 should provide a database on transport casks that are used for going from nuclear power station to hot laboratories and between hot laboratories; this cask database will be hosted on the same website as hot cell facilities of WP1.

During session 1 of the 2004 HOTLAB Plenary Meeting, the three work package leaders presented the status report of their respective tasks. As this is handled inside Contract N° FI60-CT-2003-508850 granted by the European Commission, the results are restricted to Hotlab members.

However some papers are open. The first paper, presented by Håkon K. Jenssen (IFE Kjeller, Norway), described the IAEA database on Post Irradiation Examination (PIE) Facilities Database. This database can be found on the IAEA site, inside the Integrated Nuclear Fuel Cycle Information System -- iNFCIS pages, at the following address: <http://www-nfcis.iaea.org/Default>. This database is derived from a catalogue of such facilities worldwide that the IAEA issued in the 1990s, in the frame of the Examination and Documentation methodology for Water Reactor Fuel programme (EDWARF-2). It includes a complete survey of the main characteristics of hot cells and their PIE capabilities. Although carefully built and somehow similar to the HOTLAB database, the IAEA database has a different goal (only LWR examinations), a different area (worldwide instead of European), is less flexible (in updating or enclosures) and does not deal with a cask catalogue.

The presentation given by Geert Thys (SCK-CEN Mol) was a demonstration of the actual status of the HOTLAB database. The part of the site open to the public can be found at the above given address: <http://www.sckcen.be/hotlab/>. Evolutions of this base will be available for the public after the completion of HOTLAB project, by end of June 2005.

The next technical presentation by Florentin Lange (GRS – Köln, Germany) was expressing some needs concerning the safety of nuclear material transportation (see also the Patram 2004 conference in Berlin). Some work has already been realised with the Franhauser Institute to simulate and quantify the aerosols generated by the crash of a cemented radioactive waste block. A specific attention should be given to the possible transformation of UO<sub>2</sub> into U<sub>3</sub>O<sub>8</sub>. F. Lange suggested that the same kind of work should be performed on irradiated material in hot cells, using a Pellini hammer to measure the energy during the crash and a sieve to classify the aerosols. He proposes to elaborate a European Research Programme on that topic together with ITU, the Fraunhofer Institute, BNFL, ACL, etc.

The last presentation given by Martin Mandla (NCS – Hanau, Germany), explained all the requirements needed for correct control of nuclear transports and dose rate measurements. The importance for good control of neutron dose rate was emphasised by Gilbert Bruhl (CEA, Fontenay-aux-Roses, France).

## ***Session 2 "Refabrication and Instrumentation" chaired by Karl Silberstein (CEA Cadarache, FR) and co-chaired by Hans-Jörg Kleemann (IFE Kjeller, NO)***

In this session five presentations were given, describing the needs for advanced hotlab work in the future. These needs can be divided into three parts:

The necessity of hotlabs to modify and provide material for further testing in an experimental reactor. This was described in the presentation - Instrumentation and experimental fuel and future needs for PIE and hotcell work - given by H. Thoresen (IFE HRP Halden, Norway). The presentation described the research facility of the OECD Halden Reactor Project, an international cooperation directed to improve safety and economy for operation and design of nuclear power plants. In detail the possibilities of irradiation of test rigs with instrumented fuel rods and material specimens were given. Different instrumented fuel rod designs and experimental rigs were described and the type of online measurement in the reactor shown. The presentation also described the need for more material tests since the reactors are getting older. Some key words are: Cracking of irradiated materials, effect of water chemistry on crack growth and initiation, pressure vessel ageing, qualification of replacement materials, life extension of existing power plants.

The burn up of fuel is more and more increasing and the need for updated data under those extended irradiation condition is still essential. One way to get those data for evaluation of fuel and cladding under extended burnup is by re-fabrication of base irradiated fuel rods and attaching of calibrated measuring instruments before further testing under controlled conditions in a test reactor. This work is performed in hotlabs equipped with special designed machines. Three presentations are describing the capability for re-fabricating and instrumentation of pre-irradiated fuel rods. The presentation given by K. Silberstein (CEA Cadarache, France) described the development and qualification of a new technique called RECTO related to a double-instrumented rod re-fabrication process developed by CEA/LECA hot laboratory facility at Cadarache. The first technique development includes manufacturing of the properly dimensioned cavity in the fuel pellet stack to house the thermocouple. The new process allows to drill the fuel without cryogenic cooling and to preserve integrity of the drilled fuel stack. The second part is the use of a newly designed pressure transducer. The pressure sensor design is based on the counter-pressure principle. An in pile test has been performed, and a good accuracy has been obtained without drift from irradiation. The first double-instrumented fuel rod has been fabricated and its re-irradiation will be performed in OSIRIS test reactor starting in October 2004. The next development step is the laser welding, which is already in qualification and integrated on a new machine.

The presentation by H.J. Kleemann (IFE Kjeller, Norway) gave a review of the development of the re-fabrication used at IFE Kjeller since 1991 and the work on the quality control and quality assurance, adapted over the years. Such as visual inspection, neutron radiography, leak tests, flow measurement, weld qualification, instrument tests etc. The main machines, a modified lathe for the cutting and grinding, a centre-line drilling machine and the TIG welding machine were shown and described. New machines are under construction, such as a welding chamber for seal welding of irradiated fuel rods up to 120 bar and a machine for spot welding of thermocouples on the outer surface of the irradiated cladding. Those machines will be used for the production of a test rig for a LOCA simulation with irradiated fuel. Until now over 130 segments/canning were machined, modified and partly instrumented at Kjeller. 33 thermocouple holes were drilled successfully during the years and a drilling depth of 65 mm into the fuel is now reached.

One poster presentation by C. Verdeau et al. (CEA Saclay, France), described the design and installations of a circumferential TIG and laser welding at the Leci Laboratory.

After samples are cut out from a full-length fuel rod for PIE, several segments are leftovers. To reduce the costs of storing of those segments separately, they are collected and new endplugs are welded to both ends of each segment. Afterwards, those segments can be screwed together to a full-length fuel rod and inserted back to the original fuel rod bundle where it was taken out. The presentation "Refabrication of fuel rod qualification of the end plug welds", L. Sannen (SCK-CEN Mol, Belgium) gave an overview of the

process where the fuel segments are machined, de-fuelled and new end caps welded to it. In addition the qualification of the welding process for the circumferential weld and the seal weld is explained in detail.

### ***Session 3 "Post irradiation examination (PIE) techniques" chaired by Enrique H. Toscano (CEC ITU Karlsruhe, GE) and co-chaired by Didier Gavillet (PSI Villigen, CH)***

The session was dedicated to the presentation of new or updated post irradiation techniques and instrumentation available in European hot-laboratories. Nine papers given by authors working in seven institutes were presented. Two papers presented general information on the PIE capabilities of Hot laboratories: Available PIE Techniques at the Romanian Institute for Nuclear Research, M Parvan, NRI, Pitești, Romania. PIE techniques used for fuel performance evaluation, R. Källström, Studsvik Nuclear Nyköping, Sweden. The two presentations concentrate on the description of PIE analysis capabilities of fuel rod irradiated in CANDU reactor (in Romania) and PWR (in Sweden). R. Källström shows an analysis of the fuel pellet swelling based on profilometry and metallography measurements of the rods.

Three papers presented the development and implementation of new equipment for the analysis of the mechanical and micromechanical properties of irradiated materials: Versatile Equipment for Mechanical Testing of Active Materials, Johannes Bertsch (presented by D. Gavillet), PSI Villigen, Switzerland. Dead weight equipment used to perform creep measurements on highly irradiated beryllium, M. Scibetta, SCK-CEN Mol, Belgium. Microhardness methods used for determination of mechanical properties of nuclear materials, E. Toscano, CEC ITU Karlsruhe, Germany. These equipment are dedicated to the measurement of highly radioactive specimens or / and contaminated specimens. These equipments have been designed and developed primarily for the investigation of fusion reactor materials but they are versatile enough also to be used with any radioactive specimens.

Four presentations discussed modern analytical tools for the analysis of radioactive material available in three hot laboratories: Spectrometry and chemical methods for the burnup determination of irradiated fuel rods, E. Toscano, CEC ITU Karlsruhe, Germany. Scanning Electron Microscopy Analysis of CRUD-material in the PSI-Hotlab, R. Brüttsch, PSI Villigen, Switzerland. Possibilities and Prospects of Irradiated Constructional and Fuel Materials Investigation with Application of Scanning Electron Microscope PHILIPS XL 30 ESEM-TMP Installed in the Hot Cell, V. Jakovlev, RIAR Dimitrovgrad, Russia. New Possibilities in Investigation of Isotope Distribution in Irradiated Absorbing Materials Using SIMS Method, L. Evseev, RIAR Dimitrovgrad, Russia. These presentations show the development of very modern and versatile analytical tools for the microanalysis of the irradiated materials. Technique like ICP-MS, SEM, TEM or SIMS are used for quite a long time in the hotlaboratories but commissioning of new and modern instrument enlarge the field use and new idea like the CRUD structure determination with TEM or the use of SIMS for burnup analysis are popping up and will be further investigated in the future.

One paper presented the PIE investigation of innovative fuel irradiated in the Halden reactor. Post-irradiation characterization of zirconia- and spinel-based inert matrix fuels – the OTTO experiment, given by G. de Haas, NRG Petten, Netherlands. The first PIE analyses of the Halden irradiated IMF fuel is presented. The results are encouraging and indicate satisfactory fuel behaviour. The session gave an overview of the use of available PIE techniques and the development of new measurement procedures or tools in the European hot laboratories. It demonstrated the increasing use of complex analytical tools like SIMS, TEM or micro-hardness for the determination of the microstructure, microchemistry and local physical properties of the irradiated and nuclear materials. It must also be noted that only half of the papers were dedicated to PIE analysis of nuclear fuel and cladding, indicating a broadening of the investigation and research activities.

### ***Session 4 "Refurbishment and decommissioning" chaired by Javier Quinones (Ciemat Madrid, ES) and co-chaired by Rikard Källström (Studsvik Nuclear AB, SE)***

Seven papers were presented in this session. Three presentations were given by CEA (France) and moreover one from each of the following organization PSI (Switzerland), NRG (The Netherlands), BNFL (UK) and Ciemat (Spain). In this session one of the issues debated was the fact that many of our facilities have now been used for more than fifty years of working. About this topic, some of the countries have to consider a new political conception or organizations (UK or Spain, as they show in their communications)

associated with the public opinion. However, in other countries as France (as the CEA contributions reflected), the idea is to perform refurbishment and decommissioning of the facilities: attending to the particular case of each one of them, a different treatment will be given.

Related to these topics CEA, NRG and PSI present new equipments and methods implemented in all of their facilities, developing the national technology. These new equipments allow broaching of new R+D projects. Two presentations were given about cleaning and dismantling of hot facilities. The Spanish presentation was focused on the refurbishment and dismantling of the nuclear facility at Ciemat. The idea is to convert the old nuclear centre into a new research centre with irradiation facilities. For this reason, a refined cleaning operation in buildings and equipments were done in order to recover the great part of the obsolete facilities. The other decommissioning paper was related to a French facility, which will be converted in a biological research facility.

### ***Session 5 "Waste and transport" chaired by Lars P. Roobol (NRG, NL) and co-chaired by Pascal Bros (CEA, FR)***

This session was mainly devoted to waste processing. A large variety of waste was taking in account: irradiated nuclear fuel from PWR reactors, spent radioactive sources, AVR fuel elements, operating waste, and liquid waste.

One of the reference routes to perform HLW management is the separation and transmutation of long lived radionuclides contained in spent fuel. For the separation step, hydrometallurgical processes are generally used. At Ciemat (Nuclear Fission Department), pyrometallurgical processes are studied as an alternative with obtaining thermodynamic data as the main objective. Electrochemical study of uranium, samarium and molybdenum has been performed in LiCl/KCl molten salt.

At the Atalante facility, dissolution studies and characterisation of spent fuel have been carried out since 1999. High burnup fuel ( $UO_x$  – 67 GWD/t – cooling time less than 2 years) has been dissolved in a solution of nitric acid. Dissolution kinetics was determined and, after trapping, the gas ( $^{14}C$ ,  $^{129}I$ ) has been characterised. A part of the dissolution solutions was reused to perform chemical separation tests with genuine material. All these experiments resulted in the production of a large amount of both liquid and solid waste that needs specific equipment to be managed. Atalante is thus equipped with hot cells devoted to waste treatment.

As a supplier of sources, Atalante is required by law to recover both spent gamma and neutron sources with an activity of more than 300 mCi. High intensity neutron sources are a mixture of actinides ( $^{239}Pu$ ,  $^{238}Pu$ ,  $^{241}Am$  and  $^{244}Cm$ ). Inventories made by CEA show that a lot of AmBe sources have to be recovered. Therefore, studies have been carried out with this type of source to develop a chemical process capable of separating americium from beryllium and to obtain pure end products. Be is considered to be waste. The activity of the resulting waste package does not exceed 50 MBq after 300 years. In the case of Be arising from neutron sources, the techniques used in Atalante facility (passive neutron counting and gamma spectrometry) are unreliable and it has been decided to characterise the waste prior to conditioning. Procedures have then been developed using alpha spectrometry and X-ray fluorescence for activity determinations and ICP/AES and ICP/MS for beryllium quantity analysis.

A different case is the spent fuel from the AVR Reactor of FZJ in Jülich. There, spent fuel (coated particles (TRISO) in pebbles) is stored without chemical treatment. Specific packaging methods and storage cans have been developed by FZJ and the fuel behaviour in interim storage conditions has been studied. Results show that during interim storage, only  $^3H$ ,  $^{85}Kr$  or  $^{14}CO_2$  can be released, which data served as input for a safety report for the licensing of commercial storage casks.