RAPHAEL JOURNAL

n° 1
March 2006

ReActor for Process heat, Hydrogen And ELectricity generation

(Very) High Temperature Reactor (HTR/VHTR): Small size,Big potential

Key issues of the next decades will be growing energy demand, global warming and fossil fuel depletion. Today, the nuclear option addresses only electricity, not transport and heat; by addressing the whole spectrum, the (V)HTR will enable nuclear fission to play a major part in the future energy mix. In the line of EU-supported projects since 1998, the RAPHAEL Integrated Project explores the viability and performance of this next generation innovative system.

High temperature for a wide range of industrial applications

Innovation

New designs for new applications

Its high temperature will enable the HTR/VHTR to offer a wide range of applications, from electricity production to industrial heat (for recovery of oil from tar sands, refineries and other chemical plants, hydrogen production…) or lower temperature uses (desalination, district heating). Its inherent safety, waste minimisation solutions, fuel flexibility and cost effectiveness are all key assets regarding public acceptance of nuclear fission and its positive impact on economy, environment, and security of energy supply in Europe.

The RAPHAEL consortium

Technological Breakthrough

Using results from FP5, RAPHAEL explores the performance of fuel, materials and components in challenging conditions, the reactor physics models, nuclear safety and spent fuel disposal, and shall integrate the results to assess the viability of the whole system. This shall assist the development of a HTR/VHTR prototype possibly within 15 years.

Cooperation

European Synergies

33 organisations from 10 countries (see p.4) aim at achieving these challenging objectives. Synergies are sought with other FP6 projects: HYTHEC - to explore interfaces with hydrogen production, GCFR - for synergies with this other Gen IV concept, or ExtreMat - to investigate materials in extreme conditions. Collaboration is also foreseen with the Gen IV International Forum, NEA, IAEA and ISTC.

Editorial

Dear Reader,

The publication of the first newsletter coincides with the first anniversary of the RAPHAEL Project.

It also comes at a time of intensive discussions for international collaboration in the frame of the Generation IV International Forum and of bilateral relations with partners such as PBMR (South Africa) or INET (China). On the other hand, we are happy to welcome the Italian ENEA, interested in joining our partnership.

With the strong support of the European Commission, the scope and objectives of RAPHAEL have been presented at "Communicating European Research 2005" in Brussels, receiving great attention. It will be of major importance for the Project to continue informing the public and the decision makers.

This newsletter can be a useful tool for keeping RAPHAEL visible in the European arena: it will endeavour to arouse the interest for HTR/VHTR, as a unique flexible nuclear energy source addressing not only electricity, but also industrial process heat needs without CO_2 release, to explain how RAPHAEL contributes to its development and to promote European excellence by highlighting examples of good collaborative practices encouraged in the Project.

Moreover the RAPHAEL newsletter should be a link between researchers, engineers and students scattered in 10 countries and 33 organisations, who contribute to the Project. It will allow them understanding and sharing its global objectives and will give to some of them, in each of its issues, the opportunity to have their work known from the whole partnership.

We hope that our newsletter will fulfil these objectives while raising your interest.

Dominique Hittner
Edgar Bogusch
Sylvie Casalta

Fuel technologies

Irradiations and characterisations are needed for the fuel behaviour simulation. Focus on the European irradiation activities

The FP5 European programme launched state-of-the-art fuel irradiations (last German fabrication) at very high burn up and high and very high temperature. First results are coming. The FP6 is completing this phase with PIE and safety tests and is interested in newly fabricated coating layer properties.

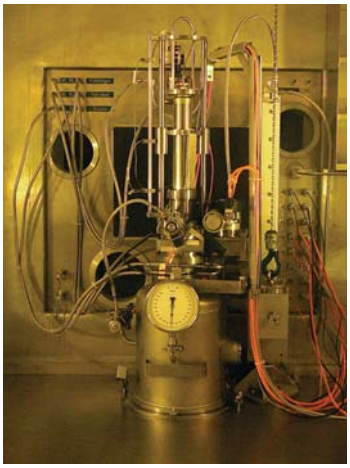
HFR-EU1bis, the new very high burn up irradiated pebbles ready to be examined.

The HFR-EU1bis experiment has been completed at an operating temperature simulating VHTR conditions (outlet core temperature about 1000°C) the 18th of October 2005. The burn up estimation is 15.4 %FIMA and the fluence ~ 4 x 1025 n.m-2 (> 0.1 MeV) for irradiation duration of ~ 250 equivalent full power days. The post-irradiation examinations just begin. The transport from Petten to Karlsruhe for KUFA testing is being investigated.

The fuel behaviour simulation: an attractive domain for young researcher

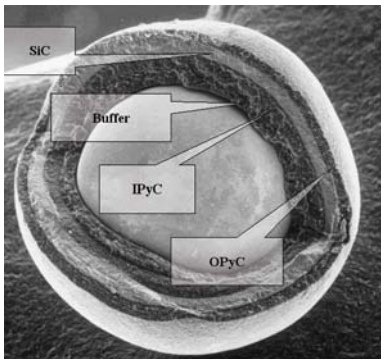
First of all, it is necessary to introduce myself : my name is Claire Cannaméla, I'm preparing a Ph.D. Thesis at Commissariat à l'Énergie Atomique about statistical approach of HTR fuel particle failure.The final goal of the project is to estimate failure probabilities of particles samples (fixed situation) so as to calculate the fraction of fission product release, potential origin of contamination.The methodology is to couple the CEA HTR fuel code ATLAS PLEIADES, which simulates the physical, chemical and mechanical behavior of one particle, with advanced Monte Carlo methods. Diverse strategies will be implemented and compared to choose the best suited one for our problem.This subject is very interesting and rewarding for different reasons, first it combines multi scale and multi physic modelling in several scientific areas (materials, mechanics and statistics), and secondly I can always have a brainstorming with specialists' crews of fuel behavior, particles' fabrication and with many others.

The KUFA furnace: an operational tool for TRISO fuel depressurised heat up accident simulation.



Developed within the FP5 programme, the so-called KÜFA furnace has been successfully tested for the first time with an AVR pebble having 2,5 % Burn up at 1600°C and 1800°C for a few hours last year. The goal of this test was the commissioning of the KÜFA under remote controlled conditions.
A second test, long term (15 days), with an AVR-Pebble having 4.8% burnup has been just finished. The next step will be to test an HFR-K6 pebble having 9.7 % burn up, waiting for testing are the HFR-EU1bis pebbles.

Analytical fuel material irradiation in HFR: a significant Euratom contribution to GENIV ?



A major activity of the sub-project is the carrying out of an irradiation of SiC and Pyrocarbon layers for irradiation induced material property changes. January 16-19, a Gen IV workshop was held in Cadarache, with one day dedicated to property acquisition. This irradiation was strongly supported by the members of the workshop. The irradiation is expected to start in mid to late 2007. Given the current schedule for the irradiation, a working framework or memorandum of understanding for interested GIF parties is now needed so that the design of the sample holder and the types and number of samples can be finalized.

Graphite irradiation

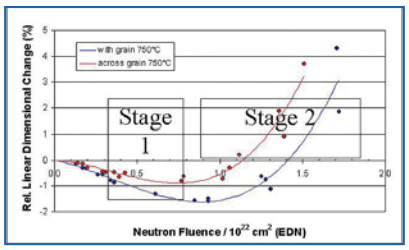
Tests generate vital data on new graphite grades

The graphite components of the reactor form the permanent inside and outside reflectors, the core blocks (in the case of a block-type core reactor), and the core supports.

Graphite has important safety implications for the reactor as in loss of cooling situations the core decay heat is extracted by thermal conduction through the graphite internals. But conduction as well as other physical properties of graphite are changing in a different way depending on the graphite grade, when it is irradiated.

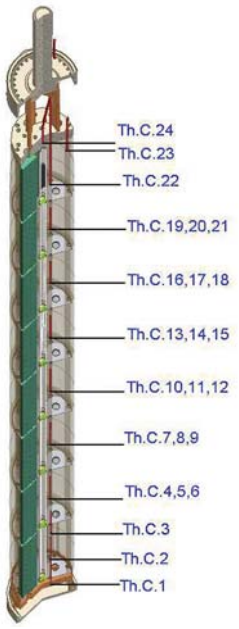
RAPHAEL and Materials

The investigations led in Sub Project "ML" on graphite are seen as crucial in establishing new materials for future VHTRs, given that almost all the graphites previously irradiated are no longer manufactured. Information on property variations are required (especially dimensional change) under VHTR conditions. Irradiation tests are currently being carried out in the High Flux Reactor (HFR) at Petten on 8 selected graphite grades (in two stages) to establish the irradiation behaviour at 750°C. The 1st stage is complete, achieving fluences sufficient to cover prismatic core designs, and the 2nd stage, about to commence, will achieve fluences sufficient to cover pebble-bed designs.
A 2-stage experiment at 950°C is also about to start.



The figure shows the irradiation behaviour of the ATR-2E graphite used in the German HTRs. It clearly shows the typically anisotropic behaviour of graphite. The 'ideal' graphite for a VHTR will have a low initial shrinkage rate, a moderately high fluence at which turn-around occurs, a high fluence at which it goes into positive growth (i.e. original dimensions/volume attained), and a low anisotropy.

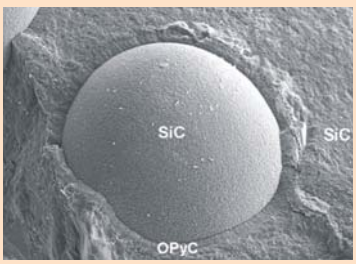
Graphite blocks were supplied by 3 manufacturers (SGL, GrafTech and Toyo Tanso) and ~200 samples were machined, pre-characterised and inserted into a specially instrumented rig: INNOGRAPH (drum-based with gamma heating, thermocouples and neutron detectors), which was inserted into the HFR for irradiation testing.



Specially developed shielded facilities are being used at NRG to measure the irradiated properties. The work together with corrosion testing, microstructural modelling and design rule development supports the selection and qualification of the most promising grades for the next generation of VHTRs.

Embedding of Coated-Particles

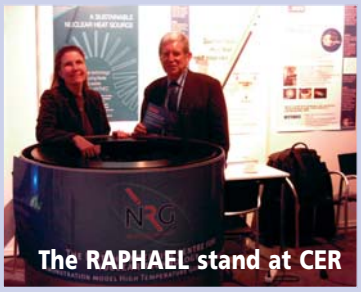
As practical training during education for the degree of a European Master of Nuclear Science, Signe Neumann was working with the FZJ team to study the feasibility of embedding spent coated particle fuel into a leach resistant matrix. Although direct disposal of spent HTR fuel is a viable option, the porosity of the graphite fuel matrix allows ingression of corrosive media attacking the integrity of the coated particles in a final repository. Separation of the coated particles from the graphitic moderator material would also allow to significantly reduce the volume of High-Level Waste for final disposal.
Silicon Carbide (SiC) was chosen as embedding material due to its well known leach resistance, high thermal conductivity and mechanical strength.
The green bodies were produced by filtrating slips consisting of coated particles in aqueous SiC / Si / graphite powder suspensions. Subsequent reaction-bonding with molten silicon at nearly 1600°C formed composites of high quality and homogeneous distribution of coated particles.
Investigation of the penetration depth of the molten silicon into the outer pyrocarbon (OPyC) layer of the coated particles reveals good adhesion of coated particles to the new SiC matrix. Thus, the principal feasibility of embedding coated-particles into reaction-bonded SiC is now proven.



In brief

"Communicating European Research"

Out of the 250+ FP6 projects presented at the EC's CER-2005 conference last November in Brussels, ten were selected for a press briefing, and 2 were nuclear projects - RAPHAEL and ITER. D.Hittner (FANP) and M.T.Dominguez (EA) had a chance to dialogue with journalists from all over Europe. Following the event, the journalists of the European Commission underlined the project's "ambitious technical objectives" and "high value for education and communication" in an article titled "RAPHAEL, a Renaissance for Nuclear?" in conference journal *The ExCERpt*.



The RAPHAEL stand at CER

Visit the RAPHAEL website! [www.raphael-project.org]

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Eurocourse

PhD or MS students, and young engineers, are invited to participate to a Eurocourse that will focus on HTR technology, also allowing discussion with experts and insight on RAPHAEL.
The European Nuclear Education Network (ENEN), grouping 40+ universities and research centres, is a partner of this course. Grants shall be available for students to refund part of their travel & accommodation expenses.
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European excellence

The RAPHAEL consortium unites 33 organisations with complementary expertise in HTR technology

Most already participated in the previous EU HTR projects and are members of the European HTR Technology Network (HTR-TN). Their involvement in RAPHAEL corroborates the thriving interest in this technology in Europe and provides related projects with further momentum. The consortium encompasses diverse and complementary expertise:

- Nuclear engineering firms provide experience in design & licensing, necessary for focusing on actual needs of industry, assessing the R&D results, and establishing an accepted safety approach.
- Leading fuel companies join their know-how in fuel design, fabrication and fuel cycle technologies.
- Utilities provide experience in operating nuclear reactors and focus RAPHAEL on utility requirements.
- Nuclear research centres provide long-standing expertise as well as research capabilities and essential facilities - such as material test reactors, hot labs or test loops.
- Universities and engineering schools provide specialised technology contributions, fundamental science basis, and ensure the lion's part of education and training.
- Specialised industrials and institutes bring their unique competence for key components (coolant pumps, gas circulators, magnetic bearings), graphite manufacturing, and helium purification, providing essential added value in strategic areas.
- An independent consulting firm brings its know-how in international project management.

In addition, several of the partners introduce their decades-long experience with the past German HTR programme.

The Steering Committee meets in Paris in November 2005

Special thanks to Claire Cannamela, Sylvie Casalta, Signe Neumann, Edgar Bogusch, Derek Buckthorpe, Vincent Chauvet, Dominique Hittner, Mayeul Phelip, Walter Scheuermann, Werner von Lensa, for their contribution to this first issue of the RAPHAEL Journal.