RAPHAEL Project

HTR Specific Waste Characterization Programme

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P. Bros / CEA - M.H. Mouliney / AREVA NC - D. Millington / AMEC NNC
A. Sneyers / SCK CEN - D. Roudil / CEA - F. Cellier / AREVA NP
T.J. Abram / NEXIA - J. Fachinger / FZJ - K. Vervondern / FZJ

Introduction

- RAPHAEL European project
- Back end of the fuel cycle
- Waste legislation
- Bibliographic data
- Characterisation programme in Atalante facility with samples provided by FZJ

RAPHAEL Project

- The **Re**A**ctor for **P**rocess heat, **H**ydrogen **A**nd **El**ectricity generation project is coordinated by AREVA ANP
- 19 M€, supported by Euratom in its 6th framework programme
- 35 partners
- Cooperation with GIF, Russia and OECD-NEA
- RAPHAEL aims at developping the HTR/VHTR technologies in the fields of fuel, materials, components, reactor physics, nuclear safety and waste disposal

Expected results

The RAPHAEL project will :

- Provide elements for the verification and validation of the computer tools and models,
- Assess the behaviour and performance of fuel and materials in normal and accident conditions for a normal operating Temperature up to 1000°C
- Analyse the behaviour of spent fuel in disposal conditions
- Develop innovative technologies for system components, exploring in particular the interfaces with hydrogen production or process heat exploitation
- Elabore an acceptable nuclear safety approach
- Integrate results in order to provide preliminary assesments of concepts of VHTR plants, coupled with hydrogen production processes
- Promote the VHTR/HTR technology as a major option for securing future sustainable energy supply un Europe, and organise educational actions to promote carreers in the field

Organisation
Sub-Projects

The RAPHAEL Project is subdivided into eight Sub-Projects

- Coupled reactor physics and core thermo fluid dynamics
  NRG - The Netherlands
- Fuel technology
  CEA Cadarache - France
- ***Back end of the fuel cycle***
  FZJ - Germany
- Materials development
  NNC - United Kingdom
- Component development
  AREVA NP - France
- Safety
  Suez Tractebel - Belgium
- System integration
  AREVA NP - France
- Project management
  AREVA NP - France

Back end of the fuel cycle

Back end options

Objective:

- Characterisation of spent fuel by experimental programme,
- Analysing behaviour of advanced coatings (ZrC) and advanced kernel composition (UCO),
- Continuation of separate effect leaching tests,
- Improving geochemical modelling of HTR and V/HTR fuel,
- Feasibility of encapsulation of less porous matrix,
- Confirming the spent HTR, V/HTR spent fuel performance.

Three Work Packages

- *WP1 : Characterisation of HTR/VHTR-specific Waste*
- **WP2 : Conditioning & Spent Fuel Performance Modelling ➔ Model developments to :**
  - Assess coated particle performance and radionuclide release from spent fuel under geological disposal conditions
  - Identification of the ralative importance of different release barriers : graphite matrix, SiC (or ZrC), PyC, matrix UO_2 (or UCO), grain boundaries
  - Quantification of the effect of material choices (ZrC vs SiC), (UCO vs UO_2) on spent fuel performance
- **WP3 : Disposal Behaviour**
  - Leaching behaviour of fuel kernels during final disposal
  - Aqueous phase penetration into graphite and diffusion of radionuclides through the graphite
  - Best choice of coating material (SiC or ZrC)

WP1 : Chracterization of specific HTR / VHTR waste

Main objective

- To get more precise data allowing to predict the fuel behaviour in conditions of a long term geological disposal

The work includes

- The establishment of disposal specifications and/or decontamination requirements in relation with the regulation for waste management in different countries,
- The compilation of existing data for characterisatiion concerning the solid state of HTR spent fuel,
- The acquisition of physical, chemical, radiological states and inventory data of irradiated and fresh coated particles and pebbles (UO_2, UCO).

Disposal specifications and requirements

- Review about waste disposal legislation and classification schemes in operation within several EU states (Germany, UK, Belgium, France) and the US :
  - Identification of common denominators → Not so easy….but the EU scheme, which is itself an implementation of IAEA recommendations, forms a useful basis for discussing HTR spent fuel disposal.
  - Specifications for disposal of future HTR waste → depends of HTR reprocessing

Bibliographic survey on European data on HTR spent fuel characterisation

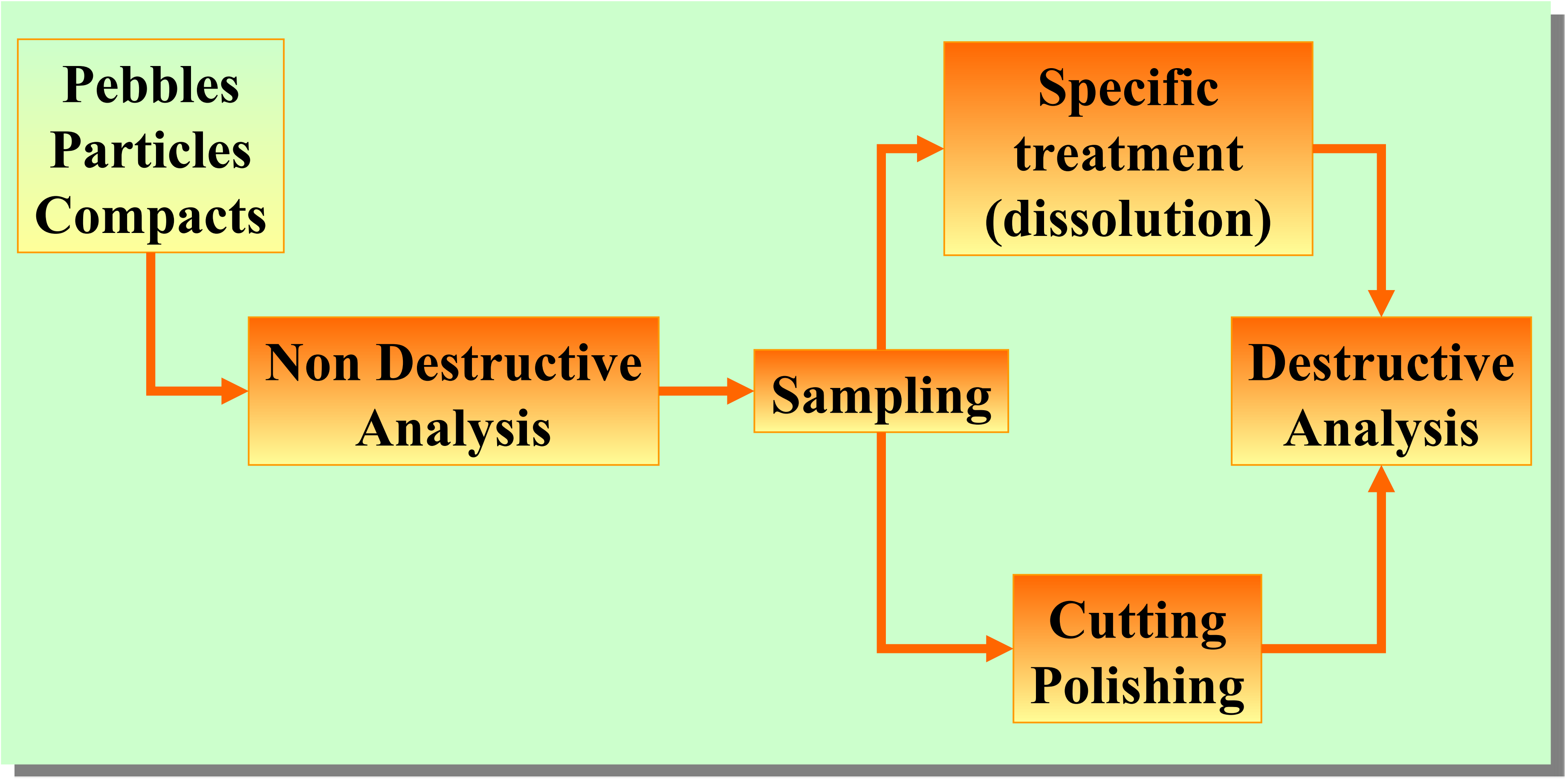
- Data in Germany
  - Experience from both AVR and THTR reactors
  - Irradiation tests in HFR Petten
- Data in UK
  - Experience from DRAGON reactor operating period between 1964 and 1975
- Data in France
  - Results from past collaborations that conducted to experiments at Saclay (OSIRIS), Grenoble (SILOE) and Cadarache (RAPSODIE)

Characterisation programme

Fuel Behaviour in disposal conditions

- Where is the contamination ?
- Form ?
- Radionuclides ?
- Ratio ?
- Morphological aspect ?
- Microstructure ?

Characterization schema in Atalante facility



Inventory data

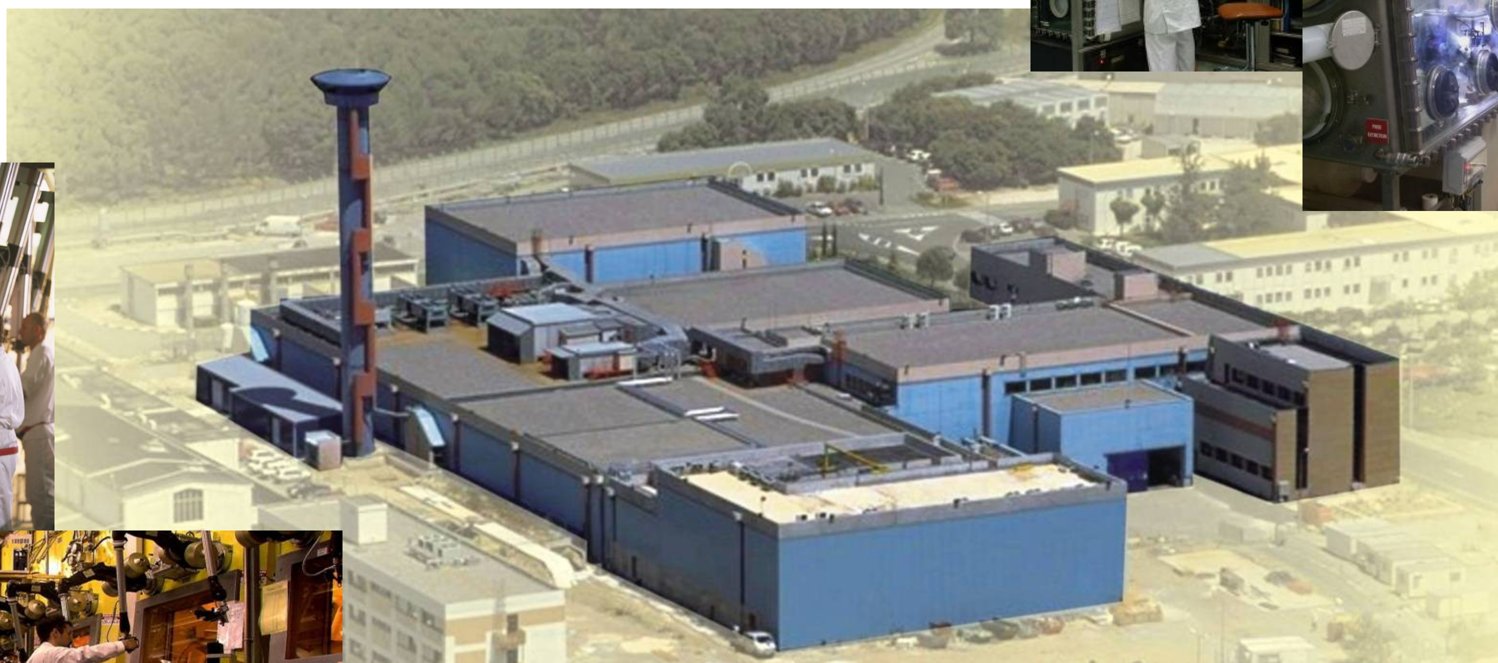
- Non destructive analysis
  - Active and passive neutronic counting ➔ contents of fissile materials and ^{244}Cm
  - Gamma collimation spectrometry ➔ homogeneity of $\beta\gamma$ contamination
- Destructive analysis
  - ICP/AES and ICP/MS ➔ chemical composition
  - γ and β spectrometries ➔ radiochemical composition
  - TIMS ➔ isotopic composition of actinides
  - X ray fluorescence ➔ Pu and U quantities

Structural and morphological data

- Optical microscope ➔cracks, rouphness
- X ray diffraction ➔ structural properties (lattice parameter)
- EPMA ➔ FP quantification in coatings
- Helium picnometer ➔ opened and closed porosities
- Calorimeter ➔ thermophysical properties
- Electronic microscope ➔ localization of the contamination and particles aspect

Atalante facility

Labs



Hot cells

Juelich samples characteristics

HFR
FRJ2

- **TRISO Coated particles (UO_2, UCO, $(U,Th)O_2$)**
  - Burn up : 10 to 55,7 FIMA
  - Center temperature : 1168 to 1400 °C
  - End of irradiation : 1979
- **Pebbles (UO_2, $(U,Th)O_2$)**
  - Center temperature : 1156 °C
  - Burn up : 10 FIMA
  - End of irradiation : 1980
- **Compacts (UO_2, UCO, $(U,Th)O_2$)**
  - Center temperature : 850 to 1620°C
  - Burn up : 8 to 22 FIMA
  - End of irradiation : 1979

Samples Transport

- According to the European Agreement concerning the International Carriage of Dangerous Goods by Roads (ADR), two kinds of transport are under consideration :
  - low activity samples (only coated particles in small quantities) can be carried out using a type A package
  - high activity samples (pebbles and so on) can be performed in a type B package like the RD15IIB (Padirac) one that can be used in both Marcoule and FZJ facilities.

RD15IIB cask

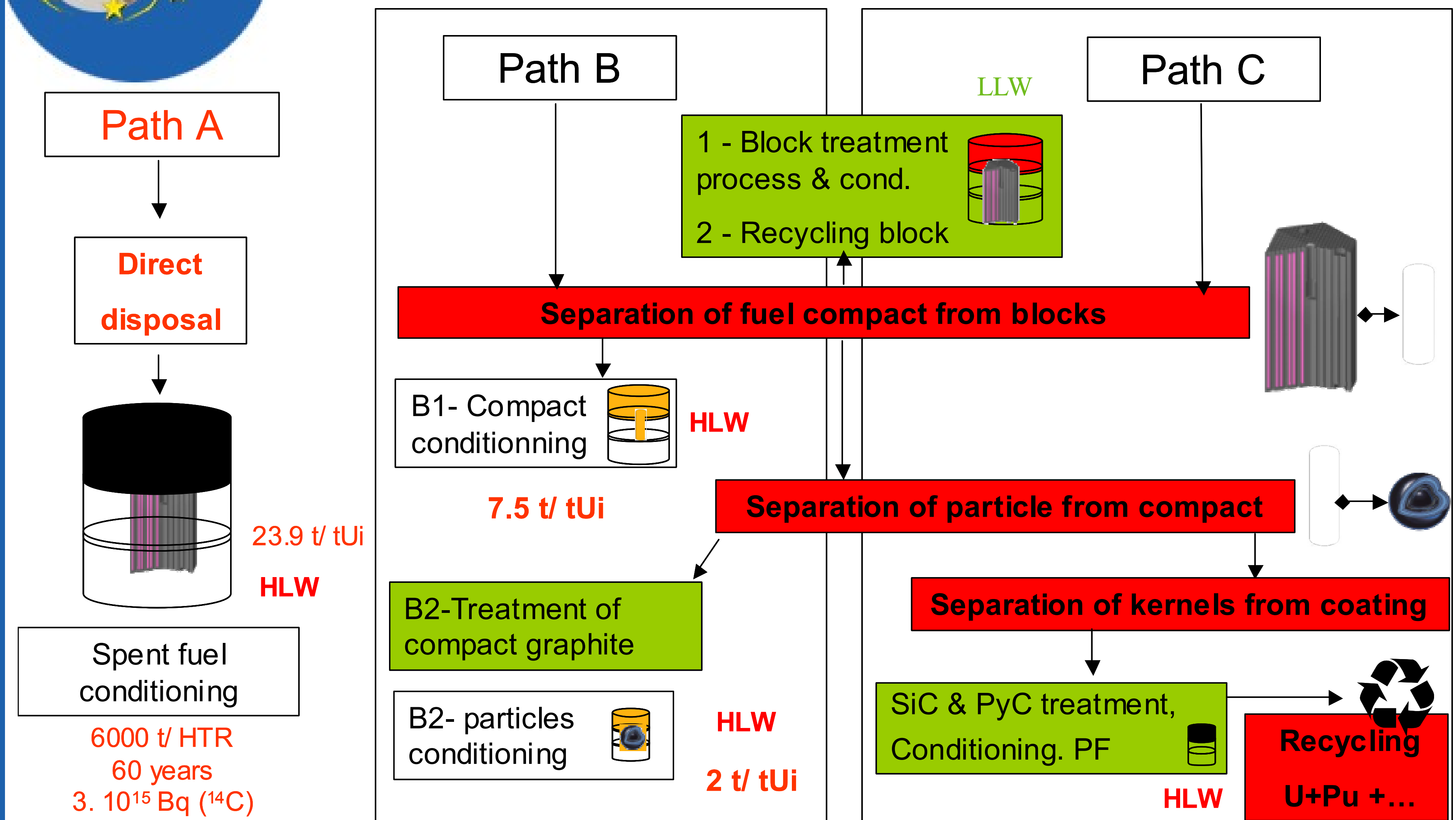
Time schedule

- Due to the specificity of HTR samples (kernel, graphite matrix and so on), a safety file is needed to handle these materials in Atalante facility. The examination is under way
  ➔ **end of 2006**
- Low activity samples transport in a type A package ➔ **beginning of 2007**
- Characterisation programme start ➔ **beginning of 2007**
- High activity samples transport in a RD15IIB cask when the licence will be obtained (expected date, second semester of year 2007) ➔ **end of 2007**
- Programme continuation with high activity samples ➔ **2008**

Conclusions

- Back end of fuel cycle is now identified as an issue of major importance with regard to the development of HTR reactor.
- In this field, data coming from past investigations have to be completed.
- An overview of the specifications and requirements for disposal of HTR waste has been obtained from the analysis of waste disposal legislation and classification schemes in operation within several EU states and the US.
- Samples transport is an important step to achieve

Back end options



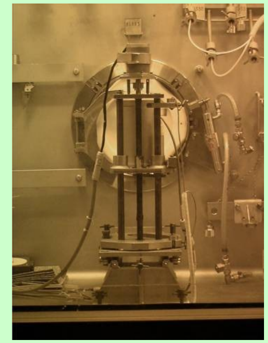
Organisation of the project
Participants

1 AREVA NP (FR)
2 Ansaldo Nucleare (IT)
3 Belgonucleaire(BE)
4 British Nuclear Fuel Ltd (UK)
5 AREVA NC (FR)
6 Commissariat à l'Energie Atomique (FR)
7 Delft University of Technology (NL)
8 Association pour la Recherche et le Développement des Méthodes et Processus Industriels (FR)
9 Electricité de France (FR)
10 Empresarios Agrupados Int'l (ES)
11 Framatome ANP GmbH (DE)
12 Forschungszentrum Jülich GmbH (DE)
13 IKE der Universität Stuttgart (DE)
14 Pebble Bed Modular Reactor (Pty) Ltd (ZA)
15 Jeumont SA (FR)
16 Joint Research Center (EU)
17 Arbeitsgemeinschaft Versuchsreaktor GmbH (DE)
18 National Nuclear Corporation (UK)
19 Nuclear Research and consultancy Group (NL)
20 Nuclear Research Institute Rez plc (CZ)
21 Paul Scherer Institut (CH)
22 S.G.L. Carbon GmbH (DE)
23 Studiecentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire (BE)
24 Serco Assurance (UK)
25 Services Trading European Partners (FR)
26 Société de Mécanique Magnétique (FR)
27 Suez Tractebel (Tractebel Engineering Division) (BE)
28 UCAR snc - GrafTech Int. Ltd (FR)
29 University of Pisa (IT)
30 University of Applied Sciences Zittau/Goerlitz (DE)
31 University of Manchester (UK)
32 Von Karman Institute (BE)
33 VUJE Trnava Inc (SK)
34 Institut de Radioprotection et de Sûreté Nucléaire (FR)
35 Institute of Nuclear and New Energy Technology (CN)

36 ENEA (Observer)

Hot cells

Optical microscope



Sample device

Detector

Gamma collimation spectrometry

ICP/AES implemented in HA

Argon plasma

Samples

LABS