Partitioning and Transmutation of High Level Nuclear Waste in an Accelerator Driven System

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Joachim U. Knebel
Forschungszentrum Karlsruhe
Research Centre Karlsruhe
Germany
Motivation

- Today’s nuclear power plants are essential for the electricity production in Europe, especially the base load electricity.
- Nuclear power is safe, economic, CO\textsubscript{2}-free and reduces energy imports.
- But: Nuclear power plants produce high level nuclear waste.
- Nuclear waste is of public concern.
Objectives (1/2)

- Since 2005, the Project EUROTRANS is devoted to the study of transmutation of high-level waste from nuclear power plants.
- In parallel, the Project ACSEPT develops chemical separation processes compatible with fuel fabrication techniques.
- EUROTRANS assesses the design and the feasibility of an industrial Accelerator Driven System (ADS) which shall reduce the high level waste to be finally disposed of.

Sketch of an ADS-type transmutation machine.
Proton accelerator
+ Spallation target to produce high power neutrons
+ Subcritical assembly (core) and Pu and MA

Accelerator Driven Subcritical System (ADS)
Partitioning and Transmutation of High Level Nuclear Waste

**ADS: Major Components (2/3)**

- Proton accelerator

- Spallation target to produce high power neutrons => MEGAPIE-TEST

- Subcritical assembly (core) and Pu and MA

- Accelerator Driven Subcritical System (ADS)
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**ADS: Major Components (3/3)**

- Proton accelerator
- Spallation target to produce high power neutrons
- Subcritical assembly (core) and Pu and MA

- Accelerator Driven Subcritical System (ADS)
We make available the necessary R&D results in the areas of
(1) partitioning, (2) accelerator components, (3) fuel development,
(4) structural materials, (5) thermal-hydraulics, (6) heavy liquid metal
technology and (7) nuclear data.

Finally, we demonstrate the (8) coupling of the major ADS components.
EC Project MEGAPIE-TEST

- **Challenge:** Realisation of a prototypic spallation target.
- **Result:** Development, construction and successful operation of a HLM cooled spallation target of 1MW beam power at PSI in 2006: 4 months irradiation, 95% availability, increase in neutron flux by 80%.
- Collaboration between EURATOM, Japan, Korea, and USA.
Objectives (2/2)

- In 2010, we will provide a reasonably reliable assessment of the technological feasibility and a cost estimate for ADS based transmutation. This forms the basis for politics and stakeholders to possibly decide on the detailed design of an experimental ADS and its construction in the future.

- ACSEPT and EUROTRANS provide high level Education & Training of young nuclear engineers in close cooperation with European universities.
How does Partitioning and Transmutation work in a Closed Fuel Cycle?

What are the Benefits?
Simple recycling of plutonium is state-of-the-art today in Light Water Reactors (LWR).

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**Closed Fuel Cycle with P&T**

- **New Strategy**: Partitioning (separation) and transmutation (burning) of Plutonium and Minor Actinides in an ADS.
- **Advantage**: Reduction of radiotoxicity, volume and heat load to be put in a final repository.
- **Radiotoxicity**: Hazard potential of the high level nuclear waste.
Radiotoxicity

- Direct disposal of the overall nuclear wastes
Radiotoxicity

- Separation and transmutation of 99.9% of Pu and U
Radiotoxicity

- Separation and transmutation of 99.9% of Pu, U and MA

- Achievement: Disposal times are shifted from geological to historical time scales in nuclear waste disposal.
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Examples of Transmutation

- Transmutation is the conversion of one element to another and by extension one isotope to another, thus transforming long-lived isotopes to short-lived or even stable ones. Sometimes several captures and decays must take place.

- Three examples:

  1. \( n + ^{239}\text{Pu} \text{ (24000 years)} \rightarrow ^{134}\text{Cs} \text{ (2 years)} + ^{104}\text{Ru} \text{ (stable)} + 2 \text{n} + 200 \text{ MeV} \)

  2. \( n + ^{240}\text{Pu} \text{ (6600 years)} \rightarrow ^{241}\text{Pu} \text{ (14 years)} \)

  \hspace{1cm} n + ^{241}\text{Pu} \text{ (14 years)} \rightarrow ^{134}\text{Xe} \text{ (stable)} + ^{105}\text{Rh} \text{ (35 hours)} + 3 \text{n} + 200 \text{ MeV} \)

  3. \( n + ^{241}\text{Am} \text{ (432 years)} \rightarrow ^{242}\text{Am} \text{ (16 hours)} \) [capture]

     \hspace{1cm} ^{242}\text{Am} \text{ (16 hours)} \rightarrow ^{242}\text{Cm} \text{ (163 days)} \) [decay \( \beta \)-]

     \hspace{1cm} ^{242}\text{Cm} \text{ (163 days)} \rightarrow ^{238}\text{Pu} \text{ (88 years)} \) [decay \( \alpha \)]

     \hspace{1cm} n + ^{238}\text{Pu} \text{ (88 years)} \rightarrow ^{142}\text{Ce} \text{ (stable)} + ^{95}\text{Zr} \text{ (64 days)} + 2 \text{n} + 200 \text{ MeV} \)

From: Enrique Gonzalez CIEMAT
Vision for a Closed Fuel Cycle

- The use of critical or sub-critical fast neutron reactors reduce the waste radiotoxicity in a geological repository to that of the original ore (used to produce energy) after only some hundred years, i.e. within feasible/credible capabilities of engineering segregation. If no transmutation, the time horizon to reach the same result is several hundred thousand years.

- Moreover, these transmutation devices can both stabilise or reduce the amount of Pu and Minor Actinides, according to the strategy / policy of the respective country.

- Finally, transmutation has the potential to reduce the burden on a geological disposal, since it allows volume and residual heat reduction.

From: GIF (top) and SCK-CEN (bottom)
Our Consortium:

46 partner from 16 European countries
(10 industry, 19 research centres, and ENEN representing 17 universities)
plus
Belarus, Japan and USA.
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Possible Realisation of P&T

- The Belgium nuclear research centre SCK·CEN in Mol offers a site to erect an ADS demonstration facility, called FAst Spectrum Transmutation Experimental Facility, based on MYRRHA and XT-ADS.

- Time horizon: The demonstration facility shall be in full operation around 2020.

From: SCK-CEN
For any further information please contact

Joachim U. Knebel
Co-ordinator of EUROTRANS
at
Forschungszentrum Karlsruhe
Programme Nuclear Safety Research

http://www.fzk.de/nuklear
mailto: ipeurotrans.knebel@nuklear.fzk.de
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Nuclear Energy: Economic, ecologic, safe.

Five good reasons to use nuclear energy in a balanced energy mix:

- Nuclear energy is sustainable.
- Nuclear energy protects European competitiveness.
- Nuclear energy strengthens the our technology area.
- Nuclear energy protects us from dependencies and lacks of electricity.
- Nuclear energy is safe.