R-07-68

System and safety studies of accelerator driven systems for transmutation

Annual report 2006

Vasily Arzhanov, Jan Dufek, Mikael Jolkkonen, Christina Lagerstedt, Calle Persson, Nils Sandberg, Janne Wallenius and Daniel Westlén

Division of Reactor Physics
Royal Institute of Technology

December 2007

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Summary

Within the project "System and safety studies of accelerator driven systems for transmutation", research on design and safety of sub-critical reactors for recycling of minor actinides is performed. During 2006, the reactor physics division at KTH has developed procedures for calculating fission and activation product vapour pressures over molten lead and lead-bismuth, as part of the source term evaluation for XT-ADS and EFIT. Reactivity of two sub-critical configurations of the YALINA-Booster experiment in Minsk were estimated, together with a preliminary noise analysis of data from an experimental campaign made in June. Studies of basic radiation damage physics included calculations of vacancy formation and activiation energies in bcc niobium and phonon dispersion curves in Fe-Cr alloys. The latter indicate a significant stabilisation of disordered Fe-Cr with direct implications for the temperatures and compositions at which embrittling alpha-prime precipitation is expected during irradiation. Design studies of gas cooled ADSs showed that they may provide a 10% increase in proton source efficiency and a faster approach to equilibrium, as compared to lead cooled ADSs. Finally, fuel cycle studies underlined that a reduction of Swedish TRU inventories by a factor five can be accomplished with ADS during 50 years.

Sammanfattning

I projektet ”System- och säkerhetsstudier av acceleratordrivna system för transmutation” utförs forskning om design och säkerhet för underkritiska reaktorer avsedda att förbränna mindre aktinider. Under 2006 har avdelningen för reaktorfysik på KTH utvecklat metoder för att beräkna ångtryck för klyvnings- och aktiveringsprodukter över flytande bly och bly-vismut, som del i utvärderingen av källtermerna för XT-ADS och EFIT. Reaktivitesuppskattningar för två underkritiska konfigurationer av YALINA-Booster-experimentet i Minsk har gjorts, samt preliminär brusanalys av data tagna vid ett experiment utfört i juni. Studier av grundläggande strålskadefysik har innefattat beräkningar av vakansformations- och aktiveringsenergier i niob med bcc-struktur samt fonondispersionskurvor för Fe-Cr-legeringar. De senare indikerar ökad stabilitet för oordnat Fe-Cr, med direkt inverkan på temperaturer och sammansättningar där man förväntar sig urskiljning av alfa-prim-fas under bestrålning och därav resulterande försprödning. Designstudier av gaskylda ADS visat att de kan möjliggöra 10 % ökning av källeffektiviteten samt att jämvikt uppnås snabbare än i blykylda ADS. Slutligen har bränslecykelstudier utförts som visar att en minskning av det svenska transuraninventariet med en faktor fem kan åstadkommas med ADS under en 50-årsperiod.

Contents

1 Introduction

Research on accelerator driven systems (ADS) for transmutation of nuclear waste is performed at the division of reactor physics at KTH. Presently, the major context of this research is the EUROTRANS project in the 6th framework programme of the European Commission, where design of an experimental ADS with MOX fuel and lead-bismuth coolant (XT-ADS) and an industrial demonstration facility for minor actinide transmutation (EFIT) is made. Development of ADS fuel and structural materials are integrated into the project.

The division of reactor physics at KTH is participating in all domains of the EUROTRANS project, in particular with the following activities:

Domain DESIGN: Co-ordination of the safety work package.
Assessment of the source term in case of severe accidents.

Domain ECATS: Development and testing of methods for sub-criticality monitoring.

Domain AFTRA: Fuel modelling.

Domain DEMETRA: Modelling of radiation damage in Fe-Cr-C steels.

Furthermore, KTH is coordinating the 6th FP RedImpact project. In this project, scenario studies of partitioning and transmutation and their impact on geological repository design and performance is assessed.

The division of reactor physics has also performed studies on design of helium cooled accelerator driven systems within the frame of the present project, resulting in the PhD dissertation of Daniel Westlén.

In the present report, a summary of activities performed during 2006 is provided, including an account for participation in conferences and project meetings.

2 Safety studies of XT-ADS and EFIT

In the safety analysis of any reactor concept, the source term is an important factor. It consists of the inventory of radioactivity which would be released into the containment assuming a core disruptive event. For the nobel gases, this inventory is simply considered to be equal to their production rate. For volatiles, a thermo-chemical assessment of their retention in the coolant is necessary. Within the EUROTRANS project, KTH has evaluated the volatility of caesium, strontium, iodine and polonium contaminants in liquid lead and lead-bismuth. This work includes predictions of the predominating chemical forms in solution and gas phase, with special emphasis on the degree of non-ideality in very dilute solution. These investigations make it possible to predict the equilibrium (i.e. maximal) vapour pressure of radiotoxic species over a coolant spill or breached reactor vessel at a given temperature. In combination with other relevant data (an accident scenario), the radiological consequences can be estimated.

There has been some speculation regarding the chemical state of iodine in the gas phase over hot LBE. Figure 2-1 shows that in a melt of roughly similar amounts lead and bismuth, lead iodide is significantly more stable than bismuth iodide. We then postulate chemical equilibrium between PbI_2 in liquid and gas phase, and calculate the upper limit concentration of gaseous PbI_2 from the vapour pressure of PbI_2, an assumed iodine concentration in the melt, and an estimate (from literature) of its thermodynamic activity coefficient in LBE.

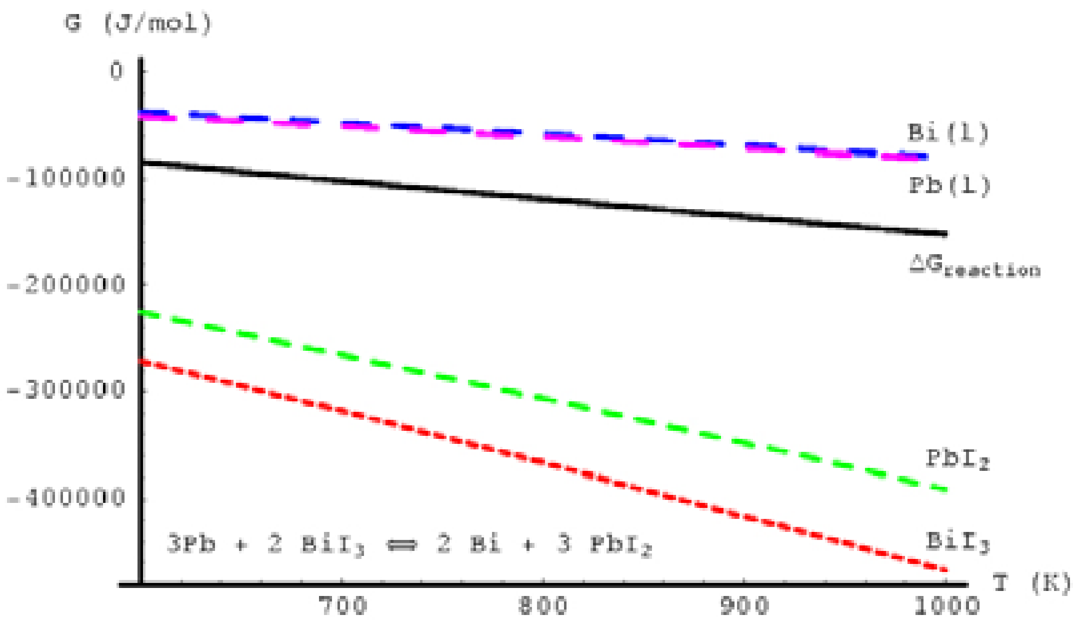

Figure 2-1. *Gibbs energy for Iodine compounds in lead-bismuth.*

Figure 2-2 further shows that the amount of free iodine in the gas phase (in which the lead concentration is easily calculated in a corresponding way) is negligible compared to that of lead iodide. Thus the total iodine concentration in the gas phase is practically equal to the PbI_2 concentration, which can be calculated.

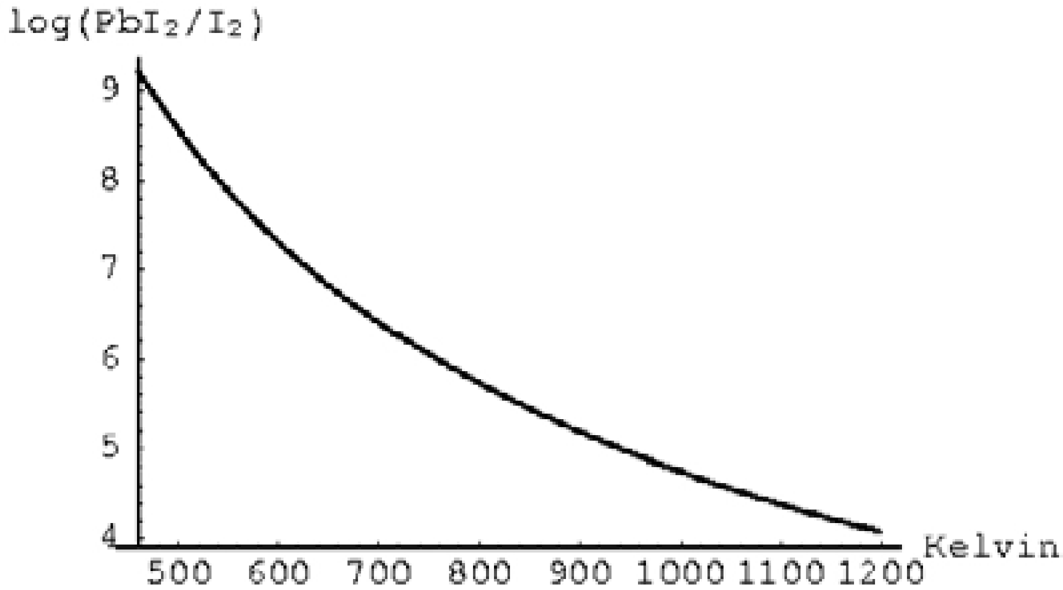

Figure 2-2. *Concentration of lead iodide in the gas phase, relative to that of free iodine.*

3 Sub-criticality monitoring

3.1 Experimental work: YALINA-Booster

The main activity has been the preparation and analysis of experiments performed at the sub-critical experiment YALINA-Booster in Minsk, Belarus. The data taken in June 2006 has been analyzed during the second half of 2006 and is ready for publication in the beginning of 2007. The main result is reactivity estimations of two subcritical configurations using pulsed neutron sources in parallel with neutron noise techniques. For these measurements a data acquisition system was developed.

Some results from the neutron noise analysis are presented here.

3.1.1 Noise measurements

The noise measurements were performed in two subcritical configurations of YALINA-Booster with 1,132 and 1,061 EK-10 fuel pins respectively. For each configuration three measurements were performed with a ^{3}He-detector, of active length 250 mm, in the experimental channels EC5T, EC6T and EC7T. For the 1132-configuration, one measurement were performed in EC9R as well. In each measurement a ^{252}Cf-source with source strength 842 n/s was located in the core centre. The core layout can be found in Figure 3-1.

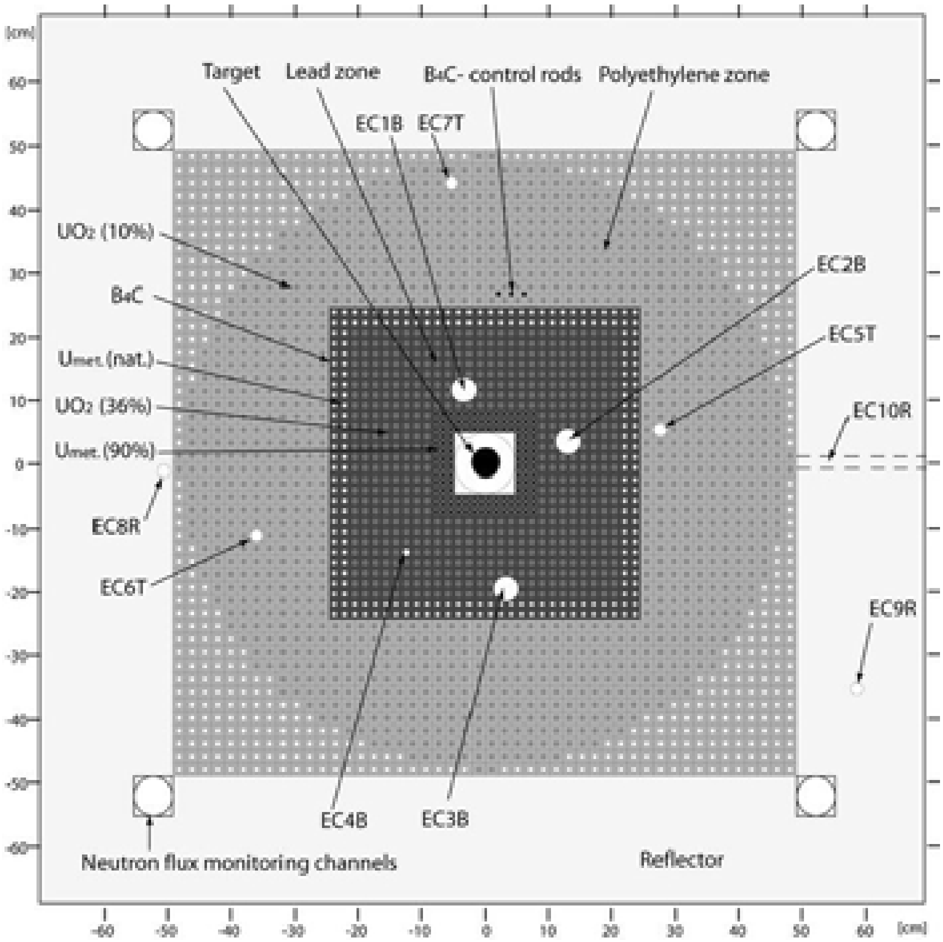

Figure 3-1. *Cross-sectional view of YALINA-Booster (the 1132-configuration).*

Data was recorded using a counter/timer card from National Instruments, by which it is possible to store the exact arrival time of each neutron detection on a hard drive. The accuracy of the counter/timer is 12.5 ns and the total dead time of the system was 3.3 μs. It can be assumed that the dead time has no effect on the result since the time intervals taken into consideration were much longer than the dead time itself. When having all arrival times it is easy to calculate the time intervals between all events in a time window of width T and to put the result in a histogram with time bin dt. The histogram will obey Equation (1).

The count rate of each experiment could be determined with very high accuracy, simply by dividing the number of events with the measurement time. Therefore, the histograms were normalized to the count rate and, thereby, the fitting parameters were reduced from three to two:

$$p(t) = A * \mathrm{Exp}[\alpha * t] + 1 \qquad (1)$$

Moreover, in this way Rossi-α histograms from different measurements can be compared with each other. Results are displayed in Figure 3-2 and Figure 3-3.

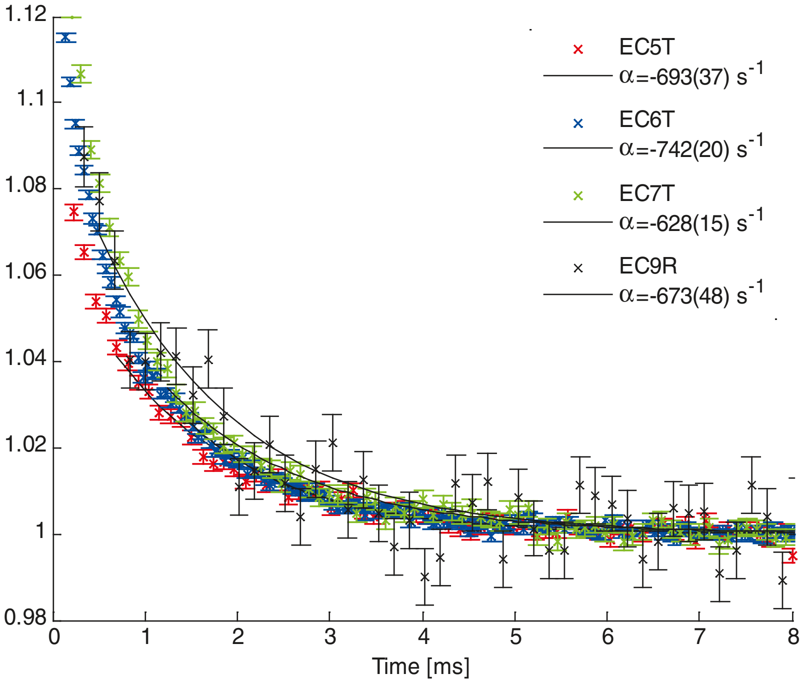

Figure 3-2. *Results for the 1132-configuration.*

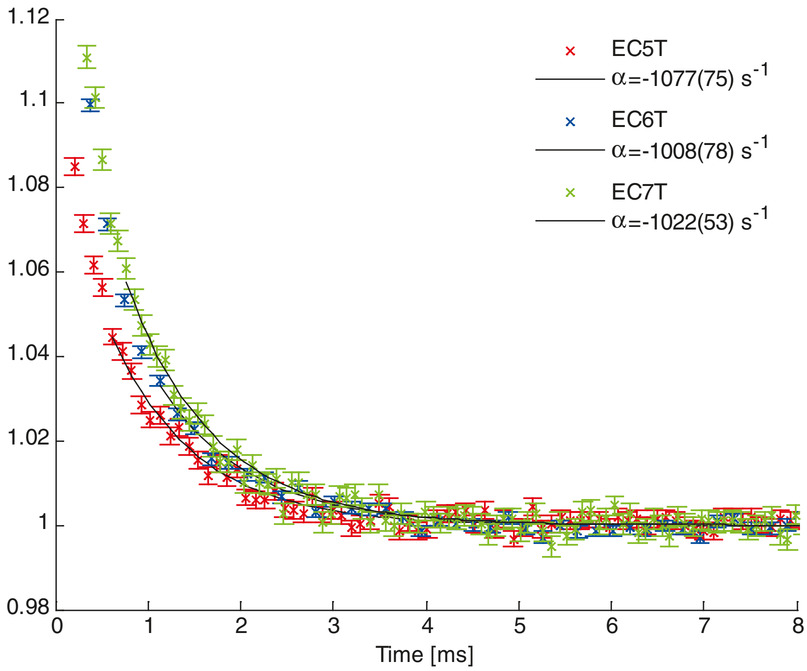

Figure 3-3. *Results for the 1061-configuration.*

3.2 IAEA benchmark

The YALINA-Booster facility will be extensively analysed by simulations since it will be a part of the IAEA initiative "Analytical and Experimental Benchmark Analysis of Accelerator Driven Systems". The benchmark specification was created in cooperation with the Joint Institute of Power and Nuclear Engineering in Minsk and Argonne National Laboratory in Chicago, with KTH being thee main editor. The benchmark document is given as an appendix. The benchmark will be running 2007–2009.

3.3 Proton induced spallation

During a visit at the Institute of Theoretical and Experimental Physics (ITEP) in Moscow, Russia, some collaborative work was initiated. KTH performed some MCNPX calculations for their experiment. This work is under publication process.

4 Fuel modelling

The work on thermochemical modelling of advanced fuel materials, suitable for transmutation of nuclear waste, has been given new impetus and is now being aligned with related efforts at other research groups in Europe (at ECN/NRG, ITU and CEA). This will include the migration of existing ALCHYMY database functions to a common software platform, increased focus on highly realistic phase descriptions and experimental determination of such thermodynamical parameters that are missing in literature. Our part of the work will chiefly concern CerMet and nitride fuels. Our new PhD student Odd Runevall will perform much of this work with Mikael Jolkkonen as supervisor.

5 Modelling of radiation damage

In previous years, much effort has been put into the modeling of FeCr alloys. During 2006, our research was extended to include investigations into diffusion in bcc materials. We have chosen Nb as a model bcc material since there exists a plenitude of experimental data for this element. Ab initio calculations of vacancy formation and activation energies have been performed within density functional theory (DFT). The results agree well with experimental data and we will continue our work with calculations of impurity formation and activation energies in Nb. If experimental values are well reproduced, the next step will be to continue investigations into the diffusive properties of bcc materials of nuclear reactor interest such as Fe and Cr and their alloys. The results will then be used in simulations of alloys under irradiation.

A new direction in our research is the calculation of thermodynamic quantities, other than the mixing enthalpy, in disordered FeCr. Specifically, the vibrational (phonon) mixing entropy and the electronic mixing entropy were calculated using firstprinciples methods. Figure 5-1 and 5-2 show the calculated vs experimental phonon dispersion curves and densities of states in the pure elements. The corresponding calculation in mixed FeCr show that the deviation from an ideal mixing law is appreciable, in qualitative agreement with experiments. This leads to a significant stabilization of disordered FeCr (lowering of the phase boundary), with direct implications for the temperatures and compositions at which embrittling alphaprime precipitation is expected during irradiation.

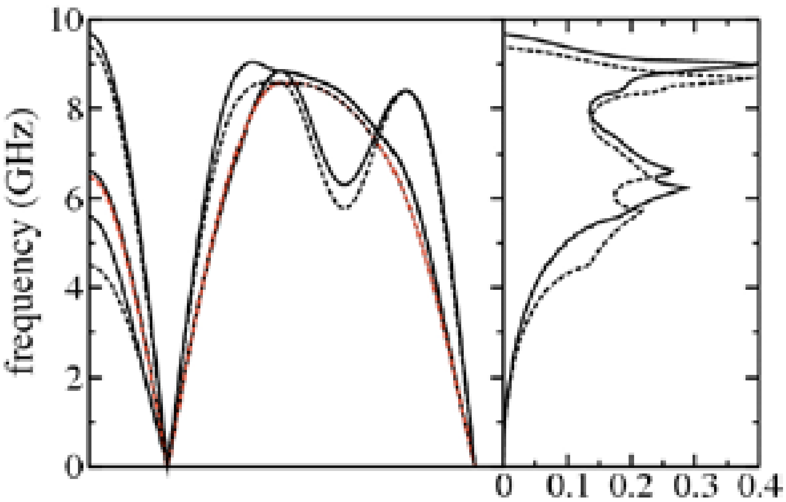

Figure 5-1. *Calculated (solid) and experimental (dashed) phonon dispersion curves and density of states in Fe.*

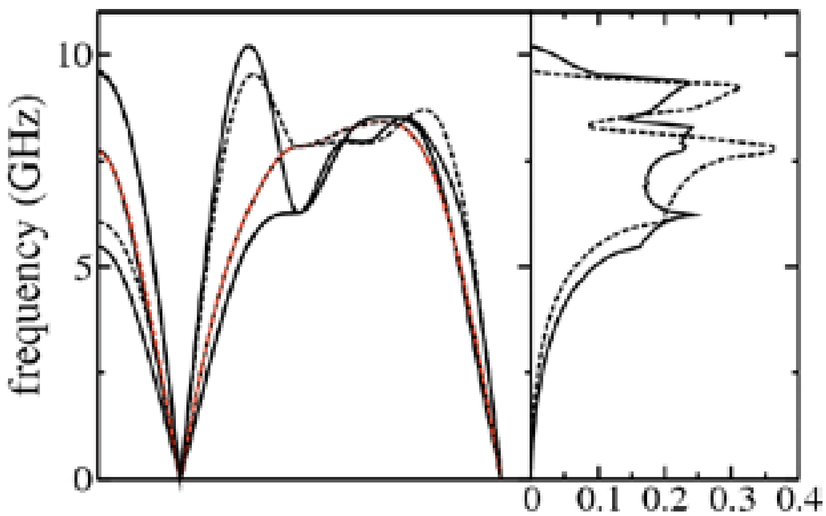

Figure 5-2. *Calculated (solid) and experimental (dashed) phonon dispersion curves and density of states in Cr.*

Another set of calculations were carried out in order to determine the solubility and diffusivity of C in Fe, Cr and mixed FeCr, see Figure 5-3. We find that dissolution and migration activation energies are all within 0.05 eV from the most reliable experimental data for bcc Fe and Cr. The effective interactions between Fe/C and Cr/C, to be incorporated in MD code, are currently being fitted.

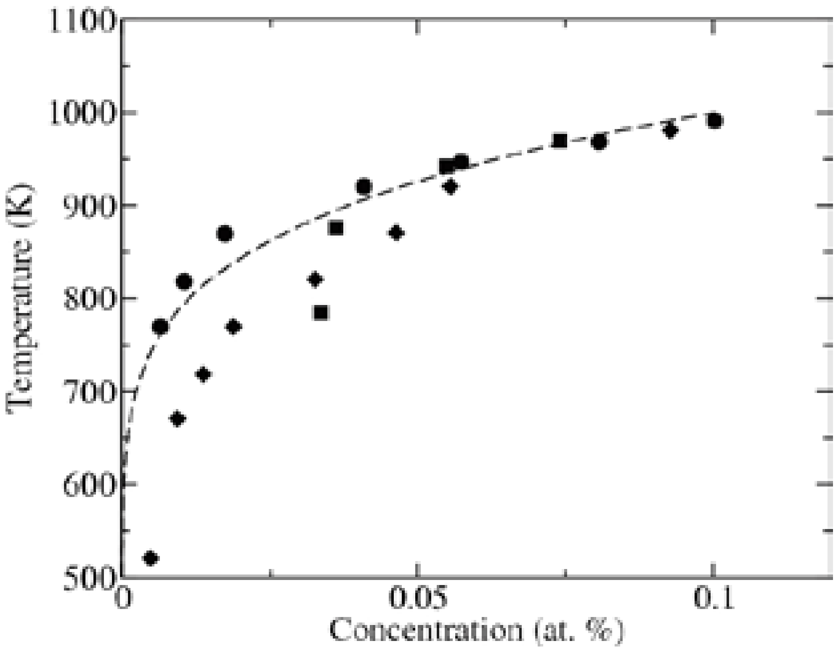

Figure 5-3. *Solubility limit of C in bcc Fe calculated according to an Arrhenius form with the activation energy taken from the present calculations and the prefactor roughly fitted. Experiments from various sources are included.*

6 Design of gas cooled accelerator driven systems

An extensive study of the potential for helium cooling of ADS has been performed over several years and was finalised during 2006. Two core designs have been published, out of which one, ”On TiN-particle fuel based helium-cooled transmutation systems”, was published in 2006 (14 August). A paper on proton source efficiency is also part of the work, as well as a comparison of helium and LBE-cooled systems in a full fuel cycle.

6.1 Source efficiency

The work on proton source efficiency in helium and LBE-cooled ADS was finalised during the spring of 2006. Our paper ”Source efficiency as function of fuel and coolant in accelerator-driven systems” was accepted for publication in Annals of nuclear energy on 17 March.

The main conclusions of the paper are that helium coolant yield a 10% higher proton source efficiency. Also the source efficiency differs by around 10% between standard MOX fuel and more exotic fuel with a higher minor actinide content. Both of these effects result from the presence of americium in the fuel.

6.2 Fuel cycle studies

Helium-cooling of subcritical transmutation cores yield harder neutron spectra than LBE-cooling. Consequently, more efficient minor actinide incineration may be achieved. Quantification of the statement requires detailed analysis of the fuel cycles for the two concepts though. This has been performed using the code Orion, developed by Nexia Solutions.

Three scenarios were examined:

1) PWR phase out with ADS, two subsequent generations of PWRs, phase out after 100 years, ADS employed to consume plutonium and the minor actinides.
2) Double strata, PWRs gradually replaced by fast reactors, ADS to burn actinindes.
3) Fast breeder economy, PWRs replaced by fast reactors as soon as the plutonium is made avaliable, closed fuel cycle for the fast reactors.

The two ADSs assumed was the helium cooled TiN-particle fuelled core developed within the helium-cooling project and a Spannish LBE-cooled core, which was also the reference ADS-core in the European comission project RedImpact. Unterweser in Germany served as model for the PWRs and the sodium cooled European Fast Reactor was assumed as the fast reactor.

In the phase out scenario, the curium inventory reach an equilibrium for the helium-cooled ADS already 23 years after its introduction. For the LBE-cooled ADS, equilibrium is not reached within the 60 year life-time of the core. This confirms the high transmutation efficiency achievable with helium as coolant. Figures 6-1 and 6-2 display the evolution of the curium inventories in the two cores.

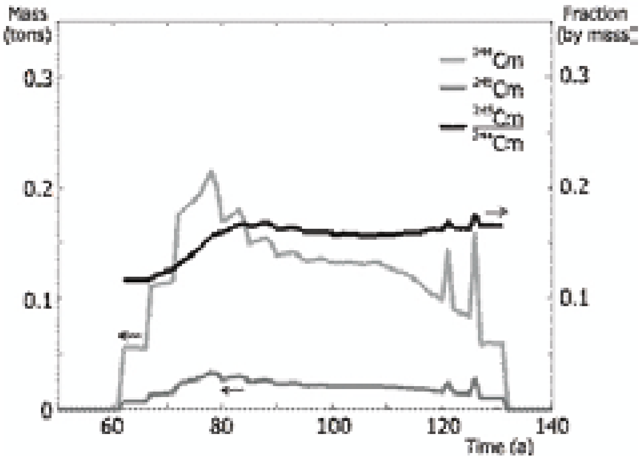

Figure 6-1. Evolution of the Cm inventory in the helium-cooled ADS operating in the phase out scenario.

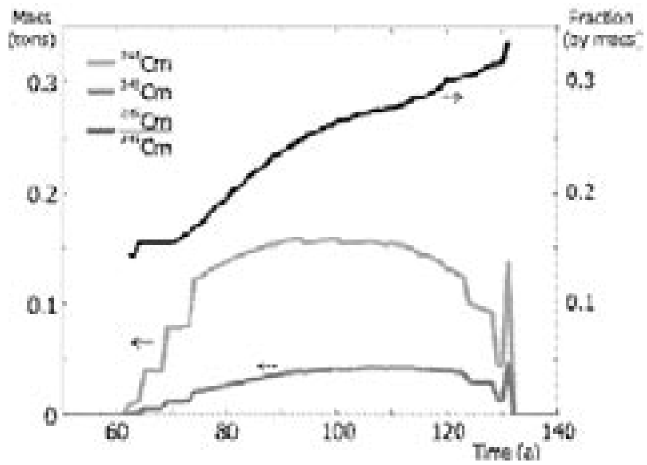

Figure 6-2. Evolution of the Cm inventory in the LBE-cooled ADS operating in the phase out scenario.

A main conclusion of the study is that in case fast reactor introduction is forseen, ADS is likely to have a very limited role. Figure 6-3 shows how the production of minor actinides in the fast reactors is smaller than the maximum amount that may be introduced in critical reactors. Consequently, there is room to transmute legacy wastes from the present park of thermal reactors in a future nuclear park with a large fraction of fast spectrum cores.

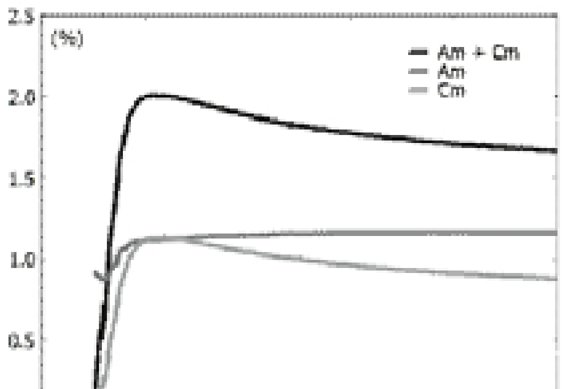

Figure 6-3. Americium and curium content of the fast reactor fuel in the fast reactor economy.

7 Scenario studies of partitioning and transmutation

A characteristic feature of the Swedish nuclear power programme, what regards the management of spent nuclear fuel, is interim storage for cooling and decay for about 30 years followed by direct disposal of the fuel in a geologic repository. In various contexts it is of interest to compare this strategy with other strategies that might be available in the future as a result of ongoing research and development. Several scenarios, which may be realized in Sweden, have been investigated. In particular partitioning and transmutation is one such strategy that is subject to considerable R&D-efforts within the European Union and in other countries with large nuclear programmes.

The following scenarios were studied by the help of a specially developed computer programme:

- Phase out with direct disposal.
- Burning plutonium and minor actinides as MOX in BWR.
- Burning plutonium and minor actinides as MOX in PWR.
- Burning plutonium and minor actinides in ADS.
- Combined LWR-MOX plus ADS.

As a general conclusion it was found that BWR is more efficient for burning plutonium in MOX fuel than PWR. The difference is approximately 10%. Furthermore the BWR produces about 10% less americium inventory.

An ADS reactor park can theoretically in an ideal case burn 99% of the transuranium isotopes. The duration of such a scenario heavily depends on the interim time needed for cooling the spent fuel before reprocessing. Assuming 10 years for cooling of nuclear fuel from ADS, the duration will be at least 200 years under optimistic technical assumptions. The development and use of advanced pyro-processing with an interim cooling time of only 2 years may decrease the duration for burning 99% of the transuranium to about 50 years. ADS reactors have turned out to be a necessary component to decrease the americium inventory because neither BWR nor PWR alone can provide prevalence of americium destruction over its production during the operation time. Nevertheless, the economic advisability of these scenarios calls for further investigation.

A scenario using in total six ADS reactors during a 100 year period from 2035 to 2135 is analysed in some detail. It would reduce the TRU-inventory projected from the current LWRs from about 100 tonnes in 2025 to about 6 tonnes in 2135. The ADS reactors would produce on the average 840 MWe giving in total some 740 TWhe of electricity during the 100 year period. The costs for the system are assessed to about 95 GSEK for investments and about 62 GSEK for fuel cycle costs. All these numbers depend on some optimistic assumptions concerning ongoing technical development. They are thus subject to large uncertainties.

In addition, a combination of LWR-MOX plus ADS has been found somewhat more efficient in reducing the transuranium inventory than ADS alone.

In what follows, several interesting plots from /Dufek06/ are presented. For example, plutonium inventory from the Swedish nuclear power programme was calculated as shown in Figure 7-1.

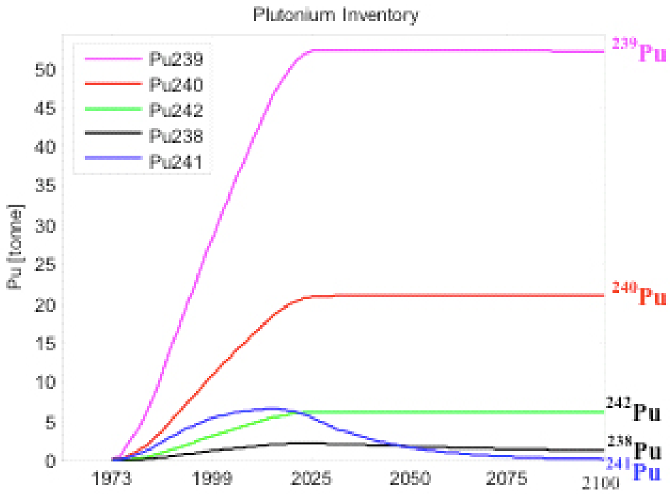

Figure 7-1. *Total inventory of plutonium isotopes in the spent fuel from the Swedish reactors in the Phase-out scenario.*

Minor actinides inventory from the Swedish nuclear power programme was calculated as shown in Figure 7-2.

The next picture, Figure 7-3, shows that if the ADS waste is cooled for at least 2 years then the plutonium inventory can be reduced from 78.3 tons (in 2035) to 16.0 tons, which gives a better performance than burning plutonium in the MOX fuel.

Figure 7-4 shows the americium inventory which is always reduced in ADS whereas is increased by burning MOX fuel. The thermal reactors (BWR and PWR) change a considerable amount of plutonium into americium, which is partially the reason why BWRs can so efficiently decrease the plutonium inventory using the MOX fuel.

Figure 7-5 shows that if the ADS waste is cooled at most 2 years then the TRU inventory can be decreased from 100 tons to approximately 20 tons during 50 years in ADS units of constant thermal power of 4,700 MW. Moreover the remaining TRU inventory can still be reduced later with smaller size ADS afterwards.

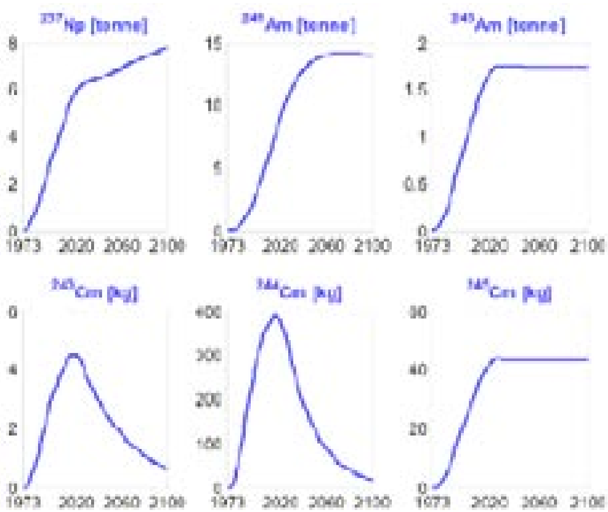

Figure 7-2. *Inventory of minor actinides in the spent fuel from the Swedish reactors in the Phase-out scenario.*

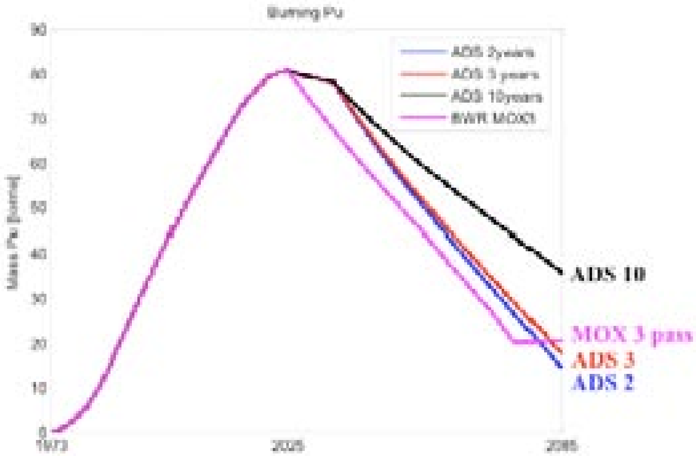

Figure 7-3. *Burning Pu: 3 pass MOX reactor vs. ADS units with 2, 3 and 10 years of fuel recycling.*

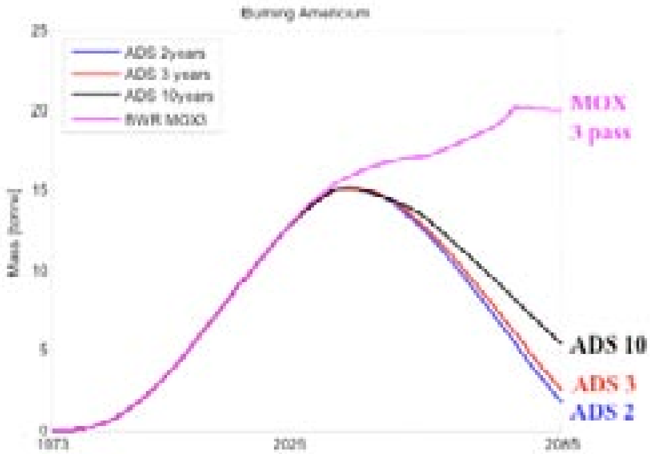

Figure 7-4. *Burning Am: 3 pass MOX reactor vs. ADS units with 2, 3 and 10 years of fuel recycling.*

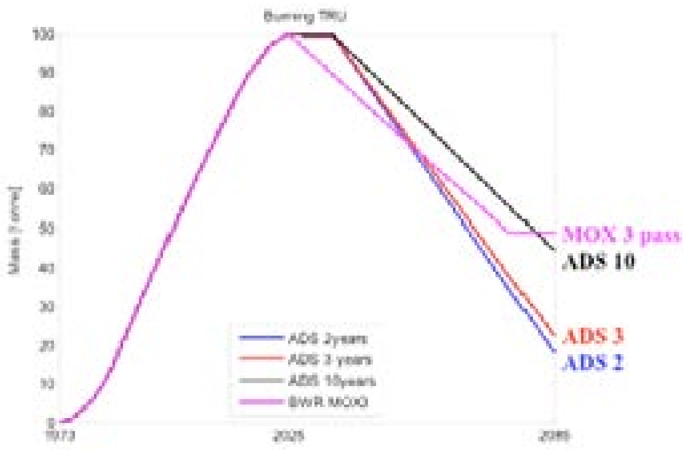

Figure 7-5. *Burning TRU: 3 pass MOX reactor vs. ADS units with 2, 3 and 10 years of fuel recycling.*

Far more details, regarding various scenarios, their characteristics, comparison, cost evaluation and so on, are found in the report SKB Rapport R-06-61 /Dufek 2006/.

8 List of publications

Bournos V, et al. 2007. YALINA-Booster Benchmark Specifications for the IAEA Coordinated Research Projects on Analytical and Experimental Benchmark Analysis on Accelerator Driven Systems, and Low Enriched Uranium Fuel Utilization in Accelerator Driven Sub-Critical Assembly Systems. IAEA, January 2007.

Dufek J, Arzhanov V, Gudowski W, 2006. Nuclear Spent Fuel Management Scenarios. Status and Assessment Report, SKB Rapport R-06-61, Svensk Kärnbränslehantering AB.

Fokov Y, Persson CM, 2006. Subcriticality Monitoring in ADS – the Yalina Experiments, Proceedings of the International Youth Nuclear Congress, Stockholm, Sweden – Olkiluoto, Finland, 18–23 June 2006.

Nordlund K, Wallenius J, Malerba L, 2006. Molecular dynamics simulations of threshold energies in Fe. Nuclear Instruments and Methods in Physics Research B 246, 322.

Olsson P, Abrikosov I, Wallenius J, 2006. Electronic origin of anomalous stability of Fe rich bcc Fe-Cr alloys. Physical Review B 73 (2006) 104416.

Olsson P, Domain C, Wallenius J, 2007. Ab initio study of Cr interactions with point defects in bcc Fe. Physical Review B 75 014110 (2007).

Terentyev D, Malerba L, Chakarova R, Nordlund K, Olsson P, Rieth M, Wallenius J, 2006. Displacement cascades in Fe-Cr: A molecular dynamics study. Journal of Nuclear Materials 349 (2006) 119.

Terentyev D, Lagerstedt C, Olsson P, Nordlund K, Wallenius J, Becquart CS, Malerba L, 2006. Effect of the interatomic potential on the features of displacement cascades in a-Fe: A molecular dynamics study. Journal of Nuclear Materials 351 (2006) 65.

Titarenko Yu E, Batyaev V F, Lipatoy K A, Titarenko A Yu, Butko M A, Pavlov K V, Mashnik S G, Ignatyuk A V, Titarenko N N, Gudowski W, Těšinsky M, Persson C-M L, Abderrahim H Ait, Kumawat H, Duarte H, 2008. Cross-sections for nuclide production in ^{56}Fe target irradiated by 350, 500, 750, 1000, 1500 and 2600 MeV protons as compared with the data on hydrogen target irradiated by 350, 500, 750, 1000 and 1500 MeV/nucleon ^{56}Fe ions, submitted for publication. Los Alamos Report, LA-UR-08-2219, Los Alamos National Laboratory (2008).

Tucek K, Jolkkonen M, Wallenius J, Gudowski W, 2007. Studies of an accelerator-driven transuranium burner with hafnium based inert matrix fuel. Nuclear Technology 157 (2007) 277.

Wallenius J, Olsson P, Malerba L, Terentyev D, 2007. Simulation of thermal ageing and radiation damage in Fe-Cr. Nuclear instruments and methods in physics research B 255 (2007) 68.

Westlén D, Wallenius J, 2006a. Neutronic and safety aspects of a gas-cooled sub-critical core for minor actinide transmutation. Nuclear Technology 154 (2006) 41.

Westlén D, Wallenius J, 2006b. On TiN-particle Fuel Based Helium-Cooled Transmutation Systems, Annals of Nuclear Energy, 33, 1322–1328 (2006).

Westlén D, Seltborg P, 2006. Source Efficiency as Function of Fuel and Coolant in Accelerator-Driven Systems, Annals of Nuclear Energy 33, 829–836 (2006).

9 List of participation in conferences and project meetings

Mikael Jolkkonen

- Genoa, Italy, Sepember 20–24 (ELSY kick-off meeting).
- Lyons, France, October 10–12 (EUROTRANS WP 1.5 safety meeting).

Calle Persson

- EUROTRANS, ECATS-meeting in Karlsruhe, Germany, Januray 31–February 1.
- EUROTRANS, ECATS-meeting in Cadarache, France, March 7–9.
- Participation in the ERANOS Workshop in Cadarache, France, May 28–June 3.
- Experiments in Minsk, Belarus, June 6–16.
- Meeting on the minimization of Highly Enriched Uranium in the civilian sector, Oslo, Norway, June 17–19.
- Participation in the International Youth Nuclear Congress in Stockholm and Olkiluoto, June 18–23.
- Participation in the World Nuclear University Summer Institute held in Stockholm and France, July 8–August 18.
- IAEA Technical Meeting on "The use of low enriched uranium for ADS experiments", Vienna, Austria, November 5–9.
- ITEP (Institute of Teoretical and Experimental Physics), Moscow, Russia, February 3–11. Preparation of YALINA-Booster experiments to be performed during 2006 and helping with calculations.
- Beijing and Shanghai, China, April 3–14. Preparation of student reactor exercises and technical visits.
- Trip to Japan with the Young Generation Network, November 11–25.
- Trip with last year students to Mol, Belgium, December 3–9.

Nils Sandberg

- Fe-Cr workshop in Oxford, UK, March 20–21.
- Fe-Cr workshop, Helsinki, Finland, August 28–29.

Janne Wallenius

- Fe-Cr topical day in Mol, Belgium, February 21.
- EUROTRANS WP1.5 meeting in Brussels, Belgium, March 17.
- Fe-Cr workshop in Oxford, UK, March 20–21.
- EUROTRANS AFTRA project meeting, Cadarache, France, April 4–5.
- EUROTRANS DEMETRA meeting, Karlsruhe, May 16–17.

- Public lecture, Dalarö, May 19.
- Fe-Cr working meeting in Helsinki, Finland, May 29.
- EUROTRANS WP 1.5 meeting, Lyon, France, June 1.
- COSIRES conference, Richmond, USA, June 19–23.
- Asia-link summer school in Beijing & Harbin, China, July 9–23.
- Fe-Cr workshop, Helsinki, Finland, August 28–29.
- 9th Information Exchange Meeting on P&T, Nimes, France, September 25–29.
- EUROTRANS WP1.5 meeting in Lyon, France, October 10–11.
- EUROTRANS DM1 CC meeting in Lyon, France, October 12–13.
- EUROTRANS AFTRA meeting in Saclay, France, November 7–9.
- Lecture at Tallinn's technical university, Tallinn, Estonia, November 20.
- Generation IV and transmutation seminar, Helsinki, Finland, November 21.
- Fe-Cr working meeting, Edinburgh, UK, November 22–24.
- MATINÈ final meeting, Obninsk, Russia, December 4–7.

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- China, Beijing and Shanghai, preparing for student laboratory exercises in Beijing and study visits in the Shanghai area, 2006-04-03–2006-04-14.
- RedImpact meeting on transition scenarios in Paris, May 3.
- RedImpact semi annual meeting, Penrith, United Kingdom, June 5–7.
- Pateros kick off, Brussels, September 4.
- World Nuclear Association Symposium, London, September 6–8.
- RedImpact scenario discussion, Madrid, September 12.
- RedImpact working meeting, Brussels, October 9.
- Visit to Westinghouse, Västerås, October 24.
- Uranium seminar, Helsinki, November 3.
- RedImpact semi annual meeting, Gorleben, Germany, November 27–29.
- Work with the Orion code at Nexia, Sellafield, November 30–December 1.
- Laboratory exercises with the students, Mol, Belgium, December 4–8.
- Work with the Orion code at Nexia, Sellafield, December 11–14.