International Atomic Energy Agency

Meeting Report

Consultancy to "Review the Supplementary Analysis of Stages 1 and 2 of the IAEA CRP on the 'Use of Thorium-based Fuel Cycle in Accelerator Driven Systems (ADS) to Incinerate Plutonium and to Reduce Long-term Waste Toxicities', and to Elaborate Stage 3 of this CRP as an Analytical and Experimental Study of the ADS Simulator", held in Minsk, Belarus, from 10 - 11 July 2000 (622-I3-CT-04864)

Work done

The consultancy was held at the "SOSNY" State Scientific and Technical Centre, Academy of Sciences of Belarus, Minsk, from 10 to 11 July 2000.

Experts from the State Scientific and Technical Centre "SOSNY" of the Academy of Sciences of Belarus are actively participating in the Agency's activities on Accelerator Driven Systems (ADS), in particular in the Co-ordinated Research Project (CRP) on the "Use of Thorium-based Fuel Cycle in Accelerator Driven Systems (ADS) to Incinerate Plutonium and to Reduce Long-term Waste Toxicities". Recently, S. Chigrinov, Director "SOSNY", as Chief Scientific Investigator of the Belarus Research Contract within the framework of the mentioned CRP, proposed to include the analytical and experimental ADS simulator study "YALINA", planned within the framework of the ISTC project #B70, into the work scope of the last stage of the current CRP as well as of possible future ones. The participants in the last Research Co-ordination Meeting (RCM) of the CRP held in Vienna from 8 to 10 November 1999 recommended adopting the "SOSNY" proposal. It was also agreed to conduct a special consultancy to elaborate the precise specifications (experimental set-up, measurement programme), work scope and tasks linked to this proposal.

On the other hand, a comprehensive review of the first two stages of the CRP (concluded in 1999) which was undertaken at the mentioned RCM lead to the conclusion that, prior to issuing the final report, more in depth analyses of the results of these stages were necessary. At the same time, along with the "SOSNY" proposal, some other suggestions for stage 3 of the CRP were made and the initiation of some preparatory studies was decided upon.

Summarising, the purpose of the consultancy held at the "SOSNY" State Scientific and Technical Centre, Academy of Sciences of Belarus, Minsk, from 10 to 11 July 2000 was to finalize all the actions decided at the last RCM of the CRP. In particular:

- to approve the final draft reports of the first two stages of the CRP taking into account the latest revised/updated results;
- to agree on supplementary studies for a "detailed burn-up benchmark" as part of stage three of the CRP;
- to discuss the results of the "blind study" defined in view of the "YALINA" experiment;

– to agree on the specifications of the "YALINA" experimental programme (i.e. finalize the analytical and experimental work scope and tasks related to the thermal ADS simulators being set up at "SOSNY").

On 10 July 2000, after the welcome by the "SOSNY" directors (Messrs. Salnikov and Chigrinov), A. Stanculescu presented the objectives of the meeting and introduced the Agency's project "Technology Advances in Fast Reactors and Accelerator Driven Systems for Actinide and Long-lived Fission Product Transmutation". There were individual presentations by participants summarising the revised results of the stages 1 and 2 of the CRP. The final draft of the reports of these stages was discussed.

On 11 July 2000, stage 3 activities of the CRP were discussed, in particular the specifications of the "YALINA" experimental study (experimental setup, measurement programme, benchmark calculations). Finally, an extensive technical visit and inspection of the "YALINA" facility took place.

Results achieved

The following procedure to finalize the report of the first two CRP stages was agreed upon:

– The final report will draw on the existing draft material. In addition, a "Analysis/Summary/Conclusions" section will discuss the results, point out discrepancies and their interpretation/explanation. Proposals for this "Analysis/Summary/Conclusions" section will be prepared by E. Gonzales, Y. Kadi, H. Klippel, W. Gudowski and C. Broeders and sent **not later than 15 September 2000** to I. Slessarev. W. Gudowski will also perform additional Monte Carlo calculations.
– Slessarev and Y. Kadi will perform the final analysis of the contributions received and issue the first draft of the complete report (including the "Analysis/Summary/Conclusions" section) **not later than 15 October 2000**.
– The report will contain Annexes to be sent electronically to A. Stanculescu by E. Gonzales, Y. Kadi, H. Klippel, I. Slessarev and W. Gudowski (**as soon as possible**). The final editing of the report (draft prepared by I. Slessarev and Y. Kadi plus Annexes) will be performed by A. Stanculescu.

As regards contributions to the "Broeders proposal" (stage 3.1) only H. Klippel and C. Broeders produced results. H. Klippel encountered difficulties (criticality increases) and aborted the analysis. It was decided that H. Klippel will distribute his MCNP input **as soon as possible** to C. Broeders, W. Gudowski, Y. Kadi, E. Gonzales and V. Korobeinikov who will perform the calculations and send their results to C. Broeders **not later than 15 October 2000**.

G. G. Kulikov (MEPhI and ISTC) presented the results of a study performed with A. N. Shmelev on "Ultra Long-life LWR with Thorium-based Fuel". This concept is based on ^{231} Pa containing fuel. Fuel doped with this burnable poison could lead to LWR cores having residence times up to 40 years. The link to ADS is given by the fact that hybrid systems could be used to produce, in the sub-critical blanket, ^{231}Pa from ^{232}Th (via (n,2n) and (n,3n) reactions). An ISTC project proposal will be prepared on this subject. The Agency will be approached by MEPhI to provide an opinion on the technical content of this proposal. Parties interested to collaborate in this project should contact G. G. Kulikov.

M. Hron (Nuclear Research Institute Rez) and K. Matejka (Czech Technical University Prague) briefly presented the experimental programme which has been under preparation in the Czech Republic within the framework of a molten salt systems oriented project. The description of

the training reactor VR-1 being operated at the Czech Technical University in Prague was given. The experiments so far realised were also briefly introduced, and the current status of the experimental devices as well as the experimental programme with fluoride salts containing assemblies was described in detail. The experiments planned to be realised in the nearest future are:

- reactivity changes caused by graphite and NaF,
- basic critical experiment with cores containing a central graphite block with an empty hole or the hole filled with NaF,
- preparation of the "25 block" blanket containing graphite, NaF and fuel pins of the EK-10 type,
- preparation and realisation of basic critical experiment with the core containing central "25 block" blanket,
- oscillation measurements in the same cores as above.

It was proposed to consider for the future ADS-related IAEA CRPs the analyses of these and other molten salt system experiments.

The first stage of the experimental programme performed in the "YALINA" sub-critical facility (a thermal neutron sub-critical core driven by a powerful D-D or D-T neutron generator) being set-up under ISTC Project # B70 has been incorporated into the CRP on "Use of Th-based Fuel Cycle in Accelerator Driven Systems to Incinerate Plutonium and to Reduce Long-term Waste Toxicities". This CRP gives the opportunity to widen the international participation in benchmarking and validation activities based on a well-defined and refined experiment

Preparatory Monte Carlo simulations ("blind calculations") of the "YALINA" experimental set-up have been performed on the basis of the specifications distributed by S. Chigrinov. The participants appreciated the convenient formulation of the benchmark and the distribution of the complete geometry and source specifications in the form of a MCNP input file that could be directly checked and used. The calculations concentrated on the definition of the reference configuration for the requested keff values, the source neutron multiplication and the source efficiency for these configurations (i.e., taking into account the three different sources Cf, D-D and D-T). Additional calculations on the effect of fuel pin removal, reaction rates and the spatial distribution of the neutron flux were also performed.

The results based on MCNP 4b and MCNP 4c with ENDF/B-VI.4 and ENDF/B-VI.6, respectively, agree for the main parameters. Calculations with EA-MC and MCNP 4b using mainly JENDL3.2 libraries show larger reactivity values (+500 pcm), whereas MCNP 4c including unresolved resonance treatment with probability tables show better agreement among the different data libraries used. Some apparent differences were found between ksource and ϕ^*, mainly due to different definitions and simulation conditions (KCODE vs. source calculations, i.e., eigenvalue vs. ksource calculation).

The participants in the meeting appreciated the opportunity to visit the experimental facility. This provided valuable insights into the details of the set-up and the applied measurement techniques. The experimental data acquired since the beginning of the experiment in May 2000 were presented. Detailed descriptions of the following measurements were given: keff and ksource for different fuel loadings, neutron flux spatial distributions, reaction rates at different detector positions, and preliminary noise analyses. The keff and ksource measurements were performed in static and dynamic modes, respectively (continuous and pulse modes).

Preliminary comparisons indicate already at this level satisfactory agreement between measured and calculated criticality as a function of fuel loadings. These preliminary results and comparisons presented during the meeting are already of great interest for the participating parties.

The recommendations and conclusions regarding both the future experimental activities and the benchmark formulation can be summarised as follows:

- All participants agreed that the reference configuration would be based on a 280 rods symmetric loading. Action **on S. Chigrinov** to provide **by the end of July 2000 a new detailed geometry description of this configuration** (use extensively comments in the input file!)
- Slightly modified loadings for the configurations with keff equal to approximately 0.90 and 0.95, having 216 and 245 rods, respectively, were decided**. The completely defined geometry models for these cases will also be provided by S. Chigrinov**.
- The benchmark objectives will be focused as much as possible on directly measurable parameters (e.g., counting rates for specified detectors).
- Reactivity worth measurements will be simulated by direct and perturbation calculations of fuel rod replacement experiments (for Cf, D-D and D-T cases). One, two and four rods located in different positions will be removed. **S. Chigrinov will provide the exact locations of these rods**.
- Ksource is to be calculated from the net multiplication of every source neutron.
- When calculating reaction rate distributions appropriate cross section weighting functions or, whenever possible, detailed descriptions of the detectors will be used.
- **S. Chigrinov will provide the data and experimental set-up for the calibration of the detectors**.
- As regards the benchmark specifications, the following additional information is needed:
  - source intensities
  - for the time evolution calculation, specify whether the delayed neutrons are included or not, as well as the time step and the time intervals for the presentation of the results
  - PHI* evaluation from ksource and directly measurable parameters.
- MCNP 4c simulations, including the perturbation option, should be verified for unresolved resonance treatment (action upon **W. Gudowski**).
- All numerical results should state the associated uncertainties.
- The **modified benchmark specifications** ("recommended parameters for inter-comparison") will be **distributed by S. Chigrinov together with the model descriptions**.
- S. Chigrinov will provide the list of the equipment/samples needed to improve the quality of the experimental results, as well as the list of possible problems encountered in the implementation of the experimental programme.
- S. Chigrinov will provide the time schedule of the experimental programme.

Conclusions

The conclusions from this working meeting and the visit to the actual experimental facility are that this experiment is able to deliver valuable data in the following fields:

- investigation of physics of the sub-critical systems driven by a neutron generator,
- measurements of transmutation rates of the fission products and minor actinides,
- investigation of spatial kinetics of the sub-critical systems with the external neutron sources,
- validation of the experimental techniques for, e.g., sub-criticality monitoring, neutron spectra measurement, etc

– investigation of dynamics characteristics of the sub-critical systems with the external neutron sources in pulse mode of the neutron generator operation.

The "YALINA" set-up is considered by the experts to be an important experiment having the potential to resolve some of the existing discrepancies in the simulation of sub-critical systems, and to give an indication on the quality of widely used evaluated nuclear data libraries. Moreover, it can also serve as an experimental facility for benchmarking and/or validating Monte Carlo perturbation modules. Such a validation is an important and urgent task for the extensively used MCNP 4b and MCNP 4c codes.

The experimental programme of the "YALINA" facility has a high degree of complementarity to the other European activities in the field of accelerator driven systems, transmutation and partitioning, particularly to the MUSE experiment being performed at Cadarache (MASURCA facility) as part of the 5th Framework Programme of the European Union.

Recommendations

The experts in the consultancy reached agreement on deadlines and assignments for the final drafting of the stage 1 and 2 report of the IAEA CRP on the "Use of Thorium-based Fuel Cycle in Accelerator Driven Systems (ADS) to Incinerate Plutonium and to Reduce Long-term Waste Toxicities". The results of the "blind" calculations of the "YALINA" thermal ADS simulator experiment were compared, understanding of discrepancies achieved the detailed specifications of the experiment as well as the work plan for stage 3 of the CRP finalized. It was recommended to fully integrate the current CRP and the future ones into the IAEA project "Technology Advances in Fast Reactors and Accelerator Driven Systems for Actinide and Long-lived Fission Product Transmutation".

The experts in the consultancy recommended new tasks to be included in the experimental programme of the "YALINA" facility. These new tasks require more experiments to be performed, new equipment to be installed around the sub-critical core and consequently require a prolongation of the project. Western collaborators in the ISTC project #B70 (Gonzales, Kadi and Gudowski) offered also experimental help in the form of a sophisticated data acquisition system and other hardware, which can be borrowed for the experiments in "YALINA".

It was strongly recommended to maintain and strengthen the link between, on the one side, IAEA's present and future CRPs and, on the other side, the "YALINA" experimental programme.