Review Paper

European Fast Neutron Transmutation Reactor Projects (MYRRHA / XT-ADS)

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Abstract. The main focus of the Satellite Meeting was on the European projects implemented in the area of fast-fission reactor concepts and fuel cycles that offer the flexibility needed to contribute decisively towards solving the problem of growing "spent" fuel inventories by utilizing fissionable isotopes and greatly reducing the volume of high-level waste that ultimately must be disposed of in long-term repositories.

1. Introduction

According to the projections published by the Intergovernmental Panel on Climate Change, the median electricity increase till 2050 will be by a factor of almost 5. It is reasonable to assume that nuclear energy will play a role in meeting this demand growth. However, there are four major challenges facing the long-term development of nuclear energy as a part of the world's energy mix: improvement of the economic competitiveness, meeting increasingly stringent safety requirements, adhering to the criteria of sustainable development, and public acceptability. Issues linked to meeting the sustainability criteria define the scope of this Satellite Meeting.

While not involving the large quantities of gaseous products and toxic solid wastes associated with fossil fuels, radioactive waste disposal is today's dominant public acceptance issue. In fact, small waste quantities permit a rigorous confinement strategy, and mined geological disposal is the strategy followed by some countries. Nevertheless, public opposition arguing that this does not yet constitute a safe disposal technology has largely stalled these efforts. One of the primary reasons that are cited is the long life of many of the radioisotopes generated from fission. This concern has led to increased research and technology development efforts to establish a technology aimed at reducing the amount of long lived radioactive waste through transmutation in fission reactors or hybrid systems like the Accelerator Driven System (ADS).

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2. Summary of the satellite meeting

The Meeting has been divided into first a series of invited papers, and then a round table to facilitate the discussion and agreement on conclusions and recommendations. Hamid Aït Abderrahim, Director of the Advanced Nuclear Systems and MYRRHA Project Leader (SCK•CEN) and Didier De Bruyn, MYRRHA Project coordinator (SCK•CEN) have chaired the meeting.

After a brief introduction by Hamid Aït Abderrahim, Didier De Bruyn in his first talk "From MYRRHA to XT-ADS: lessons learned and towards implementation" described the evolution of the MYRRHA project from an internal SCK•CEN project to the small-scale XT-ADS facility, currently under study within the integrated EUROTRANS project in the 6th Euratom Framework Programme. Several lessons were learned from this evolution: the size of the plant has increased and several internals have been simplified, but the main MYRRHA design assumptions have been confirmed. Starting from the present XT-ADS design, conclusions can also be drawn for future developments.

Luigi Mansani (ANSALDO NUCLEARE) showed in his talk "XT-ADS & EFIT: two machines not so different for the same goal" that despite having different objectives (demo facility versus industrial transmuter), sizes (50 – 100 MWth versus 400 MWth), time frames (2020 versus 2040) and maturity levels of design (detailed versus conceptual), the two machines still have common characteristics. Among others, one can mention the accelerator type (LINAC), the beam line entry from the top of the reactor, the windowless target, the integrated primary system, and the remote fuel handling. For diverging characteristics, the rationale behind the choice was presented and clearly justified.

Gert Van den Eynde (SCK•CEN) presented "The XT-ADS core design". The constraints under which the design of the core of XT-ADS is done are quite strict: use existing technology as much as possible. Also, the design did not start from scratch: SCK•CEN offered the preliminary design of MYRRHA as a starting point for the XT-ADS. Some major design options for XT-ADS are the fuel, the choice of coolant and inlet/outlet temperatures, as well as the core geometry. The core is fuelled with MOX (albeit with a high plutonium enrichment), and not with an innovative minor actinide fuel. A series of modifications have occurred in fuel pin and fuel assembly designs. A reference core configuration has been calculated. The damage caused by neutron irradiation on some components (core barrel, core support plate) was the driving force behind these significant changes. An in-depth analysis of the XT-ADS irradiation capabilities was also presented.

"The reliability requirements of the XT-ADS and EFIT accelerator" was presented by Alex Mueller (CNRS). An ADS for transmutation of spent nuclear fuel typically requires a 600 MeV - 1 GeV accelerator delivering a proton flux of a few mA for demonstrators (like XT-ADS), and a few tens of mA for large industrial systems (like EFIT). Such a machine belongs to the category of high-power proton accelerators, with an additional requirement for exceptional "reliability", as the number of unwanted "beam-trips" should not exceed a few per year, which is a requirement that is far above usual performance. To reach such reliability levels, several guidelines have been followed during the conceptual design phase of the ADS accelerator. Dedicated R&D is performed on this topic within the EUROTRANS programme, and the main results obtained so far were presented.

Antony Woaye-Hune (AREVA) described the "Feedback to the designers from research and from safety". Design activities were initiated at the very beginning of the EUROTRANS project, with R&D activities running in parallel. Once a first version of the design was obtained, the safety analyses could also start (most of the time at least one year after the start of the design work). Only at the very end of the project R&D results and safety calculations become available. Usually, there is no time window available to perform another complete iteration. Hence, at the end of the EUROTRANS project, the coordinator will provide a list of both the verified assumptions and the required modifications. The different assumptions made by the engineering teams were presented, as well as the possible consequences for the design, should those assumptions be inaccurate. Preliminary results from the materials studies and from the safety calculations were also summarized.

On behalf of Piet Van Duppen (University of Leuven) who could not attend the meeting, Alex Mueller then presented "ISOL@MYRRHA; an application of the MYRRHA accelerator for nuclear physics". In order to explore new research opportunities offered by the MYRRHA proton accelerator, a preparatory feasibility study was initiated within the framework of the "Belgian Research Initiative on eXotic nuclei" (BriX) network. This study investigates unique possibilities for fundamental research using high intensity proton beams. One of the possible interesting approaches for fundamental research using the 600 MeV proton accelerator is the installation of an Isotope Separator On-Line (ISOL) system to produce intense low-energy radioactive ion beams for experiments requiring very long beam times. From a technical point of view the ISOL@MYRRHA project will closely follow radioactive ion beam production schemes that are similar to those developed and successfully used at the ISOLDE-CERN (Switzerland) and TRIUMF (Canada) facilities. The prospects with ISOL@MYRRHA were discussed and a limited number of possible physics cases were presented.

The present status of "GUINEVERE: Construction of a Zero-power Lead Fast ADS at Mol" was then described by Annick Billebaud (CNRS). In the first place, GUINEVERE's objective is to construct a fast ADS mock-up (with fuel arranged in a lead array) at SCK•CEN for the purpose of ADS sub-criticality monitoring experiments. Beyond that, the project will support the design of a Transmutation Experimental Facility (MYRRHA/FASTEF). The existing VENUS reactor at SCK•CEN will therefore be coupled with a new GENEPI neutron source under construction by CNRS. The VENUS reactor core has been modified to be loaded with fuel assemblies (provided by CEA) made of enriched uranium and solid lead pins, and hold radial and axial lead reflectors. The new GENEPI-3C neutron source is designed to be operated in pulsed mode, but also in continuous mode to permit investigation of the current-to-flux reactivity indicator in conditions representative of a powerful ADS. The global planning was presented as well as already foreseen experimental programmes in the framework of fast transmutation system studies.

To close the first part of the meeting, Didier De Bruyn presented "The next step for MYRRHA: the Central Design Team FP7 project". SCK•CEN in association with eighteen European partners from industry, research centres and academia, responded to the second FP7 call to establish a Central Design Team for the design of a FAst Spectrum Transmutation Experimental Facility (FASTEF) able to demonstrate efficient transmutation and associated technologies on the basis of a nuclear fission system working in sub-critical and/or critical mode. The proposal has been accepted for funding and the project has started on 1 April 2009 for a period of three years. The objectives of FASTEF are three-fold:

(i) to provide a flexible high-flux fast spectrum irradiation facility;

(ii) to serve as a test-bed for transmutation by demonstrating both the ADS technology, and the efficient transmutation of high-level waste; and finally

(iii) to contribute to the demonstration of the Lead Fast Reactor technology without jeopardizing the first two first objectives. FASTEF will be designed to an advanced engineering level leading to a decision milestone at the horizon of 2012 whether to embark on its construction.

Finally, a round table discussion took place on the subject "The perspective of ADS development and rationale". Experts from various countries in the world could briefly describe their national or international programmes: Ved Bhatnagar for the European Commission, Haihong Xia for China, Pramod Nema for India, Eric Pitcher for the United States of America and Alex Mueller for Europe. A contribution from Japan (Hiroyuki Oigawa) was also received and transmitted to the audience.