Nuclear Fuel Cycle and Materials Technologies

Objective

To strengthen the capabilities of interested Member States for policy making, strategic planning, technology development and implementation of safe, reliable, economically efficient, proliferation resistant, environmentally sound and secure nuclear fuel cycle programmes.

Uranium Production Cycle and Environment

Accurate knowledge of uranium resources is essential for planning nuclear development activities and for analysing the potential role of nuclear power in the development of sustainable energy. The latest update of the biennial 'Red Book' — *Uranium 2005: Resources, Production and Demand* — was published jointly by the Agency and the OECD/NEA in 2006. Reviewing data from 43 countries, the results of the most recent world uranium market fundamentals were presented and a statistical profile of the world uranium industry as of 1 January 2005 was provided. In 2004, uranium production totalled 40 263 t, an increase of almost 12% over production in 2002 (Fig. 1).

The uranium market is uncertain in the medium term, due to limited information on available secondary supplies and on new uranium production centres. Secondary supplies are expected to decline in importance as stockpiles diminish. By 2015, reactor requirements will need to be met increasingly by the expansion of existing production capacity and by the development of additional production centres.

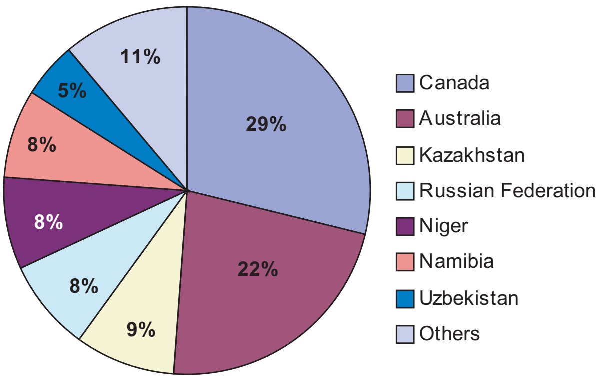

FIG. 1. Uranium production by country.

Uranium resources are adequate in the longer term. Approximately 4.7 million tonnes of conventional uranium can be mined for less than \$130/kg, which is sufficient, at the 2004 consumption rate, for 85 years. However, total world uranium resources are considered to be much higher. The recent rise in the spot price has led to increased exploration worldwide. A significant number of new mining projects have been announced that could substantially boost the world's uranium production capacity, and will be needed to meet demand.

The 2006 version of the 'Red Book' was the 21st edition of this important joint publication. To mark the anniversary, the OECD/NEA published *The Red Book Retrospective*, which analyses the key data and information in the first 20 editions of the 'Red Book' and gives a historical profile of the world uranium industry. Two general conclusions are that, historically, increased prices are rapidly followed by increased exploration, and that the ratio of identified resources to production has been fairly stable over the past 15–20 years, indicating that new resources are continuously found even when prices are low.

The increasing interest in uranium production increases the demand for skilled labour and for information. In this connection, the Agency organized four meetings on different aspects of uranium exploration and production, in Argentina, China, India and Kazakhstan. These meetings covered subjects such as aerial and ground geophysical techniques for uranium exploration, advanced mining and milling methods and equipment, in situ leaching of uranium deposits, mine remediation and environmental issues.

Nuclear Fuel Performance and Technology

To assist Member States in improving the utilization of nuclear fuel, several Agency activities in 2006 addressed increasing fuel burnup. A technical meeting reviewed the current performance of high burnup LWR fuel and discussed the technical and economic issues associated with even higher burnup, concluding that there is still some limited scope for extending fuel burnup with current technology. An important task is to enhance the predictive capability of codes used in modelling high burnup fuel behaviour. A second technical meeting considered the modelling of PHWR fuel, where there is a significant potential to increase burnup using slightly enriched uranium oxide fuel.

Changes in water chemistry can profoundly influence fuel oxidation rates and the migration of corrosion products from the steam generators to the fuel, where they can deposit as crud. As reactor performance increases and reactors age, the problem of controlling the water chemistry becomes ever more challenging. Optimization and control of water chemistry can help minimize problems with fuel oxidation and deposit buildup, and control operational exposure. A CRP was started in 2006 to study the influence of water chemistry parameters on fuel performance; Member States will be able to use the results to ensure that optimum water chemistry is specified for their nuclear reactors, ensuring safe and reliable generation of electricity.

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Delayed hydride cracking (DHC) of zirconium alloys is an important mechanism for reactor core materials degradation and failures. An earlier CRP dealt with zirconium materials for CANDU and RBMK pressure tubes. Work began in 2006 on a follow-up CRP with the objective of transferring experimental knowledge and establishing concerted testing procedures for DHC rates measurement in cladding tubes made of different zirconium alloys.

Management of Spent Fuel

Inventories of spent nuclear fuel are growing. By the end of 2004, approximately 280 000 tonnes of heavy metal (t HM) of spent fuel had been discharged globally. Roughly one third of this has been reprocessed, leaving about 190 000 t HM of spent fuel in storage. An increasing interest in reprocessing was seen in 2006, at least for the longer term.

In the area of spent fuel performance assessment and research, the Agency, in cooperation with the OECD/NEA, organized a conference on the management of spent fuel from nuclear power reactors. Held in Vienna in June, this conference addressed, among other things, emerging initiatives that may have a significant impact on future spent fuel management, such as the US Global Nuclear Energy Partnership (GNEP), the Russian Federation's Global Nuclear Power Infrastructure initiative, the French choices for the back end of the fuel cycle and the Indian plans for an advanced closed fuel cycle, anticipating significant growth in civilian nuclear power capacity. Sessions covered safety and technology issues connected to the storage of spent fuel for shorter or longer periods, in particular the trend away from wet storage to dry storage in containers. The conference concluded that spent fuel management is one of the more important factors influencing the future of nuclear energy, and that new initiatives, including recycling options, will be needed. Storage will remain a mature and safe interim solution, but continued follow-up is important as storage periods are extended. Irrespective of the fuel cycle option, geological disposal will eventually be required. It was also recognized that continued work is required to further develop safety standards, and more progress needs to be made in the framework of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, both in terms of ensuring wider adherence to it and in improving the process for its review.

Topical Advanced Nuclear Fuel Cycle Issues

In the area of high temperature gas cooled reactors (GCRs), the Agency held a technical meeting on the current status and future perspectives of GCR fuels. The meeting reviewed conventional and advanced fuel designs, fabrication technology, quality assurance and quality control, fuel irradiation qualification, fuel performance, fuel modelling and overall fuel cycle issues. The meeting recognized critical areas of work on GCR fuel — such as the generation of a new set of modern coated particle materials data, and pyro-carbon creep and shrinkage — that will assist in designing fuels with high fuel performance at high temperatures. In addition, the meeting emphasized the importance of preparing a

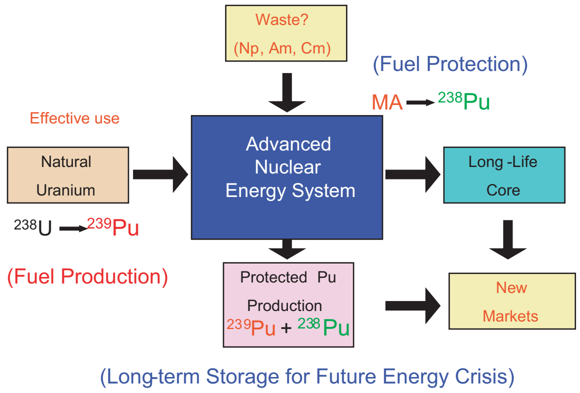

FIG. 2. Schematic of the P^3 concept (MA: minor actinides).

detailed waste management plan to facilitate future growth in the area of GCRs.

In evaluating the issue of proliferation resistance associated with different advanced fuel cycles, the Agency began work in 2006 on protected plutonium production (P^3) and utilization, in collaboration with the Tokyo Institute of Technology (Fig. 2). The P^3 concept aims to produce plutonium with higher proliferation resistance and to incinerate minor actinides. It involves the generation of a sufficient quantity of 'poison' plutonium-238 isotope by the transmutation of minor actinides that are intentionally added to fresh fuel. The addition to low enriched uranium (LEU) LWR fuel of a small amount (<1%) of neptunium-237 or americium-241 with a large neutron capture cross-section enhances the formation of plutonium-238 in spent fuel. The presence of the plutonium-238 isotope, which has very high spontaneous neutron release and high decay heat, makes nuclear weapons manufacturing and maintenance technologically difficult and reduces its usefulness as a weapon material. System studies are in progress on conceptual implementation of the P^3 model with different fuel cycle scenarios employing different advanced reactors and fuels.

Nuclear Fuel Cycle Information Systems

The Agency maintains a number of databases and simulation systems to support related Agency programmes and to provide Member States with reliable and up to date information on worldwide nuclear fuel cycle activities. The databases include the: Nuclear Fuel Cycle Information System; World Distribution of Uranium Deposits; Post-Irradiation Examination Facilities; Minor Actinide Property Database; and Nuclear Fuel Cycle Simulation System (VISTA). In 2006, a publication was issued describing the technical features of VISTA (IAEA-TECDOC-1535). ■