THE STATUS OF THE US ACCELERATOR TRANSMUTATION OF WASTE PROGRAMME

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Abstract

Since the last biannual meeting on partitioning and transmutation, the US accelerator transmutation of waste (ATW) programme has changed significantly. Two years ago, the only effort was the preparation of a research plan for developing ATW technology. Today, a significant research effort in underway, and the US is seeking opportunities to collaborate with other national programmes. Although the US fuel cycle is still based on a "once-through" process, with civilian spent fuel being stored for direct disposal in a geologic repository, the technical feasibility for transmutation is being investigated as a possible future option. Technetium-99, iodine-129 and neptunium-237 may be released from a repository over geologic time periods and are the principle radioisotopes for transmutation studies. Substantial reduction in total fissile materials and generation of useful energy are also possible benefits of ATW. New test facilities are being considered which may be useful for future multinational studies.

1. Introduction

Since the 5th Information Exchange Meeting in Mol, Belgium in November 1998, the US accelerator transmutation of waste (ATW) programme and indeed the US programme for chemical processing of spent fuel has undergone a substantial change. At the time of the Mol meeting, the US Congress had just authorised the preparation of a "roadmap" or programme plan for the development of ATW technology. The background provided by foreign transmutation programmes and commercial spent fuel reprocessing was an important part of the resulting roadmap which was published in late 1999 [1]. Based on that report, the US Congress provided $9 million in Fiscal Year 2000 (October 1, 1999-September 30, 2000) to establish an ATW research and development programme in the Office of Nuclear Energy, Science and Technology. Department of Energy appropriations for the current fiscal year (October 1, 2000 – September 30, 2001) include a substantial increase in ATW funding. The purpose of this paper is to describe the content of that programme and the status of the R&D effort.

2. The US civilian spent fuel management programme

The nuclear fuel cycle in the US is currently a once-through process. Spent fuel from the approximately 100 civilian nuclear power plants is being stored at the reactor sites with the intention of transporting it in the future to a central geologic repository for "permanent" disposal. However, any such repository, under current Nuclear Regulatory Commission requirements, must be designed to allow spent fuel retrieval for at least 50 years. The actual design of a proposed repository at Yucca Mountain, Nevada involves a retrieval capability for at least 100 years. Such retrieval is mainly for safety purposes, in the unlikely event that during performance monitoring, the repository or its contents develop significant problems.

Long term access to the contents of the repository also increases the probability of licensing, since some of the uncertainties about repository safety will be reduced during monitoring. Finally, retrievability offers the possibility that future generations may decide to recover the energy in the spent fuel (principally plutonium-239) and reduce the long half-life radioactivity in the waste through transmutation. Thus, the existence of a US programme for the development of a "once-through" geologic repository while at the same time studying the possibility of nuclear waste transmutation represents a consistent approach and provides technical flexibility. After all of the changes during the twentieth century, an allowance for future technologic advances in nuclear waste management is sound public policy.

The US Yucca Mountain project has reached a critical juncture. In December 2000, the Department of Energy is releasing to the public a Site Recommendation Consideration Report which provides interested parties with essentially all of the information which will provided in June 2001 to the President in a Site Recommendation Report. He will use the final version of the report as a basis for his decision on whether to recommend the Yucca Mountain site to Congress as one he feels meets the strict environmental and safety requirements for a permanent repository. If he does so decide, the Nuclear Waste Policy Act of 1992, as amended, provides an opportunity for the affected state (Nevada, in the case of Yucca Mountain) to object to the President's decision. Such an objection stands unless overridden by a majority of both the US Senate and the US House of Representatives. The technical content and persuasive arguments of the Site Recommendation Report will strongly influence such a Congressional override.

The Yucca Mountain site is arid. Its annual rainfall is only about 12 centimetres of rain, 95%

of which runs off or is evaporated rather than penetrating the mountain. That which does penetrate moves in unsaturated flow through cemented and uncemented volcanic rock about 300 meters before reaching the waste site and then another 300 meters before reaching saturation. The saturated zone under the proposed repository site then flows slowly toward Death Valley as part of a closed hydrology region. The water eventually evaporates in Death Valley rather than being connected with any regional river system such as the Colorado River. Approximately thirty miles from the Yucca Mountain site, there is some farming in Amargosa Valley which uses irrigation water from the same aquifer flowing toward death Valley. It is the safety of individuals in Amargosa Valley which will determine the acceptability and, if the site is found to be acceptable, the ability to license a possible Yucca Mountain repository.

The most important issues in the decision process will be the containment at the repository site of certain long-lived fission products and heavy elements within the high level nuclear waste. All past performance assessment studies of the Yucca Mountain site as a possible repository, including that reported in the Site Recommendation Consideration Report, have indicated that the dominant mobile radionuclides during the first 10 000 years of the repository life are technetium-99 (213 000 year half-life) and iodine-129 (15.7 million year half-life), both of which may be transported by underground water to points of possible human exposure. After approximately 100 000 years, the dominant isotope is neptunium- 237, with the possibility that plutonium isotopes may also be important if carried by colloids or if plutonium were present in the more soluble VI oxidation state. ^{99}Tc, ^{129}I and ^{237}Np (and other minor actinides) have been the focus of attention in US studies of transmutation. No transmutation evaluations have indicated that a repository programme will not be needed in the future; all such studies have shown that transmutation, if successful, could reduce the hazards of such repositories.

3. The current US transmutation programme

Transmutation R&D in the US initially has been focused on accelerator-driven systems and has involved a series of trade-off studies. In all cases, it has been assumed that uranium remaining in civilian spent fuel elements would be recovered, probably by a modified Purex process called UREX. Initial studies of the UREX process have shown that the uranium product will meet US Class C requirements and could be disposed of as low level waste or be stored for possible future use in a nuclear fuel cycle. The remaining process streams would be chemically separated into transmutation fuel material, long-lived fission product transmutation targets, and a waste stream that can be converted into durable waste forms capable of disposal in a high-level nuclear waste repository.

Various combinations of proton accelerator designs, spallation neutron sources, and transmutation target have been evaluated for technology readiness, and assumed irradiated targets have been studied for the effectiveness of chemical processing to recycle untransmuted long-lived isotopes. These evaluation have resulted in a base-line design which includes a linear proton accelerator (or Linac), a lead-bismuth spallation target, and sodium- cooled metallic or ceramic dispersion transmutation target/blanket non-fertile fuel elements. The initial formation of such non-fertile transmutation targets and their subsequent reprocessing is the subject of a paper to be presented later in this conference [2]. Other alternative designs have included cyclotrons, tungsten spallation targets cooled by sodium, pressurised helium, or water, and nitride transmutation targets.

Another interesting transmutation system design currently being evaluated consists of a "dual strata” approach which would involve a thermal critical reactor within which plutonium and minor actinides would fission and $^{99}Tc/^{129}I$ would be subjected to a thermal neutron flux. Technetium would probably be in metallic form and iodine as an iodide of sodium, silver or other stable cations. The thermal spectrum reactor would be an effective plutonium-239 burner along with other actinides with high thermal fission cross-sections. Higher actinide isotopes would be produced by non-fission neutron capture, and after post-irradiation chemical processing, they would be the primary targets of an accelerator-driven transmutation system. Chemical processing of such targets after irradiation would result in actinide recycle to the ATW unit and $^{99}Tc/^{129}I$ recycle to the thermal reactor. High-level waste streams for repository disposal would be produced by the initial processing of civilian spent fuel, the recycle processing of spent fuel from the thermal reactor, and the ATW recycle process.

Since transmutation produces a net energy gain, it has been of interest to design systems capable of producing electric power to off-set transmutation expenses. One concern has been the current high “trip” rate of present generation accelerators, which may experience several unplanned cut-offs each day. Quite apart from thermal shock safety considerations in the transmutation system, such interrupted power would have much lower value than conventional base-load systems. Early analysis indicates that more than ninety percent of the energy release in the “dual strata” would occur in the thermal reactor, so it may be possible to design the ATW system as a low-temperature actinide burner with much less stringent requirements for accelerator power and stability. Materials and corrosion problems in the ATW system would also be minimised. Studies of the concept are continuing.

4. Advanced accelerator applications

The ATW programme during the current fiscal year involves approximately a doubling of the Fiscal Year-2000 funding. This will allow an expansion of experimental programmes, and DOE’s Office Of Nuclear Energy, Science and Technology (NE) is actively seeking opportunities for collaborative research with foreign ADS programmes. Meanwhile, the programme is being reorganised to combine the objectives of the DOE Defense Programme’s Accelerator Production of Tritium programme with those of NE’s ATW efforts. The combined programme is known as Advanced Accelerator Application, and it will be administered by NE. Congress has requested a report by March 1, 2001 on how the new activity will be carried out. It will be a public document, and it may be of interest to many attending this conference. It will be available on the World Wide Web as well as in hard copy.

One objective of the new programme will be to help strengthen the nuclear science infrastructure in America. To accomplish this, graduate thesis projects related to the programme objectives will be sponsored at many universities. Another objective will be to strengthen nuclear test facilities, and an accelerator driven test facility is under active consideration. The need to make better use of limited test facilities throughout the world is also one of the reasons why DOE will be seeking to increase international ADS/ATW collaboration. The coming years may see a considerable expansion of the international quest for effective transmutation systems.

REFERENCES

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