# AUSTRALIAN NUCLEAR FORUM

## Reactor Spent Fuel Radioactive Waste

**Policy**

**1. An international reactor spent fuel reprocessing plant and a repository for the storage of immobilised fission product wastes should be built in Australia when technically, economically and environmentally feasible.**

**2. Australia should be involved with further development of SYNROC and seek to collaborate in other research and development programs on spent reactor fuel reprocessing and storage methods.**

(Adopted 8/12/05)

**Summary and Conclusions**

With the prospects of an increasing use of nuclear power worldwide comes an opportunity for Australia to assist in the management of the increasing amounts of spent fuel generated. Australia has been very active in the head-end of the nuclear fuel cycle by supplying uranium to the world market but has not been comparably involved in the tail-end of the cycle - spent fuel management. Understandably there is some political sensitivity to this from both non-proliferation and waste disposal aspects, however the prospects of improvements in spent fuel reprocessing and the development of waste-burning reactors should change the perspective. Also, the acceptance of foreign fission product wastes in this country would facilitate the use of nuclear power in countries that might be more vulnerable to diversions of nuclear materials and have less ability to store wastes. Such facilities should bring significant economic benefits to Australia.

It is proposed that a reprocessing plant that would accept spent fuel from overseas reactors should be built when feasible. This plant would separate the actinides (U, Np, Pu, Am Cm) from the waste stream and re-export these to be destroyed by irradiation in reactors. The remaining fission product waste would then be immobilised in a medium such as SYNROC and placed in the proposed repository. Since this repository would be primarily for fission product wastes it would need to have a design lifetime of no more than about a 1000 years at which time the radiotoxicity of the waste should be on the order of geologic deposits of naturally occurring radioactive materials. Such a repository could also accept the same type of immobilised wastes from overseas.

Most of the research and development on managing reactor spent fuel is being conducted in North America, Europe, and Japan. Australia should seek to be involved in these programs not only as a means of having SYNROC more widely accepted, but to maintain the technical capability to contribute to the technology and to participate in devising the proposed domestic reprocessing and storage facility.

**Considerations**

1. Nuclear Fuel Cycle Wastes

The spent fuel discharged from light water power reactors consists of: uranium (U); plutonium (Pu); the minor actinides neptunium (Np), americium (Am), curium (Cm); and fission products such as strontium 90, caesium137 and technetium 99. Of these elements the uranium and plutonium constitute approximately 97% of the total mass and can and are being recycled in reactors to produce more energy. The minor actinides (0.1 % of the total mass) are presently not recycled - but could be to produce even more energy. The remaining 2.9% are fission products, the main ones with short half-lives being Cs-137 (30yr) and Sr90 (29yr), while the predominant ones with long half-lives are Tc99 (214,000yr) and 1129 (15.7Myr). Initially after discharge from a reactor, the short-lived fission products contribute over 99% of the fuel radioactivity, however these decay away after about 300 years leaving the long-lived fission products with total activities about 10,000 times less than the un partitioned spent fuel would have had at this stage. Hence it is advantageous from a waste disposal point of view to separate and dispose of the fission products separately and recycle the uranium and plutonium and use reactors or other processes to destroy the minor actinides.

## 2. Historical Developments

Nuclear reactor spent fuel wastes were accumulated during WWII and the cold war from the manufacture of plutonium based nuclear weapons. This plutonium was generated in specially designed plutonium production reactors whose fuel was reprocessed using the REDOX and then the PUREX chemical processes, the plutonium extracted and the residual uranium and fission product liquid wastes stored – generally in tanks. For example, the Hanford reactors in the US produced some 60% of the US 103t plutonium stockpile (the rest came from Savannah River reactors) and left some 2 million cubic meters of difficult-to-treat high-level "legacy" wastes consisting of uranium, some plutonium, minor actinides and fission products.

In the early 1950s uranium appeared to be a very limited resource so R&D programs were undertaken in the US, UK, France and USSR to develop breeder reactors that could extract the energy in uranium 238 (99.3% of uranium) through plutonium recycle. Nowadays much more uranium has been discovered but much more energy is required to meet projected world needs. Furthermore, the necessity to limit greenhouse gas emissions makes it more difficult to rely on fossil fuels for electricity generation consequently the use of breeder reactors with fuel recycling is becoming increasingly attractive.

During the 70's most of the world's countries took steps to limit nuclear proliferation and agreed to the Nuclear Non-Proliferation Treaty. The US, however, under the Carter presidency went further and banned all reprocessing and stopped work on breeder reactors and reprocessing technology meaning that spent fuel was destined to be disposed of essentially intact. Currently about 50,000 t of such spent fuel has been accumulated in the US. Other countries, however, do not prohibit reprocessing and this is being actively carried on commercially in the UK, France and Russia – the latter two and Japan also having operating experimental breeder reactors while India and China have breeders under construction.

## 3. Existing Waste Treatment

The PUREX process is still the primary means of separating the components of reactor fuel waste. So far about 80,000 t of spent fuel from commercial power reactors has been reprocessed. Most of this of course has been done in the countries with currently operating reprocessing plants, i.e. UK, France, Russia, with a total capacity of about 5000t per year. India has one 100t/y plant and Japan is building a major facility due to open in 2007. The largest plant is at La Hague in France where the process produces uranium and plutonium streams together with a stream of fission products mixed with the minor actinides. The uranium stream is stored for future use, the plutonium is recycled in light-water reactors while the last stream is immobilised in borosilicate glass billets. These billets then are either stored temporarily above ground or returned to the source countries (such as Germany) for storage.

## 4. Research and Development

With the prospect of increasing demand for electricity the US and nine other major nuclear power countries plus the EU have now joined together in a program called "Generation IV" to develop a range of power reactors that can be used to burn the minor actinide and even fission product waste streams while still producing and burning plutonium. A key part of this program is the further development of reprocessing technology sufficient to separate the waste streams as completely as feasible. Another option for the treatment of reactor wastes being examined internationally is destructive irradiation by high-powered particle accelerators, but this technology is less advanced at present than the use of reactors for such purposes.

Australia too is still engaged in further development of the SYNROC immobilisation medium which was initially developed to incorporate the entire fuel waste stream but which can be tailored to immobilise just the fission products if needed. Currently SYNROC has been chosen to immobilise the legacy wastes stored at Sellafield in the UK, a program that should provide useful practical experience in the large scale use of SYNROC and an accurate assessment of the costs involved.

## 5. Proposed Scheme

It is proposed that Australia develop a reprocessing plant that could accept reactor spent fuel wastes from overseas and from any reactor in this country. The reprocessing method to be employed will depend on R&D now being carried out overseas, but the main requirement as far as the proposed Australian plant is concerned, is that separation of the fission product stream from the other streams is achieved as completely as possible in order to prevent carry-over of actinides that may cause environmental problems. Other wastes from the plant would include irradiated low-enriched uranium, plutonium and the minor actinides although the exact distribution of the components would depend on the capabilities of the reactors where they would be irradiated (e.g. the minor actinides may be mixed with the plutonium for safeguards proposes).

The US Yucca Mt repository is designed to last at least 10,000 years because it is intended to hold minimally processed spent power reactor fuel as well as the at least some of the legacy wastes. At the other end of the scale the ANF proposal for Australia needs to have a design lifetime of only 1000 years because it will be used to retain just separated fission products. By design after 1000 years, the radiotoxicity of the fission products in the repository volume would be comparable with that of a similarly sized uranium ore body (e.g. a uranium assay of ~1%) and of similarly minor radiological concern. The repository should be located in a remote area of stable geology, low seismicity, little volcanicity and limited groundwater. Such areas are common in this country as was found by the studies previously carried out by Pangea International. A repository such as this could also serve as a site for disposal of Australia's existing intermediate level wastes plus that which will eventually be returned to this country from overseas processing of its research reactor fuel.

Incentives for this scheme include both the economic and strategic. Australia is a technically advanced and politically stable country that is geographically isolated from all others and has strong ties with countries that would actively support its defence. It also has a long history of active involvement with the IAEA and the pursuit of its nuclear non-proliferation program. As such, Australia offers advantages for the location and operation of sensitive facilities such as a reprocessing plant and a fission product waste repository plus the necessary temporary storages for irradiated fuel, separated irradiated uranium, reactor grade plutonium, minor actinides and immobilised fission products. Many countries that have nuclear power plants or are considering them would welcome access to such facilities. Furthermore, the operation of these facilities would provide this country with considerable long-term economic benefits.

## References


1. G.L. Hanna, "Does Australia Have a Role in High Level Radwaste Management?", ANF Discussion Paper 15 (draft), 1 March 2005.

2. K.D. Crowley and J.F. Ahearrne, "Managing the environmental Legacy of U.S. Nuclear – Weapons Production, American Scientist (Nov-Dec 2002).

3. J.H. Black and N.A. Chapman "Siting a High-Isolation Radioactive Waste Repository", Pangea Technical Report PTR-01-01 (2001).

4. "A Technology Roadmap for Generation IV Nuclear Energy Systems," GIF 002-00, USDOE (December 2002).

5. "Processing of Used Nuclear Fuel," UIC Nuclear Issues Briefing Paper N0. 72 (March 2005)