PLUTONIUM CHALLENGES

CHANGING DIMENSIONS OF GLOBAL COOPERATION

BY NOBORU OI

Global developments in the 1990s have presented the international community with a new and serious challenge: a growing accumulation of plutonium originating from both civilian and military nuclear programmes. It arises from a number of developments. They include the end of the Cold War — notably the steps toward dismantling nuclear weapons and transferring surplus plutonium once used in warheads to the civilian sector — and changes affecting the nuclear industry, specifically delays in the commercialization of fast-breeder reactors that can burn plutonium as fuel. In response to these developments, among others, new realities are influencing the safe and effective management of plutonium and countries are defining associated policies and programmes.

At the end of 1997, more than 130,000 tonnes of spent fuel from power reactors were estimated to be stored worldwide containing about 1000 tonnes of plutonium. Another 170 tonnes of separated plutonium were in storage from civilian reprocessing operations, and about 100 tonnes of excess plutonium from dismantled warheads no longer required for defense purposes were scheduled to be released from the military sector by Russia and the United States.

The dual challenge is that plutonium is a valuable energy source (generally speaking, one gram of plutonium is equivalent to about one tonne of oil) and a matter of global concern because of its potential health hazards and possible use for the production of nuclear weapons. In this article, selected aspects of the issue of plutonium management in civilian nuclear programmes are discussed over a longer term perspective in the context of global cooperation and the IAEA's own role, which is evolving in response to the interests of its Member States. It draws upon discussions at international fora, including the International Symposium on Nuclear Fuel Cycle and Reactor Strategies in June 1997 *(see related article, page 7)*. The article does not address non-proliferation aspects of the issue, including the IAEA's established safeguards and verification activities.

STATUS & TRENDS

Plutonium from civilian programmes. Plutonium is one element formed in the fuel of nuclear reactors during their operation. It can be separated, stored, and subsequently used in recycled fuel for nuclear power plants. (Parenthetically, the use of plutonium for energy generation is not something new. Nearly 40% of the electricity produced by each thermal reactor fuelled by uranium is due to fission of plutonium isotopes accumulated during the burning of uranium.) Altogether 443 power reactors were operating in 1997 with a total electricity output of about 350 gigawatts-electric. All these power reactors produced plutonium; for example, spent fuel from light-water reactors contains about 1% of plutonium.

The IAEA estimates that in 1997 about 10,500 tonnes of spent fuel was discharged from nuclear power reactors worldwide; this amount contains about 75 tonnes of plutonium. It is estimated that the annual production figure will remain more or less the same until 2010. The cumulative amount of plutonium in spent fuel from nuclear power reactors worldwide is predicted to increase to about 1700 tonnes by 2010.

It is estimated that about 3000 tonnes of spent fuel discharged from power reactors were reprocessed in 1997, which corresponds to about 30% of the total. About 24

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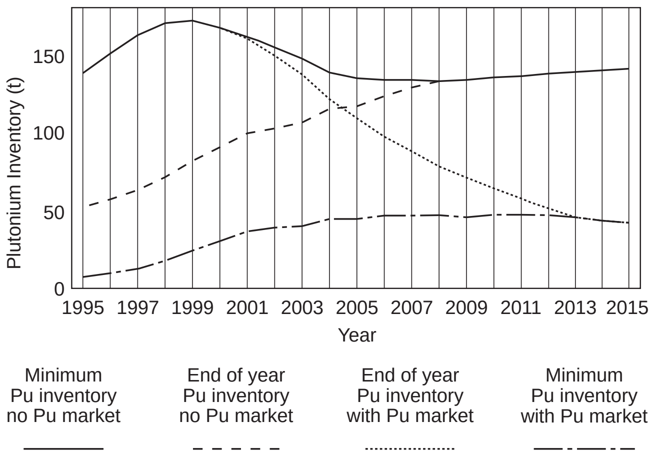
tonnes of plutonium were separated in reprocessing plants and nine tonnes of plutonium were used mainly as mixed uranium-plutonium oxide fuel (MOX) in light-water reactors. The imbalance between the separation and use of plutonium had resulted in an accumulated inventory of separated civil plutonium of about 170 tonnes at the end of 1997.

IAEA projections of plutonium inventories show that the rate of separation of civil plutonium and its rate of use will fall into balance in a few years. This is due to an enhanced capacity of MOX fuel production which will amount to 360 tonnes of heavy metal (tHM) per year in 2000. Beyond this period, the inventory is expected to decrease modestly and level off at around 130 tonnes. Despite the efforts to reduce the current inventories of separated civil plutonium, the worldwide inventories still remain at a substantial level. *(See graph.)*

Plutonium designated as no longer required for defense purposes. In addition to the amounts of civil plutonium, plutonium is being released from dismantled warheads. Under the START-I and -II Treaties, many thousands of US and Russian nuclear warheads are slated to be retired within the next decade. As a result, at least 50 tonnes of plutonium from each side are expected to be removed from military programmes.

PROJECTED WORLDWIDE CIVIL INVENTORIES OF SEPARATED PLUTONIUM



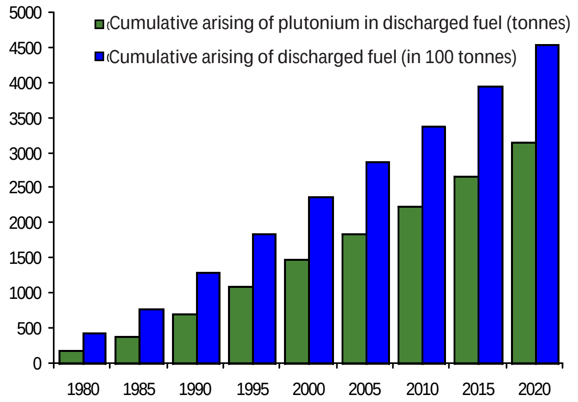
PLUTONIUM MANAGEMENT

The question arises as to what to do with plutonium either in a separated form or contained in spent fuel. A number of issues arise because of plutonium's potential use as an energy source and for the production of nuclear weapons. The US Academy of Sciences has proposed the conversion of ex-military plutonium into a form which is protected from theft and seizure by intense radioactivity (the "spent fuel standard"). Such proposals, however, would only be applicable for a rather short term. Within 200 years, the protection afforded by intense radioactivity will disappear as the result of the decay of most radioactive nuclides. If the spent fuel is buried in a geological formation, it might be regarded as a potential "plutonium mine", meaning that at some later point in time the buried plutonium could be mined and extracted.

Burning excess plutonium. Presently, plutonium is used in light-water reactors as MOX fuel and also in a small amounts for the development of fast-breeder reactors. Currently 22 power reactors in five countries (France, Germany, Switzerland, Belgium, Japan) are loaded with MOX fuel and this number is expected to rise to between 36 and 48 by 2000. The use of MOX reduces the inventory of separated plutonium and is regarded as an interim measure before plutonium's possible full-scale use in fast reactors later in the next century. It is known that multiple recycling in light-water reactors degrades plutonium, which in turn limits the number of times it can be recycled to two or three. Such degraded plutonium can, however, be used as fuel in fast reactors. Without such reactors, spent MOX fuels will still end up in a final depository or in storage facilities.

It may take another several decades before extensive use of plutonium as an energy source will become a reality. The commercialization of fast reactors has been delayed. The main reasons are economics and non-proliferation concerns. Any fast reactor being designed/constructed today appears to have no economic advantages over light-water reactors, which profit from rather abundant low-priced

CUMULATIVE ARISING OF DISCHARGED FUEL AND OF PLUTONIUM IN DISCHARGED FUELS



uranium. Although sustainable nuclear energy production can be achieved effectively by fast reactors, its introduction into the competitive electricity market is not expected before 2030 (about one to two percent of predicted nuclear energy capacity in 2030). This prediction may still be optimistic. The possibility cannot be denied that other energy sources may compete with fast reactors. Even so, the problems of managing spent fuel and plutonium will persist.

Are there any other methods for burning excess plutonium? Accelerator driven systems, burning in inert matrices, and the use of thorium to burn plutonium are being studied. But these technologies are still in an early development stage.

Disposition of plutonium from the defense sector. In the case of plutonium released from the defense sector, both the USA and Russia have taken steps addressing the problem. The United States decided in January 1997 on a "dual-track" strategy, namely to use the major portion of plutonium in light-water reactors as MOX fuel and to immobilize the rest. Russia has not formally declared its policy but the emphasis is to use plutonium as fuel in reactors. Once basically a bilateral concern between the USA and Russia, the demilitarization and disposition of plutonium once used in weapons is one of most important new realities facing the international community. The resolution of issues will require political will, sufficient funds, and effective international cooperation.

It is worthwhile noting that disposition of 50 tonnes of plutonium can be technically completed in the timeframe of 20 to 40 years. The amount of ex-military plutonium, therefore, does not change the nature of the overall plutonium-related problems facing the nuclear community. It should be emphasized, however, that the disposition of plutonium from the defense sector is a great step towards disarmament and should be carried out with highest priority.

Storing spent fuel. For plutonium from civilian programmes, the logical scenario is either to store spent fuel for a long time or to dispose of it in geological formations. The same applies to the reprocessing option because spent MOX fuel will end up in storage or geological disposal after being recycled two or three times.

The long-term storage of spent fuel and separated plutonium is a rather mature technology and poses no significant technical problems. The technology for geological disposal of spent fuel is still to be demonstrated. To date no disposal site has been licensed in any country.

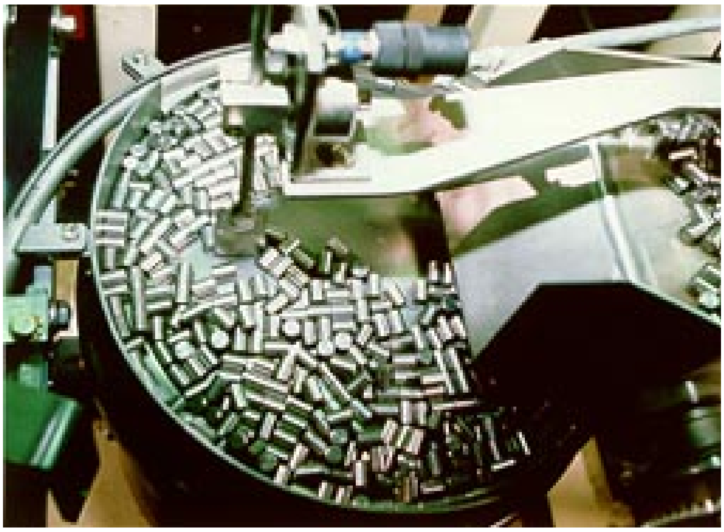
A large amount of spent fuel can be stored rather easily. The volumes are far smaller and more compact than other types of wastes being produced by modern industries. Spent fuel can be more easily isolated from the environment than waste from fossil fuel plants which is mostly released into the atmosphere. Spent fuels are inherently chemically stable and compact and the thermal condition of storage improves over time due to the decay of fission products.

Two examples illustrate that the space necessary for spent fuel storage is very modest. The "CLAB" facility in Sweden is a system of water pools 120 meters long, 20 meters wide, and 27 meters deep. It is located in an underground rock cavern which can store 5000 tonnes of spent fuel. Operation started in 1985 and by 1997, a total of 2600 tonnes of spent fuel from boiling-water reactors and pressurized-water reactors have been stored.

An example of dry storage is at Point Lepreau nuclear power plant, in Canada, where 1026 tonnes of spent fuel from Candu reactors have been stored in 100 silos since 1991. Each silo is a concrete canister, 3.07 meters in diameter and 6.1 meters in length. Dry storage can be a preferred option, especially for long-term storage following extended underwater storage, from the standpoint of ease of operation and maintenance and inherent safety features. Almost 20 years of favorable experience exists with the dry storage of spent fuel. The dry storage systems can be concrete canisters, steel-lined concrete storage containers, and vaults. Even though dry storage is a younger technology compared to wet storage, it has become a mature technology and the quantities being placed into dry storage are beginning to increase significantly. At the end of 1997, about 3600 tonnes of spent fuel (about 3% of the total in storage worldwide) have been placed into dry storage in eight countries.

In the past, the storage of spent fuel has been regarded as an interim step in the management of spent fuel. But this perception will have to change as long-term storage over many decades will become a necessary measure.

In summary, today's nuclear fuel cycle issues seem to boil down to considerations of the use of mixed-oxide fuel (to the extent States are committed to reprocessing) and of separated plutonium, and the long-term storage/disposal of spent fuel foreseeably in geological repositories. As plutonium is released from the military sector, the issue of its direct disposal adds to these considerations.



INTERNATIONAL CONTEXT

Since the early 1990s, plutonium-related issues have received greater international attention.

- In 1992-93, the IAEA held two meetings to discuss the the issues connected with the accumulation of separated plutonium from civilian programmes. In this connection, the concept of an international plutonium storage, dormant since mid-1980, was touched upon. In the following years, discussions on plutonium management were carried out by nine states (Belgium, China, France, Germany, Japan, Russia, Switzerland, the United Kingdom, and the United States) who formed a Working Group independent of the IAEA. The Group has recently completed International Guidelines for the Management of Plutonium (published March 1998 in INFCIRC/549). The guidelines set out the policies which each government has decided to apply to the management of plutonium in peaceful nuclear use. With a view to increasing the transparency and public understanding of the management of plutonium, the States have agreed to publish occasional statements explaining their national strategies for nuclear power and the fuel cycle, and their general plans for managing national holdings of plutonium. In addition, the States also committed themselves to publishing an annual statement of holdings of plutonium subject to the Guidelines.
- In 1994, an ad hoc expert group under auspices of the Nuclear Energy Agency was formed to study the broad technical questions related to plutonium management. Its report, published in May 1997, covered technical options for management of civil plutonium. The group had a membership drawn from fifteen countries and three international organizations, including the NEA, IAEA, and European Commission.
- In 1995, the Review and Extension Conference of the

Photo: Mixed-oxide fuel pellets containing about 5% plutonium. (Credit: Cogema)

Treaty on the Non-Proliferation of Nuclear Weapons (NPT) called for greater transparency in the management of plutonium for civil purposes, including stock levels and their relationship to national nuclear fuel cycles. One of the main Conference Committees also called for continued international examination of policy options concerning the management and use of stocks of plutonium, including the option of an arrangement for deposits with the IAEA, and the options for a regional fuel cycle centre.

■ In 1996, the participants in the Moscow Summit on Nuclear Safety also underscored the importance of global cooperation. While recognizing that the primary responsibility for the safe management of weapons fissile materials rests with those States which have produced and possess it, they stated that "other States and international organizations are welcome to assist where desired".

■ Later in 1996, following up on the Moscow Summit, an "International Experts Meeting on Safe and Effective Management of Weapons Fissionable Materials Designated as No Longer Required for Defense Purposes" was held in Paris. The IAEA was represented together with ten countries and the European Commission. This was the first meeting at which a current and primarily bilateral plutonium issue was discussed in an international forum. The IAEA used the occasion to describe its experiences and expertise in matters relevant to international plutonium management.

■ In September 1996, the so-called Trilateral Initiative of the USA, Russia and IAEA was established during the IAEA General Conference on the verification of nuclear materials removed from the defense sector. It was agreed jointly to explore the technical, legal, and financial issues connected with the verification of such materials.

■ From a global perspective, the IAEA "International Symposium on Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities" examined major issues and developments in June 1997. The objectives of the Symposium were to prepare for decision makers and the public a scientific assessment of different fuel cycle and reactor strategies with particular reference to the production, use, and disposal of plutonium.

■ In 1997, States adopted international safety norms for spent fuel management. The Joint Convention on the Safety of Radioactive Waste Management and the Safety of Spent Fuel Management was opened for signature at the Agency's General Conference in September 1997.

The IAEA's role. The IAEA's role in this area is evolving in response to the interests of its Member States. In addition to carrying out its established nuclear safeguards and verification activities, the Agency's existing and planned activities related to civil plutonium management involve:

■ *Serving as a forum for information exchange.* This entails providing an impartial perspective for a common understanding of various important aspects of the nuclear fuel cycle; the regular publication of the estimated world inventories of plutonium; assisting efforts to enhance transparency to increase public confidence through periodic objective reports and studies; and promoting necessary research and development, including possible international co-operation related to fast reactors, to contribute to the reduction of inventories of plutonium.

■ *Assisting countries in formulation of infrastructures for the safe and secure handling of plutonium and spent fuel.* As an example, the IAEA has published Safety Guides for the safe storage of spent fuel from power reactors, and recently prepared for publication a Safety Report on safe handling and storage of plutonium.

■ *Formulation of necessary international arrangements.* This includes activities addressing the possibility of international plutonium management or storage from safety and security perspectives, as well as arrangements for regional and international co-operation to find economically effective ways of resolving plutonium and spent fuel management issues.

As a result of the IAEA's 1997 Nuclear Fuel Cycle Symposium, the International Working Group on Nuclear Fuel Cycle Options was established in 1998 to maintain a dialogue among States on important issues in the field. The Working Group is intended to be a major forum for discussion of cooperative tasks, including the IAEA's role in the disposition of spent fuel and plutonium, international storage of spent fuel from power and research reactors, and international plutonium management. ❑