

Nuclear Proliferation Resistance Technologies as a Part of Fuel Cycle Technologies

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1. Past Reviews

It is well known that the INFCE (International Nuclear Fuel Cycle Evaluation) made late in the 1970s reviewed nuclear proliferation resistance technologies.

The technologies reviewed at that time can be roughly divided into 3 types as described below.

(1) Nuclear Proliferation Resistance focusing on the compositions and forms of nuclear materials

Concerning nuclear materials handled in the fuel cycle, reviews were made on the compositions and forms of materials in which it would be generally difficult to produce metallic plutonium and highly enriched uranium (HEU) and use them for the components of nuclear explosive devices.

Concretely, the following technologies were reviewed:

- Technologies using irradiation before use, spiking and partial decontamination & reprocessing to build up radiation barriers inaccessible to human beings around nuclear materials; and
- Technologies using for mixing & extraction, mixing & conversion and MOX to prevent simple plutonium and uranium substances from being handled.

(2) Nuclear Proliferation Resistance focusing on the structures of facilities

Reviews were made on the safety of facility structures and their inaccessibility to thieves; the facilities were collectively constructed on one site to eliminate the need for transporting nuclear materials between facilities and reduce the possibility of theft. Methods for preventing the removal of nuclear materials from facilities in order to use them for the production of nuclear explosive devices were also reviewed.

(3) Nuclear Proliferation Resistance focusing on management methods

Preventive systems against the use of nuclear materials for nuclear explosive devices include the safeguards system established by IAEA (International Atomic Energy Agency). Apart from this

system, reviews were made on the proposals that only specified countries should be permitted to use the reprocessing and enrichment technologies in order to prevent the spread of these technologies to other countries, and that many countries should jointly manage the produced nuclear materials.

The results of reviews on (2) nuclear proliferation resistance focusing on the structures of facilities and (3) nuclear proliferation resistance focusing on management methods as describes above will not be discussed here, because they are related to elements regarding nuclear facility sites and commercial activities and include few technical elements.

Concerning the results of reviews on (1) nuclear proliferation resistance focusing on the compositions and forms of nuclear materials, it was pointed out that the compositions and forms of nuclear material from which it would be generally difficult to produce metallic plutonium and highly enriched uranium (HEU) and use them for the components of nuclear explosive devices might have so high a radioactivity as to make such nuclear materials inaccessible to human beings and consequently make it difficult to confirm the presence of nuclear materials, and that impurities contained in such compositions and forms of nuclear materials might make it difficult to measure the quantities of nuclear materials.

In short, it was argued that the technologies to make the production of nuclear explosive devices difficult might make it rather difficult to implement the IAEA safeguards system for the purpose of verifying the presence of nuclear materials.

2. The Value of Nuclear Proliferation Resistance Technologies as Technical Barriers

Any technical problem may be eventually solved, given enough time, funds and human resources. Therefore, it is reasonable to think that an explosive device may be eventually produced given enough time, funds and human resources.

In other words, this means that what is important is whether or not there really is enough time, funds and human resources to produce a nuclear explosive device.

From the viewpoint of whether or not these technical barriers can be broken down, it can be considered as a matter of course that these technical barriers are meaningless to countries holding reprocessing and enrichment plants, and that they are of value to countries having no such plants.

The value of nuclear proliferation resistance technologies under the IAEA safeguards system may be considered as follows:

Inspections under the IAEA safeguards system are made on the basis of the following concept:

Before any nuclear explosive device is completed (or at any proper time), it shall be verified that the necessary (or significant) quantity of nuclear materials is not used to produce such device.

Under this system, the “proper time” is fixed, on the assumption that a country holds a reprocessing or enrichment plant and in consideration of the required time to produce metallic plutonium or highly enriched uranium (HEU) for the components of nuclear explosive devices from nuclear materials. Therefore, it can be expected that nuclear proliferation resistance technologies may be able to change the existing procedure for implementing IAEA safeguards.

Nuclear proliferation resistance technologies are of value to the countries to which IAEA safeguards apply, whether or not they have any reprocessing or enrichment plant, in that these technologies may necessitate changes to the procedure for implementing the IAEA safeguards system.

3. Considerations on Nuclear Proliferation Resistance Technologies

In the studies of nuclear proliferation resistance technologies, the following points raise issues regarding resistance technologies:

These resistance technologies make it difficult to implement IAEA safeguards;

These technologies may not completely prevent the production of nuclear explosive devices, however their resistances are technically improved;

The safeguards system may be abolished at any time for politically reasons.

It is supposed that the unclear definition of nuclear proliferation resistance technologies has caused confusion in the course of nuclear fuel cycle technology development projects. More particularly, engineers have always wavered in deciding whether priority should be given to improving the radiation intensities of nuclear materials or facilitating the application of safeguards.

In other words, a simple definition of nuclear proliferation resistance technologies will be valuable for future nuclear fuel cycle technologies development projects that.

There may be consensus on the following points:

- Nuclear proliferation resistance technologies are of little value to countries holding reprocessing and enrichment technologies.
- Nuclear proliferation resistance technologies are of value to countries holding no reprocessing and enrichment technologies, though their value decreases with time.
- The countries to which the IAEA safeguards apply may make changes to the procedure for implementing these safeguards, and consequently may reduce the costs for IAEA safeguards paid by the facility operators and IAEA.

4. Method of Introducing Nuclear Proliferation Resistance Technologies into Fuel Cycle

To implement the R & D project for a new nuclear fuel cycle technology, it is generally necessary to determine the feasibility, economy and safety of the technology and consider the environmental impact and nuclear proliferation resistance of the technology. However, the nuclear proliferation resistance is generally more difficult to clearly evaluate than the environmental impact of the technology.

Under the IAEA safeguards system, nuclear non-proliferation can be verified by using various techniques. The existing inspection technique is not only one method of verification.

To review the safeguards application procedure, therefore, a realistic development technique is to take the qualitative approach of changing the compositions and forms of nuclear materials present

in the fuel cycle into those that are as difficult to use as possible for the production of nuclear explosive devices.

5. Effect Examples of Nuclear Proliferation Resistance Technologies

As an example, we evaluated the required time to produce about 8 kg of metallic plutonium using nuclear materials sampled in the fuel cycle.

The results of the evaluation largely depended on the assumed size of a processing facility.

In this evaluation, we assumed a large-sized research facility having the following features:

Total quantity of plutonium processed by the facility: *Approx. 10 kg*

Quantity of plutonium in a dissolver or pulse column: *Approx. 5 kg*

Quantity of plutonium by batch of solution: *Approx. 0.5 kg*

Quantity of plutonium by batch of solid: *Approx. 1 kg*

Number of operators having expertise: *About 10*

In addition, safety and criticality controls were carried out.

The process of conversion from nuclear materials into metallic plutonium was as follows:

Dissolution Pu Separation Precipitation of oxalic acid Roasting (oxide) Reduction
(metal)

The following fuel cycles were assumed:

We made the evaluation by using an assumed fuel cycle nearly as large as that for the Japanese demonstration FBR “Monju.”

(1) Case 1: Conventional wet reprocessing cycle

A mixture of core spent fuel and blanket fuel was reprocessed.

Simple plutonium and uranium substances were extracted.

(2) Case 2: Advanced wet reprocessing cycle

Both plutonium and uranium were extracted from spent fuel.

Low decontamination factor (DF 100; Pu and U product solutions contained a trace of FP.)

Np and Am were added into the product solutions.

(3) Case 3: Dry reprocessing cycle

The RIAR process was used for oxide fuel.

The results of evaluation were as follows:

Case 1:

- The required time was about 190 days to produce about 8 kg of metallic plutonium from the solution of plutonium nitrate produced by the conventional wet reprocessing method.
- The required time was about 80 days to produce about 8 kg of metallic plutonium from a new fuel assembly produced by the conventional wet reprocessing method.

Case 2:

- The required time was about 350 days to produce about 8 kg of metallic plutonium from the mixed solution of plutonium and uranium produced by the advanced wet reprocessing method.
- The required time was about 260 days to produce about 8 kg of metallic plutonium from a new fuel assembly produced by the advanced wet reprocessing method.

Case 3:

- The required time was about 170 days to produce about 8 kg of metallic plutonium from a new fuel assembly produced by the dry reprocessing method.

The results indicate that the required time was 2 to 3 times longer for the advanced wet reprocessing method than for the conventional wet process. These findings can be considered to be reasonable because the advanced wet process involved the separation of Np, or Am and FP.

The required time to produce metallic plutonium from a new fuel assembly produced by the dry reprocessing method was relatively short, because it was assumed that plutonium dioxide (PuO₂) particles were present in the fuel.

6. Future Nuclear Proliferation Resistance Technologies

With the worldwide increase in communication speed, technological information is more rapidly disseminated. As a result, the service life of technical barriers is shorter.

Recently, IAEA introduced a new safeguards system under the INFCIRC540 (additional protocol). This is a system in which various kinds of information declared and not disclosed by a country are

reviewed to confirm that the country is not carrying on any nuclear activity that they have not declared to IAEA.

It is considered that the transparency of nuclear activities information, such as the operation of nuclear facilities, will contribute to this safeguards system. In short, a higher transparency may improve nuclear proliferation resistance.