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Fast reactors and nuclear nonproliferation problem

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Abstract

The growing number of countries wishing to use nuclear energy, and the expansion in the geography of NPPs entails the risk of nuclear weapons proliferation, given that political leaders in some countries may want to purchase or develop sensitive nuclear technologies. A certain risk of proliferation through nuclear power technologies and materials cannot be excluded altogether. In the nuclear fuel cycle there are large inventories of nuclear materials, including fissile materials, (many hundreds and thousands of tons). The problem of spent nuclear fuel with plutonium in it, especially for novice countries and countries with small nuclear power program, also increases the risk of proliferation, including the growing risk of actions on the part of subnational or terrorist organizations because of the proliferation of nuclear technologies and materials as respective protection measures are insufficient in these countries.

In the event of thermal reactors, uranium enrichment is indispensable to production of fuel. Long-term storage of SNF from thermal reactors in an open fuel cycle, which is a common practice nowadays, entails an increased risk of proliferation due to the weakening of the radiation barrier over time and the potentiality of unauthorized removal of fuel by the proliferator state and its theft by criminals and terrorists.

Fast-neutron reactors started up and operating on plutonium fuel do not require uranium enrichment. There is no long-term storage of SNF in the closed fuel cycles of fast reactors. Gradual replacement of thermal reactors by fast reactors, due to natural uranium being in short supply, creates prerequisites for phasing out uranium enrichment. However, countries having small nuclear power programs and, therefore, a limited number of nuclear units will use thermal reactors still for a long time, which will require uranium enrichment.

Creation of nuclear weapons based on energy-grade plutonium using a simpler "gun-type" design is practically impossible because of a high neutron background inherent in this kind of plutonium. However, this does not exclude the potentiality of terrorist attempts to fabricate a primitive nuclear explosive device.

Both sensitive technologies (uranium enrichment and SNF processing with separation of plutonium) will be used to start up fast reactors on uranium fuel with the subsequent transition to plutonium fuel. In this case, plutonium with a small content of higher isotopes will be bred not only in the blanket, but also in the reactor core in much greater quantities.

The paper considers various technological and institutional approaches to solving the problem of fast reactor blankets in terms of ensuring a strong proliferation resistance.

Keywords: Nuclear fuel cycle; Nonproliferation of nuclear weapons; Fissile materials; Plutonium; Enriched uranium; Fast reactors; Thermal reactors.

Introduction

In more than 50 years of its existence, international nuclear power has come a long way of evolution and has expanded worldwide. However, the underlying nuclear technologies, though improved over time, remain the legacy of the military and require careful attention to nonproliferation issues.

The evolution of the nuclear power system and infrastructure, with a great deal of fissile materials being still in the system, creates motivation and prerequisites for the peaceful material of the nuclear fuel cycle (NFC) to be used for building nuclear weapons (NW) or stolen for making nuclear explosive devices (NED).

The 1978 decision by the administration of the US President J. Carter to give up the processing of SNF and wind up the fast breeder reactor program because of the alleged risk of nuclear

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proliferation from the use of plutonium in fast-neutron reactors has been harmful to the progress of this technology both in the USA in and some other countries. Besides (primarily owing to the USA), there has been a negative attitude formed in the world towards fast reactors and their NFC as being most dangerous in terms of nuclear proliferation. At the same time, the decision by Carter's administration ignored the danger of proliferation from the uranium enrichment technology. Apparently, the reason for this was the fact that the development of the centrifuge enrichment technology in the USA at the time was not successful, and the US-designed centrifuges as such were rather cumbersome and up to 12 m high. And the gas-diffusion technology demonstrated at the time was introduced at large-size facilities with much electricity and water consumed. For example, a plant in Paducah, Kentucky, of the capacity ~7 million SWR/started up in 1954, consumed 22 billion kW per year, and its cooling water consumption exceeded several-fold the water consumption by New York's municipal water supply system [1].

It was only natural to imagine then that such facility could not be 'hidden' for the covert production of enriched uranium. The success of the centrifuge technology, especially in the USSR, small dimensions of centrifuges (no more than one meter high), and a several-fold decrease in the consumption of electricity and water have brought about a certain risk of high-enriched uranium to be covertly produced.

Problem definition

Existing definitions of proliferation resistance

In one of its earliest definitions, the notion "proliferation" was used in a publication by Silvennoinen and Vira, US scientists, in 1986: "The development of the material and technical resources required for the production of nuclear explosives in countries that now do not have such a capability" [2].

Later on, the term "nonproliferation" was given a more specific meaning as applied to nuclear power systems. Thus, in the INPRO international project, "nonproliferation" or "proliferation resistance" is defined as follows: "Proliferation Resistance is defined as that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by States intent on acquiring nuclear weapons or other nuclear explosive devices." [3].

The definition of "proliferation resistance" in the Generation IV International Forum is practically the same as in the INPRO project: "Proliferation resistance is such characteristic of a nuclear power system that impedes (prevents) the diversion or undeclared production of nuclear material or undeclared use of the technology by the holder state so that to possess nuclear weapons or other nuclear explosive devices". This definition is used in the Generation IV International Forum together with the notion of "physical protection": "Physical protection is such characteristic of a nuclear power system that impedes (prevents) the theft of materials fit for nuclear explosive of radiation dispersing devices, as well as other acts of sabotage against plants or transport by subnational organizations and adversaries other than belonging to the holder state" [4].

As can be seen from the above definitions, "nonproliferation" in both international projects is concerned with proliferation at the state level. And in the Generation IV International Forum, emphasis is also placed on physical protection for prevention of potential nuclear terrorist acts by subnational organizations and groupings other than belonging to the holder state.

Potential ways for proliferation through NFC

Nuclear power is not the only way to creation of nuclear weapons, at the same time, it may be easier for threshold states to build nuclear weapons covertly, under the disguise of nuclear power.

The NFC's initial fissile materials may be processed into materials to be suitable for use in weapons at the state level or stolen by subnational or criminal groups.

The following steps can be made at the state level towards the creation of nuclear weapons:

– use of nuclear technologies, plants or nuclear power materials for a covert military program;
– use of the expertise and experience of nuclear experts for a parallel covert military program;
– withdrawal from the NPT and direct use of the NFC technologies, plants and materials for military purposes.

At the subnational (terrorist) level, nuclear materials can be stolen from the NFC facilities for making a primitive NED or a "dirty bomb".

Potential increase in proliferation risk in modern conditions

Prior to the accident at Fukushima-Daiichi nuclear plant in Japan in March 2011, about 40 countries declared their intent to use atomic energy for peaceful purposes. The number of such countries remains large despite the accident in Japan, and, as predicted, some 15 to 20 countries will have the first nuclear power units in their territories by 2030 [5].

The growth in the number of the countries wishing to use nuclear energy and the expansion in the NPP deployment geography may lead to an increase in the proliferation risk because political leaders in some countries may want to buy or develop sensitive nuclear technologies.

Recently, in connection with the intensive activities undertaken by Iran in the direction of uranium enrichment, some countries become suspicious that Iran is seeking to develop nuclear weapons. While neglecting the question of how justified are such suspicions, it should be noted that some of Iran's neighbor countries have also concerns in this respect. In particular, *The Guardian*, a British newspaper, said on 30 June 2011 that Saudi Arabia had warned the NATO that it would seek to get nuclear weapon if it was created by Iran [6]. One may suggest in this connection that the creation of nuclear weapons by Iran may trigger a "chain reaction" in the neighboring country for the purchase(creation) of such weapons and, as the result, the appearance of the whole range of threshold countries is concerned.

De-facto, the appearance of nuclear weapons in India and Pakistan, tests of nuclear devices in North Korea and the disabil-