

Non-Proliferation Aspects of Civilian plutonium Programs

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The United States has been concerned about the separation and use of plutonium in civilian reactor fuel for some time. These concerns are based on a combination of two facts. The first fact is that access to fissile material is the most significant barrier to the acquisition of nuclear weapons. The second is that the plutonium contained in spent reactor fuel—so-called “reactor-grade” plutonium—can be used to make nuclear weapons. Some analysts continue to argue that reactor-grade plutonium is unsuitable for weapon manufacture, but its usability for this purpose is beyond dispute. The U.S. Department of Energy has made authoritative statements to this effect. (See box.)

Carson Mark, the long-time former head of the theoretical division, showed that if reactor-grade plutonium, of any burn-up, had been used in the “Fat Man” bomb, the yield would have been no lower than about 1 kiloton. With greater sophistication of design, weapons using reactor-grade plutonium could have yields, weights, and degrees of reliability comparable to those of weapons made using weapon-grade plutonium.

It is true that reactor-grade plutonium is not as desirable as weapon-grade plutonium for the manufacture of nuclear weapon. These disadvantages are not as severe as some imagine, however, and they can be overcome by any country or group capable of building a nuclear weapon with weapon-grade plutonium.

Reactor-grade plutonium contains a lower percentage of isotopes that are fissile (i.e., capable of sustain a chain reaction in a thermal neutron spectrum)—60 to 70 percent versus 94 percent for weapon-grade plutonium—but all plutonium isotopes can sustain a chain reaction in a fast-neutron spectrum, and the amount of reactor-grade plutonium required for a weapon would be only about 20 percent greater than the amount of weapon-grade plutonium. (See table 1.)

The much higher percentage of plutonium-240 in reactor-grade plutonium results in a higher rate of neutron emission from spontaneous fission, increasing the possibility that the chain reaction would be initiated before the plutonium has

been fully compressed. In crude nuclear weapons, this would result in greater statistical variability of yield, and a lower probability of achieving the full design yield. However, as Carson Mark showed, the yield of such a weapon would be no lower than about 1 kiloton. With a more sophisticated design, this disadvantage can be overcome completely, and the full design yield can be achieved as reliably as with weapon-grade plutonium. (See table 2.)

Reactor-grade plutonium also emits more gamma-rays and more heat than weapon-grade plutonium. Workers who fabricate weapons and military personnel spending long periods of time in close proximity to weapons would receive higher radiation doses, and certain weapon components might need to be replaced more frequently. The design of the weapon might also be modified to facilitate the removal of decay heat. The disadvantages of using reactor-grade plutonium are more accurately described as “inconvenient” than as catastrophic or fatal.

As long as the plutonium remains embedded in the spent fuel, it is protected from theft or diversion by the difficulty of handling and chemically separating the highly radioactive spent fuel. It also is easy to provide assurance that no material has been diverted, simply by counting the number of fuel assemblies. When the spent fuel is reprocessed and the plutonium is separated and reused, however, this creates several types of security concerns.

First, there is the problem of providing adequate assurance that plutonium has not been diverted for weapons purposes. The IAEA’s goal is to be able to provide high confidence (90 percent) of detecting the diversion of a significant quantity (8 kilograms of plutonium) in a timely manner (one month). The ability to meet this goal in large reprocessing or MOX fuel fabrication plants, which would handle more than a thousand significant quantities of plutonium per year, has not been demonstrated. The error in measuring the plutonium balance in reprocessing plants typically is 1 percent, or about ten significant quantities per year for a large plant.

Moreover, many consider the IAEA standard too lax, both because nuclear weapons could be made using far less material and because plutonium in the form of pure or mixed oxide could be converted into weapon components in far less than one month. A more justifiable goal—for example, to provide high confidence of detecting the diversion of 1 kilogram of plutonium in less than one week—probably is impossible to meet.

Plutonium recycling involves the separation and transportation of 200 to 600 kilograms of plutonium per year per gigawatt of installed nuclear capacity. In a

world with ten times as many reactors as today, this would involve the handling of over a million kilograms of plutonium per year. It is difficult to believe that any system of technical safeguards could, by itself, provide detection of diversions down to one part in a million.

Second is the problem of provided adequate physical security. Because access to fissile material is the most significant barrier to the acquisition of nuclear weapons, such materials should be afforded the same degree of physical security as nuclear weapons. This is not true today. Matthew Bunn will cover this in detail, so I will not say more about it here.

Third is the problem created by having large stocks of weapon-usable materials in non-nuclear weapon states. About 160 tons of separated civilian reactor-grade plutonium exists today—enough for 25,000 nuclear weapons. Most of this is stored in nuclear weapon, mostly in the UK, France, and Russia. The separation and use of plutonium would, and has, lead to large and increasing stockpiles in nuclear weapon. Japan has about 20 tons of separated plutonium, of which 5 tons are stored in Japan. For comparison, the UK, France, and China are each estimated to each have 3 to 6 tons of plutonium in their weapons stockpiles.

Even if civilian plutonium could be accounted for in ways that would give high confidence that a significant amount could not be diverted without timely detection, and even if this plutonium could be protected well enough to rule out the possibility of theft, there would always remain the possibility that any state with plutonium could, at any time of its choosing, withdraw it from safeguards and use it to build nuclear weapons. This possibility can create concern in neighboring states, particularly if plutonium stockpiles are larger than the minimum required to support the civilian nuclear industry.

Even if Japan's plutonium stockpile and plutonium-use programs did not create such concerns, they set an unfortunate precedent for other countries in which these concerns might be far more severe. In general, countries should not do something that they believe that all countries should not be permitted to do. If Japan can reprocess and stockpile plutonium, then why shouldn't North and South Korea, Taiwan, Iran, Iraq, Syria, Libya also be permitted to do so? Again, even if safeguards and physical protection were good enough to detect diversion and prevent theft, the very existence of plutonium stockpiles in certain countries could create instability.

Of course, double-standards do exist in the international community. One of the most glaring is the fact that five states are permitted, under the Non-

Proliferation Treaty, to possess nuclear weapons, while all other states may not. Some of us would like to remove this double-standard, and move toward a global prohibition on nuclear weapons. The existence of stockpiles of plutonium and facilities capable of separating plutonium under national control would pose a major barrier to achieve this goal, however. These stockpiles and facilities would form the basis for a rapid breakout from a nuclear disarmament agreement, which would threaten the stability and political feasibility of ever reaching such an agreement.

We might choose to accept the risks and disadvantages associated with separating and using plutonium if there were compelling advantages for doing so. There are no such advantages, however, either today or in the foreseeable future.

Most obvious is the lack of any economic justification for separating and using plutonium. Today, low-enriched uranium fuel (LEU) is many times less expensive than equivalent MOX fuel, particularly if the costs of reprocessing are included. Even if there is strong growth in nuclear power, LEU should remain cheaper than MOX for the next 50 to 100 years. Thus, we can defer for decades the building of reprocessing plants, MOX fuel-fabrication plants, and breeder reactors, even if it was believed that a shortage of cheap uranium will eventually render economical the use of plutonium fuels.

It is not obvious, however, that we would *ever* be driven to the use of plutonium. Nuclear power may not grow, in which case LEU fuel could remain cheap for centuries. Terrestrial resources may be much larger than is now thought, and the cost of extracting low-grade ores may decline markedly. At today's low uranium prices there is little exploration or research on extraction. The huge amount of uranium present in seawater may become available at prices competitive with MOX. Finally, one could pay very high prices for uranium—500 or more dollars per kilogram—without adding substantially to the price of nuclear-generated electricity. If the security problems associated with plutonium use cannot be resolved satisfactorily, it may be worth paying a premium for uranium in order to avoid these problems.

Other, non-economic rationales for the separation and use of plutonium are sometimes mentioned. In Japan, for example, plutonium-use programs are justified as providing “energy security” for a country without significant uranium or other energy resources. But the security of Japan's nuclear fuel supplies could be assured at much lower cost by stockpiling uranium at current low prices. For example, a strategic reserve of uranium could be purchased at far less cost, and the

plutonium resource would remain available for extraction in the stored spent fuel.¹ Nor is reprocessing a solution to the waste-disposal problem. The high-level fission-product wastes resulting from reprocessing contain nearly all the heat and biological hazard originally in the spent fuel, ensuring that the cost and public acceptance of disposing of the waste will not be substantially different from those of spent fuel.

Regardless of the costs and benefits of plutonium use today, there remains the possibility that plutonium fuels will be used in the future. To prepare for this possibility, we should begin to investigate technical and institutional options for minimizing the security concerns that this would raise. For example, reprocessing and fuel-fabrication processes could be developed in which plutonium would not be present in weapon-usable forms. Schemes that have been suggested include mixing or precipitating plutonium with uranium and transuranics. This might, of course, add significantly to the costs and hazards of fabricating and handling reactor fuel. Concerns about diversion also could be reduced by internationalizing certain parts of the fuel cycle. For example, facilities in which weapon-usable materials are handled, such as reprocessing, enrichment, and fuel-fabrication plants, could be managed directly by the IAEA or, as envisioned in the Baruch Plan, an “International Atomic Development Authority.” National reactors might be permitted to burn only LEU fuels, with the spent fuel turned over to international reprocessing or storage centers; reactors burning plutonium fuels would be managed by an international authority.

In summary, the plutonium in civilian reactor fuel can be used to make reliable and deadly nuclear weapons. Many countries and groups could build nuclear weapons if they had access to this material. It has not been demonstrated, however, that divisions of significant amounts of plutonium would be detected with high confidence in a timely manner. Existing stocks of plutonium are not adequately protected from theft. Such stocks create an ever-present risk of breakout, and plutonium-use programs in “responsible” states, such as Japan, provide a ready excuse for other states to pursue such programs for other purposes. Today, there are no countervailing reasons—economic or otherwise—to accept the security risks posed by the separation and use of plutonium. Reprocessing

¹ A one gigawatt reactor requires 27 to 17 tons of LEU per year, for burn-ups of 33 to 53 gigawatt-days per ton (initial enrichments of 3.25 to 4.4 percent uranium-235). Assuming a tails assay of 0.2 percent uranium-235, 6.0 to 8.3 kilograms of natural uranium is required to produce 1 kilogram of uranium enriched to 3.25 to 4.4 percent. Thus, 140 to 160 tons of natural uranium is required per year per gigawatt. Japan has about 50 gigawatts (GW_e) of nuclear electrical capacity in operation or under construction. About 150,000 tons of uranium could supply all of these reactors for about 20 years, at a cost of less than \$4 billion at today’s prices. This can be compared with the \$26 billion estimated cost of the Rokkoshomura reprocessing plant.

therefore can be deferred for many decades, while we explore technical and institutional arrangements to make plutonium use more acceptable, should it become economical in the future.