Chapter 1

Why Countries Might Choose Reactor-Grade Plutonium for Their First Weapon

Weapon-grade plutonium is preferred to reactor-grade plutonium for the production of nuclear weapons. It has a relatively low spontaneous fission neutron output, low heat output, and will produce less gamma radiation. All things being equal, a country will always choose to use weapon-grade plutonium instead of reactor-grade plutonium.

But today all things are not equal. In particular, any country looking to become a nuclear weapon state will find it much harder to obtain weapon-grade plutonium than reactor-grade plutonium. The greater ease of access to reactor-grade plutonium is what makes the question of whether reactor-grade plutonium can be used to produce nuclear weapons of great importance.

In the 1940s and 1950s, there was little plutonium anywhere in the world, and the United States, the Soviet Union, the UK, and France built graphite moderated, natural uranium fueled plutonium production reactors to produce weapon-grade plutonium for nuclear weapons. These countries would have found it difficult to produce reactor-grade plutonium even if they had wanted to. Indeed, the first U.S. attempt to produce significant quantities of reactor-grade plutonium in the late 1950s failed (see chapter eight). In the 1960s, China built its own graphite moderated, natural uranium fueled plutonium production reactor and France was happy enough to sell a heavy water moderated, natural uranium fueled plutonium production reactor to Israel.

Today the situation is quite different. A decade ago, Syria attempted to build a plutonium production reactor, but it was bombed and destroyed by Israel. Countries have attempted to disguise their plutonium production reactors by calling them research reactors. Indeed in the 1950s and 1960s, Canada was naïve enough to sell two heavy water moderated, natural uranium fueled “research reactors” to India and Taiwan. Both reactors became the linchpins of the nuclear weapon programs in these two countries.

However, when China attempted the sale of such a research reactor to Algeria in the 1980s, concerns were raised and the reactor was converted to enriched uranium fuel so as to significantly reduce (but did not eliminate) its production of plutonium. When Iran made its first attempt to acquire a plutonium production reactor in the early 1990s by purchasing a heavy water moderated, natural uranium fueled “research” reactor from India, international pressure forced India to drop the sale. More recently Iran attempted to build such a plutonium production reactor at Arak but as part of the negotiated Joint Comprehensive Plan of Action, the original reactor vessel was destroyed and any follow-on reactor must use enriched uranium fuel to significantly reduce its plutonium production.

In contrast, a number of different vendors from countries as diverse as South Korea, Russia, France, and Canada are willing to build nuclear power reactors in any country willing to pay for them. As of today, there are over 400 operating nuclear power reactors worldwide, which have generated a stockpile of about 2,400 metric tons of plutonium.[7] Most of this plutonium is likely reactor-grade but some of it is no doubt fuel-grade. A small amount may even

7. David Albright et al., “Civil Plutonium Stocks Worldwide, End of 2014,” *Institute for Science and International Security*, November 16, 2015.

be weapon-grade. In contrast to Iran's plutonium production reactor at Arak, the Joint Comprehensive Plan of Action barely mentions Iran's nuclear power reactor at Bushehr even though the reactor produces about 240 kilograms of plutonium every year.

Over 2,100 metric tons of the world's plutonium stockpile are contained in highly radioactive spent fuel. Analysis that I participated in at Pan Heuristics over forty years ago indicated that as long as a country does not possess a reprocessing plant, this plutonium is relatively safe from being diverted to the production of nuclear weapons given the time and difficulty in extracting the plutonium from the spent fuel.[8] We estimated that it could take many months for a country to reliably produce sufficient plutonium for multiple nuclear weapons. However, 40 years ago scientists at Oak Ridge National Laboratory raised concerns that the extraction process might not be that difficult.[9] Indeed, it is possible that with the diffusion of solvent extraction technology now used in the processing of uranium ores, the extraction of plutonium from spent fuel is less of a barrier than it was forty years ago. However, even if the Oak Ridge analysis were correct, it would not make reactor-grade plutonium safe. Rather it would raise questions about the wisdom of having nuclear power reactors in any non-nuclear weapon state.

Of greater concern is the 270 metric tons of plutonium that has already been separated from spent fuel. The bulk of this material

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8. Albert Wohlstetter, Thomas A. Brown, Gregory Jones, David McGarvey, Henry Rowen, Vincent Taylor, and Roberta Wohlstetter, "Moving Towards Life in a Nuclear Armed Crowd?" ACDA/PAB-263, Pan Heuristics, December 4, 1975, Revised April 22, 1976, available from http://www.npolicy.org/article_file/Moving_Toward_Life_in_a_Nuclear_Armed_Crowd_(1975).pdf. This analysis was updated in: Albert Wohlstetter, Thomas A. Brown, Gregory Jones, David McGarvey, Henry Rowen, Vincent Taylor, and Roberta Wohlstetter, *Swords from Plowshares,* Chicago: The University of Chicago Press, 1979.

9. D. E. Ferguson, "Simple, Quick Processing Plant," Oak Ridge National Laboratory, August 30, 1977.

is in the nuclear weapons states of the UK, France, and Russia but significant quantities are held in a half a dozen non-nuclear weapons states of which Japan has the largest stockpile. 37 metric tons of Japan's stockpile are being held in the UK and France and 9.8 metric tons are in Japan itself. About 2.7 metric tons of the stockpile in Japan is held as either a pure plutonium nitrate solution or as pure plutonium dioxide.[10] Either form could be converted into a metal core for a nuclear weapon in only days or weeks.[11]

Most of the rest of the 9.8 metric ton stockpile is in the form of a mixture of plutonium and uranium oxides (MOX), either in powder form, in the process to produce MOX fuel, or in the unirradiated MOX fuel. Extracting the plutonium from the MOX powder or unirradiated fuel would not be difficult and could probably be performed using lab scale equipment since the plutonium in these forms is not highly radioactive and would not need to be handled remotely.[12] Further, the plutonium is seven to fifty times as concentrated as it is in spent LWR fuel. The time required to extract the

10. "The Status Report of Plutonium Management in Japan-2016," Office of Atomic Energy Policy, Cabinet Office [Japan], August 1, 2017, available from http://www.aec.go.jp/jicst/NC/about/kettei/170801_e.pdf.

11. Albert Wohlstetter, Thomas A. Brown, Gregory Jones, David McGarvey, Henry Rowen, Vincent Taylor, and Roberta Wohlstetter, *Swords from Plowshares*, Chicago: The University of Chicago Press, 1979.

12. This would include MOX powder which has aged for decades and has accumulated a significant quantity of americium. MOX fabrication plants limit worker radiation exposure from americium to just 0.5 rem. However, the U.S. limit for worker radiation exposure is 5 rem (chapter 6). Therefore though aged MOX powder might contain more americium than is allowed in a MOX fabrication plant, one could easily extract the plutonium from the MOX powder without exceeding the 5 rem limit. See, K. Fukuda et. al., "MOX Fuel Use as a Back-End Option: Trends, Main Issues and Impacts on Fuel Cycle Management," IAEA-SM-358/I, 1999. In the case of Japan this operation could be carried out in the plutonium purification section of the Tokai reprocessing plant.

plutonium and convert it into a metal core for a nuclear weapon is again only days to weeks.

What then would be Japan's options if it wanted plutonium for nuclear weapons? If it wanted to build a plutonium production reactor to produce weapon-grade plutonium, it would either have to acquire at least 20 metric tons of heavy water or hundreds of metric tons of nuclear-grade graphite. Neither task would be easy. Then the reactor would have to be constructed, a process that could take years and cost at a minimum hundreds of millions of dollars. The reactor would then have to operate for at least a year to produce enough plutonium for several nuclear weapons. The spent fuel would then have to cool for a number of months before the plutonium could be extracted in a reprocessing plant. If this operation was to be strictly a military one, a reprocessing plant would also need to be constructed concurrently with the construction and operation of the plutonium production reactor and would cost hundreds of millions of dollars as well. This whole process could take three to five years and probably cost at least one billion dollars. During this time, Japan would face enormous pressure from not only its enemies but also its allies to halt this process. Japan would also need to worry that an adversary might preemptively strike the reactor before the plutonium could be produced.

In contrast, if Japan was willing to settle for reactor-grade plutonium, it could simply seize the plutonium nitrate or dioxide and convert it into metallic weapon cores in a matter of days or weeks. It could probably use existing plutonium facilities to carry out this operation but if not it could build new "plutonium research" facilities in advance. The cost might only be tens of millions of dollars. The production of the nuclear cores could be carried out in such a short time that there would be little danger that an enemy could strike before the diversion of plutonium was detected.

Which option a country chooses depends strongly on the viability of using reactor-grade plutonium to produce nuclear weapons. If reactor-grade plutonium is truly denatured or very difficult or dangerous to use then a country would have no option but to go the plutonium production reactor route to produce weapon-grade plutonium or to give up its nuclear weapon ambitions entirely. However, as this book shows, simply by using a smaller plutonium mass as the weapon core, a country can use early 1950s U.S. technology and modern high explosives to produce nuclear weapons that are the same size and weight and have the same predetonation probability as weapons using weapon-grade plutonium. The smaller plutonium mass would keep its heat output within the limits required to ensure that the weapon's high-explosives are safe. The weapon would require no special cooling. By coating the core with just one half a centimeter of uranium, the gamma radiation would be well below that of an unshielded weapon-grade plutonium core. The destructive area of such a weapon would be 40% of that of a weapon using weapon-grade plutonium. Given the long time, significant expense and major risk associated with acquiring weapon-grade plutonium, a country might well decide to use reactor-grade plutonium instead.

Clearly, the possession of a reprocessing plant by a non-nuclear weapon state is a problem since it gives easy access to plutonium in the form of plutonium nitrate or plutonium dioxide. This plutonium can be quickly converted into a nuclear weapon core. The Pan Heuristic's analysis that I participated in recommended the obvious solution to ban the use of such plants in non-nuclear weapon states. This analysis led to a major change in U.S. policy under the Carter administration ending plutonium reprocessing in the United States and attempting to end it in other countries as well.

Further, the Pan Heuristic's analysis showed that even if reprocessing plants were banned from non-nuclear weapon states, if these states continued to use plutonium containing MOX fuel (produced perhaps in international fuel cycle centers), the problem would still remain. A single reactor reload of fresh MOX fuel can contain over seven hundred kilograms of plutonium, which is enough for over one hundred nuclear weapons. This fuel is not highly radioactive and a country could use simple hands-on procedures to quickly separate the plutonium from this fuel.

Only if both reprocessing plants and plutonium containing fuels are banned from non-nuclear weapon states can these countries be prevented from having easy access to the plutonium needed for nuclear weapons. However, at the moment, Japan is moving ahead with plans to open a large reprocessing plant which would produce eight metric tons of plutonium each year. In addition, the Joint Comprehensive Plan of Action allows Iran to reprocess after the deal expires in 13 years.

Note that the proponents of the view that plutonium is either denatured or too difficult to use in a practical nuclear weapon strongly oppose either of these steps. Indeed it is the possibility that concerns over the use of reactor-grade plutonium in nuclear weapons might lead to restrictions on the use of plutonium as a nuclear reactor fuel that drives these proponents to promote their erroneous views regarding reactor-grade plutonium. But their arguments are self-defeating. The more that their false narrative is accepted, the more accessible reactor-grade plutonium will be in non-nuclear weapon states and the more likely that such a country would choose to use reactor-grade plutonium to produce nuclear weapons.

The fact that five established nuclear powers chose to use weapon-grade plutonium instead of reactor-grade plutonium is a product of the circumstances of the time when they were developing nuclear weapons and not a universal law. In these countries at those times, weapon-grade plutonium was more easily produced than was reactor-grade plutonium. For a country today where reactor-grade plutonium is easily and quickly obtainable and weapon-grade plutonium is time-consuming, costly and perhaps even dangerous to produce, using reactor-grade plutonium to produce nuclear weapons would be the obvious choice.