Gregory S. Jones[1]
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The Arak Reactor and the Iran Nuclear Deal's Prohibition on the Production of Weapons-Grade Plutonium

As part of its nuclear weapons program, Iran is constructing a plutonium production reactor (which it claims is a research reactor) at Arak. The reactor's original design utilized natural uranium fuel, heavy water as the moderator and had a power level of 40 MW. This reactor would have produced nine to ten kilograms of plutonium per year.

Under the terms of the Iran nuclear deal (the Joint Comprehensive Plan of Action, JCPOA) the reactor will be redesigned to use approximately 3.5% enriched uranium fuel and have its power level reduced to 20 MW. The reactor will still produce significant amounts of plutonium, about one to one and one half kilograms of plutonium a year. Though Iran is required to export the spent nuclear fuel containing the plutonium, Iran is allowed to keep the fuel for at least one year, which would allow Iran to accumulate at least two to three kilograms of plutonium, enough for a nuclear weapon.[2] Though the Administration claims that the JCPOA blocks Iran's plutonium path to a nuclear weapon, this clearly is not the case.[3]

While reducing the amount of plutonium produced by this reactor would seem to be an important accomplishment, it is not. The JCPOA will accelerate the completion of the Arak reactor and the start of its plutonium production by having the IAEA and countries such as Russia provide technical, material and financial assistance.

One of the more puzzling terms of the JCPOA requires the Arak reactor "not to produce weapon-grade plutonium in normal operation."[4] Instead the reactor is to produce fuel-grade plutonium.[5] I use the term "puzzling" because the U.S. revealed almost forty years ago that even reactor-grade plutonium, let alone fuel-grade, can be used to produce nuclear weapons. The U.S. successfully conducted a nuclear test using reactor-grade plutonium in 1962. Therefore whether

[1] This paper is the product of the author's personal research and the analysis and views contained in it are solely his responsibility. Though the author is also a part-time adjunct staff member at the RAND Corporation, this paper is not related to any RAND project and therefore RAND should not be mentioned in relation to this paper. I can be reached at GregJones@proliferationmatters.com

[2] Though the IAEA uses eight kilograms of plutonium as a "significant quantity" of plutonium, it is well known that a nuclear weapon can be made with far less plutonium. The U.S. has declassified the fact that approximately six kilograms of plutonium were used in the Nagasaki weapon and that nuclear weapons can be made with four kilograms. The Russians have revealed that early in their nuclear program they conducted nuclear tests using just two kilograms and 0.8 kilograms of plutonium, which produced yields of 5.8 and 1.6 kilotons respectively. See Gregory S. Jones, "A Nuclear Deal That Spreads Nuclear Weapons," August 10, 2015, p.5. http://nebula.wsimg.com/de41a0d1cf9f9c51df7637d3b8df3d05?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

[3] To recover the plutonium, Iran could clandestinely build a reprocessing plant at an Iranian military site where the International Atomic Energy Agency (IAEA) would have trouble finding it.

[4] Annex 1, Part B, Paragraph 2.

[5] See the Appendix for an explanation of these terms and details of U.S. statements regarding the weapons usability of all grades of plutonium.

the Arak reactor's plutonium is weapons-grade or fuel-grade is of little significance with respect to Iran's capability to develop a nuclear weapon.

President Obama, however, has been seriously misinformed and has said that weapons-grade plutonium is *necessary* to produce a nuclear weapon.[6] In my analysis of the Iran nuclear deal[7] I asked how it was that the Secretary of Energy, Ernie Moniz, has allowed the President to be so misinformed.

On August 26, 2015, the Administration released a video by Secretary Moniz entitled: "A Nuclear Physicist Explains the Science Behind the Iran Nuclear Deal."[8] The video lasts only four and one half minutes. In such a short video it is not surprising that Secretary Moniz provides almost no scientific explanation of the deal but rather mostly restates the Administrations claims regarding the deal.

On plutonium he says:

> Plutonium on the other hand does not exist in nature. It is generated in the fuel of a normally operating nuclear reactor when a U238 atom absorbs a neutron. When used solely to produce electricity, reactors would not produce plutonium with the quality of that used in a nuclear weapon. But just to make sure, Iran has agreed to take all of the irradiated fuel that contains the plutonium and send it out of the country. So we feel very very secure that the plutonium pathway is very very well blocked.

It is hard to decide what to make of Moniz's statements. He does not discuss the Arak reactor at all but rather talks about an electricity-generating nuclear power reactor. Iran does have one such reactor at Bushehr but it is only discussed peripherally in the nuclear deal. In contrast, many pages of the nuclear deal are devoted to the Arak reactor.

His statement that the plutonium produced by nuclear power reactors in normal operation (i.e. reactor-grade) does not have the "quality of that used in a nuclear weapon" is very ambiguous. At best it is carefully worded to mislead a nontechnical listener into believing that since such plutonium is not normally used to produce nuclear weapons, it cannot be used to produce nuclear weapons. What is worse, the beginning of his next sentence "But just to make sure…" implies that Secretary Moniz himself may believe that reactor-grade plutonium cannot be used to produce nuclear weapons.

Whatever the case, the President's false statements that only weapons-grade plutonium can be used to produce nuclear weapons needed to be corrected. The U.S. Department of Energy has

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[6] For example, he has said: "Because of this deal, Iran will not produce the highly enriched uranium and weapons-grade plutonium that form the raw materials *necessary* for a nuclear bomb."[Emphasis added] "Read President Obama's Remarks on Iran Nuclear Deal," *Time,* July 14, 2015.

[7] Gregory S. Jones, "A Nuclear Deal That Spreads Nuclear Weapons," August 10, 2015, p.5. http://nebula.wsimg.com/de41a0d1cf9f9c51df7637d3b8df3d05?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

[8] http://www.popsci.com/ernest-moniz-explains-science-iran-deal

stated on more than one occasion that all grades of plutonium can be used to produce nuclear weapons (see Appendix).

This is not the first time that a political figure has made incorrect statements regarding reactor-grade plutonium. In 1993, UK Foreign Minister Lady Chalker, attempting to reassure the British House of Lords regarding concerns that British commercial reprocessing activities would lead it to export plutonium to nonnuclear weapon states said that reactor-grade plutonium was "not suitable" for nuclear weapons. However, ten days later the British Foreign Office had to retract this statement saying that Lady Chalker had been "improvising." Unfortunately it has been far longer than ten days and the President's incorrect statements have not been retracted.

The President's false statements as well as Secretary Moniz's at best misleading statement threaten to undermine broader U.S. nonproliferation policy to restrict plutonium stockpiles in non-nuclear weapon countries. There are still some in the nuclear industry who continue to deny the weapons usability of reactor-grade plutonium. Indeed in the past the former head of the IAEA Department of Safeguards suggested that safeguards on reactor-grade plutonium should be significantly relaxed since he incorrectly believed that this plutonium was not really very dangerous.[9]

Regarding the Iran nuclear deal itself, since the Arak reactor will be permitted to produce significant quantities of fuel-grade plutonium, the Administration should admit that the deal does not block Iran's plutonium pathway to a nuclear weapon.

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[9] Bruno Pellaud, "Proliferation aspects of plutonium recycling," *Journal of the Institute of Nuclear Material Management,* Fall 2002, p.8. Pellaud was head of the IAEA Department of Safeguards from 1993-1999.

Appendix

Reactor-Grade Plutonium Produces Kiloton Yields in a Nagasaki Type Nuclear Weapon

Nuclear reactors fueled by either natural or low enriched uranium will produce substantial amounts of plutonium due to neutron capture in the U-238 that makes up the preponderance of these fuels. The plutonium produced is the isotope Pu-239. One can readily produce a nuclear weapon using this isotope. However, in order to create significant amounts of plutonium one must keep the fuel in the reactor for some time to allow the plutonium to accumulate. As a result the Pu-239 itself can capture a neutron and be transformed into Pu-240. All reactor produced plutonium must contain some amount of Pu-240.[10]

The Pu-240 has a small but not insignificant rate of spontaneous fission as one of its decay modes. This spontaneous fission results in the significant production of neutrons which can complicate the functioning of a nuclear weapon. When a nuclear weapon detonates, a subcritical quantity of nuclear material (either highly enriched uranium or plutonium) is converted into a supercritical configuration. Once the nuclear material has reached a critical state, a neutron can cause the weapon to produce a runaway chain reaction and explode. If the neutron is introduced into the system before the weapon has reached the desired degree of supercriticality, the weapon will produce less than the planned yield and is said to predetonate.[11]

Since a greater percentage of Pu-240 in the plutonium increases the chance that a nuclear weapon will predetonate, the U.S. limited the percentage of Pu-240. This was especially the case for early nuclear weapons which produced the desired supercritical configuration relatively slowly. The U.S. has defined three grades of plutonium, weapons-grade, fuel-grade and reactor-grade, depending on the percentage of Pu-240 in the plutonium.[12]

In the mid-1940s and persisting into the mid-1970s there developed an erroneous belief that the yield of a nuclear weapon manufactured using reactor-grade plutonium would be so low as to be insignificant and that such plutonium was "denatured." The truth of the matter remained classified.

In 1976 a research team at Pan Heuristics led by Albert Wohlstetter[13] discovered two declassified memos from 1945 that revealed the predetonation characteristics of the Nagasaki nuclear weapon.[14] In particular there is a lower limit on the yield of any predetonating weapon, which is referred to as the fissile yield. This is the yield that would be produced if a neutron started the

[10] As the irradiation of the plutonium continues, additional isotopes of plutonium are formed but the resulting plutonium can still be used to produce nuclear weapons.

[11] Samuel Glasstone and Leslie M. Redman, "An Introduction to Nuclear Weapons," Wash-1037 Revised, U.S. Atomic Energy Commision, June 1972, declassified but heavily redacted. See in particular, Figure 2.1, p.26.

[12] The U.S. defines weapons-grade plutonium as containing less than 7% Pu-240. Fuel-grade contains 7% to less than 19% Pu-240 and Reactor-Grade 19% or more Pu-240. *Plutonium: The First 50 Years*, DOE/DP-0137, U.S. Department of Energy, February 1996, p.17.

[13] In addition to Albert Wohlstetter, the key persons involved in this discovery were Arthur Steiner and myself.

[14] Albert Wohlstetter, "Spreading the Bomb without Quite Breaking the Rules," *Foreign Policy*, No. 25, Winter 1976-77, pp. 160-161. http://www.npolicy.org/userfiles/file/Nuclear%20Heuristics-Spreading%20the%20Bomb%20without%20Quite%20Breaking%20the%20Rules.pdf

chain reaction just as the weapon became critical. One of these memos stated that for the Nagasaki weapon the minimum yield would be about one kiloton. Since the lethal area of a one kiloton nuclear weapon is about 20% of that of the full yield 21 kiloton weapon, this yield can hardly be considered insignificant.

Further even for plutonium containing fairly high percentages of Pu-240, most weapons will produce yields substantially higher than their fissile yield since the probability of a neutron appearing in the weapon just as it becomes critical is low. More recently a former nuclear weapon designer, Harmon Hubbard, has used the information contained in these 1945 memos to quantify the probability that various yields would be produced in a Nagasaki type weapon for various Pu-240 percentages.[15] He has shown that the average yield of a Nagasaki weapon using fuel-grade plutonium would still be about four kilotons which would produce a lethal area of about one third of that of the full yield weapon.[16]

In addition, the Nagasaki weapon was the least advanced type of nuclear weapon that can use plutonium and any country that developed nuclear weapons today, including Iran, would have weapons with significantly higher performance.[17] Hubbard has shown that for such weapons the average yield using fuel-grade plutonium would be about eleven kilotons which would have a lethal area about two-thirds of that of the full yield weapon.

When the Energy Research and Development Agency (ERDA--the predecessor to the current Department of Energy) found out that Wohlstetter was going to publish the predetonation probabilities and yields of the Nagasaki weapon, its first impulse was to attempt to reclassify the information. When this was not possible, ERDA decided to preempt Wohlstetter. In mid-November 1976 Robert Selden of the Lawrence Livermore National Laboratory and Carson Mark of Los Alamos National Laboratory gave a series of briefings explaining that reactor-grade plutonium can be used to produce nuclear weapons. The final slide of Selden's briefing[18] said:

> All plutonium isotopes can be used directly in nuclear explosives. The concept of "denatured" plutonium (Pu which is not suitable for nuclear explosives) is fallacious. A high content of the Pu-240 isotope is a complication, but not a preventative.

In July 1977 the Department of Energy revealed that in 1962 it had successfully tested a nuclear weapon using reactor-grade plutonium. In 1994 the Department of Energy released additional information regarding this test.[19] Part of this information said:

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[15] Harmon W. Hubbard, "Plutonium from Light Water Reactors as Nuclear Weapon Material," pp. 61-62, Appendix 3 in: Victor Gilinsky, Marvin Miller, Harmon Hubbard, "A Fresh Examination of the Proliferation Dangers of Light Water Reactors," Nonproliferation Policy Education Center, October 22, 2004 http://npolicy.org/article_file/A_Fresh_Examination_of_the_Proliferation_Resistance_of_Light_Water_Reactors.pdf

[16] Note roughly ten percent of weapons would not predetonate and have the full 21 kiloton yield.

[17] Even fifty years ago, France's and China's first nuclear tests involved weapons significantly more advanced than the Nagasaki weapon.

[18] Robert W. Selden, "Reactor Plutonium and Nuclear Explosives."

[19] "Additional Information Concerning Underground Nuclear Weapon Test of Reactor-Grade Plutonium." https://www.osti.gov/opennet/forms.jsp?formurl=document/press/pc29.html

> The test confirmed that reactor-grade plutonium could be used to make a nuclear explosive…The United States maintains an extensive nuclear test data base and predictive capabilities. This information, combined with the results of this low yield test, reveals that weapons can be constructed with reactor-grade plutonium.

Despite these definitive statements, there is still confusion even among experts. For example a guide to the Iran nuclear deal published by Harvard's Belfer Center recognizes that under the deal the Arak reactor will produce fuel-grade plutonium. But the guide believes that the Iran nuclear deal does effectively block the plutonium pathway in part because it overestimates how much plutonium is required to produce a nuclear weapon. The guide also finds the deal's prohibition on the production of weapons-grade plutonium significant since it says "Nuclear weapons can be made with reactor-grade plutonium, although this requires relatively sophisticated nuclear weapons designs."[20]

However, as the discussion above has indicated, this statement is clearly incorrect. Even the most primitive nuclear design using plutonium ever employed by the U.S. (the Nagasaki weapon) can produce kiloton range nuclear yields using reactor-grade plutonium. Today countries developing their first nuclear weapons would use substantially more sophisticated nuclear designs which would allow an average yield of roughly ten kilotons to be produced from fuel-grade plutonium such as will be produced by Iran's Arak reactor under the terms of the Iran nuclear deal.

[20] "The Iran Nuclear Deal: A Definitive Guide," Harvard, Belfer Center, August 2015, p.20.