

Fueling the Tehran Research Reactor: Technical Considerations on the Risks and Benefits

On October 1, 2009, it was reported that Iran had agreed to send much of its current low enriched uranium stockpile (with an enrichment of 3.5%) abroad to have it enriched to 19.75% so that it could then be manufactured into fuel elements and returned to Iran to fuel the Tehran Research Reactor. Much of the public analysis that followed this announcement has contained inaccurate technical details (sometimes wildly so). It is my intention here to provide accurate information related to this proposal so that its pros and cons can be weighed more precisely.

The Tehran Research Reactor (TRR) was built in the 1960s. It had a power of 5 MW and was fueled by 93% enriched uranium. According to the DOE a total of 6 kilograms of 93% enriched uranium was sent to Iran.¹ This material was never returned to the U.S and is still in Iran, presumably as spent research reactor fuel.

In the late 1980s, Argentina agreed to help Iran convert the TRR to use 19.75% enriched uranium and to provide fuel for this reactor. The conversion was completed and the reactor began operation in 1993. Its power remained at 5 MW. Argentina provided a total of 116 kilograms of 19.75% enriched uranium to Iran in the form of fuel. This fuel consists of uranium oxide particles (U_3O_8) dispersed in an aluminum metal matrix.

The core of the reactor is reported to consist of 18 standard fuel elements and five control elements.² Each standard fuel element contains 1.47 kilograms of 19.75% enriched uranium and each control element contains 1.08 kilograms of 19.75% enriched uranium.³ The entire core then contains 31.9 kilograms of 19.75% enriched uranium. However, the hallmark of research reactors is their flexibility and it would be expected that the amount of enriched uranium in the core could vary somewhat depending on how the reactor was operated and for what purpose.

The annual fuel consumption of a reactor depends on its power level, the number of day per year that it is operated and the percent burnup of the fuel before it needs to be replaced. Iran has indicated that the reactor runs at a power of 5 Mw for about 100 days per year. The target fuel burnup is 42%.⁴ Glaser has calculated that a 30 MW research reactor operated 300 days per year and having a target burnup of 40% would require

¹ *Highly Enriched Uranium: Striking A Balance*, U.S. Department of Energy, January 2001, Revision 1.

² M.S. Terman and H. Khalafi, "Analysis of Tehran Research Reactor Dynamics Behavior in Reactivity Insertion Accidents by Recurrent Neural Network", *Trends in Applied Sciences Research*, Vol. 1, No. 6, 2006, pp. 586-596.

³ M. Gharib, "Power Upgrading of the Tehran Research Reactor", *Transactions: Research Reactor Fuel Management*, European Nuclear Society and International Atomic Energy Agency, April 30-May 3, 2006.

⁴ *IAEA Research Reactor Database*, <http://www.iaea.org/cgi-bin/rrdb.page.pl/rrdeta.htm?country=IR&site=TRR&facno=214>

135.6 kilograms of 19.75% enriched uranium per year.⁵ Since the annual fuel consumption varies linearly with respect to these quantities, it is easy to calculate that the TRR would require 7.2 kilograms of 19.75% enriched uranium per year. Again this quantity could vary depending on the actual reactor usage.

Another way of looking at the TRR's annual fuel consumption is to note that the reactor has been able to operate from 1993 to the present on the 116 kilograms of 19.75% enriched uranium provided by Argentina. Assuming that the TRR will exhaust this supply of fuel next year would lead to an average fuel consumption over this period of 6.8 kilograms. The bottom line that the annual fuel consumption for the TRR has been around 7 kilograms of 19.75% enriched uranium.

For a number of years there have been concerns that Iran's ongoing centrifuge enrichment program could be a means for providing Iran with the highly enriched uranium needed to produce nuclear weapons. This author recently performed an evaluation of this issue.⁶ As of August 12, 2009, the IAEA reported that Iran had installed 8,308 centrifuges, of which 4,592 were in operation. Through this effort, Iran had already produced 1,019 kilograms of 3.5% enriched uranium (as of July 31, 2009, in the form of 1,508 kilograms of uranium hexafluoride). Its operating centrifuges were producing 57 kilograms of 3.5% uranium per month.

There are two ways whereby Iran could use its ongoing centrifuge enrichment program to produce highly enriched uranium. First, Iran could build a clandestine centrifuge enrichment facility of roughly 3,000 to 6,000 centrifuges. Then by feeding this facility either natural uranium or part of its preexisting stockpile of 3.5% enriched uranium, Iran could produce highly enriched uranium. If Iran were to use 3.5% enriched uranium as feed, it could produce a bomb's worth of highly enriched uranium (about 20 kilograms with an enrichment of 90% or more), for every 920 kilograms of 3.5% enriched feed. This option has gained in importance since President Obama revealed on September 25, 2009 that in fact Iran was constructing a clandestine centrifuge enrichment facility which would hold roughly 3,000 centrifuges.

Second, Iran could use a two step batch recycle process at its existing centrifuge enrichment facility at Natanz to produce highly enriched uranium. The process would begin by Iran feeding the plant 3.5% enriched uranium from its existing stockpile. About 1,900 kilograms of 3.5% feed would be needed to produce a weapons worth of highly enriched uranium.

This concern over Iran's current centrifuge enrichment effort then provides the logic for the plan to send part or all of Iran's stockpile of 3.5% enriched uranium out of the

⁵ Alexander Glaser, *Neutronics Calculations Relevant to the Conversion of Research Reactors to Low-Enriched Fuel*, Darmstadt, 2005. Glaser's estimate includes the contribution from the plutonium produced in the fuel during the course of its irradiation. http://tuprints.ulb.tu-darmstadt.de/epda/000566/aglaser_thesisrev.pdf

⁶ Gregory S. Jones, "Iran's Centrifuge Enrichment Program as a Source of Fissile Material for Nuclear Weapons: An Update", August 17, 2009, appendix added August 31, 2009. [http://www.bipartisanpolicy.org/sites/default/files/Iran%20Enrichment%20Update%20\(2\).pdf](http://www.bipartisanpolicy.org/sites/default/files/Iran%20Enrichment%20Update%20(2).pdf)

country to be made into 19.75% enriched fuel for the TRR. Diminishing Iran's stockpile of 3.5% enriched uranium would delay the threat of Iran's producing highly enriched uranium by the methods discussed above. But at best it will be only a delay. As long as Iran can continue to enrich uranium at Natanz, it can add to its stockpile of 3.5% enriched uranium. As we said, Iran is currently producing 57 kilograms of 3.5% enriched uranium per month. If it were to start using all of the centrifuges that it had installed on August 12, 2009 (8,308), then its production rate would be 103 kilograms of 3.5% enriched uranium per month and as Iran installs even more centrifuges, its production rate could be even higher. Bottom line is that even if Iran sends all of its current stockpile of 3.5% enriched uranium to be made into TRR fuel, the West, at best, could only hope to buy a year or two delay in Iran's accumulation of enough 3.5% enriched uranium to provide Iran with capability to make highly enriched uranium for nuclear weapons. Further, as will be discussed below, by providing Iran with 19.75% enriched uranium fuel for the TRR, the West will be providing Iran with a different pathway to highly enriched uranium that is just as threatening as our current situation.

Some accounts of the TRR fuel deal with Iran have indicated that Iran will send 1,200 kilograms of 3.5% enriched uranium out of the country to be made into 19.75% enriched uranium. One thousand two hundred kilograms is actually more 3.5% enriched uranium than Iran had on July 31, 2009 but with its continuing enrichment effort, it will have produced that amount of 3.5% enriched uranium by around the end of October 2009. Assuming standard 0.3% tails, 1,200 kilograms of 3.5% enriched uranium could be used to produce 197 kilograms of 19.75% enriched uranium. If the tails were 0.0711% (i.e. the same enrichment as natural uranium) then 176 kilograms of 19.75% enriched uranium could be produced. These amounts would be a 25 to 28 years supply of 19.75% enriched uranium for the TRR given its past rate of fuel consumption. If in the future Iran were to increase the reactor power and the number of days per year that the reactor operated then the reactor's annual fuel consumption would increase proportionally. For example, if the TRR were to operate at a power of 7.5 MW (something that has been proposed)⁷ and run 200 days per year (a fairly standard number) then the annual fuel consumption would be about 21 kilograms of 19.75% enriched uranium.

Henry Sokolski has raised the issue as to whether the conversion of Iran's current stockpile of 3.5% enriched uranium into 19.75% fuel for the TRR is desirable since it will open up a new pathway for Iran to produce highly enriched uranium for nuclear weapons.⁸ He points out that it will take even less time to enrich 19.75% enriched uranium to 90% enriched uranium (i.e. weapons-grade) than it would take to enrich the 3.5% enriched stockpile to 90% enriched uranium.

This point can be illustrated by my previous analysis of the threat of batch recycling at Natanz.⁹ This is a two step process. In the first step 3.5% enriched feed is enriched to 16.1% product. In the second step the 16.1% enriched uranium is used as feed to produce

⁷ Gharib op cit.

⁸ Henry Sokolski, "Fueling Around with Iran and the Bomb", <http://npec-web.org/essays/20090710-IranNuclearDeal.asp>

⁹ Jones op cit. See Table 5.

91.1% product. The time required for this enrichment depends on the number of centrifuges that Iran has in operation. Assuming Iran has 10,004 centrifuges in operation (which will likely occur next year), the first step of the process would take 50 days and the second step 15 days. Adding in the time needed to fill the cascades and for each step to reach equilibrium, the total time would be 69 days. Starting with 19.75% feed would allow one to skip the first step and the total time would only be about 18 days (including cascade fill and equilibrium times). This is only 26% of the time required to produce highly enriched uranium starting from 3.5% enriched feed. Starting with 176 to 197 kilograms of 19.75% enriched feed would allow the production of about 23 to 25 kilograms of 91.1% highly enriched uranium which is more than enough to produce a nuclear weapon. Varying the number of centrifuges that Iran uses for batch recycling changes the overall time required to produce highly enriched uranium but does not change the proportion of the time required by the first and second steps in the batch recycling process.

Sokolski recognizes that before the 19.75% enriched uranium could be enriched to highly enriched uranium, it would first have to be separated from the fresh TRR fuel and then converted to uranium hexafluoride. However, there is no mystery to this process. The recovery procedure has been published by Argentina as part of research reactor fuel manufacture scrap recovery.¹⁰ The process involves dissolution by nitric acid, followed by purification by solvent extraction. These are standard processes in the nuclear industry and Iran uses them as part of its uranium ore processing.¹¹ The recovered uranium oxide would then be hydrofluorinated and then fluorinated to produce the uranium hexafluoride. To prepare for this process, Iran would have to build a clandestine processing facility that was critically safe but Iran has shown that it has no qualms about building clandestine nuclear facilities. The time required from the removal of the fresh TRR fuel from safeguards to the time to produce 19.75% enriched uranium hexafluoride would be only “days to weeks”.¹²

The overall time required for Iran to convert its 19.75% enriched uranium in fresh TRR fuel to highly enriched uranium (including both the time to produce uranium hexafluoride and the time to enrich it to greater than 90% enrichment) would be on the order of a month or two. My analysis of Iran’s centrifuge enrichment program showed that by next year Iran will likely be able to have the capability to produce a weapon’s worth of highly enriched uranium by batch recycling at Natanz. The time required would be two months or less. Since these two time are roughly the same, it is not at all clear that the proposal to convert Iran’s current stockpile of 3.5% enriched uranium into 19.75% enriched uranium fuel for the TRR will do anything to deny Iran the capability of producing highly enriched uranium for nuclear weapons.

¹⁰ Ing. Bonini et.al., “Nuclear Fuel Cycle Head-End Enriched Uranium Purification and Conversion into Metal”, Presented at the 1998 International Reduced Enrichment for Test Reactor Conference, October 18-23, 1998.

¹¹ Mohammad Saedi, “Nuclear Fuel Cycle Activities in Iran”, World Nuclear Association Annual Symposium, September 7-9, 2005.

¹² Albert Wohlstetter et.al., *Swords from Plowshares*, The University of Chicago Press, Chicago, 1979.