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Iran's Conversion of Uranium Hexafluoride to Uranium Metal Not a Bottleneck to an Iranian Nuclear Weapon

As I have previously written, Iran's sizable stockpile of 60% enriched uranium has very likely survived both Israeli and American bombing attacks.[2] Even if only a very small fraction of Iran's centrifuge enrichment capacity has survived, Iran will be able to produce the 90% enriched uranium desired for nuclear weapons in less than a month once electric power is restored to the enrichment centrifuges. Iran's ability to produce 90% enriched uranium means that these bombing attacks have not eliminated the threat of an Iranian nuclear weapon.

However, Secretary of State, Marco Rubio, has argued that even if that is the case, the bombing destroyed Iran's facility in Esfahan that would convert the uranium hexafluoride used in the enrichment process into uranium metal which is the form used in nuclear weapons.[3] Rubio has claimed that the Iranian nuclear program has been set back by "years."

However, the conversion process from hexafluoride to metal is fairly simple. Due to criticality concerns, Iran could only process small batches of around four kilograms of 90% enriched uranium at a time. Therefore, the conversion facility would use only laboratory scale equipment. Even if Iran needed to start from scratch to build a new metal production facility, Iran can have this facility ready by the time it has restored its enrichment capacity and produced 90% enriched uranium.

Conversion from hexafluoride to metal is a two-step process. In the first step, the hexafluoride is reacted with hydrogen to produce uranium tetrafluoride and anhydrous hydrogen fluoride. The reaction is:

$$UF_6 + H_2 = UF_4 + 2HF$$

The HF must be handled with care and will require special materials such as nickel or Monel (a nickel/copper alloy) but HF is sometimes used in oil refineries and Iran probably already has the expertise and equipment needed to safely handle it.

[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] Gregory S. Jones, "Iran's Nuclear Weapon Program is Still a Threat," June 27, 2025. https://nebula.wsimg.com/2d7466f68214e953f932ba28294292ef?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

[3] William J. Broad and Ronen Bergman, "Israel and U.S. Smashed Iran Nuclear Site That Grew After Trump Quit 2015 Accord," The New York Times, June 28, 2025. https://www.nytimes.com/2025/06/28/science/iran-nuclear-uranium-metal.html This article incorrectly refers to the production of uranium metal from uranium hexafluoride as "metallization."

In the second step, the uranium tetrafluoride is reduced to metal via a thermite type reaction with either metallic magnesium or calcium:

$$UF_4 + 2Mg = U + 2MgF_2$$
or
$$UF_4 + 2Ca = U + 2CaF_2$$

This step requires little in the way of specialized equipment and is carried out in a stainless-steel container lined with a refractory material.[4] The container is shaped so as to protect against an accidental critical nuclear reaction. A large amount of heat is generated by the chemical reaction and the uranium metal melts and collects in the bottom of the container. In the past this production of uranium metal has been performed in college nuclear engineering classes (using natural or depleted uranium, of course).

The Iranian facility in Esfahan that was bombed was only under construction, so it is not known how much equipment was even at the site when the bombing took place. Even if Iran needed to start from scratch, it would take only a few months for Iran to build a new lab-scale facility to convert uranium hexafluoride into uranium metal. The ease of this process was illustrated by the U.S. nuclear weapon designer Ted Taylor, who in 1974 described in detail how terrorists could produce uranium metal from uranium hexafluoride using equipment obtained from scientific supply houses.[5]

The preparation for the production of uranium metal could be performed in parallel with the Iranian efforts to restore its ability to produce the 90% enriched uranium. Iran could test the new facility by practicing using natural uranium. This way, there would be no delay when the highly enriched uranium actually became available. Though Rubio and some other analysts have described the destruction of the facility in Esfahan that would produce uranium metal as a "bottleneck" or "roadblock" to Iran's obtaining a nuclear weapon, this is not the case.

None of this is to say that Iran will necessarily start an immediate push for nuclear weapons. Iran might find it prudent to "lay low" for a while. Still, the elimination of the Iranian nuclear weapon threat will require Iran to give up its entire enriched uranium stockpile and permanently shut down its centrifuge enrichment program.

[4] R. F. Hibbs and A. E. Sands, "Highly Enriched or Fully Enriched Uranium Recovery," *Reactor Handbook, 2nd Edition, Volume II, Fuel Reprocessing*, S. M. Stoller and R. B. Richards editors, Interscience Publishers, Inc., New York, 1961, pp. 409-412.
[5] John McPhee, *The Curve of Binding Energy*, Farrar, Straus and Giroux, New York, 1974, pp. 132-134.