IRAN FACT FILE

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Fact Sheet

Iran's Centrifuge Program

Natural uranium consists of several different atomic isotopes, each with its own nuclear characteristics. Only 0.7% of natural uranium is uranium-235 (U-235), the isotope useful in both nuclear reactors and nuclear weapons. To be used for nuclear weapons or as nuclear reactor fuel the U-235 proportion of uranium needs to be increased by essentially removing the more plentiful uranium-238 isotope (U-238). The process of removing less useful uranium isotopes of U-238 to increase the concentration of U-235 is called "enrichment".

Isotopes can be separated from each other using a variety of means that exploit the slight mass differences between them. In the case of uranium, the difference between U-235 and U-238 is less than 1% in mass. Trying to separate one from the other is cumbersome and is like trying to separate grains of salt from grains of sugar one at a time by hand.

The most widely used systems for enriching uranium require the material to be converted into a gas, usually uranium hexafluoride (otherwise known as "hex" and has molecular formula UF_6). "Hex" is a solid at room temperature and atmospheric pressure but when the pressure is lowered, it changes to a gas. The technological requirements for this process are within reach of dozens of countries with chemical industries. Iran has mastered mining uranium ore and turning it into hex for use in the enrichment process.

Centrifuges

A centrifuge is essentially a cylinder (known as a rotor) filled with low pressure UF_6 gas that is spun at high velocity inside of another cylinder called the casing. As the rotor spins, the slightly heavier U-238-rich UF_6 (heavier since it has a higher proportion of U-238 isotope) will tend to congregate towards the wall of the rotor, and the slightly lighter U-235-rich UF_6 molecules will tend to move towards the central axis. In addition, a centrifuge uses a “trick” by extracting the U-235 rich and poor UF_6 from the ends of the centrifuge rather than the central axis and wall making the gases much easier to extract (see Figure 1).

The challenge for Iran and for other countries that want to enrich uranium is that meaningful enrichment requires the use of thousands of centrifuges for several reasons. First, the mass difference between U-235 and U-238 is extremely small so that the process itself is extremely inefficient. Each enrichment step in itself is very small. This is compounded by the fact that Iran’s centrifuge types are early generation designs dating back several decades and not as efficient as modern centrifuges. Consequently, many interconnected stages of centrifuges are necessary to reach higher enrichment levels. The second problem common to all centrifuge facilities is the fact that UF_6 is loaded into centrifuges as a gas. Since, gas is less dense then liquids or solids, only small amounts of material can be loaded into a centrifuge and the separation within each rotor is only a small amount. Thus, in order to separate large quantities of U-235 (higher levels of enrichment), many centrifuges need to be connected in parallel (known as a stages) and the output from one stage needs to be fed into the input of many other stages until the desired enrichment and throughput is reached. Stages assembled into large networks of centrifuges are called cascades and can hold many thousands of centrifuges.

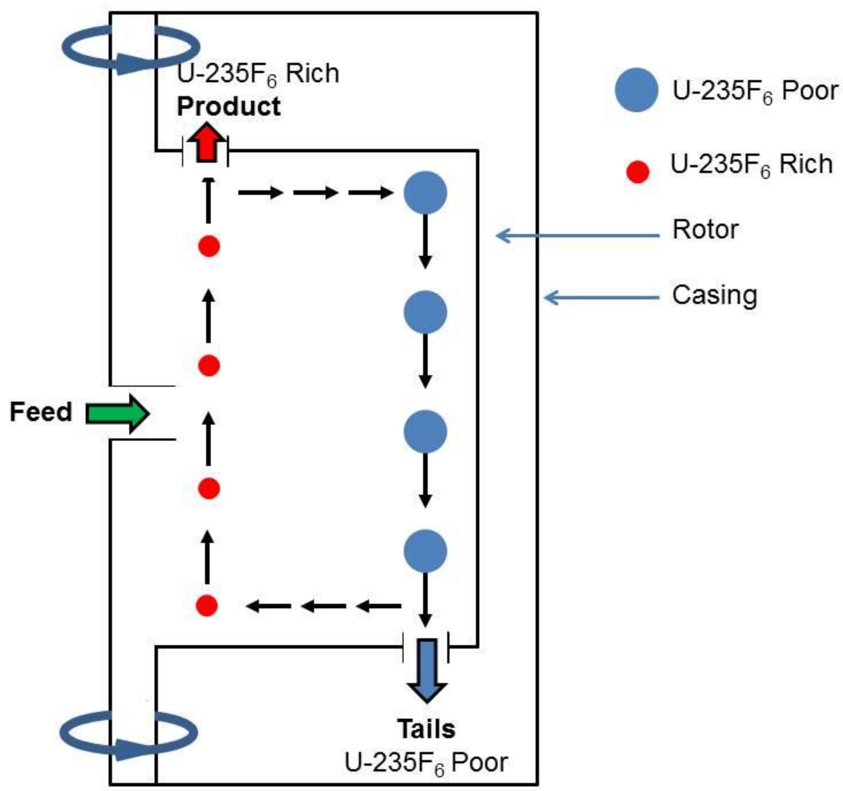

Figure 1: Figure of a gas centrifuge showing that by employing a “trick” the U-235 rich and poor UF6 are extracted at both ends of the centrifuge rather than at the central axis

and wall of the centrifuge. Also shown is the rotor and the casing in which it spins. The space between the casing and the rotor is evacuated to reduce the drag on the rotor.

History of Iran's Centrifuge Program

Iran has shown an interest in uranium enrichment since the 1970's, and their current centrifuge enrichment program started in the mid-1980s. According to the IAEA, [1] Iranian scientists searched open technical literature to obtain as much information as possible about gas centrifuges and in 1987 obtained [2] technical drawings of the P-1 centrifuge along with a set of centrifuge components from the A.Q. Khan network. However, the quality of the P-1 centrifuge drawings reportedly provided by the Khan Network lacked sufficient detail to be efficiently duplicated. In an unpublished letter purported to be written by A.Q. Khan himself, parts were claimed to be "old, mostly rejected due to being out-of-tolerances". Furthermore, the P-1 centrifuge allegedly provided by the Khan Network was considered to be of an "outmoded and inferior" design. Nevertheless, Iran is thought to have embarked on a persistent effort to produce its version of the P-1 centrifuge and after several years of struggling with the design it reconnected with the Khan Network. [3]

Gas centrifuge testing started in 1988 at the Tehran Nuclear Reactor Complex but was subsequently moved to the Kalaye Electric Company, a company directly connected to the Atomic Energy Organization of Iran (AEOI) in 1995. Despite, the difficulties with earlier contacts with the Khan Network, in 1993 Iran made a deal [4] with the network to obtain enough components for 500 centrifuges as well as technical drawings of the more useful P-2 centrifuge. After another set of "13 meetings with the Khan Network", [5] Iran managed to duplicate the P-1 dubbed the IR-1. However, while this design is central to the Iranian centrifuge program, it is very inefficient in its U-235 separation, essentially corresponding to an early generation centrifuge from the 1950's. In 2002, Iran began feeding UF_6 it secured from China in 1991, into a small network of 19 centrifuges [6] violating Iran's safeguards agreement with the IAEA and launching Iran into to an era of mass production of enriched UF_6.

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[1] See, GOV/2003/75,pg. 8, para 47
[2] See link at:
http://web.archive.org/web/20050308175103/http://www.iaea.org/NewsCenter/Statements/DDGs/2005/goldschmidt01032005.html
[3] See forthcoming issue of International Security: R. Scott Kemp, "The Nonproliferation Emperor Has No Clothes: The gas centrifuge, supply-side controls, and the future of nuclear proliferation," International Security, vol. 38, No. 4 (Spring 2014), pp. 39-78. doi:10.1162/ISEC_a_00159
[4] GOV/2007/58, para 15; see also GOV/2005/67, para 16
[5] http://isis-online.org/country-pages/iran
[6] GOV/2004/83, para 23. See also http://isis-online.org/publications/iran/kalayeelectric.html

From Experimental Scale to Mass Production

According to the IAEA, Iran began constructing a large facility in Natanz about 250 km South of Tehran in 2001. [7] The Natanz facility has two main areas, the production area known as the Fuel Enrichment Plant (FEP) and the R&D area known as the Pilot Fuel Enrichment Plant (PFEP). The PFEP at Natanz, was the first facility built and was revealed in 2002 by an independent Iranian opposition group. In 2003, Iran reported to former IAEA Director General Mohammed El Baradei that another commercial-scale enrichment plant (FEP) was also under construction. Iran divided the FEP into two principal areas, Production Hall A and Production Hall B. Not much is known about Production Hall B, but Hall A has 8 units where each unit houses 18 cascades with 164 or 174 [8] centrifuges per cascade. Iran used 8 units in Hall A, 3 units for near-5% UF_6 enrichment, 3 units for testing different centrifuges, and 2 units without centrifuges installed. The PFEP adjacent to the FEP was the first facility constructed at Natanz and before the JPoA was used both for production of 20% UF_6 (Units 1 and 6) and for testing experimental types of centrifuges in a cascade environment (Units 2 to 5). See the By the Numbers Webpage for a figure showing the trend of types of centrifuges installed. [9] It has not been revealed what the differences are between the different types of centrifuges, however, a presentation by Olie Heinnonen the former IAEA Head of Safeguards suggested that the IR-2m separation is at least 5-10 times more efficient than the IR-1 centrifuge. [10] Prior to the implementation of the Joint Plan of Action in January 2014, 3 units from the FEP produce 11,111 kg near-5% enriched UF_6 of which 15% was fed into PFEP to produce 201.9 kg near-20% UF6. [11]

In 2009, an additional enrichment facility was revealed South-West of Tehran at Fordow, which was already under construction at the time of discovery. The facility is considerably smaller than Natanz and can hold a total of 3,000 centrifuges in 2 units containing 8 cascades of 186 centrifuges each. The facility has been of concern to the international community because of the secret way it was constructed and because of repeated modifications of purpose as described in the "Design Information Questionnaire".

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[7] Iran's Nuclear Programme: A Collection of Documents, Presented to British Parliament, Jan 2005.
[8] Iran has been upgrading different cascades to 174 centrifuges, at the time of writing 30 cascades have been converted to 174 centrifuges per cascade.
[9] http://www.iranfactfile.org/2014/02/08/numbers/
[10] http://ats-fns.fi/index.php?option=com_joomdoc&task=doc_details&gid=168&Itemid=0&lang=en
[11] See Annex 2, GOV/2014/10, (Feb 20 2014).

Before the implementation of the Joint Plan of Action, 16% of the near-5% UF_6 produced from the FEP was used as a feed for the FPEP, and 245.9 kg was withdrawn in the form of near-20% UF_6. The PFEP was a former base of the Iranian Islamic Revolutionary Guards Corps (IRGC) located underground in a fortified tunnel presumably to ensure continuation of the facility in case of an aerial strike. The total near-20% UF6 produced by Iran was 447.8 kg. [11]

Uranium Enrichment After the Joint Agreement

After the JPoA went into force, Iran agreed to halt production of near-20% UF_6 in the PFEP at Natanz and the FFEP in Fordow. Instead Iran has been feeding cascades originally used for near-20% UF_6 production with natural UF_6 to produce near-5% UF_6. Figure 2 displays the flow of UF6 before and after the JPoA was in force. Notice that the right side of Figure 2 has no arrows pointing to the near-20% storage. In addition, as agreed to in the JPoA, Iran has been blending down the near-20% stockpile, as well as converting them into fuel assemblies for the Tehran Research Reactor so that only a small amount of near-20% UF_6 is left in storage but is under safeguards. The total quantity of stockpiled 20% UF_6 is 56 kg UF_6 as of April 20th report.

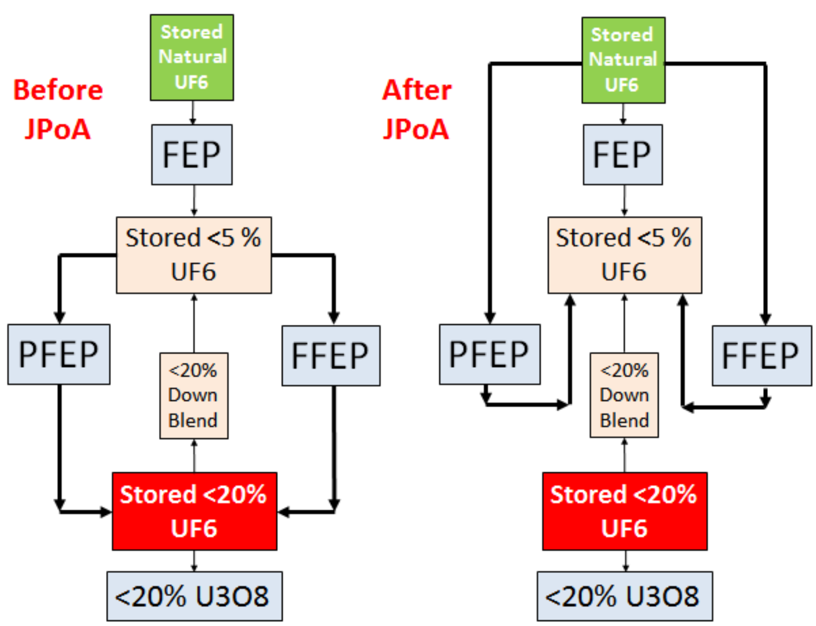

Figure 2: Figure showing the enrichment of UF_6 before and after the Joint Plan of Action (JPoA). On the left side the centrifuge facilities are shown first producing near-5% UF_6 and then feeding a portion of this material into the PFEP at Natanz and the FFEP at Fordow, to produce further enriched near-20% UF_6 which could be re-enriched further to weapons grade. The figure on the right shows that after the Joint Plan of Action came into force Iran reconfigured the enrichment plants to just produce near-5% UF_6. The changes before and after the agreement are emphasized with thicker arrows.