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Fact Sheet

Iran's IR-40 Heavy Water Nuclear Research Reactor

The IR-40 is an as yet incomplete Iranian heavy water moderated research reactor with a declared power rating of 40 MW. The reactor was under construction until January 20, 2014 but work has been stopped under the terms of the Joint Plan of Action agreed to by Iran, the United States and other world powers (see IranFactFile fact sheet on Joint Plan of Action). Research reactors can be used for a number of legitimate civilian goals, including the production of medical isotopes. However, such facilities can also be used to produce plutonium for use in nuclear weapons. While the full design details of the IR-40 are not publicly available, what is known suggests that the IR-40 reactor may be able to produce about 10 kg of plutonium per year if and when it is completed and enters into operation. However, Iran is not known to possess the facilities needed to separate plutonium from spent nuclear fuel, a step that would be needed if this material were to be used in nuclear weapons.

All nuclear reactors produce plutonium, but heavy water moderated reactors are particularly well suited for this purpose. The quality of plutonium produced is a function of the type of nuclear reactor and the length of time the fuel is inside the reactor. Heavy water reactors have been the reactor of choice for many countries such as Israel, India, and Pakistan for their nuclear weapon programs. Iran's interest in such a design has added to broad concerns about its nuclear intentions.

Stated Purpose of the IR-40

According to Iran and International Atomic Energy Agency (IAEA) reports, the IR-40 reactor will be used to "research and development and the production of radioisotopes for medical and industrial use.[1]" In a presentation to the IAEA in 2003, Iran explained that it had not been able to purchase a reactor from foreign sources to replace the aging Tehran Research Reactor (TRR) and in the mid-1980's concluded that "the only alternative was a heavy water reactor which could use domestically produced UO2 and zirconium." The TRR was originally provided to Iran

[1] Director General, "Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran", GOV/2003/75, para 42, pg 8.

by the United States under the Atoms for Peace program in the 1960s. Iran stated that it had decided to replace TRR because, "after 35 years of operation, it was reaching the safety limits for which it had been designed and because of its location within what had become the suburbs of the city of Tehran." Iran decided a new reactor should be constructed away from Tehran in the "Khondab area near Arak". Iran further declared that in order to meet its isotope requirements, such a reactor must have a "neutron flux of 1013 to 1014 n/cm 2s, based on a power of the order of 30-40 MW when using natural UO2 fuel.[2]"

Iran has legitimate civil need for medical isotopes including molybdenum-99 (Moly-99). Moly-99 is critical for cancer therapy and certain medical procedures. Iran currently imports the Molybdenum-99 (about 600 Ci at production or 70 Ci at destination[3]) that it needs from Russia but a large fraction of the isotope decays during travel. Because of its short half-life, Moly-99 cannot be stockpiled and must be constantly produced.

Heavy Water Research Reactors

In some respects, design, production and operation of a heavy water reactor is easier than other reactor alternatives. Heavy water reactors do not need enriched uranium fuel and it is technically easier and less expensive to produce heavy water than to enrich uranium. In addition, heavy water reactors do not need to be shut down for refueling, meaning they can be operated for longer periods of increased reliability. These two factors, however, also make heavy water reactors major proliferation concerns. It is not clear why, after having demonstrated an ability to enrich uranium that Iran has continued to pursue the heavy water reactor route, since Tehran could produce a light water reactor for research and medical isotope production purposes. The director of the Iranian Atomic Energy Institute Ali Akbar Salahi has recently indicated that Iran was open to redesigning the reactor[4]. A redesign could reduce, but not eliminate the proliferation concerns surrounding this aspect of Iran's nuclear program.

What is Known about the IR-40?

Iran has declared that the power of this reactor will be 40 MW, a number consistent with estimates of the cooling capacity of the mechanical draft cooling towers from satellite images which ranges from 40-50 MW.[5] The fuel assemblies for the IR-40 appear similar to that of the Russian RBMK and consists of 18 vertical tubes (fuel rods) isolated from each other containing natural uranium oxide (UO2) fuel pellets and a central carrier rod. We estimate that 1 fuel rod contains ~3.1 kg natural uranium so that a single fuel assembly contains 56.5 kg uranium. There

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[2] Neutron flux, measured in the number of neutrons emitted per cm2 area in one second, is a measure of the intensity of the neutron source and can be seen as a measure of the usability of the reactor. If the flux is high, more isotopes can be produced, better probes of materials can be done, and a range of other applications are improved. The only thing that does not necessarily scale with intensity is the usefulness of the reactor for teaching and training.

[3] Molybdenum-99 production is actually quoted in units of 6-day Ci which is the molybdenum-99 produced after 8 days of decay after the end of irradiation in a reactor. It is called 6-day Ci because it generally takes 2 days of processing of the target so that the total number of days after end of irradiation is 8 days.

[4] http://uk.reuters.com/article/2014/02/06/uk-iran-nuclear-arak-idUKBREA151BD20140206

[5] IAEA Board of Governors Reports GOV/2003/75, GOV/2004/83, GOV/2013/27

is evidence that the Russian company, the producer of RBMK fuel assemblies, and another company in Obninsk assisted Iran in "modifying the design of a RBMK fuel rod bundle for use in the Arak heavy water reactor" in the 1990s[6]. This would explain the similarity in the design to the RBMK fuel assemblies that are for graphite-moderated nuclear reactors not heavy water reactors. The RBMK reactor fuel assemblies are pressurized and contain UO2 pellets in a Zirconium metal tube.

Figure 1 shows a picture of an IR-40 fuel assembly reportedly released by the Atomic Energy Organization of Iran in 2011. The fuel assembly is similar to the RBMK fuel assembly displayed in Figure 2. There will be 150 fuel elements inside the reactor core with an expected active length of 340 cm[7]. According to Iranian declared specifications the IR-40 reactor will require about 10,000 kg UO2/year. Iran is able to produce this material at the Fuel Manufacturing Plant (FMP) at Esfahan.

Nuclear reactor fuel must be able to withstand high temperatures and pressures without deteriorating and must be able to resist a strong radiation field. Therefore the fuel needs to be adequately tested to ensure that the fuel will perform as expected. Although, the IR-40 fuel appears to be a variant of the Russian RBMK fuel type it still needs to be rigorously tested before the fuel is used inside the reactor. Furthermore, to our knowledge the RBMK fuel type has not been utilized in a heavy water reactor before. This lack of testing could be a significant constraint on Iran's ability to operate the reactor, if and when it is completed.

Current Status of the IR-40

The IR-40 has ceased construction and has not yet been commissioned. Before work was stopped under the Joint Plan of Action, the IR-40 was to "be commissioned using nuclear material" in the first quarter of 2014. However, the agreement requires the IR-40 not to "commission the reactor or transfer fuel or heavy water to the reactor site and will not test additional fuel or produce more fuel for the reactor or install remaining components." In the February 2014 report the IAEA confirmed that since January 2014, "Iran had ceased the production of nuclear fuel assemblies for the IR-40 Reactor at FMP". The IAEA has recently carried out a Design Inspection Verification (DIV), an initial and periodic inspection of a facility to verify the correctness and completeness of the design as compared to the declared design of the facility at the site. The DIV was authorized under the Framework for Cooperation signed November 11, 2013 by the Director General IAEA, Yukiya Amano, and the Vice-President of Iran.

Supporting Facilities

The construction and operation of the IR-40 reactor requires Iran to operate several key support facilities. These include a Heavy Water Production Plant (HWPP) and a Zirconium Production Plant (ZPP), both of which are located near the IR-40 site in Arak. The Fuel

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[6] David Albright, Paul Brannan, and Robert Kelley, "Mysteries Deepen Over Status of Arak Reactor Project," Institute for Science and International Studies, August 11, 2009, http://www.isisnucleariran.org/assets/pdf/ArakFuelElement.pdf; David Albright, Paul Brannan, and Robert Kelley, "Update on the Arak Reactor in Iran," Institute for Science and International Studies, August 25, 2009, http://www.isisnucleariran.org/assets/pdf/Arak_Update_25_August2009.pdf.

[7] M. Moguiy, A. H. Fadaei, A. S. Shirani, Analysis of different variance reduction techniques in research reactor beam tube calculations, Annals of Nuclear Energy, 41, 2012, p106.

Manufacturing Plant (FMP) and the Uranium Conversion Facility (UCF) at Esfahan also play critical roles in supporting the IR-40 project. A notional diagram is shown in Figure 2 illustrating how some of the components for the IR-40 are provided by different facilities. Each one of these nodes should be seen as a potential bottleneck in the completion of the IR-40.

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1 Director General, "Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran", GOV/2003/75, para 42, pg 8.

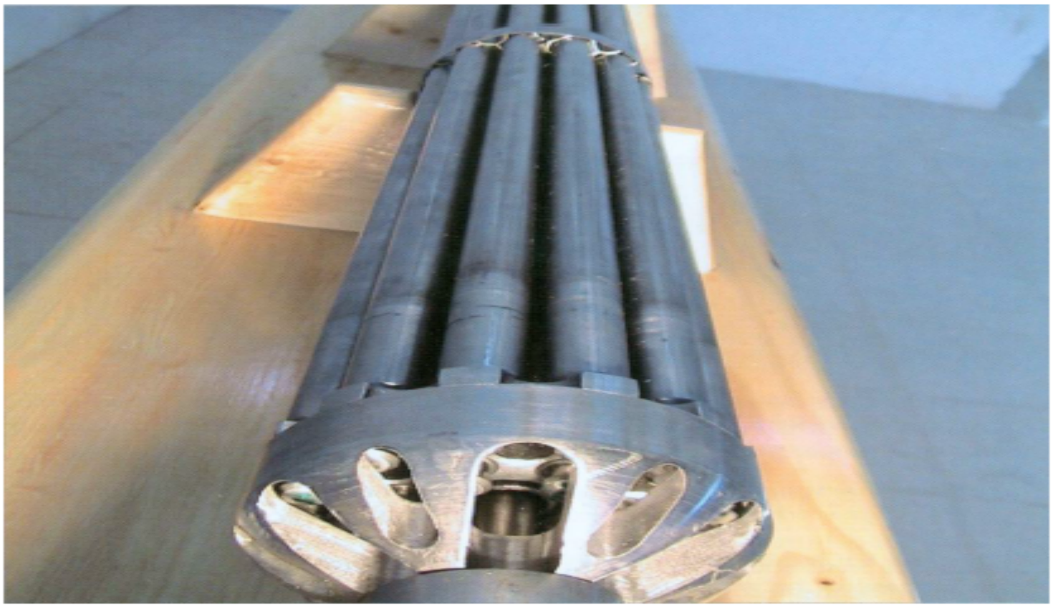

Figure 1: Apparent picture of the IR-40 fuel assembly taken from Figure 8-3 Thomas Mo Willig's thesis[8].

[8] T. Willig, Feasibility and benefits of converting the Iranian heavy water reactor IR-40 to a more proliferation-resistant reactor, Norwegian University of Life Sciences, Department of Mathematical Science and Technology, Masters Thesis, Dec 2011. Original source: Atomic Energy Organization of Iran, "Nuclear Industry in IRAN An overview on Iran's activities and achievements in nuclear technology," 2011. The authenticity of this picture has not been determined.

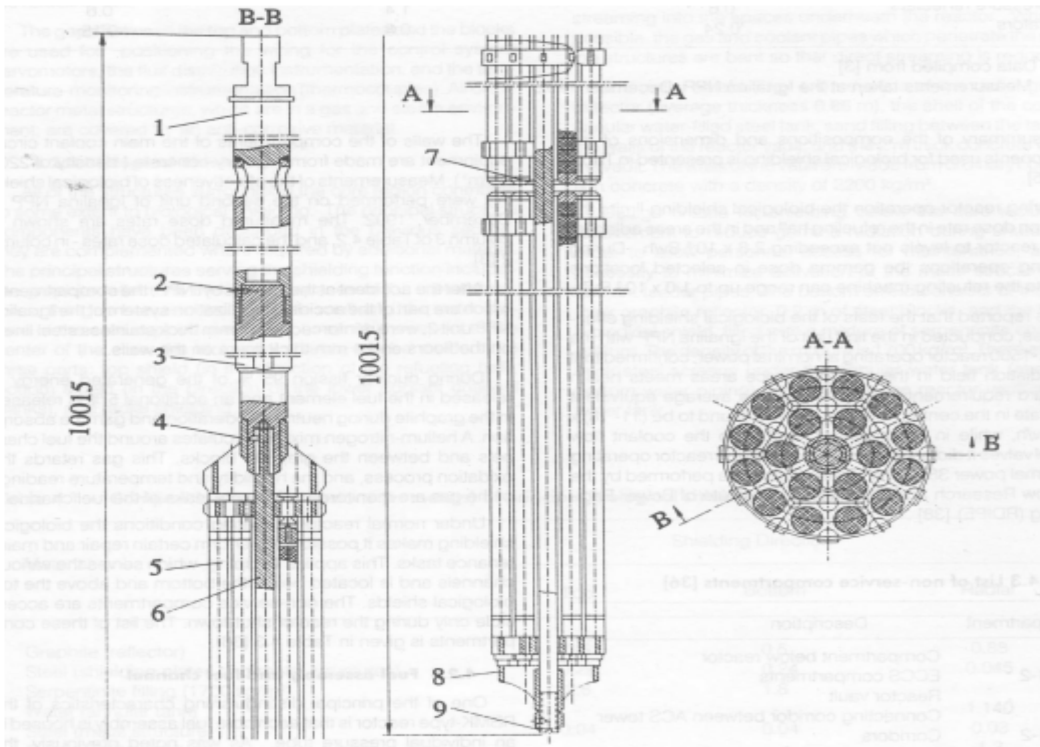

Figure 2: Diagram of RBMK fuel assembly taken from the Ignalina RBMK-1500 nuclear power plant source book[9]. The numbers correspond to the following parts: 1: Suspension bracket, 2: top –plu, 3: adapter, 4: connecting rod, 5: fuel element, 6: carrier rod, 7: end-sleeve, 8: end cap, 9: retaining nut[10].

Table 1: Significant components of the IR-40 that have and have not yet been installed.

Installed	**Not Yet Installed**
- Overhead crane is installed	- Control room not installed
- Moderator and primary coolant heat exchangers installed	- Refueling machine not installed
- Circuit piping installed	- Reactor cooling pumps not installed
- Purification systems installed	

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[9] K. Almenas et al., Ignalina RBMK-1500 – A Source Book, Ignalina Safety Analysis Group, Lithuanian Energy Institute, 1993.

[10] K. Almenas (1993)

- Moderator storage tanks installed	
- Pressurizer for reactor cooling system installed	
- Reactor Vessel connected to cooling and moderator piping	

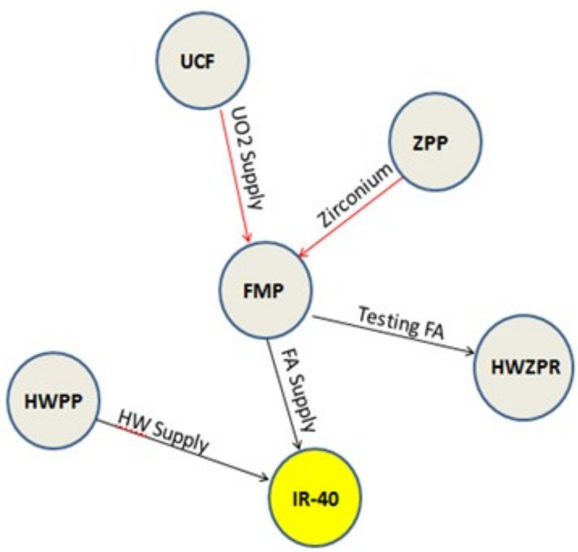

Figure 3: Sketch showing the supply of relevant nuclear components for fueling the IR-40. See text for further details.

Table 2: Various known specifications of the IR-40 and source of information.

Aspect of IR-40	**Source**
Power = 40 MW	Iran declaration reported in IAEA (GOV/2003/75, GOV/2004/83, GOV/2013/27, GOV/2013/40). Also, consistent with the existing Mechanical Draft Cooling Towers from satellite images.
10 kg/year plutonium production = equivalent of what is needed for 1-2 bombs. Will remain weapon grade plutonium for at	CNS study based on power. Independent assessment ISIS: http://www.isisnucleariran.org/sites/detail/arak/. For a thorough study using SCALE computer

least ¾ of a year fuel exposure.	code see T. Willig's thesis.
Fuel assembly has 18 places for fuel rods	Picture from T. Willig's thesis attributed to a report from the Atomic Energy Organization of Iran (AEOI)and RBMK source manual. The picture in Figure 1 has not been verified that it corresponds to an IR-40 fuel assembly.
Mass of uranium in fuel assembly is 56.5 kg and therefore fuel rod is expected to contain 3.2 kg of uranium.	GOV/2014/10
Fuel is UO2 with Zirconium cladding	Iran declaration reported in IAEA (GOV/2003/75)
Purpose for research and medical isotope production	IAEA (GOV/2003/75)
Russian assistance to Iran on fuel	ISIS report[11] "Based on interviews with knowledgeable officials, NIKIET and a Russian company in Obninsk provided key technology for the Arak reactor. This assistance included modifying the design of a RBMK fuel rod bundle for use in the Arak heavy water reactor. As a result of U.S. pressure, this assistance for Arak stopped in the late 1990s."
Active length of fuel assembly is 340 cm and 150 fuel assemblies.	Report from Iranian scientists in Annals of Nuclear Energy[12]. See also: GOV/2013/27 and GOV/2013/40.
Iran Molybdenum-99 requirement is 70 6-day Ci.	Oct 5 2011, atominfo.ru http://www.atominfo.ru/news6/f0616.htm
Uranium Conversion Facility (UCF) produces 14 t UO2 / year	As reported in GOV/2012/55

[11] David Albright and Christina Walrond, *Update on the Arak Reactor*, Institute for Science and International Security, July 15, 2013. See: isis-online.org/uploads/isis.../Arak_Update_25_August2009.pdf

[12] M. Moguiy, A. H. Fadaei, A. S. Shirani, Analysis of different variance reduction techniques in research reactor beam tube calculations, Annals of Nuclear Energy, 41, 2012, p106

Iran Fact File is a project of the James Martin Center for Nonproliferation Studies.