Order Code RS21391
Updated March 18, 2005

North Korea's Nuclear Weapons: How Soon an Arsenal?

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Summary

North Korea ended the eight-year-old freeze on its nuclear program in December 2002, expelling international inspectors and restarting its plutonium production facilities. Before 2002, the CIA estimated that North Korea might have enough plutonium (Pu) for 1 or 2 weapons. If the 8000 spent fuel rods at Yongbyon, which had previously been under seal, were successfully reprocessed in 2003, as North Korean officials claim, North Korea would have enough Pu for 6 or 8 weapons. The new fuel at the Yongbyon reactor could yield enough material for 3 more weapons by 2007. An unknown factor is the status of North Korea's uranium enrichment efforts, particularly given the aid of Pakistani scientist A.Q. Khan. This report will be updated as warranted.

Background

In the early1980s, U.S. satellites tracked a growing indigenous nuclear program in North Korea. A small nuclear reactor at Yongbyon (5MWe), capable of producing about 6kg of plutonium per year, began operating in 1986.[1] Later that year, U.S. satellites detected high explosives testing and a new plant to separate plutonium (a necessary step before turning the plutonium into metal for a warhead). In addition, the construction of two larger reactors (50MWe at Yongbyon and 200MWe at Taechon) added to the mounting evidence of a serious clandestine effort. Although North Korea had joined the Nuclear Nonproliferation Treaty in 1985, safeguards inspections began only in 1992. Those inspections raised questions about how much plutonium North Korea had produced covertly that still have not been resolved. In 1994, North Korea pledged, under the Agreed Framework with the United States, to freeze its plutonium programs and eventually dismantle them in return for several kinds of assistance.[2] At that time, Western intelligence agencies estimated that North Korea had separated enough plutonium for one to two bombs; other sources claimed it was enough for 4-5 bombs.

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[1] 5MWe is a power rating for the reactor, indicating that it produces 5 million watts of electricity per day (very small). Reactors are also described in terms of million watts of heat (MW thermal).

[2] See CRS Issue Brief IB91141, *North Korea's Nuclear Weapons Program.*

Weapons Production Milestones

Acquiring fissile material — plutonium-239 or highly enriched uranium (HEU) — is the key hurdle in nuclear weapons development.[3] Producing these two materials is technically challenging; in comparison, many experts believe weaponization to be relatively easy.[4] North Korea has industrial-scale uranium mining, and plants for milling, refining, and converting uranium; it also has a fuel fabrication plant, a nuclear reactor, and a reprocessing plant — in short, everything needed to produce Pu-239. In its nuclear reactor, North Korea uses magnox fuel — natural uranium (>99%U-238) metal, wrapped in magnesium-alloy cladding. About 8000 fuel rods constitute a fuel core for the reactor.

When irradiated in a reactor, natural uranium fuel absorbs a neutron and then decays into plutonium (Pu-239). Fuel that remains in the reactor for a long time begins to become contaminated by the isotope Pu-240, which can "poison" the functioning of a nuclear weapon.[5] Spent or irradiated fuel, which poses radiological hazards, must cool after removal from the reactor. The cooling phase, estimated by some at five months, is proportional to the fuel burn-up.

Reprocessing — or separating the plutonium from waste products and uranium — is the next step. North Korea uses a PUREX separation process, like the United States. After shearing off the fuel cladding, the fuel is dissolved in nitric acid. Components (plutonium, uranium, waste) of the fuel are separated into different streams using organic solvents. In small quantities, separation can be done in hot cells, but larger quantities require significant shielding to prevent deadly exposure to radiation.[6]

Many experts agree that North Korea has mastered the engineering requirements of plutonium production. Its 5MWe nuclear reactor operated from 1986 to 1994, restarting in January 2003. North Korean officials claimed to have separated plutonium in hot cells and tested the reprocessing plant in 1990, and to have reprocessed all 8000 fuel rods from the 5 MWe reactor between January and June 2003. Some analysts have reported that the 5MWe reactor operated at low efficiencies. The January 2004 unofficial U.S. delegation reported that "All indications from the display in the control room are that the reactor is operating smoothly now... However, we have no way of assessing independently how well the reactor has operated during the past year."[7] The same delegation reported that the reprocessing "facility appeared in good repair," in contrast to a 1992 IAEA assessment of the reprocessing plant as "extremely primitive." In the end, however, North Korea's potential for developing a large nuclear arsenal depends on the completion of the two larger reactors and progress in the reported uranium enrichment program.

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[3] Highly enriched uranium (HEU) has 20% or more U-235 isotope; weapons-grade uranium is 90% or more U-235.

[4] While the physical principles of weaponization are well-known, producing a weapon with high reliability, effectiveness and efficiency without testing holds significant challenges.

[5] Plutonium that stays in a reactor for a long time (reactor-grade, with high "burn-up") contains about 20% Pu-240; weapons-grade plutonium contains less than 7% Pu-240.

[6] Hot cells are heavily shielded rooms with remote handling equipment for working with irradiated materials.

[7] Siegfried Hecker, January 21, 2004, testimony before Senate Foreign Relations Committee.

There is little information on North Korean nuclear weapons design. The simplest design, a gun-type assembly, cannot use plutonium. Many believe North Korea is capable of manufacturing implosion-type devices, which require sophisticated lenses of high explosives to compress plutonium in the core. In 1986, U.S. satellites reportedly detected high explosives testing with the kind of compression patterns associated with implosion devices, although North Korea claimed the tests were for civilian purposes.[8] Revelations that Pakistani scientist A.Q. Khan provided Libya with a Chinese-origin nuclear weapon design have led many to wonder whether Khan also provided such a design to North Korea.[9] If he did, it might be easier for North Korea to develop a warhead for its ballistic missiles. Although states typically have used relatively crude delivery methods for first nuclear weapons, North Korea has concurrently produced ballistic missiles with sufficient range and payload to carry nuclear warheads. Nonetheless, such a warhead would need to be small and light enough to fit on a missile, and robust and sophisticated enough to tolerate the extreme conditions encountered through a ballistic trajectory.

In January 2004, North Korean officials showed an unofficial U.S. delegation what they claimed was "scrap" from a plutonium (Pu) casting operation; the officials stated that the metal was alloyed. Alloying plutonium with other materials, according to Dr. Siegfried Hecker of Los Alamos National Laboratory, is "common in plutonium metallurgy to retain the delta-phase of plutonium, which makes it easier to cast and shape," and casting plutonium is a step in weapons production.[10] Hecker, a delegation member, assessed that the stated density of the material was consistent with plutonium alloyed with gallium or aluminum. If true, this could indicate a certain sophistication in North Korea's handling of Pu metal. Nonetheless, Hecker could not confirm that the metal was indeed plutonium, that it was alloyed, or that it was from the most recent reprocessing campaign, without conducting actual tests of the material.

Estimating Nuclear Material Production

Most estimates of nuclear weapon stockpiles are based on estimated fissile material production. To determine how much plutonium is produced, one must know: the average power level of the reactor; days of operation; how much of the fuel is reprocessed and how quickly, and how much plutonium is lost in production processes. According to North Korea, the 5MWe reactor performed poorly early on, unevenly irradiating the rods. There is no data on the reactor's current performance. Likewise, the reprocessing facility's efficiency is hard to judge. Before the reported 2003 reprocessing campaign, the reprocessing plant had not operated after the "hot test" in 1990. North Korea told the IAEA that during the 1990 test, it recovered 62 grams of plutonium, losing almost 30% in the waste streams.[11] A key consideration is whether or not the reprocessing plant can successfully run continuously, since frequent shutdowns can lead to plutonium losses.

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[8] Don Oberdorfer, *The Two Koreas,* (MA: Addison-Wesley), 1997, p. 250.

[9] See also CRS Report RL32745, *Pakistan's Nuclear Proliferation Activities and the Recommendations of the 9/11 Commission: U.S. Policy Constraints and Options.*

[10] Hecker, January 21, 2004 testimony before SFRC.

[11] David Albright and Kevin O'Neill, editors, *Solving the North Korean Nuclear Puzzle*, ISIS Report, ISIS Press, 2000, p. 88.

According to North Korean officials in January 2004, the plant throughput is 110 tons of spent fuel annually, about twice the amount of fuel in the 5MWe reactor.

Finally, North Korea's technical sophistication will ultimately determine how much plutonium is needed per bomb. The international standard is 8kg of Pu per weapon (and 25kg for HEU), but technical experts agree that it is possible to make nuclear weapons with less than half that amount. North Korea's abilities in this area are unknown.

What Does North Korea Have Now?

Beginning in 2002, U.S. official statements were more confident that North Korea actually had nuclear weapons. Secretary of State Powell stated in December 2002 that "We now believe they [North Koreans] have a couple of nuclear weapons and have had them for years."[12] On February 10, 2005, North Korea announced that it had manufactured "nukes" for self-defense and that it would bolster its nuclear weapons arsenal.[13]

Has North Korea reprocessed the existing spent fuel?. On April 17, 2003, North Korean officials announced they were successfully reprocessing plutonium. One week later, officials softened that statement to "successfully going forward to reprocess work."[14] On July 13, 2003, North Korean officials told U.S. officials in New York that they had completed reprocessing the 8000 fuel rods on June 30.[15] On January 8, 2004, North Korean officials told the unofficial U.S. delegation that the reprocessing campaign began in mid-January 2003 and ended at the end of June 2003. In all, they reportedly reprocessed 50 tons of spent fuel in less than six months. This tracks with earlier estimates that if North Korea reprocessed about 11 tons/month, it might produce enough plutonium for 1 bomb per month.

The unofficial U.S. delegation visiting in January 2004 concluded that the spent fuel pond no longer held the 8000 fuel rods and surmised that those fuel rods could have been moved to a different storage location, but not without significant health and safety risks. The delegation was not allowed to visit the Dry Storage Building, where the fuel rods likely would have been stored before reprocessing. If the 8000 fuel rods from the 5 MWe reactor have been reprocessed, they would yield, according to one estimate, between 25 and 30kg of plutonium, enough for 5 or 6 weapons.

The exact amount of plutonium that might have been reprocessed is not known. The January 2004 U.S. visitors to the plant were not allowed to visit waste facilities, and North Korean officials did not reveal any operating difficulties with the plant, stating that the reprocessing campaign was conducted continuously (four 6-hr shifts). U.S. efforts to detect Krypton-85 (a by-product of reprocessing) reportedly suggested that some reprocessing had taken place, but were largely inconclusive.

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[12] Transcript of Dec. 29, 2002 "Meet the Press."

[13] "North Korea Says It Has Nuclear Weapons and Rejects Talks," *New York Times*, February 10, 2005.

[14] "North Korea Shifts Tone on Nuclear Plan," *International Herald Tribune*, April 22, 2003.

[15] "North Korea Says It Has Made Fuel For Atom Bombs," *New York Times*, July 15, 2003.

Adding to the Arsenal

Make New Plutonium. On February 6, 2003, North Korean officials announced that the 5 Mwe reactor was operating, and commercial satellite photography confirmed activity in March. In January 2004, North Korean officials told the unofficial U.S. delegation that the reactor was now operating smoothly at 100% of its rated power. The U.S. visitors noted that the display in the reactor control room and steam plumes from the cooling towers confirmed operation, but that there was no way of knowing how it had operated over the last year.

A common estimate is that the reactor generates 6kg of Pu per year, roughly 1 bomb per year, but the reactor would likely be operated for several years before fuel is withdrawn. In three years, it could generate about 14-18kg of plutonium, enough for 2 to 3 weapons. Shorter cycles are possible, but would waste considerable fuel. Assuming a six-month cooling period for plutonium, North Korea would be ready to reprocess by August 2006, and ready to convert into metal by February 2007. This would bring the total number of weapons possibly to between 8 and 11 weapons.

Bring New Reactors On-Line. The reactors at Yongbyon (50MWe) and Taechon (200MWe) are likely several years from completion. U.S. visitors in January 2004 saw heavy corrosion and cracks in concrete building structures at Yongbyon, reporting that the reactor building "looks in a terrible state of repair," but they did not visit the Taechon site.[16] The CIA estimates that the two reactors could generate about 275kg of plutonium per year.[17] In January 2004, North Korean officials told the unofficial U.S. delegation that they are evaluating what to do with both reactors.

Produce Highly Enriched Uranium for Weapons. A 2002 unclassified CIA working paper on North Korea's nuclear weapons and uranium enrichment estimated that North Korea "is constructing a plant that could produce enough weapons-grade uranium for two or more nuclear weapons per year when fully operational — which could be as soon as mid-decade."[18] Such a plant would need to produce more than 50kg of HEU per year, which would require cascades of thousands of centrifuges. The paper noted that in 2001, North Korea "began seeking centrifuge-related materials in large quantities." Although not much is known about the program or facilities, Pakistan's A.Q. Khan might have offered the same relatively sophisticated P-2-design centrifuges to North Korea as he did to Libya and Iran. North Korea has alternately admitted and denied having such a program.

An enrichment program offers three advantages over Pu. Since centrifuge enrichment plants are difficult to locate and target, they are less vulnerable to military strikes. Second, HEU could give the North Koreans the option of producing either simpler weapons (gun-assembly type) or more sophisticated weapons (using composite pits or boosted fission techniques. Third, it is another potential bargaining chip to use with the United States.

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[16] Hecker January 21, 2004 testimony before SRFC.

[17] CIA unclassified point paper distributed to Congressional staff on November 19, 2002.

[18] *Ibid.*

How to Verify North Korean Claims?

Information about North Korea's nuclear weapons production has depended largely on remote monitoring and defector information, with mixed results. Satellite images correctly indicated the start-up of the 5 MWe reactor, but gave no detailed information about its operations. Satellites detected truck movements at Yongbyon in late January 2003, but could not confirm that the trucks were moving spent fuel to the reprocessing plant.[19] And, satellite imagery could not peer into an empty spent fuel pond, which was shown to U.S. visitors in January 2004. Although satellite imagery reportedly detected some activity at the reprocessing plant in April 2003, U.S. officials could not confirm that large-scale reprocessing was taking place.[20]

The unofficial U.S. delegation in January 2004 could not confirm North Korean claims of having reprocessed the spent fuel. Specifically, it could not confirm that the material shown was in fact plutonium, or that all the spent fuel had been reprocessed. It may be possible for future delegations to carry out tests to verify such claims. At a minimum, it would be necessary to prove that the North Korean plutonium had been separated from fission products in the last year, by using isotopic measurement techniques. At most, it would be desirable to prove that 25-30kg of Pu had been separated (in 2003), which had been converted to metal and cast into weapon components. Absent an opportunity to measure a specific quantity of Pu (25-30kg), measuring waste products from the reprocessing plant could yield valuable information. Similarly, taking samples in glove boxes where conversion had taken place could be helpful. North Korean cooperation would be necessary for any of these measures.

In February 2005, NSC officials reportedly tried to convince Asian allies of North Korea's Pu reprocessing and production of UF6 (an input to enrichment plants) by sharing information that plutonium had been found on the outside of Libyan shipping containers.[21] However, allies and experts questioned how the plutonium was characterized as North Korean (some say be a process of elimination) and suggested that North Korea might have been transhipping UF6 for Pakistan to Libya.[22]

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[19] "Reactor Restarted, North Korea Says," *Washington Post*, February 6, 2003.

[20] "US Suspects North Korea Moved Ahead on Weapons," *New York Times*, May 6, 2003.

[21] "North Korea May Have Sent Libya Nuclear Material, U.S. Tells Allies," *Washington Post*, February 2, 2005.

[22] "China Doubts U.S. Data on North Korean Nuclear Work," *New York Times*, March 7, 2005.