# US-DPRK NEXT STEPS WORKSHOP

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## *Getting Back to Go:*
## *Re-establishing a Freeze on North Korea's Plutonium Fuel Cycle*

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## Introduction

The current standoff over North Korea's nuclear activities centers on its now active plutonium and uranium enrichment programs. While the discovery of the uranium enrichment development program thrust North Korea's nuclear behavior back into the headlines after an 8 year hiatus, it is Pyongyang's plutonium production infrastructure that is the most advanced, best understood and most capable of producing nuclear weapons. This paper examines the North Korean plutonium infrastructure and production capabilities, as well as how a freeze over that capability might be reconstituted if an agreement to freeze those activities can be reached. The paper does not pre-judge what form a freeze might take or how it might be negotiated or by whom it will be implemented. This paper is meant to provide a broad view of what hurdles anyone trying to reestablish a freeze might encounter, given the various scenarios that might unfold.

## Plutonium Stocks

The full extent of North Korea's current plutonium holdings is not known. North Korea is known to possess, in the form of spent fuel, enough plutonium (25-30 kilograms) to produce 5-6 nuclear weapons[1]. In addition, North Korea may have also produced an additional 5-10 kilograms of plutonium in the early 1990s, although not enough evidence has been obtained to prove or disprove this scenario. This is the basis upon which some intelligence analysts believe North Korea may already posses 1-2

[1] For nominal purposes, the Carnegie Endowment has assumed that North Korea could produce a nuclear device with 5 KG of weapons-grade plutonium – see Deadly Arsenals: Tracking Weapons of Mass Destruction.

nuclear weapons[2]. If this material was in fact produced, its whereabouts are unknown. Deciding once and for all the history of North Korea's past nuclear activities is an additional goal of U.S. policy in North Korea, and would require more extensive access to North Korea's plutonium infrastructure than that needed to re-establish and verify a freeze over all "known" activities.

Summary of North Korea's Plutonium-related Nuclear Facilities

| Facility[3] | Plutonium production/year | Weapons/year |
|---|---|---|
| 5MWe reactor Operational | **6 kilograms** | **1** |
| 50MWe reactor Under Construction | **56 kilograms** | **11** |
| 200 MWe reactor Under Construction | **220 kilograms** | **44** |
| Reprocessing facility Operational | **220-250 ton throughput (as of 1994) enough for the fuel produced annually from the 50 and 5 MWe reactors** | |

[2] "Foreign Missile Developments and the Ballistic Missile Threat Through 2015 – Unclassified Summary of a National Intelligence Estimate", Central Intelligence Agency, December 2001.
[3] Sources: Deadly Arsenals: Tracking Weapons of Mass Destruction (Carnegie) and Solving the North Korean Nuclear Puzzle (ISIS).

The current Pu infrastructure was frozen from 1994-2002 under the U.S.-DPRK Agreed Framework. While successfully frozen during the nominal lifetime of the agreed framework, North Korea's decision to lift the freeze over its reactors and other Pu-associated facilities once again threatens to provide North Korea with the ability to produce significant amounts of weapons-grade plutonium within a few months time, and to vastly expand that production capability in the years to come. If all of North Korea's current facilities (completed and in construction) were in operation, the isolated country could produce enough weapons grade plutonium for more than 50 weapons per year.

Current efforts by the United States and other regional countries to engage North Korea are designed, in part, to refreeze North Korea Pu-based activities. U.S. officials have repeatedly stated that a condition for any meaningful talks is for North Korea to verifiably freeze all of its nuclear activities. At a minimum, steps would need to be implemented that would provide strong confidence that North Korea's Pu-based program is not active, to say nothing about the lingering questions regarding North Korea's past plutonium activities. Many of the tools that *could* – under certain circumstances - be applied to refreeze the Pu program are well understood and straightforward. The task of implementing a freeze that recreates the same situation as of late 2002 may provide difficult, if not impossible, depending on what steps North Korea has taken in the absence of IAEA inspectors. Information on the exact steps North Korea has taken to date is limited, and since the IAEA inspectors left North Korea on December 31, 2002, totally unconfirmed. Under even the best circumstances now possible, additional uncertainties will undoubtedly be connected with the full extent of North Korea's plutonium holdings.

**Key Elements**

There are three critical components of North Korea's Pu-based program that were previously frozen and would need to be covered by any newly implemented freeze.

- spent fuel;
- the graphite moderated, gas cooled nuclear reactors;
- 5MWe (completed and operational);
- 50MWe and (construction not yet completed); and
- 200 MWe reactors (construction not yet completed)
- the reprocessing facility.

**Spent Fuel**:

After any agreement to refreeze the Pu-program is reached, a top priority will be to determine the status of the spent fuel previously known to be stored in the spent fuel building at Yongbyon. North Korea irradiated and then released some 8,000 magnesium-clad, natural uranium fuel irradiated (spent) rods from the 5MWe reactor at Yongbyon in 1994. Those rods are believed to contain between 25 and 30kg of plutonium suitable for use in the production of some 5-6 nuclear weapons, depending on the amount of material that may be required for a weapon.

After their removal from the reactor, these rods were stored in a spent fuel pond next to the reactor building for over 2 years, during which time a considerable amount of corrosion took place. As a result, much of the magnesium cladding and some of the uranium metal broke loose from the fuel rods themselves. These were the conditions that US government officials found when they first arrived on site to stabilize the fuel and prevent its reprocessing, as called for in the Agreed Framework.

Over the course of the next several years, under IAEA monitoring, the rods in the spent fuel pond were placed in 400 stainless steel canisters, which hold approximately 20 rods each. These cans were filled and sealed by US contractors on site in North Korea, and then placed in underwater racks on which IAEA seals were then placed. Each can has a serial number and records of how many rods were inserted into each can were retained by the IAEA and DOE officials[4].

The status of these cans is not presently known. According to an IAEA press release, "Seals in the 5MW(e) reactor's spent fuel pond containing some 8,000 irradiated fuel rods have been removed by the DPRK, and the functioning of essential surveillance equipment has been impeded."[5] There is no public evidence that North Korea has removed the fuel from the canisters or that the cans or the fuel have been shipped to the reprocessing facility at Yongbyon which is located within a short distance (1/4 mile) from the storage building. US officials are confident that national technical means could be used to observe the start of reprocessing activities, and possibly even the shipment of fuel from the spent fuel pond to the reprocessing facility[6].

Steps to a New Freeze

Upon the completion of any agreement to re-freeze North Korea's nuclear activities, some outside monitoring agent (presumably the IAEA) would quickly need to gain access to the spent fuel building and determine if the cans remain in the spent fuel pond and, if so, that they are the same ones previously placed under IAEA seals.

The job of verifying that the spent fuel cans have not been disturbed became greatly complicated with the North Korea violation of IAEA tamper indication devices (TID) on the spent fuel. Even the most successful scenario possible introduces an increased element of uncertainty to the re-establishment of a baseline regarding North Korea's nuclear history. Under the best possible scenario, where the cans are found intact and unopened, the job of re-verifying the freeze to the highest level of confidence would still require in-depth access to the spent fuel cans and could take months, if not years.

[4] Discussion with DOE officials.
[5] IAEA Press Release PR 2002/23 (22 December 2002), www.iaea.org
[6] Conversation with USG officials.

Given the lack of details obtained by IAEA and US government teams regarding the radiation signature of each fuel rod, however, it may never be possible to provide with 100 percent confidence that the fuel in the cans when monitoring was interrupted are the same rods found in the cans upon the return of the monitoring system. As part of the canning process, IAEA and US officials were only allowed by North Korean officials to take basic gamma radiation readings (to verify each rod had been irradiated in a reactor) and to weigh each rod to verify it was made of uranium metal. Teams were not allowed, however, to take detailed spectral analyses of individual rods during the canning process despite efforts to obtain such rights made by IAEA officials. Such information would have allowed the agency to help verify the length of time the rods had been in an operating reactor, and therefore, provide additional insight into North Korea's nuclear history. This lack of a detailed rod by rod "fingerprint" means there is no way to re-verify the presence of the original spent fuel rod by rod. Any confidence that the fuel found on site is the same fuel canned in the mid 1990s will be based, in part, on circumstantial evidence and have to include elements of subjective assessment.

If the cans are found intact and "apparently unopened" upon the resumption of monitoring, there are a number of clues that can be found to help provide a subjective assessment of whether the cans had been disturbed in the absence of IAEA monitors. If the clues point to some movement of the cans, more detailed and extensive sampling may be required to verify that the fuel rods remain in the spent fuel pond. In addition, despite the fact that the IAEA and DOE do not possess detailed radioactivity profiles of each rod, there is a lot of information in their possession that might be used to provide confidence that cans found in the spent fuel pond had been undisturbed. These include:

1) A record of the contents of each numbered can;
2) A measurement of the weight of one quarter to one-third of the cans; and
3) Possible physical evidence of the location of each can in the spent fuel rack.

These data sets can be used to make an initial assessment of whether the cans had been tampered with during the monitoring hiatus. Findings that suggest the cans had been moved and accessed would necessitate a more extensive set of measures to help determine if the spent fuel rods found in the pool are the same one canned by the Department of Energy.

Visual Clues: A visual inspection could be made to judge if the cans had been moved in any way. There is reportedly a fine layer of silt that has formed on the cans and the bottom of the spent fuel pond. This particulate matter (sodium hydroxide?) covers most horizontal surfaces in the spent fuel pond, including the tops of the cans, etc. This silt may provide clues of any major activities in the spent fuel pond.

Moreover, DOE teams have routinely traveled to the spent fuel site to repair leaking can and perform maintenance on the pool filtration system. It is possible that recent photos exist of the spent fuel racks that could be compared with the facts found upon re-entry of outside experts. Together, these visual clues could be used to provide a basic estimate of whether the cans had been disturbed. Also, each spent fuel can is also tagged with an identifying number. It is possible (although not known to the author) that the IAEA or the Department of Energy has maintained a register of which can is located where on the racks. If there is such a record, comparing the existing and previous locations of the cans could help determine if they had been disturbed in the interim period.

Physical Clues: Each can is sealed with a ring of approximately 20 bolts and filled with an argon/oxygen gas mixture to help prevent further corrosion. It might be possible that a physical inspection of the cans can help determine if they have been opened in the interim. Damaged or missing bolts would suggest some tampering. Moreover, if North Korean officials have attempted to replace the fuel rods in the cans with dummies, large amounts of sentiment (magnesium and uranium oxide) would be deposited into the pool, leaving sign of such activities.

If intact cans are found in the pool, additional basic tools such as weighing each can or testing to see if the cans continue to be filled with the argon/oxygen mixture might also provide evidence that the cans have been undisturbed.

Sampling Methods:

To obtain greater confidence that seals cans found in the spent fuel can have not been tampered with, several options for radioactive sampling exist to help determine if the cans contain their original loading of fuel. These include sensing radiation levels from the outside of each can or a significant, random sampling of the cans to determine the basic radiation level of separate fuel rods. In addition, a more detailed survey can be done requiring the opening of each can or a significant/random sampling of each can and a subsequent basic radioactive sampling of each rod.

Timing:

Each spent fuel can weigh several hundred pounds and is sealed shut with approximately 20 bolts. The cans are all filled with argon and oxygen (2%) to slow additional corrosion of the spent fuel, and the lids of each can are equipped with a valve used to remove water and fill the can with the argon/oxygen mixture.

Rough estimates suggest that at most North Korea might be able to safely open and remove the contents of 8-10 cans per day, using all 4 canning stations. This would require between 40-50 days to completely empty the contents of the cans. However, 2 of the canning stations are in poor, if not inoperable shape, and a third was never efficiently utilized by the North Korea technicians. Thus, the time required for North Korea to safely empty the spent fuel cans could be up to 4 times longer (160-200) days. North Korean technicians, however, have been able to cut corners and accelerate their normal operations when motivated. Thus, estimates on any time frame should be considered loose, at best. If such activities had begun the day inspectors left the facility on December 30, opening the contents of each can could take anywhere from 1-6 months. If an attempt was made to refill the cans to deceive IAEA or outside inspectors, that time could easily double given the complexities of refilling and releasing each can.

While North Korean teams could conceivably move the cans loaded with the spent fuel to the reprocessing facility, the author assumes that they would want to open and unload the cans in the spent fuel basin, where the equipment to open the cans is located. It is not known if the reprocessing facility/radio-chemical plant (RC plant) is capable of accepting the sealed stainless steel cans at the front end of the radiochemical plant. The logistics of shipping the sealed cans and opening them at the RC plant, however, would appear to suggest that North Korean officials would first remove the cans at the spent fuel pond before shipping them to the RC plant.

**The Reactors:**

North Korea's plutonium production reactors fall into two categories: complete and under construction. Only one of the three facilities – the 5Mwe facility at Yongbyon – had operated previously, producing at least one fuel load of 8000 spent fuel rods. It is also possible that this reactor, which shut down for 100 days in 1989, discharged an earlier load of spent fuel. The other 2 facilities are a 50MWe reactor and a 200Mwe reactor, both of which are several years away from being able to operate.

**5MWe Reactor:**

North Korea has removed the seals from the 5Mwe reactor at Yongbyon and, according to press accounts of North Korea statements, have begun re-fueling the reactor with natural uranium fuel rods. The last public accounts report that 2000 fresh fuel rods have been inserted into the reactor.[7] North Korean officials has also stated that the reactor could re-start operations in a matter of weeks.

Any effort to re-freeze North Korea's plutonium program would have to verify the shutdown of activities at the 5Mwe reactor. If the facility has not yet restarted operation by the time a hypothetical freeze is reinstated, then the fresh fuel could be removed from the reactor and returned to the fresh

[7] "Korea Orders Inspectors to Leave", *The Washington Times*, December 22, 2002.

fuel fabrication facility for storage. This would be well within the IAEA's range of experience to verify with basic methods of safeguards.

If the reactor has been completely refilled with fuel and restarted (something that would be observable with US Intelligence assets), then any freeze would need to incorporate plans to remove the spent fuel from the reactor and provide for their storage in the spent fuel pond adjacent to the reactor. At this point, the same issues surrounding the need to can and stabilize the batch of spent fuel released from the reactor in 1994 would come into play. The "magnox" fuel is not suited to long term storage. Depending on the amount of time the fuel has been irradiated, the fuel would need to cool in the spent fuel pond and then canned.

While the terms of any future agreement, such a deal could provide for either the extended storage of the spent fuel in cans – as with the already existing spent fuel – or for a more rapid remove from North Korea. This removal would presumably take place at the same time the original fuel was also shipped out of North Korea.

History in Graphite

One other issue that could be addressed with regards to the 5MWe reactor has to do with accessing the reactor for the means of more firmly establishing an accurate history of North Korea's nuclear activities. It has been suggested that through a sampling of the graphite that makes up the 5Mwe reactor some details of the operating history of the reactor could be determined. This, in sum, could provide an additional piece of evidence in determining if North Korea did produce a load of fuel previous to the fuel canned by DOE teams in the mid-1990s.

If the 5MWe reactor is restarted, the process of deciphering the reactors operating history would be somewhat complicated, but according to some technical experts not completely compromised.

Larger Reactors:

The 50Mwe and 200Mwe reactors, located at Yongbyon and Taechon respectively, were still under construction when the nuclear freeze took affect in 1994. These reactors were a number of years away from completion at that time, and no additional construction took place in the 1994-2002 timeframe.

Just as before, the IAEA would be well qualified to verify that no new construction activities were taking place at the reactor. Given that the reactors are years away from start-up, there is not the same time imperative associated with inspection of these facilities as compared with the 5MWe reactor, the spent fuel and the RC plant.

**The Reprocessing Plant**

North Korea has constructed and previously operated a reprocessing facility at the nuclear complex at Yongbyon. The building is located across the river from the 5Mwe reactor and the associated spent fuel storage pond. While no maintenance or operational activities took place at the reprocessing plant during the 1994-2002 freeze, North Korea and the IAEA have announced that North Korean technicians have removed seals from the plant and resumed some activities at the site.

If the facility has not yet resumed reprocessing when a freeze is re-implemented, the IAEA would be well able to verify the cessation of operations and maintenance at the facility. Seals and routine monitoring could then be installed to maintain a freeze.

In the extreme, where spent fuel had been removed from the spent fuel pond and reprocessing activities had begin at the reprocessing plant, then establishing a freeze would be much more complex and add greater elements of uncertainty. While the IAEA has vast experience in safeguarding reprocessing facilities, not having safeguards in place before the start of any operations greatly complicates any effort to verify what activities have taken place.

Given what is known about how much spent fuel was in the spent fuel pond at the time the inspectors were ejected, it could be possible for the IAEA and outside experts to conduct a materials balance assessment assessing:

1) spent fuel not yet de-clad or dissolved
2) amount of spent fuel “in process”
3) amount of material (separated plutonium, waste products, chemical, etc) discharged from the facility.

The risk factor of this approach comes from the lack of safeguards on the facility before the start of operations. In normal safeguards, inspectors can rely on both material balance (including waste streams) and perimeter monitoring to detect if all materials brought into a reprocessing plant are accounted for. In addition, safeguards on reprocessing plants require an intimate understanding of the architecture and "plumbing" of the facility. This information is needed to detect possible "diversion points" and apply monitoring mechanisms to detect any diversion of special nuclear materials.

In addition, the IAEA or outside inspectors could use sampling to help verify operating records of the facility normally kept by the North Korean technicians. Given the success of this process in uncovering inconsistencies in past North Korean declarations of its nuclear activities, North Korea would presumably be more sophisticated should it undertake any attempt to deceive inspectors of their operations. At a minimum, inspectors would need to gain detailed access to any separated materials and to the waste streams produced by reprocessing operations.

This, in turn, could also create complications for uncovering the history of North Korea's nuclear activities. One key objective of the special inspections requested by the IAEA in 1993 was to gain access to two suspected, underground waste storage facility located near the reprocessing facility. It was hoped that gaining access to these waste storage sites that the IAEA could more fully verify how much, if any, additional plutonium North Korea produced before the start of IAEA inspections.

If, as is believed, waste from North Korea's reprocessing facility would also be shipped to the suspected waste storage sites, this would dilute the contents of those facilities and greatly complicate efforts to use those materials to reconstitute North Korea's nuclear history.