Policy Forum 03-01A: The DPRK Enrichment Program: A Freeze and Beyond

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The DPRK Enrichment Program: A Freeze and Beyond

By Fred McGoldrick

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I. Introduction

In the essay below, Fred McGoldrick responds to North Korea's January 10, 2003 announcement of their intended withdrawal from the Nuclear Nonproliferation Treaty by outlining what concrete steps the DPRK could take to implement a freeze of its uranium enrichment activities. McGoldrick also attempts to answer the following questions: What enrichment activities should the DPRK "freeze"? Who should verify such a freeze? How should such a freeze be verified?

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The views expressed in this essay are those of the author and do not necessarily reflect the official policy or position of the Nautilus Institute. Readers should note that Nautilus seeks a diversity of views and opinions on contentious topics in order to identify common ground.

II. Essay by Fred McGoldrick

"The DPRK Enrichment Program: A Freeze and Beyond"
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Introduction

This paper began as an effort to identify steps that the Democratic People's Republic of Korea (DPRK) might take to reduce international concerns about the clandestine uranium enrichment program it had acknowledged to the United States in early October 2002. Its original purpose was to identify actions that the DPRK might take to put a break on, or "freeze", the uranium enrichment program. The "freeze" could serve as an interim confidence-building step that could lead ultimately to the verified dismantlement of the North Korean uranium enrichment program and any nuclear weapons activities. The premise of the exercise was that the DPRK might at some point find it in its interest to freeze its uranium enrichment program and to invite the International Atomic Energy Agency (IAEA) or some other entity to verify that North Korea was maintaining the freeze. In other words, while the DPRK may be unlikely to agree to move immediately into full compliance with all its nonproliferation obligations, it may at some point and as part of some negotiation process agree to a verified freeze of its uranium enrichment program.

When this exercise began, the DPRK was maintaining a freeze on the nuclear facilities at Yongbyong and Taechon pursuant to the Agreed Framework of 1994 between the United States and the DPRK, and this freeze was subject to verification by the IAEA. However, in December, the DPRK announced that it had decided to restart the 5 Mw reactor at Yongbyong and to resume construction of the 200 MW reactor at Taechon and the 50 MW reactor at Yongbyong. In late December, the DPRK removed seals from 5Mwe reactor's spent fuel pond containing some 8000 irradiated spent fuel rods and cut the seals and impeded the functioning of the essential surveillance equipment that had been installed at both the fuel fabrication plant as well as the reprocessing facility at Yongbyong. On December 25, 2002, the DPRK announced that it would expel the two remaining IAEA inspectors from North Korea and subsequently did so. The North Koreans then announced that they intended to reopen the reprocessing facility at Yongbong in order to give "safe storage" to the spent fuel from the 5MW reactor. As a result of these actions, the IAEA is no longer in a position to verify that material from the 5Mw reactor remains in peaceful use. The removal of the safeguards equipment from the reactor and the reprocessing facility means that the DPRK could reprocess the spent fuel rods stored at that facility and separate weapons-grade plutonium perhaps within a few months. On January 10, 2003, the DPRK announce that it would leave the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).

Obviously the situation has changed radically. A DPRK decision to freeze its enrichment program would be relatively meaningless unless the North Korean Government also took steps to re-institute the freeze of operations at the nuclear facilities covered by the Agreed Framework. The latest actions by the DPRK to restart its reactors and remove IAEA seals and monitoring devices from the reactors, fuel fabrication and reprocessing facilities and expel IAEA inspectors make it imperative that a freeze of the North Korean plutonium and enrichment programs be examined as a whole. If a freeze on the North Korean enrichment program still represents a possible interim way forward in resolving this crisis, then it would have to be accompanied by a resumption of the freeze on the facilities covered by the Agreed Framework.

If the North Koreans were now prepared to freeze their enrichment program, verifying a freeze of North Korean enrichment activities would present different issues and challenges than those involved in the IAEA re-instituting its monitoring procedures at the reactors and reprocessing facility covered by the Agreed Framework. The 5 Mw reactor and reprocessing plant at Yongbyong and the two reactors under construction at Yongbyong and Taechon are large, denotable facilities where the IAEA has already operated a verification regime. By contrast, based on the information made publicly available so far, there appear to be significant limitations in our knowledge of North Korean enrichment activities. For example, there are uncertainties concerning the nature, number and location of activities associated with the enrichment program, how long the activities have been taking place, and what progress the DPRK has made in enriching uranium. (See below.) To initiate a verified freeze of the North Korean enrichment program, the DPRK would need to make a detailed declaration concerning its program, and the verifying agency would need broad authority to determine the correctness and completeness of that declaration.

The first part of this paper will seek to identify the steps that the DPRK could take to implement a freeze of its uranium enrichment activities, including acceptance of some mechanism to verify or monitor such a freeze. (It assumes that the North Koreans would also agree to resume a verified freeze of the facilities at Yongbyong and Taechon. However, it does not address the specific steps that would be required for the IAEA to re-establish the freeze at the reactors and associated facilities.) The second part of the paper will address how the interim step of a freeze might lead to a transition to full DPRK implementation of its various nonproliferation obligations, namely those set forth in the NPT, its NPT safeguards agreement with the IAEA and the 1992 Joint Declaration between the DPRK and the Republic of Korea (ROK). The paper will address the following specific questions:

1. What enrichment activities should the DPRK "freeze"?

2. Since any verification or monitoring of the freeze will require that the DPRK make a declaration of its uranium enrichment program, what specifically should the DPRK declare?

3. Who should verify such a freeze?

4. How should such a freeze be verified?

5. What level of confidence can the international community have in the accuracy and completeness of the DPRK declaration?

How might the monitoring of the freeze facilitate North Korea's full compliance with its nonproliferation obligations, including acceptance of full-scope IAEA safeguards and verification of the dismantlement of all their sensitive nuclear activities?

Background

On October 16, 2002, the United States reported that, in October 3-5, 2002, meetings with representatives of the DPRK, U.S. representatives had confronted the DPRK with intelligence information about the existence of a clandestine uranium enrichment program and that, during the course of those meetings, North Korean officials had acknowledged having such a program. Since this revelation, the North Koreans have said that they are open to discussion of international inspections of the uranium facilities and that "everything will be negotiable" including the dismantling of the enrichment program. However, they have apparently laid down certain conditions, namely that the U.S. would agree to a non-aggression treaty, recognize the North Korean Government and sign a U.S.-North Korean peace treaty. The U.S. has taken the position that it will not negotiate about such matters until North Korea dismantles its nuclear weapons program.

What do we know about the North Korean enrichment program?

Based on what the U.S. Government has said and what has appeared in the media, we do not appear to have many details about this program. Douglas Feith, Under Secretary of Defense, has been quoted as saying that, "There is much about the program that we do not know. I cannot answer with precision exactly what they have accomplished with their uranium enrichment program to date." (AP 11/7-Yahoo! News). The Washington Post of October 18, 2002, quoted an anonymous U.S. Government official as saying that U.S. intelligence analysts were unanimous in their readings of the intelligence reports, but he conceded that, "There is a lot we do not know." Nevertheless, statements by U.S. officials and leaks to the press have suggested certain information about the North Korean program. Recognizing the inherent limitations and distortions that might appear from such sources, the following picture emerges. (A summary of statements by U.S. officials and press reports is at Annex I.)

The North Koreans apparently began in earnest their efforts to establish a clandestine uranium enrichment program based on centrifuge technology in the late 1990s, although interest in such a program may have extended as far back as the late 1980s. The DPRK was seeking to obtain frequency converters from Japan in 1999. In 2000, the U.S. apparently obtained evidence of North Korean attempts to acquire large quantities of high-grade aluminum suitable for use in centrifuges as well as equipment for use in uranium feed and withdrawal systems.

The United States does not know for sure where the North Korean uranium enrichment activities are taking place. However, U.S. officials have been quoted as saying that the U.S. has received reports of significant construction activity that appeared related to a uranium enrichment facility. There have also been press reports that the U.S. suspects that the North Korean Academy of Sciences near Pyongyang is one of three sites where the DPRK has conducted uranium-enrichment tests. The other two suspected sites are the Hagap region located in the Jagang province and the city of Yeongjeo-dong, near the Chinese border. The facilities may be underground.

It is unlikely that the North Korean effort has produced any nuclear weapons to date or even a significant amount of highly enriched uranium. It appears that they may be in the process of constructing an enrichment facility. John Bolton, Under Secretary of State for Arms Control and International Security has said, "What we have said publicly and in consultations is not that the North Koreans have nuclear weapons produced through the uranium enrichment program" but that the North Koreans "are seeking a production scope capability to produce weapons-grade uranium." As noted, press reports have quoted U.S. officials as saying that the U.S. has received reports of significant construction activity.

A few reports suggest that North Korea has actually obtained centrifuges from Pakistan. However, Pakistani assistance is not likely to have included large numbers of actual centrifuges. One report from Nuclear Fuel that appears to be based on detailed discussions with officials with access to intelligence and experts on centrifuge enrichment technology indicates that the DPRK may have acquired from Pakistan a complete design package for a proven centrifuge machine, prototype components and manufacturing and some diagnostic assistance, which might drastically reduce the timeline for producing highly enriched uranium. The North Koreans may be constructing a facility with a capacity of some 2, 000 centrifuge machines with a throughput capacity of around one (SWU)/machine/year. (SWU = separative work unit.) A Washington Times report quoted the CIA as saying that North Korea is constructing a plant that could produce enough weapons-grade uranium for two or more nuclear weapons per year by mid-decade.

The Nuclear Fuel article cited above asserts that this CIA assessment assumes, however, that the DPRK has obtained unprecedented assistance from foreign sources in building gas centrifuges, including a complete design package for a proven centrifuge machine using aluminum.

Thus it may be reasonable to conclude that the North Koreans are in the process of manufacturing and testing centrifuges and of constructing a centrifuge enrichment facility, but probably have not produced significant amounts of highly enriched uranium.

What specifically could/should the DPRK "freeze"?

Ideally the freeze should apply to all aspects of the North Korean centrifuge program, i.e., the entire range of activities and operations involved in the enrichment program. This would include

All procurement of enrichment materials, equipment and technology from abroad as well as the purchase of so-called dual-use items. This would include all enrichment items on Annex B Clarification of Items on the Trigger list of the Nuclear Supplier Guidelines (INFCIRC/254/Rev.4 Part 1, section 5, as well as the dual-use items in section 3 of the annex to Part 2 of INFCIRC/254.) (Note: These cover all enrichment technologies, not just centrifuge.) (See Annex II.)

- All research, development and testing related to the DPRK enrichment program
- Facilities for manufacturing or assembling of enrichment equipment
- Facilities for the conversion of uranium oxide to uranium hexaflouride
- Any enrichment facilities
- Preparation of any feed material for an enrichment facility
- Testing or operation of an enrichment facility
- Production of enriched uranium
- Conversion of enriched uranium to metal

If the status of the North Korean enrichment program is still in the manufacturing and construction stage as suggested by U.S. official statements and press leaks, the North Koreans may only be engaged in some of these activities and so the freeze would apply only to a subset of the operations listed above. Of course, the DPRK may not be willing to freeze all aspects of the program. For example, the North Koreans may be prepared to stop construction of an enrichment plant, but not the testing, manufacture or assembly of centrifuge machines. (See below for a further discussion of this issue.)

If a freeze on North Korean enrichment activities were to have any credibility, the North Koreans would have to invite an inspection agency to verify that the DPRK had indeed stopped all activities related to its enrichment program. A centrifuge facility is not difficult to conceal, as it has no obvious signatures that would be easily observable by national technical means. (See below.) Hence an extensive and rigorous onsite inspector presence with broad access rights and detailed information would be necessary to provide any meaningful degree of confidence that the DPRK had indeed frozen all of its enrichment activities.

Who might do the verification or monitoring of the freeze?

The IAEA. The DPRK has already rejected a resolution of the Board of Governors of IAEA on November 29, 2002, to accept the Director General's proposal to dispatch a senior team to the DPRK, or to receive a DPRK team in Vienna, to clarify the North Korean enrichment program and has ignored the January 6, 2003, resolution of the Board reiterating this request and calling on the DPRK to cooperate fully with the Agency to implement safeguards. Nevertheless, the IAEA is perhaps the most obvious candidate to undertake the job of verifying a freeze of the North Korean enrichment program for several reasons.

Inspecting nuclear facilities is what the IAEA does, and it possesses a great deal of experience and expertise in this field.

It has conducted safeguards inspections pursuant to the IAEA-DPRK safeguards agreement as provided for by the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). It has also monitored the freeze of North Korean nuclear facilities pursuant to the Agreed Framework between the United States and the DPRK of 1994.

The DPRK as well the United States and the various interested states in the region are familiar with the Vienna agency, its capabilities and it safeguards system.

The DPRK is obligated by virtue of its adherence to the NPT to accept IAEA safeguards on all its peaceful nuclear activities, including any enrichment activities. Even if the DPRK has not actually begun enrichment of uranium, the DPRK-IAEA safeguards agreement provides that the DPRK should provide design information on new facilities to the IAEA as soon as possible before nuclear material is introduced into the facility and allow the Agency to perform a design review. (For more detail on this point, see page 10 below.) The DPRK is also obliged to submit to IAEA safeguards any uranium when it is of a suitable composition and purity for isotopic separation in the enrichment plant.

Any eventual resolution of this issue must involve DPRK fulfillment of its obligations under the NPT to accept full-scope IAEA safeguards on all its nuclear activities. The transition from a freeze to full compliance with North Korea's NPT obligations would be greatly facilitated by the IAEA verifying the freeze.

Potential practical difficulties the IAEA could face in monitoring a freeze are the lack of adequate financial resources and the relative remoteness of the DPRK from Vienna. Since 1984 Member States of the UN system have held the assessed or regular budgets of the IAEA and other international organizations in the United Nations system to a policy of zero real growth (ZRG). (ZRG means no increases in the annual assessment budgets of the UN agencies that exceed the increase in the inflation rate.) Recently, a number of Member States, including the U.S., have recently strongly advocated an increase in resources for IAEA safeguards..

A Joint DPRK-ROK Verification. There are options other than the IAEA for verifying a freezing of the enrichment program in the DPRK. One is the Republic of Korea. There is a precedent for ROK nuclear inspections in the DPRK, at least in principle. The 1992 Joint Declaration between the DPRK and the ROK provided for the establishment and operation of a South-North Joint Nuclear Control Commission (JNCC), which would be responsible for conducting inspections of "particular subjects chosen by the other side and agreed upon between the two sides." The JNCC was tasked with matters "related to the exchange of information for the verification of the denuclearization of the Korean peninsula," as well as organizing the composition and operation of inspection teams. The meetings of the JNCC, however, had a short life span. Major disagreements quickly broke out over the nature of a bilateral inspection regime. The DPRK rejected South Korean demands for short-notice inspections and tried to limit the inspections to verifying that no nuclear weapons existed on the Korean peninsula, while the ROK insisted that there be an equal number of inspections by both parties, that there be no sanctuaries, and that challenge inspections should take place on 24-hour notice. In any event, the North Koreans cancelled JNCC talks altogether in 1993 when the ROK refused to cancel the Team Spirit joint military exercises with the United States.

There is some logic to having the JNCC monitor a DPRK freeze on its enrichment activities. In addition to banning the possession, and use of nuclear weapons on the Korean peninsula, the Joint Declaration also explicitly prohibits the possession of nuclear reprocessing and enrichment facilities on the peninsula. Using the ROK for verifying a freeze on enrichment activities would be an appropriate implementation of the Joint Declaration aimed specifically at verifying the freeze on the North's enrichment program. In addition, some may see certain political advantages in the ROK verifying the enrichment freeze. However, there are some important downsides. The ROK does not presently possess the experience or expertise to carry out such a monitoring function. (Nor presumably does the DPRK.) Since neither side had any experience in bilateral nuclear inspections, North and South Korean teams would have to receive extensive and time-consuming training in order to be able to carry out such inspections. The North Koreans would probably insist that such inspections be reciprocal in nature, and this introduces the complication of access to military bases in the South, including those of the United States. The question also arises as to whether such inspections should be limited to merely enrichment activities, or whether they should be expanded to encompass all the elements of the Joint Declaration. Finally, it would raise questions about the relationship of the ROK-DPRK bilateral inspection regime with the responsibility of the IAEA to implement inspections in the DPRK pursuant to the NPT and to the Agreed Framework. If the DPRK excluded the IAEA from the verification of the freeze on enrichment program, it would seem to run counter to the U.S. position that the North Koreans need to abide by their existing nonproliferation obligations as reflected in the NPT and the Agreed Framework.

Nonetheless, during the course of negotiations on this issue, the interested parties may find some political value in a North-South bilateral inspection regime. One option would be to model such a bilateral DPRK-ROK inspection regime on the Argentine-Brazilian Agency for the Accounting and Control of Nuclear Materials (ABACC) that was established to implement inspections of all Argentine and Brazilian nuclear facilities. ABACC is a party to a quadrilateral safeguards agreement with the governments of Argentina and Brazil and the IAEA, under which the IAEA has rights to independently verify ABACC's findings. In practice the IAEA has been doing most of inspection work in Argentina and Brazil. Such a DPRK-ROK-IAEA inspection regime would have the advantage of exploiting IAEA experience, minimizing the problems stemming from the lack of inspection expertise in the ROK and the DPRK and keeping the IAEA intimately involved as the DPRK progresses hopefully into full compliance with its NPT safeguards obligations. (The DPRK would, of course, have to consent to the IAEA conducting independent verification.)

The United States. The United States could also be a candidate for verifying a North Korean freeze of its enrichment program. The DPRK could conceivably invite the United States to verify it freeze as a means of drawing the United States directly into the process. The North Koreans might view U.S. participation in the monitoring exercise as some sort of political triumph as it would be part of a direct negotiation with the United States-something that the United States has thus far declined to do, and they might seek to extract a high political price for such U.S. participation. Such an action would not be unprecedented since the DPRK permitted a team of U.S. inspectors to visit an underground site at Kumchang-ri on two occasions and even proposed permanent monitoring at the site in the form of a joint venture. However, even if the interested parties saw some political value in a U.S. verification regime, they should find some way to link up with the IAEA safeguards system in order to bring North Korea into eventual compliance with its NPT obligations and its commitments under the DPRK-IAEA safeguards agreement.

A possible role for a non-governmental organization (NGO)?. If the governments involved are unable to initiate progress toward a verified freeze, it is conceivable that an NGO could play the role of catalyst. Such a role for an NGO in the arms control area is not unheard of. In the mid-1980s the Natural Resources Defense Council (NRDC) set up seismic measuring equipment at the Soviet Union's nuclear weapons test site in Kazakhstan in order to monitor the Soviet Union's nuclear testing moratorium and thereby to demonstrate the feasibility of using seismic monitoring to verify a low-threshold test ban. Soviet scientists subsequently monitored the testing at the Nevada nuclear weapons test site in the United States. In the late 1980s the NRDC applied radiation detectors near a live warhead on a Soviet cruiser to prove that detectors could verify arms-control limits. It is possible to conceive of a constructive role that an NGO could play in a freeze of the DPRK nuclear program. For example, so-called track-II discussions between an NGO and North Koreans on the modalities of a freeze and its verification might pave the way for an intergovernmental dialogue. Similarly, an NGO might take on a more ambitious role in monitoring a freeze, if the interested governments were unable to reach a formal agreement on this issue and saw some merit in using an NGO as a first step in initiating steps toward verifying a freeze. A role for an NGO might also be possible, if the North Koreans found some political value in inviting an NGO to verify a freeze it had unilaterally undertaken and could serve as a precursor to a more formal verification by the IAEA or another government. For example, the DPRK might invite an NGO to visit one or more of its enrichment facilities to determine whether it was operating or shut down. NGO visits could be conducted periodically. An NGO could also install containment and surveillance device to monitor the freeze between visits. However, an NGO would be able to play only a very limited and short-lived role in technical verification, since it would presumably possess neither the technical capability nor the financial resources to carry out the full spectrum of inspections and monitoring actions required for a credible verification regime. The installation of an effective surveillance system is not a simple task and requires a great deal of sophistication and experience, skills not typically possessed by NGOs. An NGO would also face serious obstacles in obtaining information from the U.S. intelligence community or the intelligence agencies of other governments in order to carry out inspections to verify the correctness and completeness of declared activities. Any role that an NGO might play in such an endeavor would, therefore, be limited but could be useful in clearing the way for a more formal verification regime by the IAEA and/or interested governments. And the U.S. and other interested governments would probably be anxious to bring the IAEA into the picture as soon as possible.

What is to be declared?

Any verification regime must begin with a declaration by the party whose activities are to be inspected. In the case of verifying a freeze by North Korea of its uranium enrichment program, such a declaration should encompass all aspects of its enrichment activities. These would include the following: (As noted below, the DPRK may already be obliged to declare some of these activities to the IAEA in accordance with its NPT safeguards agreement.)

Records, locations and disposition of all imports of enrichment materials, equipment, and technology as defined in the NSG Guidelines Part 1 Annex section 5 as well dual-use items as defined in section 3 of the annex to Part 2 of NSG Guidelines. (See Annex II)

Records, locations and disposition of all enrichment materials, equipment and technology that have been produced or manufactured in North Korea. Again this would include items on section 5 of the Annex to Part 1 of the NSG Guidelines as well as the dual-use items listed in section 3 of the annex to Part 2 of the NSG Guidelines.

Foreign sources of procurement of enrichment materials, equipment and technology.

All R&D and test facilities and their operating records. (If nuclear material were present in such facilities, the DPRK would be obliged under the DPRK-IAEA NPT safeguards agreement to declare such facilities to the IAEA and to make available design information.)

Manufacture and assembly facilities and their operating records.

Facilities for the conversion of uranium oxide to uranium hexaflouride. (When uranium of a composition and purity suitable for fuel fabrication or enrichment leaves the plant or process stage in which it has been produced, the nuclear material is supposed to become subject to safeguards in accordance with the DPRK NPT safeguards agreement.)

Enrichment facility (facilities) -including feed, product and tails as well as the operating records. (Under the DPRK NPT safeguards agreement, the DPRK is obliged to declare all nuclear material, design information in respect of the facility and records of each material balance area in the facility. Under an IAEA Board of Governor's decision in 1992, states concluding new full-scope safeguards agreements with the IAEA are obliged to provide design information on new facilities when the facility is being planned. This provision applies to agreements concluded prior to the 1992 Board decision only if the country volunteers to make the change. Prior to that time states with full-scope safeguards agreements had been required to provide the IAEA with design information for a new facility as soon as possible but usually not later than 180 days before that facility was scheduled to receive nuclear material for the first time. The precise requirements for the DPRK are reflected in the subsidiary arrangements negotiated between the DPRK and the IAEA, and probably contain a 180-day requirement.)

Facilities for the conversion of an HEU product to metallic uranium. (The DPRK is already obliged to declare such material to the IAEA under its NPT safeguards agreement and to provide the Vienna agency with design information and records for each material balance area.)

Are there steps short of a full freeze that the DPRK could take? The North Koreans, of course, might be resistant to accepting a verified freeze on all the activities listed above. If they had begun to operate an enrichment facility, they might be prepared to cease operations of the enrichment plant, but be unwilling to reveal any information about its operating history, thereby adopting a position much like the one they took with respect to the 5 Mw reactor at Yongbyong. This would lead to the type of interim freeze that was contemplated in the Agreed Framework, where reactor operations were halted under an IAEA monitoring regime, but the DPRK did not permit the IAEA to verify past production. (Among other things, the DPRK did not reveal the operating records of the 5 Mw reactor, refused to allow the IAEA to determine the amount of plutonium in the spent fuel from that reactor, or to implement safeguard measures at the liquid waste tanks at Yongbyong.) This would leave the international community with some confidence that the North Koreans were not currently producing HEU for nuclear weapons but not knowing for certain how much HEU they might have produced in the past. If the DPRK had not yet begun enrichment operations, it might be willing to halt construction of the enrichment facility or installation of the centrifuge cascade, but be unwilling to freeze the manufacture or assembly of centrifuges or to stop the testing of their centrifuge designs. (The DPRK did not provide the IAEA with adequate information about the amount and location of nuclear equipment that it may have manufactured for the two reactors under construction.) The advantage of even this limited kind of freeze is that the North Koreans would stop short of actually producing enriched uranium for nuclear weapons and would permit an outside agency to verify that they were not producing HEU. However, they would retain a breakout capability by continuing to test and/or manufacture centrifuges. Each of these scenarios is short of a complete freeze, but each could part of an understanding that could constitute the beginning of a step-by-step process toward a complete verified freeze of all enrichment activities and eventual dismantlement of all of North Korea's enrichment activities.

How is the "freeze" to be monitored?

The verification of the freeze on declared activities should as a technical matter be relatively straightforward. The verifying agency should have access to all declared facilities. Such facilities would be subject to inspection in order to verify correctness and completeness of the DPRK declaration. Inspectors would tag and seal all items subject to the freeze. Containment and surveillance devices (tamper-proof seals and cameras) would be situated at appropriate locations at all facilities. For facilities under construction, the inspection agency could establish an initial photographic baseline to document the status of each facility's construction. Subsequently inspectors could visit the facilities, observe them, take updated photos and compare them with the initial photos to ensure that construction has not resumed. This would be similar to the activities carried out by the IAEA at the nuclear facilities covered by the Agreed Framework. In the case of a freeze that applies to all enrichment activities, the inspecting agency should have access even to facilities where no nuclear material is present, e.g., centrifuge enrichment research, development and testing facilities as well as plants for manufacturing and assembling centrifuges. The IAEA has had extensive experience in inspecting and monitoring such facilities in Iraq under UN Security Council Resolution 687. For example, the IAEA tagged, sealed or conducted surveillance of certain machine tools at Iraqi facilities to ensure that those machine tools were not being used to manufacture enrichment or other prohibited equipment.

Most importantly the inspecting agency would have to verify that any North Korean enrichment facilities remained "frozen". If the enrichment facility were still under construction, the inspection would involve some seals and surveillance and periodic inspection to verify that construction had not been resumed. If the facility had actually been operating, the inspecting agency and the governments involved would face different and more complex issues. The IAEA has had experience in safeguarding operating centrifuge enrichment facilities in Japan and Western Europe1. The IAEA has also inspected enrichment facilities that have been shut down. Of particular note is the case of South Africa. Following South Africa's adherence to the NPT in 1991, the IAEA engaged in an extensive exercise to verify whether the declared inventory of the South African Y plant, (the enrichment facility that had produced HEU for its nuclear weapons program and that had been shut down), was consistent with the declared production and usage data, and that the amount of HEU declared to have been produced by the Y-plant was consistent with the plant's production capacity. On the basis of exhaustive studies the IAEA determined that it was reasonable to conclude that the uranium-235 balance of the HEU, LEU and depleted uranium produced by the Y-plant was consistent with the natural uranium feed and that the amounts of HEU that could have been produced by the plant were consistent with the amounts declared in the initial South African report. A similar exercise was undertaken for the Z plant, the semi-commercial enrichment plant in South Africa, which continued to operate for some time.

The IAEA exercise in South Africa was complicated by the fact that the Y plant had been operating for a number of years, which required an extensive reconstruction of the historical record. If the North Koreans have initiated the actual enrichment of uranium, it has been presumably for a fairly short period of time. Hence a similar exercise in the DPRK would not in principle be as difficult. However, in the case of South Africa, by the time the IAEA had begun its inspections, the South African Government had already decided to abandon its nuclear weapons program and to dismantle it nuclear weapons. As a result South African authorities were quite open, transparent and cooperative with the IAEA to enable effective safeguards. Given the history of the relationship of the DPRK with the IAEA at Yongbyong, it is at the very least open to question how transparent and cooperative the DRPK might be with respect to the history of its enrichment operations. If the DPRK has operated a uranium enrichment facility, it will be essential to allow inspection of operating records of the plant as well as the application of material accountancy to determine the quantity and isotopic composition of the feed, product and tails. Otherwise, we will be faced with the same situation we have had with respect to the history of the 5 Mw reactor at Yongbyong. (The DPRK did not make operating records of the 5 Mw reactor available to the IAEA.) Environmental sampling may also be appropriate inside any enrichment facility and on areas within boundaries or the immediate vicinity of an enrichment plant in order to characterize the facility operations, both historical and current as well as air, vegetation and soil, water samples and biota inside and outside the facility and to verify the absence of the production of highly enriched uranium. The IAEA has developed swipe sampling techniques and ultra-sensitive analytical techniques, such as mass-spectrometry methods, particle analysis and low-level radiometric techniques that can reveal signatures of past and present activities in locations where nuclear material was handled. (While the DPRK allowed the IAEA to apply safeguards at facilities not subject to the freeze, it did not permit the IAEA to take environmental swipe samples at those facilities, even though provision for environmental sampling is contained in the DPRK-IAEA NPT safeguards agreement.)

What level of confidence can the international community have in the accuracy and completeness of the DPRK declaration of its enrichment program?

While it may be relatively straightforward to verify the activities and facilities that the North Koreans have declared, the real challenge will be in determining whether the North Korean declaration of its enrichment program is correct and complete, or whether the DPRK may have decided to withhold certain information from the inspecting agency and to continue to operate one or more elements of its enrichment program on a clandestine basis. This is particularly important in light of the fact that North Korea apparently decided to embark on a clandestine enrichment program in violation of its international obligations.

Detecting a centrifuge enrichment program through national technical means is much more difficult than observing reactor operations. It would not be difficult to hide facilities for manufacturing or assembling centrifuges for uranium enrichment. Centrifuge enrichment itself does not require a large facility with clear signatures. A facility could be located underground, and we know that the national pastime of the DPRK is to dig tunnels. (One South Korean publication said that the North is suspected of having numerous secret underground sites (12 was cited by one publication (Joonggang Ilbo (Seoul) February 6, 1999) for its enrichment activities. A small carefully designed, constructed and maintained centrifuge enrichment plant producing only enough HEU for one or two nuclear weapons per year (about the estimated capacity of the North Korean enrichment facility), if equipped with a ventilation system using high-efficiency filters would release few emissions and could be quite difficult to detect. Gaseous diffusion, aerodynamic and electromagnetic enrichment plants are quite inefficient and release a large amount of heat. A centrifuge facility requires much less electricity. (The Office of Technology Assessment, Environmental Monitoring for Nuclear Safeguards, September 1995.)

On the other hand, centrifuge plants place unusual loads on the electric power system. In particular, the centrifuges operate at high speed and require conversion of the line frequency to much higher frequency. The converters reflect a distinct signal back into the line that can be detected. Finally under some conditions, the distinct noise generated by centrifuges might be detected and recognized. (Office of Technology, ibid.)

Without knowing what assets and technology the United States intelligence community has available to detect North Korean enrichment activities, it is not clear how much confidence we can place in national technical means for determining the correctness and completeness of a DPRK declaration of its enrichment program.

In any case, an extensive and rigorous on-site (boots and eyes on the ground) inspection regime would clearly be required to achieve any reasonable level of confidence that the North Korean declaration of its enrichment program was correct and complete. The IAEA has had extensive experience in conducting operations to detect suspect nuclear activities in Iraq under the provisions of UN Security Council Resolutions 677 and 1441. These mandates gave the IAEA extensive rights to conduct inspections in Iraq. Despite Iraqi efforts to conceal and deceive the IAEA, the Vienna Agency, with the assistance of intelligence information provided by Member States and its own inspection efforts, including the extensive use of environmental monitoring, was able to undercut Iraq's cover stories and expose its nuclear weapons program, including its enrichment efforts.

The DPRK is, of course, highly unlikely to accord any inspection agency the rights of inspection that the IAEA has had in Iraq. (The North Koreans did not even allow the IAEA to some of the technical buildings at the facilities covered by the Agreed Framework.) Monitoring imports would also be difficult and detecting the clandestine procurement of items for an enrichment program on the international market would require close cooperation of the international community especially key countries such as China, Russia and Pakistan. The detection of undeclared activities in North Korea, including research, development, manufacture and assembly of centrifuge parts and components would present particular challenges. Detecting the operation of an undeclared enrichment facility could also prove difficult. The inspecting agency would need to have broad rights of access to sites that are suspected of being associated with an enrichment program, including short-notice inspection of suspect facilities or sites. According to the Office of Technology Assessment, the analytical techniques that are available to the IAEA are sufficiently sensitive to have a high probability of detecting covert activities to produce nuclear weapons materials if the sampling is close to the facility. Long-distance monitoring, especially of the air is more problematical. The more dilute the emissions become, the less likely that critical materials can be distinguished from background or that they can be traced back to the source. A verification regime would also have to provide for the collection of environmental samples beyond declared locations when deemed necessary. This would evidently require the collection of large volume of air samples and the testing of the effectiveness of hydrological sampling along major waterways. However, the use of wide-area environmental monitoring sampling, the feasibility of which remains to be demonstrated, could be extremely costly and vulnerable to countermeasures deployed by the DPRK that could undermine its effectiveness.

The effectiveness of any such verification regime will depend on 1) the extent to which North Korea would allow extensive access, i.e., including short-notice inspections of suspect sites 2) the extent to which the DPRK would permit environmental monitoring, 3) the extent to which the inspecting agency would receive quality information from national governments on the location of suspect clandestine enrichment activities, and 4) the extent to which the inspecting agency would have access to adequate financial resources.

However rigorous the regime for monitoring a freeze of the North Korean enrichment program might be, it would not be able to assure with certainty the absence of clandestine enrichment activities, and the conclusions that an inspecting agency would draw would most likely be qualified but may be judged adequate.

How the monitoring of the freeze might lead to full-scale inspections and dismantlement of the program?

The logical next step following a verified freeze of the North Korean uranium enrichment program and the re-institution of the freeze on the reactors and associated facilities at Yongbyong and Taechen, would be a move by the DPRK toward compliance with its various nonproliferation obligations, including adherence to its full-scope NPT safeguards agreement with the IAEA and the termination and dismantlement of any program designed to acquire nuclear weapons. This could be accomplished all at once or on a gradual basis.

NPT Safeguards Agreement and the Additional Protocol. As part of this process it is imperative that an eventual resolution of the North Korean nuclear crisis include DPRK ratification of the Additional Protocol to IAEA safeguards agreements as approved in 1997 by the IAEA Board of Governors. The Additional Protocol gives the IAEA rights to increased information and access to all aspects of a state's nuclear fuel cycle-from uranium mines to nuclear wastes and to locations where nuclear material intended for non-nuclear uses is intended. Under the NPT safeguard agreements, inspectors' rights of access have been limited, and in practice the IAEA did not exercise fully the rights to conduct special inspections. For routine inspections the IAEA has been limited to key measuring points in declared facilities. The Additional Protocol gives complementary access rights to the Agency and its inspectors, e.g., access is possible to any place on a "site" or to mines or to nuclear related locations where no nuclear material is located, such as sites where related R&D or manufacturing activities are performed, in order to ensure the absence of undeclared activities. The Additional Protocol also permits environmental sampling either location-specific, or under certain conditions wide-area monitoring. (The latter may, however, require an additional Board of Governors approval and perhaps a new agreement.) In particular, the Additional Protocol provides for the following:

1. Information and access to all buildings on a nuclear site.

2. Information about and access to fuel cycle related R&D

3. Information on the manufacture and export of sensitive nuclear related technologies and inspector access to manufacturing and import locations.

4. Collection of environmental samples beyond declared locations when deemed necessary by the IAEA

5. Administrative arrangements that improve the process of designating inspectors and issuance of multi-entry visas and IAEA access to modern communications.

It is noteworthy that, if the DPRK agreed to declare all aspects of its enrichment program as part of a freeze on its existing program, it would be well on its way to accepting the added responsibilities of the Additional Protocol. For example, the Additional Protocol provides for the provision of information, among other things, on the location of nuclear fuel cycle-related R&D not involving nuclear material and specifically related to enrichment, a description of the scale of operations for each location engaged in activities related to the manufacture of centrifuge rotor tubes or the assembly of gas centrifuges, and information on the import of enrichment equipment. These rights could be crucial in helping ensure that there are not additional illicit North Korean activities (beyond enrichment facilities) that have not yet surfaced.

There are limitations on IAEA access under the Additional Protocol, e.g., there are provisions for managed access in order to prevent the dissemination of proliferation sensitive information, to meet safety or physical protection requirements, or to protect proprietary or commercially sensitive information. Nevertheless, if implemented effectively, the Additional Protocol, in combination with the DPRK's NPT safeguards agreement, would provide for as complete a picture as practical of the DPRK's holdings of nuclear material and its fuel cycle activities. However, there will remain some inherent, irreducible uncertainty concerning the completeness of the DPRK declaration.

North Korean fulfillment of its NPT safeguards obligations and its adherence to the Additional Protocol would necessarily involve the verified abandonment of its nuclear weapons program (supplemented by what is available through national intelligence.) This may involve the actual dismantlement of nuclear weapons and/or the declaration of plutonium or HEU that had been recovered from dismantled nuclear weapons, or had been stockpiled for a planned nuclear weapons program that the DPRK had abandoned prior to its implementation.

Under the NPT safeguards, the DPRK would have no obligation to explain what had been the past purpose of this material, and the role of the IAEA in implementing its NPT safeguards responsibilities would be limited to determining that all nuclear material had been declared and placed under safeguards. The IAEA has had experience in this sort of exercise in connection with the adherence of South Africa to the NPT. In 1993, the South African Government openly declared that it had developed a limited nuclear deterrent capability and that it had dismantled its nuclear weapons capability prior to its adherence to the NPT. The IAEA, in an effort to determine the correctness and completeness of the South African declaration, carried out inspections, accompanied by nuclear weapons experts, at a number of facilities that had been declared to have been involved in the dismantled South African nuclear weapons program. The IAEA also had extensive discussions with South African authorities and technical staff at the Atomic Energy Commission and the State-owned armaments corporation (ARMSCOR), which had been responsible for the production of the South African nuclear weapons. Based on documentation and interviews, the IAEA was able to document the timing and scope of the nuclear weapons program. The IAEA also carried out an audit of the records of the transfer of enriched uranium between the AEC and ARMSCORE and concluded that the enriched uranium originally supplied to ARMSCORE had been returned to the AEC and was subject to IAEA safeguards. The findings from the IAEA' examination of the records, facilities and remaining non-nuclear components of the dismantled/destroyed nuclear weapons and from the IAEA's evaluation of the amount of HEU produced by the pilot enrichment plant, showed consistency with the declared scope of the nuclear weapons program.

The IAEA conducted these various activities under its NPT safeguards agreement with the Government of South Africa and without the benefit of the enhanced rights to information and rights of access accorded by the Additional Protocol. It should be emphasized that the IAEA was able to accomplish these verification activities because the South African authorities were actively cooperative in arranging access to all facilities that the IAEA requested to visit, based on a prior decision of the South African Government to abandon and dismantle its nuclear weapons program, to adhere to the NPT and to bring all its nuclear activities under IAEA safeguards. It is unlikely that we would be dealing with a comparable situation with the DPRK, and it may prove far more difficult to verify that North Korea has abandoned its clandestine nuclear activities and declared all the past production of plutonium and highly enriched uranium.

Another Model, UNSC Resolutions 687 and 1441? It is also possible, at least in theory, to consider a second model for an eventual resolution of the North Korean nuclear crisis and one that goes beyond full implementation of full-scope safeguards and the Additional Protocol, namely an inspection regime that is comparable to that required in Iraq by UN Security Council Resolutions 687 and 1441. This inspection regime is a highly intrusive and coercive system that was imposed on a state that had initially been subject to military defeat and more recently to the threat of military force and coerced regime change. Short of war and perhaps a draconian sanctions regime rigorously enforced by China, Japan and other states, it is difficult to imagine the circumstances that might persuade or compel the highly secretive North Korean regime into accepting the kind of inspections called for in these UN resolutions and that accord UNMOVIC and the IAEA rights, among other things, of "immediate, unimpeded, unconditional, and unrestricted access to any and all, including underground, areas, facilities, buildings, equipment, records, and means of transport which they wish to inspect, as well as immediate, unimpeded, unrestricted, and private access to all officials and other persons whom UNMOVIC or the IAEA wish to interview in the mode or location of UNMOVIC's or the IAEA's choice pursuant to any aspect of their mandates."

Moreover, if the DPRK were to agree to a verified freeze of its sensitive nuclear activities (its plutonium production and uranium enrichment programs) as an interim step toward ultimate compliance with its various international nonproliferation obligations, there may little incentive to try compel the North Koreans to accept a 1441-type inspection regime.

Conclusions

With sufficient access, information and resources, it is possible to establish a regime to verify a freeze of North Korean sensitive nuclear activities (and notably its enrichment program) as an interim step toward full DPRK compliance with its nonproliferation obligations. Whether this can be translated into a reality under the present difficult circumstance is obviously an open question and will depend on variables that go beyond the scope of this paper.

Some historical grounds exists for believing that the North Koreans might be prepared to take interim steps to maintain or restore some level of assurance about its nuclear program prior to reaching a more permanent resolution. For example, even when the DPRK threatened to withdraw from the NPT in 1993, it said it was prepared to let the IAEA monitor nuclear facilities to prevent diversion. Again in the tension-filled weeks of the spring and summer of 1994 after the DPRK took the provocative step of unloading spent fuel from the 5 MW reactor at Yongbyong, it allowed the IAEA to continue to monitor the spent fuel. This situation continued until the arrangements provided in the Agreed Framework went into effect.

The North Koreans might agree to a complete freeze of all its enrichment related activities, or it might be prepared to accept a freeze of only some subset of such a activities as part of a step-by-step process. The effectiveness of any regime to verify a freeze of DPRK enrichment activities will depend on the degree of North Korean cooperation with inspection and monitoring activities, the information that the United States and other countries have with respect to DPRK uranium enrichment activities, their willingness to share that information with the inspecting agencies, and the resources available to the inspecting agency. While interested states might find some political advantage in having the ROK or the U.S. actually participate in verifying the freeze of North Korean enrichment activities, it will be important to maintain a material role for the IAEA in such an exercise in order to press the DPRK to meet its obligations to accept IAEA safeguards under the NPT and monitoring under the Agreed Framework and to facilitate the transition to full compliance by the DPRK with it various nonproliferation obligations. The use of an NGO might have some temporary value in catalyzing a monitored freeze, but the basic objective should be to bring the IAEA back into the business of safeguarding the North Korean nuclear program as soon as possible.

Given the erratic and unpredictable behavior of the DPRK, it is not inconceivable that the DPRK could unilaterally and voluntarily announce a freeze of its enrichment and reactor programs in order to convince the international community that it is not proceeding with a nuclear weapons program or as a gesture to persuade the United States that it is willing to engage in genuine negotiations leading to a dismantlement of its unsafeguarded nuclear program. However, this would not be consistent with past behavior or current steps to restart the facilities at Yongbyong. The DPRK has typically ratcheted up crises in order to extract concessions in return for easing tensions. It is far more likely that the North Koreans would move toward a freeze or toward any other confidence-building measure only under duress, or if they obtain some significant economic and/or political advantages in doing so. This paper has not examined the economic, political or security incentives, or the forms of coercion that might lead them to such a decision. Presumably a North Korean move to freeze its enrichment program and to re-institute the freeze called for by the Agreed Framework would be part of some negotiation process either with the United States or some other state or group of states in the region.

The key questions that this paper has not addressed are:

How realistic is it to assume that the DPRK can be persuaded or compelled to move toward a freeze of its enrichment activities as well as those activities at Yongbyong and Taechon?

What incentives or sanctions might be employed to induce the DPRK to accept such a freeze?

What is the DPRK really seeking to accomplish?

Are there any constructive approaches that could break the current impasse and put our nonproliferation relationships with North Korea on a more solid basis than was achievable under the Agreed Framework?

Annex I

Summary of Official Statements and Press Reports about the North Korean Nuclear Program

When did the program begin?

The United States apparently obtained evidence of the uranium enrichment program in 2000. (Washington Post (WP), October 19, 2002 and the Washington Times (WT) November 22, 2002) This evidence was presumably based on discovery of North Korean attempts to acquire large amounts of high-strength aluminum. (WP October 18, 2002) According to the WT (November 22, 2002), the CIA said that, "Last year, procurement agents for North Korea began seeking centrifuge-related materials in large quantities." The same report quoted the CIA as saying that the North Koreans also obtained equipment suitable for use in uranium feed and withdrawal systems."

The CIA report to Congress on the Acquisition of Technology Related to Weapons of Mass Destruction and Advanced Conventional Munitions for the period of July 2001 to December 2001 said that, "The North has been seeking centrifuge-related materials in large quantities to support a uranium enrichment program. It also obtained equipment suitable for use in uranium feed and withdrawal systems."

Daniel Pinkston of the Monterey Institute has written that there is evidence the North Korea's HEU program began in the 1980s. According to German intelligence, North Korea obtained "an array of nuclear-related dual-use furnace equipment in the 1980s, including a small annealing furnace from the German firm Leybold AG in 1987. In November 1991, "one western government" concluded that uranium enrichment technology "allegedly diverted to Pakistan via Switzerland may have been exported to Iran, Iraq and North Korea." The report also added that uranium melting technology may also have been shipped to North Korea. U.S and German intelligence officials also believe that Leybold personnel were in North Korea in 1989 and 1990.

Assistant Secretary Kelly said the U.S. had information on the North Korean efforts to establish a uranium enrichment capability that "is already several years old."

Secretary of State Colin Powell said on Fox News Sunday, December 29, 2002 that the North Korean enrichment program, "didn't happen just in the last year or two. It's a decision they made and a program they started four or so years ago, and we found out about it this summer." On NBC Meet the Press, Powell said, "they were motivated four, five years ago, if not earlier, to make the political decision to move down the road of finding a second way of developing nuclear weapons."

The WT (November 22, 2002) quoted the CIA as saying that, "Last year procurement agents for North Korea began seeking centrifuge-related materials in large quantities."

Condoleeza Rice told CNN in on October 20, 2002, that there was evidence of North Korea's pursuit of this program going back to at least 1999 but that they had decided to confront the North Koreans based on evidence confirmed only this past summer. The WT (October 18, 2002) reported that it had obtained a 1999 Department of Energy (DOE) report that revealed that a North Korean company tried to circumvent Japanese export controls by purchasing two "frequency converters" from a Japanese company. The report said that the purchases showed that North Korea was "in the early stages of a uranium-enrichment capability." It also said that, "On the basis of Pakistan's progress with a similar technology, we estimate that [North Korea] is at least six years from the production of highly enriched uranium, even it has a viable centrifuge design. On the other hand, with significant technical support from other countries such as Pakistan, the time frame could be decreased by several years.

Global Security Newswire (November 21, 2002) quoted sources close to U.S. intelligence that the Pyongyang had imported at least 2, 000 centrifuges, double the number previously believed. It also reported that North Korea began a uranium enrichment program in 1997 and acquired the centrifuges a year later, according to U.S. and Japanese sources (Dow Jones Business News/Yahoo.com November 19.)

The Daily Yomiuri Shimbum (December 17, 2002) reported that a North Korean defector who had belonged to the technical division of North Korea' uranium enrichment facility told South Korean authorities details of the facilities location and the technology used there. The defector reportedly said Pyongyang started its nuclear development program in 1998

Where are the enrichment activities taking place?

The Korean Herald reported (October 21, 2002) that, according to a diplomatic source, "The United States has indicated that the North Korean Academy of Sciences, near Pyongyang, is suspected of being one three sites where North Korea conducted uranium-enrichment tests as part of its nuclear program. The other two suspected sites are the Hagap region, located in the Jagang province, and the city of Yeongjeo-dong in the Yanggang province about 20 kilometers from the Chinese border.

The WP (October 18, 2002) quoted Daniel Pinkson, of the Monterey Center for Nonproliferation Studies as saying that U.S. officials have declined to reveal the location in question. Previously speculation about enrichment plants had centered on three locations, including a suspected underground facility in Changgang province known as Hagap.

CNN (December 3, 2002) cited a senior administration official as saying that U.S. intelligence does not know where the plant-most likely underground-is located.

What progress has the program made toward producing highly enriched uranium?

It is not known what progress North Korea has made toward enriching. (WP, October 18, 2002) According to the Global Security Newswire (November 8, 2002), intelligence officials assert that while they lack conclusive evidence, they believe it unlikely that the uranium enrichment effort has reached a level at which the North Koreans have produced nuclear weapons using the enrichment method. "It takes a very long time to produce a weapon based on that system,' said a U.S. intelligence official. "And there would be more fingerprints."

The New York Times (NYT) of October 17, 2002, quoted Administration officials as refusing to say whether the North Koreans had acknowledged successfully producing a nuclear weapon from the project. Nor would administration officials who briefed reporters say whether they think North Korea has produced such a weapon. "We're not certain that it's been weaponized yet", another official was quoted as saying.

In addition the U.S. received reports of significant construction activity that appeared related to a uranium enrichment facility. (WP October 18, 2002)

Another WP report (October 18, 2002) quoted an anonymous administration official as saying the North Koreans likely have not advanced far in their efforts to produce a nuclear weapon from highly enriched uranium. He said the United States received intelligence last summer that Kim's government was "trying to get equipment to move to production levels of uranium enrichment." Under Secretary of State for Arms Control and International Security John Bolton said in a press conference on October 22, 2002, "What we have said publicly and in consultations is not that the North Koreans have nuclear weapons produced through the uranium enrichment program," but that the North Koreans are "seeking a production scope capability to produce weapons-grade uranium."

WT (November 22, 2002) cited a CIA study as stating that the North Koreans could begin producing highly enriched uranium in the next three years. It quoted the CIA as saying, "We recently learned that the North 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."

The WT (October 22, 2002) reported the CIA as saying, "We recently learned that the North 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."

CNN (December 3, 2002) quoted a senior administration official as saying that a gas centrifuge plant to enrich uranium could be ready as early as next year.

An article by Jim Hoagland in the International Herald Tribune (November 11, 2002) reported that unnamed sources "say that the North Koreans possess 2, 000 to 3, 000 centrifuges and are already enriching uranium."

Nuclear Fuel (November 25, 2002) reported on a CIA estimate that the DPRK would be able to produce significant quantities of weapons-grade highly enriched uranium by around 2005. This presupposes that the DPRK has obtained unprecedented assistance from foreign sources in building gas centrifuges, plus a complete design package for a proven subcritical centrifuge using aluminum. In mid-November the CIA provided the Congress with a "consensus estimate" that concluded that last year the DPRK had begun seeking centrifuge-related materials in large quantities last year and that it could be making two or more bombs worth of HEU per year "as soon as mid-decade." This assessment assumes a vast amount of outside help with a high probability that the aid included the complete design package for a proven machine. The assessment has the DPRK beginning large-scale centrifuge production in 2001 and producing an HEU significant quantity by 2005. According to the Nuclear Fuel article Western officials would not confirm that Pakistan had exported between 2000 and 3000 centrifuge rotor assemblies to the DPRK. Sources said that information coming to light suggested that individuals with years of experience inside Pakistan's uranium enrichment program had given the DPRK the design package for an aluminum centrifuge, prototype components, and manufacturing and some diagnostic assistance, which might dramatically reduce the timeline for the DPRK to enrich uranium. The DPRK sought assistance from a variety of sources including China, Japan, Pakistan, Russia and Eastern Europe but that most of the assistance related to the rotor assembly itself came from Pakistan, including some 6,000 grade aluminum used in the components. The design of the aluminum centrifuge had at least some of the characteristics of the CNOR/SNOR design that the Pakistanis had stolen from Urenco. However, based in part on procurement information, the design of the DPRK machine is believed to represent a composite design not identical to the CNOR/SNOR. The design did not match known Western centrifuge designs.

The Nuclear Fuel report also said that some information suggests that the DPRK may have "slavishly followed a recipe" calling for some more advanced components or materials, as called for in the design package provided by its helpers. That would explain why North Korea tried to purchase more advanced materials for the machines than were in fact necessary, including the 6, 000-grade aluminum and pure cobalt for top bearing assemblies. Some of Pakistan's aluminum-design rotor assemblies relied on 2000-grade aluminum and used earlier-generation magnetic bearings, made of aluminum and nickel, not samarium and cobalt. The DPRK sought to obtain dozens of kilograms of cobalt powder with a purity in excess of 99.99%. Pure cobalt is not on nuclear commodity control lists. DPRK did not need samarium-cobalt bearings for an aluminum centrifuge, not did it require 6, 000-grade aluminum, but may have sought it in the mistaken belief that it would have shortened the path to producing HEU.

One expert told Nuclear Fuel that, if in fact the basis of the DPRK machine is a subcritical aluminum centrifuge with a throughput of around one SWU machine/year, with 2000 machines in place the DPRK could enrich "enrich at least enough HEU for a bomb a year." "If we assume the DPRK started building machines in earnest about a year ago, it might just be able to start" enriching a bomb's worth of HEU a year in 2005, assuming there were no unanticipated bottlenecks. But that also assumes that the DPRK is willing to take decisions and shortcuts which would mean that the initial failure rate of the machines might be as high as 10 % and that, "after two or three years of operation, a very large number of machines would crash." (This is the path that Pakistan followed in the 1970s and 1980s.)

JoongAngIlbo reported a senior Seoul official as saying that the South Korean Government had receive information from the United States that North Korea might have enough enriched uranium to manufacture two nuclear bombs, that U.S. intelligence had put the estimated quantity at about 30 kgs. It also reported another South Korean official as saying that North Korea probably used more than 1000 centrifuge isotope separators to enrich the uranium and that the U.S. Government had also relayed the location where the "substance" is stored."

ANNEX II

Nuclear Supplier Group Guidelines

INFCIRC254/Rev.4 Part 1

Trigger List Items

Annex B on Enrichment Equipment

-5. Plants for the separation of isotopes of uranium and equipment, other than analytical instruments, especially designed or prepared therefore. Items of equipment that are considered to fall within the meaning of the phrase "equipment, other than analytical instruments, especially designed or prepared" for the separation of isotopes of uranium include:

5.1. Gas centrifuges and assemblies and components especially designed or prepared for use in gas centrifuges

INTRODUCTORY NOTE

The gas centrifuge normally consists of a thin-walled cylinder(s) of between 75 mm (3 in) and 400 mm (16 in)diameter contained in a vacuum environment and spun at high peripheral speed of the order of 300 m/s or more with its central axis vertical. In order to achieve high speed the materials of construction for the rotating components have to be of a high strength to density ratio and the rotor assembly, and hence its individual components, have to be manufactured to very close tolerances in order to minimize the unbalance. In contrast to other centrifuges, the gas centrifuge for uranium enrichment is characterized by having within the rotor chamber a rotating disc-shaped baffle(s) and a stationary tube arrangement for feeding and extracting the UF 6 gas and featuring at least 3 separate channels, of which 2 are connected to scoops extending from the rotor axis towards the periphery of the rotor chamber. Also contained within the vacuum environment are a number of critical items which do not rotate and which although they are especially designed are not difficult to fabricate nor are they fabricated out of unique materials. A centrifuge facility however requires a large number of these components, so that quantities can provide an important indication of end use.

5.1.1. Rotating components

(a) Complete rotor assemblies: Thin-walled cylinders, or a number of interconnected thin-walled cylinders, manufactured from one or more of the high strength to density ratio materials described in the EXPLANATORY NOTE to this Section. If interconnected, the cylinders are joined together by flexible bellows or rings as described in section 5.1.1.(c) following. The rotor is fitted with an internal baffle(s) and end caps, as described in section 5.1.1.(d) and (e) following, if in final form. However the complete assembly may be delivered only partly assembled.

(b) Rotor tubes: Especially designed or prepared thin-walled cylinders with thickness of 12 mm (0.5 in) or less, a diameter of between 75 mm (3 in) and 400 mm (16 in), and manufactured from one or more of the high strength to density ratio materials described in the EXPLANATORY NOTE to this Section.

(c) Rings or Bellows: Components especially designed or prepared to give localized support to the rotor tube or to join together a number of rotor tubes. The bellows is a short cylinder of wall thickness 3 mm (0.12 in) or less, a diameter of between 75 mm (3 in) and 400 mm (16 in), having a convolute, and manufactured from one of the high strength to density ratio materials described in the EXPLANATORY NOTE to this Section.

(d) Baffles: Disc-shaped components of between 75 mm (3 in) and 400 mm (16 in) diameter especially designed or prepared to be mounted inside the centrifuge rotor tube, in order to isolate the take-off chamber from the main separation chamber and, in some cases, to assist the UF 6 gas circulation within the main separation chamber of the rotor tube, and manufactured from one of the high strength to density ratio materials described in the EXPLANATORY NOTE to this Section.

(e) Top caps/Bottom caps: Disc-shaped components of between 75 mm (3 in) and 400 mm (16 in) diameter especially designed or prepared to fit to the ends of the rotor tube, and so contain the UF 6 within the rotor tube, and in some cases to support, retain or contain as an integrated part an element of the upper bearing (top cap) or to carry the rotating elements of the motor and lower bearing (bottom cap), and manufactured from one of the high strength to density ratio materials described in the EXPLANATORY NOTE to this Section.

EXPLANATORY NOTE

The materials used for centrifuge rotating components are:

(a) Maraging steel capable of an ultimate tensile strength of 2.05 X 10 9 N/m 2 (300,000 psi) or more;

(b) Aluminium alloys capable of an ultimate tensile strength of 0.46 X 10 9 N/m 2 (67,000 psi) or more;

(c) Filamentary materials suitable for use in composite structures and having a specific modulus of 12.3 X 10 6 m or greater and a specific ultimate tensile strength of 0.3 X 10 6 m or greater ('Specific Modulus' is the Young's Modulus in N/m 2 divided by the specific weight in N/m 3 ; 'Specific Ultimate Tensile Strength' is the ultimate tensile strength in N/m 2 divided by the specific weight in N/m 3).

5.1.2. Static components

(a) Magnetic suspension bearings: Especially designed or prepared bearing assemblies consisting of an annular magnet suspended within a housing containing a damping medium. The housing will be manufactured from a UF 6 -resistant material (see EXPLANATORY NOTE to Section 5.2.). The magnet couples with a pole piece or a second magnet fitted to the top cap described in Section 5.1.1.(e). The magnet may be ring-shaped with a relation between outer and inner diameter smaller or equal to 1.6:1. The magnet may be in a form having an initial permeability of 0.15 H/m (120,000 in CGS units) or more, or a remanence of 98.5% or more, or an energy product of greater than 80 kJ/m 3 (107 gauss-oersteds). In addition to the usual material properties, it is a prerequisite that the deviation of the magnetic axes from the geometrical axes is limited to very small tolerances (lower than 0.1 mm or 0.004 in) or that homogeneity of the material of the magnet is specially called for.

(b) Bearings/Dampers: Especially designed or prepared bearings comprising a pivot/cup assembly mounted on a damper. The pivot is normally a hardened steel shaft with a hemisphere at one end with a means of attachment to the bottom cap described in section 5.1.1.(e) at the other. The shaft may however have a hydrodynamic bearing attached. The cup is pellet-shaped with a hemispherical indentation in one surface. These components are often supplied separately to the damper.

(c) Molecular pumps: Especially designed or prepared cylinders having internally machined or extruded helical grooves and internally machined bores. Typical dimensions are as follows: 75 mm (3 in) to 400 mm (16 in) internal diameter, 10 mm (0.4 in) or more wall thickness, with the length equal to or greater than the diameter. The grooves are typically rectangular in cross-section and 2 mm (0.08 in) or more in depth.

(d) Motor stators: Especially designed or prepared ring-shaped stators for high speed multiphase AC hysteresis (or reluctance) motors for synchronous operation within a vacuum in the frequency range of 600 - 2000 Hz and a power range of 50 - 1000 VA. The stators consist of multi-phase windings on a laminated low loss iron core comprised of thin layers typically 2.0 mm (0.08 in) thick or less.

(e) Centrifuge housing/recipients: Components especially designed or prepared to contain the rotor tube assembly of a gas centrifuge. The housing consists of a rigid cylinder of wall thickness up to 30 mm (1.2 in) with precision machined ends to locate the bearings and with one or more flanges for mounting. The machined ends are parallel to each other and perpendicular to the cylinder's longitudinal axis to within 0.05 degrees or less. The housing may also be a honeycomb type structure to accommodate several rotor tubes. The housings are made of or protected by materials resistant to corrosion by UF 6 .

(f) Scoops: Especially designed or prepared tubes of up to 12 mm (0.5 in) internal diameter for the extraction of UF 6 gas from within the rotor tube by a Pitot tube action (that is, with an aperture facing into the circumferential gas flow within the rotor tube, for example by bending the end of a radially disposed tube) and capable of being fixed to the central gas extraction system. The tubes are made of or protected by materials resistant to corrosion by UF 6 .

5.2. Especially designed or prepared auxiliary systems, equipment and components for gas centrifuge enrichment plants

INTRODUCTORY NOTE The auxiliary systems, equipment and components for a gas centrifuge enrichment plant are the systems of plantneeded to feed UF 6 to the centrifuges, to link the individual centrifuges to each other to form cascades (or stages) to allow for progressively higher enrichments and to extract the 'product' and 'tails' UF 6 from the centrifuges, together with the equipment required to drive the centrifuges or to control the plant. Normally UF 6 is evaporated from the solid using heated autoclaves and is distributed in gaseous form to the centrifuges by way of cascade header pipework. The 'product' and 'tails' UF 6 gaseous streams flowing from the centrifuges are also passed by way of cascade header pipework to cold traps (operating at about 203 K (-70 ºC)) where they are condensed prior to onward transfer into suitable containers for transportation or storage. Because an enrichment plant consists of many thousands of centrifuges arranged in cascades there are many kilometers of cascade header pipework, incorporating thousands of welds with a substantial amount of repetition of layout. The equipment, components and piping systems are fabricated to very high vacuum and cleanliness standards.

5.2.1. Feed systems/product and tails withdrawal systems

Especially designed or prepared process systems including: Feed autoclaves (or stations), used for passing UF 6 to the centrifuge cascades at up to 100 kPa (15 psi) and at a rate of 1 kg/h or more; Desublimers (or cold traps) used to remove UF 6 from the cascades at up to 3 kPa (0.5 psi) pressure. The desublimers are capable of being chilled to 203 K (-70 ºC) and heated to 343 K (70 ºC); Product' and 'Tails' stations used for trapping UF 6 into containers. This plant, equipment and pipework is wholly made of or lined with UF 6 -resistant materials (see EXPLANATORY NOTE to this section) and is fabricated to very high vacuum and cleanliness standards.

5.2.2. Machine header piping systems

Especially designed or prepared piping systems and header systems for handling UF_6 within the centrifuge cascades. The piping network is normally of the 'triple' header system with each centrifuge connected to each of the headers. There is thus a substantial amount of repetition in its form. It is wholly made of UF_6 -resistant materials (see EXPLANATORY NOTE to this section) and is fabricated to very high vacuum and cleanliness standards.

5.2.3. UF_6 mass spectrometers/ion sources

Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking 'on-line' samples of feed, product or tails, from UF_6 gas streams and having all of the following characteristics:

1. Unit resolution for atomic mass unit greater than 320;

2. Ion sources constructed of or lined with nichrome or monel or nickel plated;

3. Electron bombardment ionization sources;

4. Having a collector system suitable for isotopic analysis.

5.2.4. Frequency changers

Frequency changers (also known as converters or invertors) especially designed or prepared to supply motor stators as defined under 5.1.2.(d), or parts, components and sub-assemblies of such frequency changers having all of the following characteristics:

1. A multiphase output of 600 to 2000 Hz;

2. High stability (with frequency control better than 0.1%);

3. Low harmonic distortion (less than 2%); and 4. An efficiency of greater than 80%.

EXPLANATORY NOTE

The items listed above either come into direct contact with the UF_6 process gas or directly control the centrifuges and the passage of the gas from centrifuge to centrifuge and cascade to cascade.

Materials resistant to corrosion by UF_6 include stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60% or more nickel.

5.3. Especially designed or prepared assemblies and components for use in gaseous diffusion enrichment

INTRODUCTORY NOTE

In the gaseous diffusion method of uranium isotope separation, the main technological assembly is a special porous gaseous diffusion barrier, heat exchanger for cooling the gas (which is heated by the process of compression), seal valves and control valves, and pipelines. Inasmuch as gaseous diffusion technology uses uranium hexafluoride (UF_6), all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF_6 . A gaseous diffusion facility requires a number of these assemblies, so that quantities can provide an important indication of end use.

5.3.1. Gaseous diffusion barriers

(a) Especially designed or prepared thin, porous filters, with a pore size of 100 - 1,000 Å (angstroms), a thickness of 5 mm (0.2 in) or less, and for tubular forms, a diameter of 25 mm (1 in) or less, made of metallic, polymer or ceramic materials resistant to corrosion by UF_6, and

(b) especially prepared compounds or powders for the manufacture of such filters. Such compounds and powders include nickel or alloys containing 60 per cent or more nickel, aluminium oxide, or UF_6-resistant fully fluorinated hydrocarbon polymers having a purity of 99.9 per cent or more, a particle size less than 10 microns, and a high degree of particle size uniformity, which are especially prepared for the manufacture of gaseous diffusion barriers.

5.3.2. Diffuser housings

Especially designed or prepared hermetically sealed cylindrical vessels greater than 300 mm (12 in) in diameter and greater than 900 mm (35 in) in length, or rectangular vessels of comparable dimensions, which have an inlet connection and two outlet connections all of which are greater than 50 mm (2 in) in diameter, for containing the gaseous diffusion barrier, made of or lined with UF_6-resistant materials and designed for horizontal or vertical installation.

5.3.3. Compressors and gas blowers Especially designed or prepared axial, centrifugal, or positive displacement compressors, or gas blowers with a suction volume capacity of 1 m^3/min or more of UF_6, and with a discharge pressure of up to several hundred kPa (100 psi), designed for long-term operation in the UF_6 environment with or without an electrical motor of appropriate power, as well as separate assemblies of such compressors and gas blowers. These compressors and gas blowers have a pressure ratio between 2:1 and 6:1 and are made of, or lined with, materials resistant to UF_6.

5.3.4. Rotary shaft seals

Especially designed or prepared vacuum seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor or the gas blower rotor with the driver motor so as to ensure a reliable seal against in-leaking of air into the inner chamber of the compressor or gas blower which is filled with UF_6. Such seals are normally designed for a buffer gas in-leakage rate of less than 1000 cm^3/min (60 in^3/min).

5.3.5.Heat exchangers for cooling UF_6

Especially designed or prepared heat exchangers made of or lined with UF_6-resistant materials (except stainless steel) or with copper or any combination of those metals, and intended for a leakage pressure change rate of less than 10 Pa (0.0015 psi) per hour under a pressure difference of 100 kPa (15 psi).

5.4. Especially designed or prepared auxiliary systems, equipment and components for use in gaseous diffusion enrichment

INTRODUCTORY NOTE

The auxiliary systems, equipment and components for gaseous diffusion enrichment plants are the systems of plant needed to feed UF_6 to the gaseous diffusion assembly, to link the individual assemblies to each other to form cascades (or stages) to allow for progressively higher enrichments and to extract the "product" and "tails" UF_6 from the diffusion cascades. Because of the high inertial properties of diffusion cascades, any interruption in their operation, and especially their shut-down, leads to serious consequences. Therefore, a strict and constant maintenance of vacuum in all technological systems, automatic protection from accidents, and precise automated regulation of the gas flow is of importance in a gaseous diffusion plant. All this leads to a need to equip the plant with a large number of special measuring, regulating and controlling systems. Normally UF 6 is evaporated from cylinders placed within autoclaves and is distributed in gaseous form to the entry point by way of cascade header pipework. The "product" and "tails" UF 6 gaseous streams flowing from exit points are passed by way of cascade header pipework to either cold traps or to compression stations where the UF 6 gas is liquefied prior to onward transfer into suitable containers for transportation or storage. Because a gaseous diffusion enrichment plant consists of a large number of gaseous diffusion assemblies arranged in cascades, there are many kilometers of cascade header pipework, incorporating thousands of welds with substantial amounts of repetition of layout. The equipment, components and piping systems are fabricated to very high vacuum and cleanliness standards.

5.4.1. Feed systems/product and tails withdrawal systems

Especially designed or prepared process systems, capable of operating at pressures of 300 kPa (45 psi) or less, including: Feed autoclaves (or systems), used for passing UF 6 to the gaseous diffusion cascades;

Desublimers (or cold traps) used to remove UF 6 from diffusion cascades;

Liquefaction stations where UF 6 gas from the cascade is compressed and cooled to form liquid UF 6 ;

"Product" or "tails" stations used for transferring UF 6 into containers.

5.4.2. Header piping systems

Especially designed or prepared piping systems and header systems for handling UF 6 within the gaseous diffusion cascades. This piping network is normally of the "double" header system with each cell connected to each of the headers.

5.4.3. Vacuum systems

(a) Especially designed or prepared large vacuum manifolds, vacuum headers and vacuum pumps having a suction capacity of 5 m 3 /min (175 ft 3 /min) or more.

(b) Vacuum pumps especially designed for service in UF 6 -bearing atmospheres made of, or lined with, aluminium, nickel, or alloys bearing more than 60% nickel. These pumps may be either rotary or positive, may have displacement and fluorocarbon seals, and may have special working fluids present.

5.4.4. Special shut-off and control valves

Especially designed or prepared manual or automated shut-off and control bellows valves made of UF 6 -resistant materials with a diameter of 40 to 1500 mm (1.5 to 59 in) for installation in main and auxiliary systems of gaseous diffusion enrichment plants.

5.4.5. UF 6 mass spectrometers/ion sources

Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking "on-line" samples of feed, product or tails, from UF 6 gas streams and having all of the following characteristics:

1. Unit resolution for atomic mass unit greater than 320;

2. Ion sources constructed of or lined with nichrome or monel or nickel plated;

3. Electron bombardment ionization sources;

4. Collector system suitable for isotopic analysis.

EXPLANATORY NOTE

The items listed above either come into direct contact with the UF 6 process gas or directly control the flow within the cascade. All surfaces which come into contact with the process gas are wholly made of, or lined with, UF 6 -resistant materials. For the purposes of the sections relating to gaseous diffusion items the materials resistant to corrosion by UF 6 include stainless steel, aluminium, aluminium alloys, aluminium oxide, nickel or alloys containing 60% or more nickel and UF 6 -resistant fully fluorinated hydrocarbon polymers.

5.5. Especially designed or prepared systems, equipment and components for use in aerodynamic enrichment plants.

INTRODUCTORY NOTE In aerodynamic enrichment processes, a mixture of gaseous UF 6 and light gas (hydrogen or helium) is compressed and then passed through separating elements wherein isotopic separation is accomplished by the generation of high centrifugal forces over a curved-wall geometry. Two processes of this type have been successfully developed: the separation nozzle process and the vortex tube process. For both processes the main components of a separation stage include cylindrical vessels housing the special separation elements (nozzles or vortex tubes), gas compressors and heat exchangers to remove the heat of compression. An aerodynamic plant requires a number of these stages, so that quantities can provide an important indication of end use. Since aerodynamic processes use UF 6 , all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF 6 .

EXPLANATORY NOTE

The items listed in this section either come into direct contact with the UF 6 process gas or directly control the flow within the cascade. All surfaces which come into contact with the process gas are wholly made of or protected by UF 6 -resistant materials. For the purposes of the section relating to aerodynamic enrichment items, the materials resistant to corrosion by UF 6 include copper, stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60% or more nickel and UF 6 -resistant fully fluorinated hydrocarbon polymers.

5.5.1. Separation nozzles

Especially designed or prepared separation nozzles and assemblies thereof. The separation nozzles consist of slit-shaped, curved channels having a radius of curvature less than 1 mm (typically 0.1 to 0.05 mm), resistant to corrosion by UF 6 and having a knife-edge within the nozzle that separates the gas flowing through the nozzle into two fractions.

5.5.2. Vortex tubes

Especially designed or prepared vortex tubes and assemblies thereof. The vortex tubes are cylindrical or tapered, made of or protected by materials resistant to corrosion by UF 6 , having a diameter of between 0.5 cm and 4 cm, a length to diameter ratio of 20:1 or less and with one or more tangential inlets. The tubes may be equipped with nozzle-type appendages at either or both ends.

EXPLANATORY NOTE

The feed gas enters the vortex tube tangentially at one end or through swirl vanes or at numerous tangential positions along the periphery of the tube.

v 5.5.3. Compressors and gas blowers

Especially designed or prepared axial, centrifugal or positive displacement compressors or gas blowers made of or protected by materials resistant to corrosion by UF_6 and with a suction volume capacity of 2 m^3/min or more of UF_6/carrier gas (hydrogen or helium) mixture.

EXPLANATORY NOTE

These compressors and gas blowers typically have a pressure ratio between 1.2:1 and 6:1.

5.5.4. Rotary shaft seals

Especially designed or prepared rotary shaft seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor rotor or the gas blower rotor with the driver motor so as to ensure a reliable seal against out-leakage of process gas or in-leakage of air or seal gas into the inner chamber of the compressor or gas blower which is filled with a UF_6/carrier gas mixture.

5.5.5. Heat exchangers for gas cooling

Especially designed or prepared heat exchangers made of or protected by materials resistant to corrosion by UF_6.

5.5.6. Separation element housings

Especially designed or prepared separation element housings, made of or protected by materials resistant to corrosion by UF_6, for containing vortex tubes or separation nozzles.

EXPLANATORY NOTE

These housings may be cylindrical vessels greater than 300 mm in diameter and greater than 900 mm in length, or may be rectangular vessels of comparable dimensions, and may be designed for horizontal or vertical installation.

5.5.7. Feed systems/product and tails withdrawal systems

Especially designed or prepared process systems or equipment for enrichment plants made of or protected by materials resistant to corrosion by UF_6, including:

(a) Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process;

(b) Desublimers (or cold traps) used to remove UF_6 from the enrichment process for subsequent transfer upon heating;

(c) Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form;

(d) 'Product' or 'tails' stations used for transferring UF_6 into containers.

5.5.8. Header piping systems

Especially designed or prepared header piping systems, made of or protected by materials resistant to corrosion by UF_6, for handling UF_6 within the aerodynamic cascades. This piping network is normally of the 'double' header design with each stage or group of stages connected to each of the headers.

5.5.9. Vacuum systems and pumps

(a) Especially designed or prepared vacuum systems having a suction capacity of 5 m^3/min or more, consisting of vacuum manifolds, vacuum headers and vacuum pumps, and designed for service in UF_6-bearing atmospheres,

(b) Vacuum pumps especially designed or prepared for service in UF_6-bearing atmospheres and made of or protected by materials resistant to corrosion by UF_6. These pumps may use fluorocarbon seals and special working fluids.

5.5.10. Special shut-off and control valves

Especially designed or prepared manual or automated shut-off and control bellows valves made of or protected by materials resistant to corrosion by UF_6 with a diameter of 40 to 1500 mm for installation in main and auxiliary systems of aerodynamic enrichment plants.

5.5.11. UF_6 mass spectrometers/Ion sources

Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking 'on-line' samples of feed, 'product' or 'tails', from UF_6 gas streams and having all of the following characteristics: 1. Unit resolution for mass greater than 320; 2. Ion sources constructed of or lined with nichrome or monel or nickel plated; 3. Electron bombardment ionization sources; 4. Collector system suitable for isotopic analysis.

5.5.12. UF_6/carrier gas separation systems

Especially designed or prepared process systems for separating UF_6 from carrier gas (hydrogen or helium).

EXPLANATORY NOTE

These systems are designed to reduce the UF_6 content in the carrier gas to 1 ppm or less and may incorporate equipment such as:

(a) Cryogenic heat exchangers and cryoseparators capable of temperatures of -120 °C or less, or

(b) Cryogenic refrigeration units capable of temperatures of -120 °C or less, or

(c) Separation nozzle or vortex tube units for the separation of UF_6 from carrier gas, or

(d) UF_6 cold traps capable of temperatures of -20 °C or less.

5.6. Especially designed or prepared systems, equipment and components for use in chemical exchange or ion exchange enrichment plants.

INTRODUCTORY NOTE

The slight difference in mass between the isotopes of uranium causes small changes in chemical reaction equilibria that can be used as a basis for separation of the isotopes. Two processes have been successfully developed: liquid-liquid chemical exchange and solid-liquid ion exchange. In the liquid-liquid chemical exchange process, immiscible liquid phases (aqueous and organic) are countercurrently contacted to give the cascading effect of thousands of separation stages. The aqueous phase consists of uranium chloride in hydrochloric acid solution; the organic phase consists of an extractant containing uranium chloride in an organic solvent. The contactors employed in the separation cascade can be liquid-liquid exchange columns (such as pulsed columns with sieve plates) or liquid centrifugal contactors. Chemical conversions (oxidation and reduction) are required at both ends of the separation cascade in order to provide for the reflux requirements at each end. A major design concern is to avoid contamination of the process streams with certain metal ions. Plastic, plastic-lined (including use of fluorocarbon polymers) and/or glass-lined columns and piping are therefore used. In the solid-liquid ion-exchange process, enrichment is accomplished by uranium adsorption/desorption on a special, very fast-acting, ion-exchange resin or adsorbent. A solution of uranium in hydrochloric acid and other chemical agents is passed through cylindrical enrichment columns containing packed beds of the adsorbent. For a continuous process, a reflux system is necessary to release the uranium from the adsorbent back into the liquid flow so that 'product' and 'tails' can be collected. This is accomplished with the use of suitable reduction/oxidation chemical agents that are fully regenerated in separate external circuits and that may be partially regenerated within the isotopic separation columns themselves. The presence of hot concentrated hydrochloric acid solutions in the process requires that the equipment be made of or protected by special corrosion-resistant materials.

5.6.1. Liquid-liquid exchange columns (Chemical exchange)

Countercurrent liquid-liquid exchange columns having mechanical power input (i.e., pulsed columns with sieve plates, reciprocating plate columns, and columns with internal turbine mixers), especially designed or prepared for uranium enrichment using the chemical exchange process. For corrosion resistance to concentrated hydrochloric acid solutions, these columns and their internals are made of or protected by suitable plastic materials (such as fluorocarbon polymers) or glass. The stage residence time of the columns is designed to be short (30 seconds or less).

5.6.2. Liquid-liquid centrifugal contactors (Chemical exchange)

Liquid-liquid centrifugal contactors especially designed or prepared for uranium enrichment using the chemical exchange process. Such contactors use rotation to achieve dispersion of the organic and aqueous streams and then centrifugal force to separate the phases. For corrosion resistance to concentrated hydrochloric acid solutions, the contactors are made of or are lined with suitable plastic materials (such as fluorocarbon polymers) or are lined with glass. The stage residence time of the centrifugal contactors is designed to be short (30 seconds or less).

5.6.3. Uranium reduction systems and equipment (Chemical exchange)

(a) Especially designed or prepared electrochemical reduction cells to reduce uranium from one valence state to another for uranium enrichment using the chemical exchange process. The cell materials in contact with process solutions must be corrosion resistant to concentrated hydrochloric acid solutions.

EXPLANATORY NOTE The cell cathodic compartment must be designed to prevent re-oxidation of uranium to its higher valence state. To keep the uranium in the cathodic compartment, the cell may have an impervious diaphragm membrane constructed of special cation exchange material. The cathode consists of a suitable solid conductor such as graphite.

(b) Especially designed or prepared systems at the product end of the cascade for taking the U +4 out of the organic stream, adjusting the acid concentration and feeding to the electrochemical reduction cells.

EXPLANATORY NOTE

These systems consist of solvent extraction equipment for stripping the U +4 from the organic stream into an aqueous solution, evaporation and/or other equipment to accomplish solution pH adjustment and control, and pumps or other transfer devices for feeding to the electrochemical reduction cells. A major design concern is to avoid contamination of the aqueous stream with certain metal ions. Consequently, for those parts in contact with the process stream, the system is constructed of equipment made of or protected by suitable materials (such as glass, fluorocarbon polymers, polyphenyl sulfate, polyether sulfone, and resin-impregnated graphite).

5.6.4. Feed preparation systems (Chemical exchange)

Especially designed or prepared systems for producing high-purity uranium chloride feed solutions for chemical exchange uranium isotope separation plants.

EXPLANATORY NOTE

These systems consist of dissolution, solvent extraction and/or ion exchange equipment for purification and electrolytic cells for reducing the uranium U +6 or U +4 to U +3 . These systems produce uranium chloride solutions having only a few parts per million of metallic impurities such as chromium, iron, vanadium, molybdenum and other bivalent or higher multi-valent cations. Materials of construction for portions of the system processing high-purity U +3 include glass, fluorocarbon polymers, polyphenyl sulfate or polyether sulfone plastic-lined and resin-impregnated graphite.

5.6.5. Uranium oxidation systems (Chemical exchange)

Especially designed or prepared systems for oxidation of U +3 to U +4 for return to the uranium isotope separation cascade in the chemical exchange enrichment process.

EXPLANATORY NOTE These systems may incorporate equipment such as: (a) Equipment for contacting chlorine and oxygen with the aqueous effluent from the isotope separation equipment and extracting the resultant U +4 into the stripped organic stream returning from the product endof the cascade, (b) Equipment that separates water from hydrochloric acid so that the water and the concentrated hydrochloricacid may be reintroduced to the process at the proper locations.

5.6.6. Fast-reacting ion exchange resins/adsorbents (ion exchange)

Fast-reacting ion-exchange resins or adsorbents especially designed or prepared for uranium enrichment using the ion exchange process, including porous macroreticular resins, and/or pellicular structures in which the active chemical exchange groups are limited to a coating on the surface of an inactive porous support structure, and other composite structures in any suitable form including particles or fibers. These ion exchange resins/adsorbents have diameters of 0.2 mm or less and must be chemically resistant to concentrated hydrochloric acid solutions as well as physically strong enough so as not to degrade in the exchange columns. The resins/adsorbents are especially designed to achieve very fast uranium isotope exchange kinetics (exchange rate half-time of less than 10 seconds) and are capable of operating at a temperature in the range of 100 °C to 200 °C.

5.6.7. Ion exchange columns (Ion exchange)

Cylindrical columns greater than 1000 mm in diameter for containing and supporting packed beds of ion exchange resin/adsorbent, especially designed or prepared for uranium enrichment using the ion exchange process. These columns are made of or protected by materials (such as titanium or fluorocarbon plastics) resistant to corrosion by concentrated hydrochloric acid solutions and are capable of operating at a temperature in the range of 100 °C to 200 °C and pressures above 0.7 MPa (102 psi).

5.6.8. Ion exchange reflux systems (Ion exchange)

(a) Especially designed or prepared chemical or electrochemical reduction systems for regeneration of the chemical reducing agent(s) used in ion exchange uranium enrichment cascades. (b) Especially designed or prepared chemical or electrochemical oxidation systems for regeneration of the chemical oxidizing agent(s) used in ion exchange uranium enrichment cascades.

EXPLANATORY NOTE

The ion exchange enrichment process may use, for example, trivalent titanium (Ti +3) as a reducing cation in which case the reduction system would regenerate Ti +3 by reducing Ti +4 . The process may use, for example, trivalent iron (Fe +3) as an oxidant in which case the oxidation system would regenerate Fe +3 by oxidizing Fe +2 .

5.7. Especially designed or prepared systems, equipment and components for use in laser-based enrichment plants.

INTRODUCTORY NOTE Present systems for enrichment processes using lasers fall into two categories: those in which the process medium is atomic uranium vapor and those in which the process medium is the vapor of a uranium compound. Common nomenclature for such processes include: first category - atomic vapor laser isotope separation (AVLIS or SILVA); second category - molecular laser isotope separation (MLIS or MOLIS) and chemical reaction by isotope selective laser activation (CRISLA). The systems, equipment and components for laser enrichment plants embrace: (a) devices to feed uranium-metal vapor (for selective photo-ionization) or devices to feed the vapor of a uranium compound (for photo-dissociation or chemical activation); (b) devices to collect enriched and depleted uranium metal as 'product' and 'tails' in the first category, and devices to collect dissociated or reacted compounds as 'product' and unaffected material as 'tails' in the second category; (c) process laser systems to selectively excite the uranium-235 species; and (d) feed preparation and product conversion equipment. The complexity of the spectroscopy of uranium atoms and compounds may require incorporation of any of a number of available laser technologies.

EXPLANATORY NOTE

Many of the items listed in this section come into direct contact with uranium metal vapor or liquid or with process gas consisting of UF 6 or a mixture of UF 6 and other gases. All surfaces that come into contact with the uranium or UF 6 are wholly made of or protected by corrosion-resistant materials. For the purposes of the section relating to laser-based enrichment items, the materials resistant to corrosion by the vapor or liquid of uranium metal or uranium alloys include yttria-coated graphite and tantalum; and the materials resistant to corrosion by UF 6 include copper, stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60 % or more nickel and UF 6 - resistant fully fluorinated hydrocarbon polymers.

5.7.1. Uranium vaporization systems (AVLIS) Especially designed or prepared uranium vaporization systems which contain high-power strip or scanning electron beam guns with a delivered power on the target of more than 2.5 kW/cm.

5.7.2. Liquid uranium metal handling systems (AVLIS)

Especially designed or prepared liquid metal handling systems for molten uranium or uranium alloys, consisting of crucibles and cooling equipment for the crucibles.

EXPLANATORY NOTE

The crucibles and other parts of this system that come into contact with molten uranium or uranium alloys are made of or protected by materials of suitable corrosion and heat resistance. Suitable materials include tantalum, yttria-coated graphite, graphite coated with other rare earth oxides (see INFCIRC/254/Part 2 - (as amended)) or mixtures thereof.

5.7.3. Uranium metal 'product' and 'tails' collector assemblies (AVLIS)

Especially designed or prepared 'product' and 'tails' collector assemblies for uranium metal in liquid or solid form.

EXPLANATORY NOTE Components for these assemblies are made of or protected by materials resistant to the heat and corrosion of uranium metal vapor or liquid (such as yttria-coated graphite or tantalum) and may include pipes, valves, fittings, 'gutters', feed-throughs, heat exchangers and collector plates for magnetic, electrostatic or other separation methods.

5.7.4. Separator module housings (AVLIS)

Especially designed or prepared cylindrical or rectangular vessels for containing the uranium metal vapor source, the electron beam gun, and the "product' and 'tails' collectors.

EXPLANATORY NOTE These housings have multiplicity of ports for electrical and water feed-throughs, laser beam windows, vacuum pump connections and instrumentation diagnostics and monitoring. They have provisions for opening and closure to allow refurbishment of internal components.

5.7.5. Supersonic expansion nozzles (MLIS) Especially designed or prepared supersonic expansion nozzles for cooling mixtures of UF_6 and carrier gas to 150 K or less and which are corrosion resistant to UF_6 .

5.7.6. Uranium pentafluoride product collectors (MLIS)

Especially designed or prepared uranium pentafluoride (UF_5) solid product collectors consisting of filter, impact, or cyclone-type collectors, or combinations thereof, and which are corrosion resistant to the UF_5 /UF_6 environment.

5.7.7. UF_6 /carrier gas compressors (MLIS)

Especially designed or prepared compressors for UF_6 /carrier gas mixtures, designed for long term operation in a UF_6 environment. The components of these compressors that come into contact with process gas are made of or protected by materials resistant to corrosion by UF_6.

5.7.8. Rotary shaft seals (MLIS)

Especially designed or prepared rotary shaft seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor rotor with the driver motor so as to ensure a reliable seal against out-leakage of process gas or in-leakage of air or seal gas into the inner chamber of the compressor which is filled with a UF_6 /carrier gas mixture.

5.7.9. Fluorination systems (MLIS)

Especially designed or prepared systems for fluorinating UF_5 (solid) to UF_6 (gas).

EXPLANATORY NOTE

These systems are designed to fluorinate the collected UF_5 powder to UF_6 for subsequent collection in product containers or for transfer as feed to MLIS units for additional enrichment. In one approach, the fluorination reaction may be accomplished within the isotope separation system to react and recover directly off the 'product' collectors. In another approach, the UF_5 powder may be removed/transferred from the 'product' collectors into a suitable reaction vessel (e.g., fluidized-bed reactor, screw reactor or flame tower) for fluorination. In both approaches, equipment for storage and transfer of fluorine (or other suitable fluorinating agents) and for collection and transfer of UF_6 are used.

5.7.10. UF_6 mass spectrometers/ion sources (MLIS) Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking 'on-line' samples of feed, 'product' or 'tails', from UF_6 gas streams and having all of the following characteristics: 1. Unit resolution for mass greater than 320; 2. Ion sources constructed of or lined with nichrome or monel or nickel plated; 3. Electron bombardment ionization sources; 4. Collector system suitable for isotopic analysis.

5.7.11. Feed systems/product and tails withdrawal systems (MLIS)

Especially designed or prepared process systems or equipment for enrichment plants made of or protected by materials resistant to corrosion by UF_6 , including: (a) Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process; (b) Desublimers (or cold traps) used to remove UF_6 from the enrichment process for subsequent transfer upon heating; (c) Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form; (d) 'Product' or 'tails' stations used for transferring UF_6 into containers.

5.7.12. UF_6 /carrier gas separation systems (MLIS) Especially designed or prepared process systems for separating UF_6 from carrier gas.

The carrier gas may be nitrogen, argon, or other gas.

EXPLANATORY NOTE

These systems may incorporate equipment such as: (a) Cryogenic heat exchangers or cryoseparators capable of temperatures of -120 °C or less, or (b) Cryogenic refrigeration units capable of temperatures of -120 °C or less, or (c) UF_6 cold traps capable of temperatures of -20 °C or less.

5.7.13. Laser systems (AVLIS, MLIS and CRISLA)

Lasers or laser systems especially designed or prepared for the separation of uranium isotopes.

EXPLANATORY NOTE

These housings have a multiplicity of ports for electrical feed-throughs, diffusion pump connections and Instrumentation diagnostics and monitoring. They have provisions for opening and closure to allow for refurbishment of internal components and are constructed of a suitable non-magnetic material such as stainless steel.

5.9. Especially designed or prepared systems, equipment and components for use in electromagnetic enrichment plants.

INTRODUCTORY NOTE

In the electromagnetic process, uranium metal ions produced by ionization of a salt feed material (typically UCl_4) are accelerated and passed through a magnetic field that has the effect of causing the ions of different isotopes to follow different paths. The major components of an electromagnetic isotope separator include: a magnetic field for ion-beam diversion/separation of the isotopes, an ion source with its acceleration system, and a collection system for the separated ions. Auxiliary systems for the process include the magnet power supply system, the ion source high-voltage power supply system, the vacuum system, and extensive chemical handling systems for recovery of product and cleaning/recycling of components.

5.9.1. Electromagnetic isotope separators Electromagnetic isotope separators especially designed or prepared for the separation of uranium isotopes, and equipment and components therefore, including:

(a) Ion sources

Especially designed or prepared single or multiple uranium ion sources consisting of a vapor source, ionizer, and beam accelerator, constructed of suitable materials such as graphite, stainless steel, or copper, and capable of providing a total ion beam current of 50 mA or greater.

(b) Ion collectors Collector plates consisting of two or more slits and pockets especially designed or prepared for collection of enriched and depleted uranium ion beams and constructed of suitable materials such as graphite or stainless steel.

(c) Vacuum housings

Especially designed or prepared vacuum housings for uranium electromagnetic separators, constructed of suitable non-magnetic materials such as stainless steel and designed for operation at pressures of 0.1 Pa or lower.

EXPLANATORY NOTE The housings are specially designed to contain the ion sources, collector plates and water-cooled liners and have provision for diffusion pump connections and opening and closure for removal and reinstallation of these components.

(d) Magnet pole pieces

Especially designed or prepared magnet pole pieces having a diameter greater than 2 m used to maintain a constant magnetic field within an electromagnetic isotope separator and to transfer the magnetic field between adjoining separators.

5.9.2. High voltage power supplies

Especially designed or prepared high-voltage power supplies for ion sources, having all ofthe following characteristics: capable of continuous operation, output voltage of 20,000 V or greater, output current of 1 A or greater, and voltage regulation of better than 0.01% over a time period of 8 hours.

5.9.3. Magnet power supplies

Especially designed or prepared high-power, direct current magnet power supplies having all of the following characteristics: capable of continuously producing a current output of 500 A or greater at a voltage of 100 V or greater and with a current or voltage regulation better than 0.01% over a period of 8 hours.

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Enrichment Dual-Use Items

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III. Nautilus Invites Your Responses

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