LA-UR-98-3115

Approved for public release; distribution is unlimited.

Title: MEASUREMENT APPROACHES TO SUPPORT FUTURE WARHEAD ARMS CONTROL TRANSPARENCY

CONF-980733--

Author(s): Chad T. Olinger
Christen M. Frankle
M. William Johnson
Jane Poths

Submitted to: 39th Annual Meeting of the Institute of Nuclear Materials Management
Naples, Florida
July 26-30, 1998

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

Los Alamos
NATIONAL LABORATORY

DISCLAIMER

DISCLAIMER

MEASUREMENT APPROACHES TO SUPPORT FUTURE WARHEAD ARMS CONTROL TRANSPARENCY

Chad T. Olinger, Christen M Frankle, M William Johnson, and Jane Poths
Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Abstract

Transparency on warhead stockpiles, warhead dismantlement, and fissile material stockpiles in nuclear weapons states will become increasingly important as we move beyond START II toward lower quantities of warheads. Congressional support for further warhead reductions will likely depend on the degree of irreversibility, or in other words, the rapidity with which warhead inventories could be reconstituted. Whether we can satisfy irreversibility considerations will depend on monitoring dismantlement as well as constraining the available stockpile of fissile materials for possible refabrication into warheads. Measurement techniques designed to address the above problems will need to consider NPT Article 1 obligations as well as Russian and US classification regulations, which prohibit or restrict the transfer of nuclear warhead design information to other states. Classification considerations currently limit the potential completeness of future inspections of weapons materials. Many conventional international safeguards approaches are not currently viable for arms control applications because they would reveal weapons design information. We discuss a variety of technical measures that may help to improve transparency of warhead and fissile material stockpiles and may enable limited warhead dismantlement transparency.

Introduction

Since the end of the Cold War, the world community has shown increasing interest in warhead arms control. Transparency measures under consideration for START III will represent the first concerted attempt in this arena, but practical considerations are likely to limit the degree of confidence achievable in this first formal warhead dismantlement transparency regime even though implementation of this regime is not likely before 2007. Because of the lead time in implementing new technologies, we should begin planning and developing tools that will eventually enable deeper reductions beyond START III levels.

Bilateral US-Russian drawdowns beyond START III levels are limited, in part, by uncertainties and long-term stability considerations. As an example, based on compilations of open sources and ignoring civilian production, Russia has 110 ± 25 tons of separated plutonium. Using the International Atomic Energy Agency's (IAEA's) significant quantity, the *uncertainty* in this number translates to a potential clandestine production of 3125 nuclear warheads.[1]

Such uncertainties will be an impediment to US-Russian disarmament beyond START III levels. General nuclear disarmament among the five Nuclear Nonproliferation Treaty (NPT) weapons states as well as possible future arms control between the recent self-declared weapons states (India and Pakistan) will depend on reducing uncertainties in each of these states.

Problems in complete warhead and nuclear materials accounting for NPT weapons states relate, in part, to NPT Article 1, which does not allow dissemination of nuclear weapons design information to nonnuclear states. Moreover, each country with nuclear weapons maintains versions of classification laws designed to protect its own national interests. These also severely limit weapons-related information that can be revealed to nationals of other countries, whether they are from weapons states or not.

The root of the uncertainties in material quantities derives from the simple fact that each of the countries involved has produced nuclear materials outside of international safeguards. Experience in quantitatively accounting for all weapons materials not previously under international safeguards in a country can be found from when South Africa joined the NPT. This was a highly successful effort. However, the quantities were tiny compared with just the *uncertainties* in weapons material quantities in the weapons states.

The magnitude of the problem associated with retroactively bringing all weapons materials under quantitative international safeguards suggests the need for qualitatively new approaches. Environmental monitoring measures under the IAEA's strengthened safeguards system could be applied to ensure the absence of production in regions where production is not declared, but the bulk of the problem will be in gaining quantitative confidence in locations where production is declared.

Because of the above problems, new technical and procedural methods of nuclear material verification will be needed to support deep reductions in future bilateral or multilateral arms control. As with conventional safeguards, these methods will strongly depend on detailed declarations of historical nuclear materials shipping, receiving, storage, processing, and reactor operation. New technical measures will need to be developed to confirm the accuracy of such declarations.

What Would We Like to Know?

Deep reductions in nuclear weapons will generally depend on two tasks: (1) reducing uncertainties in the quantities of nuclear materials not historically under international safeguards and (2) assuring that warheads are dismantled as declared. Reducing uncertainties in nuclear material quantities includes addressing historical highly enriched uranium production, weapons-grade plutonium production, and nonweapons-grade plutonium production. As warhead reductions produce increasingly lower numbers of residual warheads, the relative importance of these uncertainties increases because access to materials will probably be the largest technical impediment to possible clandestine weapons reconstitution even within a weapons state.

On the surface, it seems a trivial matter to assure that weapons are dismantled. However, there are two technical complications. The first is verifying that the item going into the dismantlement process is a genuine nuclear warhead. Even highly intrusive gamma-ray isotopic measurements would only provide limited confidence in such an assertion from a verification perspective. The second complication is the fact that direct observation of key dismantlement steps would generally reveal weapons design information.

Verification of the destruction or demilitarization of fissile weapons components shares problems similar to those of warhead dismantlement. Again, authentication that a declared item is unambiguously a fissile component from a nuclear warhead is difficult even with extremely intrusive measurements; and most measurement data that could provide medium confidence that an item could be a component are considered classified.

Revealing weapons design information would be in violation of NPT Article 1 if the IAEA were involved in inspections or would violate the host nation's classification laws under most other scenarios. Unless these political constraints are changed, the authenticity of a warhead or weapons component entering a dismantlement regime and verification of the dismantlement process must be inferred from indirect measurements. Candidate measurements of nuclear materials to demonstrate dismantlement are discussed in several other papers within these proceedings. The rest of this paper considers possible measurement approaches other than direct, conventional measurement of special nuclear materials (SNM) to build confidence future arms control regimes. None of these concepts in isolation will solve the problem, but developing these or similar monitoring tools will be necessary if we are to construct overall monitoring systems to support deep worldwide reductions in nuclear warhead numbers.

Possible Technical Measures Supporting Future Arms Control

Historical production of fissile materials

Placing previously produced fissile materials into international monitoring is successfully being done both in the US and in Russia. Progress in the Trilateral (US, Russia, IAEA) Initiative over the past year exemplifies the efforts to place historical weapons materials under international safeguards. This important example, however, does not attempt to place or confirm that *all* excess fissile materials are placed under international safeguards. If such an effort is sought in future arms control regimes, it will be important to have tools that allow some degree of confirmation about the accuracy of declarations on total quantities of SNM produced.

Long-term arms control will particularly need to reduce uncertainties in plutonium produced in production reactors and power reactors and separated in processing plants. Safeguarding of historical production will depend strongly on declarations and then on methods to verify these declarations.

The neutron flux that produces plutonium from ^{238}U within a reactor also causes other nuclear reactions. Some of these nuclear reactions produce isotopes that are rare nature or non-existent because they have short half-lives compared with geologic time scales. Measurement of these neutron activation products may provide one means of gaining confidence in declared reactor operations (and thus plutonium production). Several favorable reactions occur in contaminants in the graphite of a graphite-moderated production reactor.[2] Some favorable reactions may also occur in the lower flux regions surrounding both production reactors and power reactors. Constraining plutonium production in both types of reactors will be important in achieving deep reductions for warhead arms control, particularly in nations where large quantities of plutonium were separated from the spent fuel of unsafeguarded power reactors.

Based on declared reactor operations and using a highly simplified model, one can predict that the accumulation of an isotope such as ^{21}Ne within mineral grains in structural concrete surrounding a reactor vessel will follow the equation:

$$C\,(^{21}Ne_N) = P(\phi) \cdot t$$

$$= \Sigma\, P(\text{geometry, chemistry, spectrum } \phi)_n t_n$$

where C is the concentration of nucleogenic ^{21}Ne; P is the production rate, which may depend on variations in reactor geometry, target chemistry, neutron spectrum, and neutron flux (ϕ); and t is the length of irradiation. These are summed over a declared *n* number of different reactor operations over the life of the reactor.

Neon has the advantage that it is extremely rare in mineral grains even as a contaminant. The very small quantities that are trapped within mineral grain boundaries have a unique atmospheric composition, whereas neon produced from neutron interactions with elements within the concrete (especially Mg) will be isotopically distinct and therefore clearly distinguishable.

Measuring the quantity of the isotope produced would provide a degree of confidence in the declaration if the predicted amount and measured amounts agreed within predicted uncertainty. It is important to note that the declared reactor operation is not a unique solution to the amount of measured isotope produced, so this tool by itself does not provide high confidence in declarations. It would only provide one check on the consistency of declarations.

Warhead authentication and dismantlement transparency

Several papers have suggested that nonnuclear weapons components might provide transparency in warhead dismantlement. Generally speaking, we believe that tracking of nonnuclear components actually takes the focus away from that deserved by SNM. However, if nonnuclear components are tracked, we considered what the best measurements might be to gain confidence that presented items actually come from nuclear weapons. As with the application of neutron activation measurements, described in the reactor verification section above, the neutron flux from spontaneous fission of ^{240}Pu within some warheads is adequate to produce measurable activation products in nonnuclear components. We demonstrated this hypothesis in one selected case within a nonnuclear warhead component that had come from a recent dismantlement operation on a US warhead.

The particular electronic component contained trace amounts of silver. Exposure to neutrons produces metastable ^{109}Ag with a 250-day half-life. Within approximately three years' exposure to a constant neutron flux, the production of ^{110m}Ag reaches secular equilibrium (Fig. 1). After dismantlement of this warhead, the electronics component was returned to Los Alamos National Laboratory and placed in a low-background high-purity germanium gamma-ray detector facility. The nonnuclear component contained 1.12 g of silver, and this produced a clearly measurable signal of 19 ± 2 dpm from ^{110m}Ag.

A declaration including the exposure geometry of the component and the age of the warhead would allow a comparison of the expected amount of ^{110m}Ag in the component with the measured amount. As with the possible reactor transparency model discussed above, the measurement would not conclusively prove that the item comes from a warhead. Exposing the component to a much higher neutron flux for a much shorter period of time could produce a similar amount of ^{110m}Ag. However, such hypothetical spoofing scenarios could be nearly ruled out by looking for other activation products with differing half lives. In particular, for an electronics component, one might look for ^{64}Cu ($T_{1/2}$ = 12.7 h) in associated metal or ^{36}Cl ($T_{1/2} = 3 \times 10^5$ year) in associated plastic components to make sure the signals are consistent with exposure to a low flux of neutrons for a long period of time.

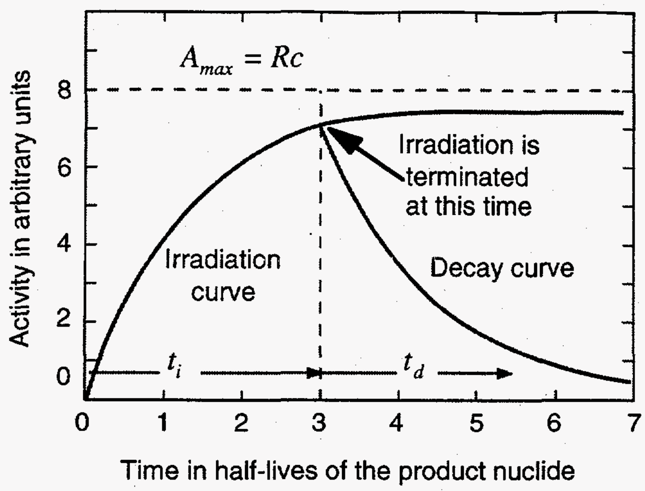

Fig. 1.
The amount of an activation isotope that would be produced as a function of time. The first part of the curve shows the ingrowth of the isotope, the second half shows the decay of the isotope once the item is removed from the neutron flux. The dashed line shows the concentration at secular equilibrium, where the production rate eventually equals the decay rate of the isotope produced.

We caution that even if this technique could conclusively prove that a component comes from a recently dismantled warhead, it still would only constitute a small part of a rigorous transparency regime. Other measures would need to be applied to provide assurance that the component offered up is not simply a "disposable" component removed during re-fabrication of the warhead. In particular, a meaningful transparency regime would have to include tracking of the SNM from the warhead until it is disposed of.

Transparent component demilitarization

As noted above, disposition of SNM resulting from dismantlement will be important in future disarmament regimes. Safeguards on such activities are complicated by the fact that much of the information associated with a particular nuclear component (mass, shape, and isotopics) is classified. Demilitarization of such items is an important step in making the materials accessible to international safeguards. A challenge, however, is maintaining confidence that materials leaving a demilitarization process result directly from the materials that entered the process. Monitoring decay products released during the process may provide such confidence.

In particular, it may be possible to monitor the amount of fissiogenic xenon released from a component during hydration/dehydration (ARIES) processing as the component is converted from a classified component to an unclassified plutonium ingot. Figure 2 shows a schematic of this process. As the plutonium in the component at the top is hydrated, it flakes apart. These flakes fall into a crucible where the hydrogen is driven off by heating. During this process, it might be expected that volatile Xe gas that has accumulated from spontaneous fission would evolve from the plutonium and can be collected cryogenically. Analysis of Xe amounts released could provide a combined (age times Xe production rate) characteristic of that component, which could then be compared to declared values. It is anticipated that this technique could work because the production rate of Xe is sufficiently high from ^{240}Pu spontaneous fission to produce Xe quantities that would be clearly detectable. Moreover, the isotopics are sufficiently different from air that small amounts of air Xe leaking into the reaction chamber would be clearly distinguishable from the fissiogenic Xe.

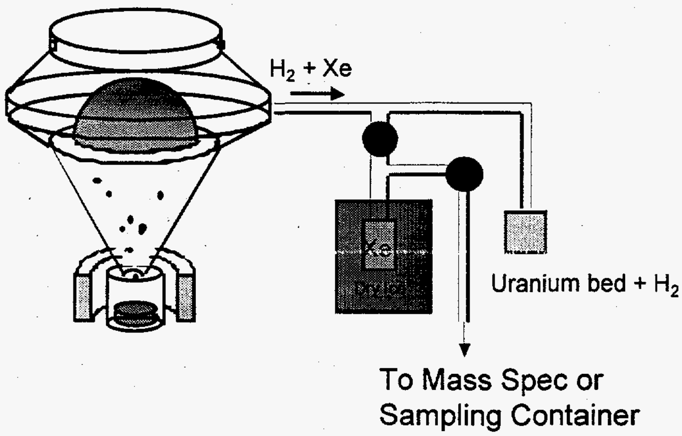

Fig. 2. Transparency on ARIES pit conversion process.

This concept is similar to monitoring approaches under the comprehensive test ban treaty (CTBT), in that both approaches look for fissiogenic Xe. They differ in that the proposed pit demilitarization monitoring measures the accumulation of stable Xe isotopes over the life of the component, whereas CTBT Xe monitoring focuses on measuring short-lived Xe isotopes from nuclear explosions.

Conclusions

Most of the potential transparency measures described above are theoretical in nature at this time. It is also important to point out that none of these techniques, in isolation, would provide high confidence in the authenticity of declarations. Rather we envision that such techniques would be implemented as parts of a well-designed system of measures that together would provide adequate confidence to enable deeper warhead reductions. Other credible approaches supporting transparent deep warhead reductions should also be pursued as they are identified.

Preliminary calculations suggest that each of these measures has merit in hypothetical future transparency regimes. However, their efficacy, cost effectiveness, and fieldable practicality need to be investigated. Moreover, depending on the application, some fundamental physical parameters would need to be better characterized. This is particularly true in the nuclear archeology approach to verifying the operating history of nuclear reactors. In many cases the reaction cross sections producing rare or long-lived radioisotopes from contaminants or structural materials are not known well enough to allow accurate neutron fluence calculations. Further detailed pursuit of this area would involve an interesting combination of basic physics research with practical implementation considerations.

References

1. F. von Hipple, D. Albright, and B. Levi, "Quantities of Fissile Materials in US and Soviet Weapon Arsenals," Center for Energy and Environmental Studies, Princeton University, Princeton, New Jersey, PU/CEES Report #168 (July 1986).
2. Steven Fetter, "Nuclear Archeology: Verifying Declarations of Fissile-Material Production," *Science & Global Security* **3**, 237–259 (1993).