Science & Global Security, 22:1–3, 2014

ISSN: 0892-9882 print / 1547-7800 online
DOI: 10.1080/08929882.2014.871871

Editors' Note

Highly enriched uranium and separated plutonium are the two key materials used in making nuclear weapons. Producing the kilogram quantities of highly enriched uranium (HEU) and plutonium needed for a weapon was the major challenge for the U.S. Manhattan Project during World War II and for all subsequent nuclear weapon programs. Modern nuclear weapons typically may contain one or both of these fissile materials. Apart from the United States and the United Kingdom, nuclear weapon states keep secret how much HEU and plutonium they have produced and what they currently hold in their stockpiles.

Writing in this journal in 1993, Steve Fetter of the University of Maryland observed that "Accounting for the past production of fissile materials ... [will be] a vital element in the worldwide movement toward nuclear disarmament" and made the case for a new field of "nuclear archaeology" to develop techniques for providing independent evidence about how uranium enrichment and plutonium production facilities were operated in the past and the amount of material they produced [Steve Fetter, "Nuclear archaeology: Verifying declarations of fissile-material production," *Science & Global Security* 3, no. 3–4 (1993): 237–259]. Confidence in nuclear arsenal reductions and their eventual elimination would be greatly increased if nuclear weapon states declared their total production of fissile materials and if these declarations could be verified.

In the first article in the current issue, a group of researchers from the U.S. Pacific Northwest National Laboratory (Thomas W. Wood, Bruce D. Reid, Christopher M. Toomey, Kannan Krishnaswami, Kimberly A. Burns, Larry O. Casazza, Don S. Daly, and Leesa L. Duckworth) report on progress over the past 20 years at their Laboratory and in collaboration with others in establishing methods for nuclear archaeology. "The Future of Nuclear Archaeology: Reducing Legacy Risks of Weapons Fissile Material" explains that isotope ratio analysis of select impurities in the graphite in a graphite moderator plutonium production reactor is sufficiently well developed as to provide a reliable and accurate ($<2\%$ error) estimate for reactor lifetime plutonium production. A similar method has been demonstrated for other reactor types (e.g., heavy-water moderated reactors) using isotope ratios in metal components associated with the reactor core.

The authors of "The Future of Nuclear Archaeology" note, however, that "the problem of estimating historical HEU production is both more technically demanding and far less experimentally mature" than that for plutonium production. They report on work at Pacific Northwest National Laboratory to develop nuclear archaeological methods that can be applied to uranium enrichment gas centrifuge plants—the most widely used enrichment technology today. The archaeological signatures include the thickness and isotopic profile of a corrosion layer formed on metal centrifuge components by reaction with the uranium-bearing gas (uranium hexafluoride, UF6) as well the amount and distribution of uranium decay products in the layer and metal components. These measurements can in principle provide estimates for the total amount of UF6 enriched, the enrichment level achieved, the number of enrichment campaigns and the time since the last campaign.

Over half of the HEU produced worldwide has been through gaseous diffusion, a technology developed during World War II by Franz Simon (1893–1956) as part of the British nuclear weapons program and established on an industrial scale by the Manhattan Project. The method relies on the relatively faster diffusion of lighter uranium-235 bearing molecules compared to uranium-238 bearing molecules in UF6 gas through porous barriers. In "Nuclear Archaeology for Gaseous Diffusion Enrichment Plants," Sébastien Philippe and Alexander Glaser of Princeton University present a proposal for using uranium particles deposited on the isotope separation barriers to independently reconstruct the operating histories of gaseous diffusion enrichment plants. The article models the operation of a gaseous diffusion uranium enrichment plant and the deposition of solid uranium particles in the tubular diffusion barriers used to separate the uranium-235 from the uranium-238 isotopes. The deposits are formed by reaction of UF6 with water vapor that leaks into the enrichment equipment and are solid particles of UO2F2. Decommissioning of gaseous diffusion plants in the United States, the United Kingdom, and France has found the diffusion barriers to be contaminated by such uranium deposits, in some cases amounting to several tons of material. The analysis suggests that nuclear forensic analysis of the uranium deposits even from a single barrier tube could yield an estimate of the uranium enrichment level and possible production history at the plant and thus how much HEU had been made at a gaseous diffusion enrichment plant. The French Pierrelatte plant which produced HEU for the nuclear weapons program and for submarine reactors is used as a case study.

Accurate and complete accounting for the production of fissile material is necessary also for the security of such materials from theft and diversion. The third article is this issue of the journal is "Securing China's Weapon-Usable Nuclear Materials," by Hui Zhang from Harvard University. It describes the general status of military and civilian fissile material production and stocks in China, how Chinese officials and experts see the threat of fissile material theft and risk of nuclear terrorism, and the laws and regulations in place to secure fissile materials and related facilities. The article offers recommendations for improving nuclear material protection in China, including through international cooperation.

This issue also carries a review by the journal's founding editor and now editor emeritus, Harold A. Feiveson, of "Engineers of Victory: The Problem Solvers Who Turned the Tide in the Second World War" by Paul Kennedy. The book describes the success of scientists and engineers in achieving the goals that were outlined by the Allied leaders in early 1943 and that proved critical to the Allied victory– gaining command of the sea and air, providing support to the Soviet Union, developing the plans to invade Europe, and taking the war to Japan in the Pacific. As Feiveson notes, the book documents the role of World War II as a turning point in making scientists and engineers "an integral part of the states' weapons complexes." The review highlights the continuing need for independent scientists to examine defense issues as a way to counterbalance this development.

The final contribution in this issue is an appreciation of the life and work of the late Allan S. Krass, a U.S. physicist who became an important independent nuclear policy analyst and informed the understanding of the proliferation risks of uranium enrichment technologies, the technology and politics of arms control verification, and the critical role of arms control as a tool of international security In their tribute to Krass, Frank von Hippel, Dan Fenstermacher, Charles Messick, and Parrish Staples describe his contribution to the policy debate on nuclear proliferation and arms control as well as his role as a government insider in the effort to minimize the use of HEU in research reactors worldwide.