IS DILUTION THE SOLUTION TO THE PLUTONIUM THREAT?

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ABSTRACT

President Obama said at the April 2010 Nuclear Security Summit that the possibility of nuclear material falling into the hands of terrorists is the "number one security threat" in the world, and he has subsequently continued his push to "secure" all vulnerable materials within four years. But his words seem to have fallen on deaf ears back home at the Nuclear Regulatory Commission (NRC), which is poised to significantly reduce security requirements for civil special nuclear materials when being transported or stored in certain forms. Specifically, the NRC is considering downgrading the security classification for mixed-oxide (MOX) fuel. MOX fuel assemblies containing 2 or more kilograms of plutonium are considered to be Category I items under current rules, and hence require the highest level of physical protection when transported or stored away from reactors. (The security requirements for MOX fuel at power reactors have already been downgraded under a 2009 rule change.) However, the Department of Energy and the Tennessee Valley Authority have pressed the NRC to downgrade the security classification of MOX fuel when being transported so that it can be shipped in ordinary trucks instead of safe secure trailers (SSTs). The rationale is presumably that MOX fuel is not an attractive material for diversion or theft provided the plutonium is diluted below a certain threshold. In 2009, the NRC staff sent the Commission a paper on this issue, "Material Categorization and Future Fuel Cycle Facility Security-Related Rulemaking" (SECY-09-0123). The Commission's response and the votes of two Commissioners were made public, although the paper itself is not. The Commission authorized the staff to develop a material categorization approach that would address, among other things, MOX fuel for the purposes of transportation. In other areas of material protection, control and accounting (MPC&A), the NRC is also authorizing significant deviations from current rules and practices, most notably with regard to the program at the MOX fuel fabrication facility at the Savannah River Site. This paper will examine the domestic and international implications of weakening MPC&A standards for plutonium at a time when the threat of nuclear terrorism is increasing.

INTRODUCTION

Until 2005, the categorization of unirradiated special nuclear material (SNM) for physical protection purposes by the Nuclear Regulatory Commission (NRC) was based solely on the quantity of strategic SNM (e.g. U-235, plutonium or U-233) contained in a given quantity of nuclear material. For example, the rules would require that the highest level of security, Category I, be applied to any item that contained more than 2 kilograms of plutonium, even if it were diluted to a low concentration in a non-fissile matrix. However, in 2005 the NRC granted Duke Energy an exemption from Category I security requirements for the receipt of four mixed-oxide (MOX) fuel

assemblies, each containing about 20 kilograms of weapons-grade plutonium oxide at a concentration of about 5 percent in a matrix of depleted uranium oxide. Overturning a ruling by the Atomic Safety and Licensing Board that partially sided with intervenors opposing the exemption, the NRC fully accepted Duke Energy's argument that the physical size and weight of the MOX fuel assemblies, together with the dilution of the plutonium in the matrix, rendered the assemblies unattractive to terrorists who might be seeking to acquire crude nuclear weapons.

Subsequently, in a 2009 revision of its physical protection rules, the NRC adopted a generic exemption for MOX fuel with plutonium concentrations below 20% from Category I security requirements when stored at power reactors. Now, at the behest of the nuclear industry and DOE/NNSA, the NRC is pursuing a broader reclassification of MOX fuel and dilute plutonium mixtures so that they would no longer be subject to Category I security and material control and accounting (MC&A) requirements when stored at any licensed facility or transported.

However, the NRC has not provided any cogent justification for this across-the-board weakening of security requirements. Specifically, it has not shown that the physical and chemical properties of plutonium mixtures provide barriers to theft and subsequent use of the material by contemporary terrorist groups that fully compensate for the major decrease in the level of physical protection that NRC is authorizing. This misuse of the attractiveness concept will send precisely the wrong signal to other nations possessing fissile materials and could undermine President Obama's call to secure vulnerable fissile materials around the world.

CATEGORY DEFINITIONS

The NRC defines a "formula quantity" of strategic SNM (SSNM) to be 5 kg or more of U-235 contained in HEU, or 2 kg or more of Pu or U-233. The NRC required licensees possessing or using formula quantities of SSNM to provide the highest level of physical protection, known as Category I. Among other requirements, Category I SSNM must be protected against the design basis threat (DBT) for theft.

The next level of security, Category II, is required for less than a formula quantity of SSNM but more than 1 kg or of U-235 in HEU or more than 500 g of Pu or U-233. (10 kg or more of U-235 in MEU with an enrichment of between 10 and 20 percent is also considered Category II.) NRC does not require Category II materials to be protected against the DBT, and therefore there is a significant qualitative difference between Category I and Category II levels of protection, as Category II materials do not require deployment of an armed response force to deny theft of the material, but only the deployment of assets capable of "early detection and assessment" of an attempted theft.

Finally, the lowest level of protection applies to Category III materials, which include quantities below the Category II threshold (and above a *de minimis* level) of Pu, U-233, U-235 in HEU or MEU, and 10 kg or more of U-235 in LEU (enrichment below 10 percent). Irradiated SNM (defined as material not separable from a matrix with an external dose rate of 100 rem per hour at a distance of 3 feet) is exempt from most of the requirements pertaining to unirradiated SNM.

The same categorizations also apply to NRC's material control and accounting regulations in Part 74, with an important exception. The NRC defines Category IA material to be "SSNM directly useable in the manufacture of a nuclear explosive device," greater than 0.05 formula kilograms, and in a form which could essentially be smuggled out inconspicuously by a single individual. Category I SSNM that does not meet these criteria is considered Category IB, and is subject to reduced MC&A requirements.

The Department of Energy has somewhat different standards than the NRC. It categorizes SNM not only with regard to quantity but also with regard to other factors generally relating to what is referred to as the "attractiveness" of the material for use in nuclear weapons. This "graded safeguards" principle has been restated in the most recent revision of its physical protection policy, which says that "physical protection for each category of SNM must consider the following factors: quantities, chemical forms, and isotopic composition purities; ease of separation, accessibility, concealment, portability; radioactivity; and self-protecting features …"[1] However, the differences between Category I and Category II protection requirements are not generally as large as those for NRC categories, in that DOE states that for both categories "protection measures must address physical protection strategies of denial and containment as well as recapture, recovery and/or pursuit."[2]

DILUTION AS A PROTECTIVE MEASURE

The two main benefits of dilution can be summarized as follows. First, as plutonium is diluted with a non-fissile isotope like U-238, the critical mass eventually becomes impracticably large and tends toward infinity. This reduces the attractiveness of the mixture for direct use in a nuclear explosive. Dilution also increases the quantity of material that must be diverted or stolen in order to acquire sufficient material for a weapon, either for direct use or after separation. Second, if the mixture is too dilute to produce a workable weapon, dilution increases the difficulty of the separation of plutonium needed to improve the weapon quality. However, the extent to which these barriers serve as significant obstacles to theft and misuse of the material depends on the capabilities of the adversary.

The notion that dilution of SNM can effectively reduce its attractiveness is a very old idea. The approach was analyzed during the GESMO (Generic Environmental Impact Statement on the Use of Mixed-Oxide Fuel) proceeding in the 1970s. The GESMO report concluded that although dilution could have some safeguards advantages (using as a benchmark the difficulty of acquiring enough plutonium to form a bare sphere critical mass, which may be excessive), it judged that "PuO_2 separation could be within the capabilities of some malefactors" and "accordingly, it is a basic premise of this assessment that lowering the concentration of plutonium through blending should not be used as a basis for reducing the level of safeguards protection."[3]

The issue of blending was also a key issue in the U.S.-Japanese negotiations in the 1970s over the startup of the Tokai reprocessing plant using a coprocessing approach, in which separated plutonium and uranium nitrate streams would be blended together before denitration, resulting in a final product blend of plutonium and uranium oxides. But again, the U.S. was unenthusiastic about the benefits of dilution. In a 1977 letter to National Security Advisor Zbigniew Brzezinski, NRC Executive Director for Operations Lee Gossick wrote that "Coprocessing and blending would have

some advantages in terms of potential subnational diversion. However, these would still be limited if the material were decontaminated since … the plutonium could be separated in a matter of days."[4]

Consequently, the NRC did not give credit to dilution when it later developed its physical protection requirements and quantity-based SNM categorization scheme.

Given this analysis, it is unclear what has changed since the 1970s that would make the NRC alter its view on dilution. The concept is the same as it was then; the properties of plutonium have not changed; but the technical capabilities and resources of terrorist groups have grown significantly.

In contrast to the NRC, DOE did adopt a graded safeguards approach that takes into account the relative attractiveness of materials based on their physical properties, which was implemented through the development of the graded safeguards table, the most current iteration of which is contained in DOE Order 474.2, "Nuclear Material Control and Accountability.[5] The graded safeguards table itself does not specifically indicate that the attractiveness level or category of a fixed quantity of plutonium diluted by uranium would vary according to the ratio of plutonium and uranium. However, a 1995 implementation guidance document contains further refinements of the policy are not addressed in the table. For instance, the guidance indicates that a MOX fuel assembly with a plutonium content of less than 10 percent would be considered Attractiveness Level D, which means that the fuel could never be greater than Category II, no matter how large the plutonium quantity. Even so, as discussed above, the differences between DOE Category I and II are not nearly as significant as those between NRC Category I and II.

The example set by DOE's implementation guidance was undoubtedly a major factor in the NRC's decision to grant the Category I exemption to Duke Energy. However, the technical basis for NRC's decision to raise the exemption level from 10 percent to 20 percent Pu concentration is unclear. One may speculate that it is related to the findings of the joint national laboratory study on material attractiveness led by Charles Bathke of Los Alamos National Laboratory. The study introduced a metric known as the "figure of merit" to characterize the attractiveness of various nuclear materials with regard to their direct use in a nuclear weapon, considering the critical mass, decay heat and dose rate. In considering reactor-grade Pu-U mixtures, the study found that as the Pu content was decreased to about 20%, the attractiveness of the mixture became comparable to that of 20%-enriched uranium, e.g. LEU, a level Bathke et al. considers "impractical" for nuclear weapons use.[6] (Although the publicly available studies refer to this level as "unattractive," Charles Bathke said in a 2010 presentation that a better description was "impractical.")

However, if this is indeed the basis for the NRC rule, it is important to note that the lab study "focused only on the attractiveness of these uranium mixtures and did not consider any subsequent reprocessing or purification by an adversary." It therefore does not address the crucial issue of how difficult it would be for a skilled adversary to steal a sufficient amount of material and subsequently process it into a form would be able to easily process the mixture into a form which could be used in a weapon. If the inherent physical properties of the mixtures themselves did not provide an effective deterrent, then there would be little justification for weakening the physical security measures needed to prevent the material from being stolen in the first place.

For instance, the size and weight of a MOX fuel assembly might not prove to be an effective obstacle to theft of a bomb quantity of plutonium by a skilled adversary. An adversary would only have to steal about half of a pressurized-water reactor assembly containing weapons-grade plutonium (or a quarter of a reactor-grade MOX assembly) in order to obtain enough plutonium for a weapon. One can surmise that certain types of controlled explosive disassembly of a transportation package could rapidly reduce a fuel assembly to pieces small enough for an adversary team to carry. The relatively low dose rates generated by plutonium would not likely be sufficient to deter potentially suicidal terrorists from such an operation. This scenario would be less hazardous than the scenario presented in the Sandia National Laboratories "Red Team Report, in which plutonium disposed of in a so-called "can-in-canister" framework was vulnerable to explosive disassembly and recovery of the plutonium cans by terrorists. And, as has previously been noted, processing of the mixture to weapon-usable form could be accomplished using relatively simple chemistry. In separating the plutonium and uranium, high decontamination factors might not be necessary if sufficient material were obtained, since the Bathke study has shown that plutonium-uranium mixtures are attractive for weapons use as long as the plutonium content is greater than about 20 percent.

"RISK-INFORMING" SECURITY AND MC&A

The weakening of security measures for MOX fuel is part of a larger effort by the NRC to adopt an attractiveness-based categorization scheme for SNM, similar to that of DOE. The NRC is in the process of developing new regulations for the licensing of reprocessing plants and revising its regulations for MC&A and physical protection of SNM. In the context of the former effort, the NRC staff has written that "the current quantity-based categorization scheme in the existing regulations may pose an undue regulatory burden in operating a reprocessing facility. Risk-informing 10 CFR Part 73, "Physical Protection of Plants and Materials," and 10 CFR Part 74, "Material Control and Accounting of Special Nuclear Material," is needed to prevent unintended consequences associated with a quantity-based material categorization scheme for potential materials resulting from a reprocessing operation."

In a 2009 NRC staff paper, the staff proposed that NRC should "risk-inform" Parts 73 and 74 by adopting an attractiveness-level approach, similar to the DOE graded safeguards table, that would modify category quantity thresholds, introduce attractiveness levels into each category, and grade security and MC&A requirements accordingly. The Nuclear Energy Institute sent a letter to the NRC in 2009 endorsing that approach but requesting expedited action on revising the security requirements for the transportation of MOX fuel. Following receipt of that letter, the staff sent another paper to the Commission: SECY-09-0123, "Material Categorization and Future Fuel Cycle Facility Security-Related Rulemaking." This paper was marked Official Use Only-Security Related Information (OUO-SRI), and is understood to also have an attachment classified as Secret. This author was told by at least one NRC Commissioner that the paper was not sensitive and that it could be released, with the exception of the classified attachment. However, a formal request to the NRC to release the document was refused. This author filed a Freedom of Information Act request in June 2011 but has yet to receive a response.

It is unclear why the NRC is so intent on keeping SECY-09-0123 from the public. The staff has said that the paper requested that the material attractiveness approach be incorporated into the reprocessing rulemaking, but it apparently contained aspects of NEI's MOX proposal as well.

Although the SECY itself is not public, the Commission's response is public (the Staff Requirements Memorandum, or SRM), as well as the votes of NRC Chairman Gregory Jaczko and Commissioner William Magwood. Commissioner Magwood's vote specifically refers to a proposal to reduce security requirements for MOX fuel: "I disapprove the staff's proposal to change the categorization of MOX fuel for the purpose of fuel transportation … it is prudent to leave the transportation of the fuel as Category I."[7] Those familiar with the paper say that it states that MOX fuel could be considered Category II or even Category III with respect to transportation – that is, it would require no more security than the transport of low-enriched uranium fuel.

The Commission's SRM made no mention of Commissioner Magwood's concerns about reducing the MOX categorization, and instructed the staff to provide a "detailed analysis and recommendations for the use of a material characterization approach for potential reprocessing facilities ..." and "…MOX fuel for the purpose of transportation…" The NRC staff has said that LANL is conducting another study of material attractiveness to support the rulemaking that will take into account not only direct usability but also ease of theft and conversion. The NRC will have to make much of this study public if it hopes to be able to convince skeptics that it will be safe to drastically reduce the level of security on MOX fuel.

A Freedom of Information Act (FOIA) request by the environmental group Friends of the Earth to the Tennessee Valley Authority (TVA) sheds additional light on this issue. TVA is currently the only utility that is expressing serious interest in using MOX fuel produced by NNSA's weapons plutonium disposition program. The FOIA request produced e-mails from 2009 that reveal that TVA, NNSA and Shaw AREVA MOX Services, NNSA's contractor for the MOX program, have all been involved in the effort to get the NRC to weaken MOX security requirements. A memorandum from TVA indicates that the expectation is that the graded security policy would eliminate the requirement for MOX fuel to be transported by Safe Secure Trailers (SSTs). The need to rely on SSTs by a commercial program would be a considerable burden. For instance, SSTs have classified features, and individuals must have security clearances to be able to enter them. This could cause difficulties at reactors using MOX fuel, because site personnel involved in receipt of the fuel from SSTs would need clearances, which are not typically required for commercial nuclear power plant employees.

Thus the managers of the U.S. MOX program, which was initiated as part of a bilateral effort with Russia to reduce the threat of unsecured plutonium in both countries, are once again undermining nuclear security by lobbying for a weakening of security measures because of their cost and inconvenience. This can only set a terrible example for the Russian MOX program, and send the erroneous signal to other countries like Japan and France that MOX fuel does not present a significant security risk. It is hard to imagine how the Obama administration could reconcile a move to weaken protections on sensitive nuclear materials with its stated goal of enhancing nuclear security around the world.

MC&A EXEMPTIONS AT THE MOX FUEL FABRICATION FACILITY

Another example of how the MOX program is undermining safeguards and security is apparent in MOX Services' cavalier approach to complying with MC&A requirements at the MOX Fuel Fabrication Facility under construction at the Savannah River Site. In 2009, MOX Services requested an exemption from certain NRC MC&A requirements associated with item monitoring

and alarm resolution because it could not meet the regulations. The intervenors who are contesting the facility operating license (and for whom this author serves as an expert) submitted a new contention in the licensing proceeding challenging the exemption.

Soon afterward, MOX Services said that it was withdrawing the exemption request because it had realized that it didn't need the exemption after all. The intervenors then filed three new contentions challenging the adequacy of the Fundamental Nuclear Material Control Plan (FNMCP). The NRC staff, however, accepted the approach in its Final Safety Evaluation Report on the FNMCP. But on April 1, 2011, the Atomic Safety and Licensing Board admitted the three contentions. Although it was a 2-1 vote, the dissenting judge, Lawrence McDade, did not challenge the merits of the contentions, but believed they were non-timely. However, all three judges agreed that the three contentions raise "significant public safety and national security issues" and even if they had been untimely, the Board would have referred the issue to the Commission for sua sponte review. Although the exact nature of the contentions cannot be publicly disclosed, from the public documents released in the case so far, the ASLB decision states that "the intervenors … have raised a question as to whether the facility will have the ability to meet the alarm resolution response time estimates provided in the 2010 FNMCP" and suggests that the problem may be related to the design of the facility. (10 CFR §74.57(b) requires that licensees must be able to resolve MC&A alarms within a time period approved by the NRC.)

CONCLUSION

By undertaking to drastically reduce physical protection requirements on dangerous weapon-usable materials like MOX fuel assemblies, the NRC staff is contributing to the myth that such materials are of no interest to terrorists, despite the large quantities of plutonium that they contain. And by turning a blind eye to serious MC&A deficiencies at the MFFF, the NRC staff is neglecting its duty to ensure that all U.S. plutonium under its purview will be rigorously accounted for. If the Obama administration really wants to address the nuclear terrorism threat around the world, it would be advised to begin at home by ensuring that all U.S. weapon-usable materials are well-secured.

REFERENCES

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