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Title: GRADED SAFEGUARDS: DETERMINATION OF ATTRACTIVENESSS LEVELS FOR SPECIAL NUCLEAR MATERIAL

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GRADED SAFEGUARDS: DETERMINATION OF ATTRACTIVENESS LEVELS FOR SPECIAL NUCLEAR MATERIAL*

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ABSTRACT

The DOE graded safeguards approach—as described in DOE Order 5633.3A, Control and Accountability of Nuclear Materials, and its guide—requires the determination of category levels of nuclear material locations to establish protection requirements for these locations. A critical parameter related to category determination is knowledge of the attractiveness level of the nuclear material with respect to use in a nuclear explosive device. DOE Order 5633.3A and its guide provide the policy basis for determining the attractiveness level of various forms and types of special nuclear material (SNM); however, these requirements and guidance are necessarily general and sometimes based on arbitrary criteria. Currently, there are large quantities of nuclear material on inventory within the DOE that need attractiveness determinations to ensure appropriate protection controls. Specific forms of these materials include materials in matrices requiring special processing, irradiated SNM that does not meet criteria for self-protecting, low concentration SNM, SNM as numerous small items, and bulk non-portable SNM items. This paper discusses the technical basis for applying material concentration limits for solids and liquids that can influence the various factors and criteria affecting the attractiveness level of SNM. Holdup and rollup considerations for determining category levels will be discussed as well.

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INTRODUCTION

This paper is a preliminary review of one problem associated with determining the appropriate levels of safeguards and security (S&S) for special nuclear material (SNM): the determination of the attractiveness level of the SNM. Safeguards requirements depend upon the nuclear material category of the SNM, which is a function of the attractiveness level of the nuclear material with respect to use in a nuclear explosive device. As a result of the increased rate of weapons returns, the lack of new storage facilities, and the emphasis within the DOE weapons complex on consolidation of nuclear material inventories, storage space for category I and II SNM has become an increasingly scarce resource. It is important that this storage space be used only for material requiring that level of protection. Additionally, higher categorization of SNM triggers more stringent S&S requirements and increases the operational expense of maintaining the SNM inventories. Currently, large quantities of SNM are on inventory for which attractiveness has not been formally studied and, therefore, there is no assurance that safeguards resources are appropriately allocated. Emphasis will be placed on defining attractiveness levels for those materials arising from facilities in transition (that is, decontamination and decommissioning).

ATTRACTIVENESS LEVEL CRITERIA SUMMARY

Figure I-2 in DOE Order 5633.3A provides policy on determining attractiveness levels for SNM. Chapter I of the guide for implementation of 5633.3A provides guidance on applying the criteria from DOE 5633.3A, including a decision tree employing the various factors used to determine attractiveness level. The factors used as criteria in DOE 5633.3A and the decision tree include chemical and physical form, SNM concentration, exposure levels from irradiated material, and isotopic content/enrichment. There are other factors to be considered, in combination with the above, that may influence the decision on the attractiveness level determined by strictly following the decision tree. These include matrices that require special processing, SNM as numerous small items, and bulk non-portable items.

The decision tree in the implementation guide for DOE Order 5633.3A provides a straightforward way to determine attractiveness levels in accordance with the requirements of the order. However, the quantitative limits used at the decision points are relatively arbitrary, and applying the model strictly may result in an assignment of a higher attractiveness level than is truly justified. To properly evaluate attractiveness levels, it is necessary to understand the intent underlying the definitions of the five levels of material attractiveness.

A. *WEAPONS: Assembled weapons, test devices, and partially assembled weapons/devices if assembly is possible using commercially available materials.* There should be no confusion or controversy concerning material assigned to level A.

B. *PURE PRODUCTS: Pits, major components, buttons, ingots, recastable metal.* Level B is primarily restricted to weapons components and SNM metals that can simply be recast to make a weapon or improvised nuclear device without chemical processing. Items that are <50 atom percent SNM (excluding cladding and matrix material subject to simple mechanical removal) and small items (<5 g) of attractiveness level B plutonium are reduced to attractiveness level C. This latter point is further discussed in the next section. The determination of what material should be assigned to level B is generally straightforward.

C. *HIGH-GRADE MATERIALS: Compounds, solutions ≥25 g/L, fuel elements and assemblies, alloys and mixtures, and uranium fluorides ≥50% enriched.* Level C materials can be easily converted to SNM metal by simple processing and are materials from which cladding or matrix material can be simply removed by a physical process. Level C solids contain <50 atom percent SNM but >10 weight percent SNM. The primary distinction between levels B and C is that level C material requires chemical processing to be converted to metal.

D. *LOW-GRADE MATERIAL: Solutions of concentrations from 1 to 25 g/L, residues, moderately irradiated material (>15 to 100r/h), ^{238}Pu (isotopic purity 20 to 60%), and uranium fluorides 20 to 50% enriched.* Level D is for material requiring extensive processing to be converted to metal (that is, more than simple precipitation and oxidation), low-concentration solutions, and partly self-protecting irradiated material. Uranium enriched in the range 20 to 50% is level D. Level D solids contain 0.1 to 10 weight percent SNM. The primary differences between C and D materials are the extent of processing required to convert them to metals and the lower concentration and purity. The distinction between levels C and D is critical in establishing protection levels and, consequently, allocating resources; there is no category I quantity defined for level D, and the category II threshold quantity for level D increases by factors of 8.0 and 8.33 for Pu/^{233}U and ^{235}U, respectively.

E. *ALL OTHER MATERIALS: Highly irradiated SNM (>100r/h), SNM solutions ≤1 g/L, uranium enriched <20%, and source and other nuclear material.* Level E is for material that does not meet the minimum requirements for level D. All E material is category IV and is not considered to be a theft/diversion target. The distinction between levels D and E is also significant in terms of resources because protection provided to category IV material is generally minimal and equates to property protection requirements.

CONSIDERATIONS IN REDUCTION OF ATTRACTIVENESS LEVELS

The focus of this paper is on the assignment of SNM to attractiveness levels C, D, and E. As noted above, decisions to assign material to D instead of C, or to E instead of D, can greatly reduce resources required to protect and maintain the inventory. Additionally, there are large quantities of SNM at DOE facilities in the form of fuel elements and assemblies, fuel fabrication scrap, alloy ingots, and process residues. A careful review of the characteristics of these materials may reduce their attractiveness level beyond that calculated using the decision tree.

Attractiveness level rankings are generally based on two factors: the effort required to convert the material into a form that can be used to produce a weapon (separating from cladding or matrix material, processing) and self-protection characteristics (radioactivity, mass). The quantitative limits for concentration, isotopics/enrichment, and radioactivity used to define attractiveness of materials were set at what were believed to be reasonable values based primarily on difficulty in acquiring a target quantity of SNM. However, it is recognized that the values are somewhat arbitrary, and it is not necessary to apply these limits rigorously, provided there is justification. We are aware of two cases in which this reasoning was applied. The first was a study by Sandia National Laboratories personnel of unirradiated uranium fuel elements containing uranium carbide/graphite-coated fuel particles.[1] The second study was performed by Los Alamos National Laboratory on unirradiated uranium fuel rods containing uranium carbide in a graphite matrix.[2] In both cases, application of the decision tree criteria indicated that the materials were attractiveness level C. The studies considered both the bulk mass of material that would have to be transported to accumulate a category I-C quantity of SNM and the processing necessary to convert the uranium to metal. The presence of graphite required a burning or oxidation step to eliminate carbon for both materials prior to dissolution, precipitation, and oxidation. Both studies concluded that the assignment of attractiveness level C was inappropriate, and the materials were assigned attractiveness level D.

The castability of small items can influence attractiveness. A third study performed by Los Alamos National Laboratory and subsequently validated by New Brunswick Laboratory determined that small plutonium metal items (<5 g per item) cannot simply be melted and recast into a single category I metal item due to surface oxidation.[3] This decreases the attractiveness level of these items from B to C due to the additional processing required to cast a larger metal item. Note that this differs from the rollup criteria in DOE Order 5633.3A, which allows smaller SNM items to be ignored in determining the material category quantity when it can be demonstrated that accumulation of a target quantity by an adversary is not a credible scenario.

Finally, while the considerations discussed above may be used to determine material attractiveness levels, it is important to note attributes that are not applicable to this concept. Attractiveness levels are associated with the material itself and should not be affected by external factors. Strengthening elements of the safeguards systems such as confinement (for example, the use of the modular storage units developed at Y-12) and surveillance (for example, continual automated monitoring of storage positions) certainly may justify reduction of some protection requirements; however, they cannot be used to reduce the attractiveness level of the material. SNM retained as holdup in process vessels and piping is another example. Generally, process holdup is difficult to access and is often spread over a large area. Again, reduction in protection levels based on accessibility may be appropriate, but the attractiveness level should remain unchanged.

CONCLUSIONS

DOE policy provides general guidelines to the determination of SNM attractiveness levels; however, more detailed direction is needed for the types of materials discussed in this paper. There are large quantities of material on inventory throughout the weapons complex that are not directly addressed by the criteria and examples provided in DOE Order 5633.3A and its implementation guide. Development of a more detailed guide would provide substantial benefits.

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