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SAFEGUARDS USES OF CONFIRMATORY MEASUREMENTS*

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ABSTRACT

An analysis is made of the role of shipper and receiver measurements in safeguarding special nuclear materials (SNM) transferred from one facility to another, with emphasis on the case where the receiver requires an analytical accounting measurement of the transferred SNM and does not need the material for process purposes at the time of receipt. Seven possible diversion periods are considered, ranging from the interval between the shipper's final accounting measurement on the material and the time it is placed in the shipper's vault, through the actual transport of the material between facilities, to the time the material is removed from the receiver's vault and placed in the process. The detection power of various combinations of six possible shipper/receiver measurements for these diversion opportunities is then evaluated; the measurements considered include the shipper's and receiver's accounting measurements, the latter at two possible times, and various nondestructive assay (NDA) confirmatory measurements. It is concluded that all safeguards measurement objectives can be met by a combination of a shipper's accounting measurement at the time the material is removed from the process, an appropriate shipper's NDA confirmatory measurement either immediately after canning or immediately before shipping, an equivalent receiver's NDA confirmatory measurement immediately after the material is received, and a receiver's accounting measurement when the material is placed in the process. Furthermore, it is found that a receiver's analytical accounting measurement immediately after receipt when the material is not yet required for process has dubious safeguards value.

INTRODUCTION

DOE Orders 5630.2 and 5630.10 require that when Category I and II quantities of unirradiated SNM are transferred between facilities then the shipper and receiver normally must independently measure the amount of SNM transferred. The receiver's measurement is used both to calculate differences in shipper's and receiver's values for the transferred SNM and to determine the receiver's inventory value for the material that will be used in subsequent facility inventory difference determinations. This receiver's measurement, which we shall refer to hereafter as an accounting measurement, is viewed as giving a valuable check on possible material loss; consequently, the Orders require that under normal circumstances the receiver's measurement must be performed within ten calendar days of receipt of the material. This ten-day requirement can be onerous in some cases, as when a multiply-canned item containing plutonium oxide that is to be assayed by analytical chemistry must be placed in a glove box, opened, blended, a sample taken, and the material placed in a new double or triple can for storage in the vault because it is not yet needed for processing. The Orders state that when the receiver's measurement cannot be performed within ten days, then confirmatory measurements may be used on an interim basis to accept the transfer; but this case is regarded as exceptional, and "confirmatory measurement" is defined only in broad terms.

It will be shown here, however, that when the meaning of "confirmatory measurements" is appropriately defined, and when these measurements are carried out by both shipper and receiver, then it is completely acceptable from a safeguards standpoint to close transfer transactions solely on the basis of such measurements and to defer the receiver's accounting measurement to the time the material is needed for processing. In fact, with appropriate care this altered procedure can sometimes provide greater safeguards effectiveness than can the procedure currently mandated by regulation. One might therefore consider the possibility of regulatory change to permit shippers and receivers the option of using appropriate confirmatory measurements to close transfer transactions on a regular, rather than exceptional, basis.

Proposed Definition of "Confirmatory Measurements"

In order that "confirmatory measurements" have the safeguards effectiveness required for

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use in transfer transactions it is necessary that they have the following characteristics:

(1) the confirmatory measurements must consist of a set of NDA measurements that will be performed in the same format by both shipper and receiver;
(2) collectively the set of raw NDA measurement results must be sufficiently reproducible for each item and sufficiently characteristic of the material in the item that substitution of a bogus item without detection is not technically credible;
(3) the SNM assay of each item must be approximately determinable—perhaps with 5 to 10% accuracy (1σ)—from the confirmatory measurement results for the item, assuming the composition of the material in the item to be as stated.

In (1) the requirement that the shipper and receiver use the same measurement format means, for example, that if the shipper does a neutron coincidence count on items in their shipping containers then the receiver must perform a neutron coincidence count on the items in their shipping containers also. In (2) the requirement that the measurements be characteristic of the material means, among other things, that some of the measurements must determine properties peculiar to SNM—such as features of the radioactive emissions—and that some of the measurements must characterize properties of the material throughout the item and not just of the material near the surface. Finally, the reproducibility requirement means that for each item and each of the NDA measurements selected the shipper and receiver should be able to obtain raw measurement results whose difference is small—perhaps of the order of 1%.

For example, for cans of plutonium oxide one might choose the set of confirmatory measurements to be the weight, total neutron count rate, and neutron coincidence count rate for each can. All of these quantities characterize the material throughout the can. Furthermore, the weight is reproducible to about 0.05%; and the total and coincidence neutron count rates are reproducible to approximately 1% and 2-3%, respectively, with modest count times. In addition, the total and coincidence neutron count rates taken together are characteristic of both the total amount of radioactive material and the amount of fissile material in the item, and allow an assay of the plutonium in the can with 5-10% accuracy or better when impurities in the material are reasonably well known. Finally, substitution of a bogus item that could mimic the weight, total radioactive material content and fissile material content of the true item to within the reproducibility limits of the three measurements is not a technically credible scenario.

Diversion Threats and Safeguards Elements Responsive to Them

Consider the case where nuclear material leaves the process at one facility, is subsequently transferred to a second facility, and eventually enters the process at the second facility. The covert diversion threats that exist during this period are listed below in order of decreasing estimated likelihood.

(1) There may exist opportunities for theft of items, possibly with substitution of bogus items,
  (a) during transfer of items from the vault to the transport vehicle at the shipper's facility, or
  (b) during transfer of items from the transport vehicle to the vault at the receiver's facility.

(2) There may be opportunities for diversion of part or all of the material in an item, possibly with substitution of bogus material,
  (a) between the shipper's accounting measurement for the item and its canning and sealing, or
  (b) between the receiver's opening a canned item for analytical sampling and the item's subsequent recanning or introduction into the process.

(3) An item may be stolen or tampered with, perhaps with substitution of a bogus item or bogus material,
  (a) during its residence period in the shipper's vault, or
  (b) during its residence period in the receiver's vault.

(4) An item may be covertly diverted or tampered with, possibly with substitution of a bogus item or bogus material, during transit between facilities.

This likelihood ordering is nonquantitative, but appears to be accepted by many safeguards personnel. The criteria used in determining it are the possibility of access to material or items without breaking seals or opening containers, and the possibility of performing unauthorized actions without detection—presumably maximized during periods of high activity such as packing/loading and unpacking/unloading. Note that the period of actual transit, when the SNM is in a locked and sealed Safe Secure Trailer and under constant surveillance by several well-armed couriers, is ranked as the least likely time for covert diversion.

DOE regulations mandate a number of physical protection, material control, and material accounting measures—some of them just alluded to—to protect against the diversion threats listed above. The matter of principal interest here is the effectiveness of shipper and receiver measurements in responding to these threats, and the analysis below is restricted to this subject. It must be emphasized, however, that shipper and receiver measurements are only one facet of the total safeguards enterprise, and that the other physical protection, material control, and material accounting measures reinforce the effectiveness of shipper/receiver measurements in areas

where those measurements can detect anomalies, and that provide protection against the above threats in cases where shipper/receiver measurements are not relevant. With the restricted scope of the analysis and its conclusions in mind, then, let us consider the ability of shipper/receiver measurements to respond to the threats given. In particular, we shall consider various combinations of the following six measurements:

(1) a shipper's final accounting measurement;
(2) a shipper's NDA measurement immediately after canning;
(3) a shipper's NDA measurement immediately before transfer;
(4) a receiver's NDA measurement immediately after receipt;
(5) a receiver's analytical accounting measurement immediately after receipt, followed by recanning;
(6) a receiver's accounting measurement immediately before the material enters the process.

The NDA measurements indicated might be either accounting or confirmatory measurements; however, if they are confirmatory measurements then it is assumed that they satisfy the criteria previously stated. Because of the accuracy of accounting measurements and the reproducibility of NDA confirmatory measurements, a comparison of shipper's and receiver's accounting measurements or of shipper's and receiver's confirmatory measurements will have a very high probability of detecting "trickle" diversion or substitution of bogus items occurring in the interval between the measurements. A comparison of an NDA confirmatory measurement and an accounting measurement is less sensitive to trickle diversion, but still has a high probability of detecting substitution of a bogus item. Furthermore, trickle diversion must be performed on a number of items to yield a significant quantity of SNM, and the probability of the divertor's escaping detection on all such diversions is the product of the probabilities for escaping detection on the individual diversions. Because it is required that the NDA confirmatory measurements allow determination of SNM amounts with an accuracy of order 5 to 10%, the product of these probabilities will be a small number—that is, the probability of detecting a trickle diversion of a significant quantity of SNM by a comparison of an NDA measurement and an accounting measurement is also high. One can use these ideas to construct the accompanying Table of diversion threat scenarios and the shipper/receiver measurements that detect them. Examination of the Table yields the following conclusions.

(1) In no case does receiver measurement 5 (receiver's analytical accounting measurement immediately after receipt when the material is not yet needed for processing) yield a "very high" detection probability for diversion when no other receiver measurement does, and in only one case (diversion threat 2a) does it provide most timely detection among measurements that provide very high detection probabilities. Furthermore, its use exposes material to diversion threat 2b, which is then not detected by any shipper/receiver measurement. It therefore seems desirable that diversion threat 2a should be (as it is!) protected against by procedural and other methods rather than by shipper/receiver measurements. Measurement 5 might be of safeguards value if the entire can-opening, sampling, and recanning process could be performed by automated equipment operating in an inert atmosphere, but even in this case it would be necessary to evaluate its cost-effectiveness relative to other safeguards actions providing similar protection.

(2) Shipper measurement 2 (NDA confirmatory measurement immediately after canning) is more effective in detecting diversion than shipper measurement 3 (NDA confirmatory measurement just before shipment), and on the basis of this consideration is the preferred measurement. However, in the case where the cans of product material must be stored in the vault before shipment the cans usually would not be placed in shipping containers until their removal from the vault for shipping. The shipper's NDA measurements would therefore be made on the individual cans, and the receiver would have to measure the cans the same way. This procedure would improve the

TABLE

DETECTION PROBABILITIES OF SHIPPER/RECEIVER MEASUREMENT COMBINATIONS FOR THE DIVERSION SCENARIOS

MEASUREMENT PAIR	SCENARIO 1a	1b	2a	2b	3a	3b	4
1, 2			H				
1, 3			H		H		
1, 4	H		H		H		H
1, 5	V		V		V		V
1, 6	V	V	V		V	V	V
2, 4	V				V		V
2, 5	H				H		H
2, 6	H	H			H	H	H
3, 4	Σ				Σ		V
3, 5	Σ				Σ		H
3, 6	Σ	H			Σ	H	H
4, 6						H	

V - very high scenario detection probability
H - high scenario detection probability
Σ - zero scenario detection probability (shown for emphasis)
Blank - not relevant to scenario detection

accuracy of the confirmatory measurements but would increase personnel radiation exposure. The balance between safeguards and health considerations might require that shipper NDA measurement 2 be made for some materials and shipper NDA measurement 3 for others. In some cases, and at some facilities, it also might be possible for the shipper to place the cans in shipping containers immediately after canning, perform the NDA measurements on the shipping containers, and store the containers themselves in the vault for a short time before shipment.

(3) Diversion scenario 4 is detected with high or very high probability by any combination of one shipper measurement and one receiver measurement. For the reasons given earlier, this is an improbable diversion scenario.

We conclude that if confirmatory measurements are to be used as a safeguards measure in transfers of material, then the greatest safeguards protection is usually provided by a combination of measurements 1, 2, 4, and 6. If reduction of personnel radiation exposure requires greater emphasis, a combination of measurements 1, 3, 4, and 6 is the best choice. Finally, when NDA measurements can be used for the shipper's and receiver's accounting measurements, then a combination of shipper/receiver measurements 2, 4, and 6 would give very good protection against all diversion scenarios that can be detected by shipper/receiver measurements. Furthermore, any of these three measurement combinations normally could be expected to give safeguards coverage comparable to or greater than that provided by any measurement sequence terminating with receiver measurement 5. Only in unusual circumstances might use of measurement 5 be warranted on safeguards grounds.

CONCLUSION

The preceding analysis has considered diversion threats in the period between removal of SNM from the process at a shipper's facility and entry of the SNM into the process at a subsequent receiver's facility, and has evaluated the ability of various possible shipper/receiver measurements to detect such diversion. The conclusion drawn from the analysis is that a combination of a shipper's accounting measurement at the time the SNM is removed from the process, an appropriate shipper's NDA confirmatory measurement (preferably) immediately after canning or immediately before shipment, a similar receiver's NDA confirmatory measurement immediately after receipt of the SNM, and a receiver's accounting measurement of the SNM when it is placed in process give high to very high probability of detecting any diversion scenario that can be detected by shipper/receiver measurements. When the material is not needed for processing at the time of receipt, this measurement sequence actually gives better safeguards coverage than that currently required by regulation because it provides a check on diversion during the period of residence in the receiver's vault. Thus there appears to be an adequate safeguards justification for permitting the optional use of confirmatory measurements (as defined here) to close a transfer transaction, with the receiver's accounting measurement then deferred to the time the material is needed for processing.