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**NEEDED IMPROVEMENTS IN SNM ACCOUNTING
AND MEASUREMENT SYSTEMS FOR SAFEGUARDS**

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NEEDED IMPROVEMENTS IN SNM ACCOUNTING AND MEASUREMENT SYSTEMS FOR SAFEGUARDS

The U.S. private nuclear industry, over the past three years, has taken important first strides toward improving its basic measurement and control practices to the extent that material balance accounting is now a more meaningful tool for safeguarding special nuclear material against unlawful diversion. We have made substantial progress in establishing the "out-of-control" indicator, material unaccounted for, and in assessing MUF more validly with the limit of error concept. In this sense, one can say we've come a long way, baby, to get where we got to today!

In spite of this progress the effectiveness of this MUF indicator in assuring the prompt detection of significant unidentified losses, whose presence could camouflage a potential diversion, is seriously limited by industry's current practices. In the absence of rigorous, quantitative performance standards set forth in comprehensive, specific regulatory requirements, industry now performs physical inventories annually or semiannually, resulting in 6 or 12-month balances that are generally based on insufficient measurements.

Can any of you who strongly support good safeguards conscientiously conclude that information from these infrequent material balances comprise a dynamically sensitive alarm system for alerting management to a

deteriorating material control program? Can they, with a sufficiently high degree of probability, promptly trigger an investigation to either identify necessary corrective actions or promptly uncover a diversion of material? In this sense of having a timely and progressively-effective alarm system, we still have a long way to go!

The AEC regulatory safeguards program, about which Dr. Thornton spoke on Tuesday, consists of many complementing facets that are in need of improvement, especially the integration of the roles of containment, surveillance and daily accountability over the entire private fuel cycle.

Because of our current heavy reliance on material balance accounting as a primary overcheck--indeed, the deciding factor concerning whether a possible diversion has occurred, major shortcomings in its present application must be identified and minimized. We in the Division of Nuclear Materials Safeguards have identified some shortcomings and are taking steps to improve the required material controls. The U.S. private nuclear industry, in general, and the Institute of Nuclear Materials Management, in particular, should cooperate in the implementation of an improved safeguards system. Dynamically effective rather than token improvements or alternatives must be accelerated to close glaring gaps in the accountability systems. The present system consists of closing a special nuclear material balance around each facility at least once a year

and calculating MUF, which is the apparent difference between what should be and what is determined to be on hand. If sufficient measurements have been made, MUF is considered significant only if it exceeds its stated limit of error-our yardstick of facility control. The purpose of the calculation is to test the null hypothesis that true MUF is not significantly different from zero with assurance that the measurement data were really sufficient to make it an adequately strong test.

Although this concept of interpreting observed MUF with its probable "noise" level is valid, the ambiguous quality and discerning ability of currently implemented limits of error dilute their utility as a MUF evaluator. In many facilities, lack of perception of MUF and its recognized limit of error has been compounded with the advent of large flows of special nuclear material and highly complex processes. A yardstick on the representativeness and magnitude of the limits of error themselves is needed before using them as a valid criterion for accepting losses.

Let me be more explicit about our misgivings about how MUF is being tested. No successful production manager is likely to make a decision without carefully weighing the risks and probable consequences involved. Quality assurance must guarantee that product specifications will be met at an acceptable risk (α) to the producer, who chances having a good product rejected. Also specified is the risk (β) to his customer, who

chances receiving a bad product. A statistical power curve graphically defines how discerning a decision is, specifying the probability of making a wrong conclusion from the available information. The curve depends on the intensity and quality of measurements made and their subsequent data analysis.

In our safeguards case, the curve would identify the industry's risk of rejecting a material balance when MUF is really zero, and it would also identify the public's risk of accepting large MUF's as not significant when in fact they are. The value $(1-\beta)$ 100% tells us a balance's chances of detecting various true MUF amounts.

Private nuclear industry should be the producer only of MUF's that are not significant and, therefore, free of diversion. MUF's significance is appraised using another of industry's products--limits of error--as a yardstick of control. Industry now runs a 5% risk of having a false alarm trigger an unnecessary investigation for scrutinizing the presence of diversion. The consumer--the public--has been expected to accept these unexplained losses with a chance that a diversion has actually occurred without detection. The AEC has not yet specified what this consumer's risk should be, and industry on the whole has been notably silent on this. It is time for us to specify this risk, at least on an interim basis. I favor setting it at 1% or less, in respect to whatever

is the maximum acceptable MUF - whether it is just less than the reported limit of error or another constraint. This is especially true when it has been estimated that the public is unwilling to accept everyday accident risks of 10^{-3} and considers risks somewhere between 10^{-4} and 10^{-7} as more acceptable.

We have, at present, a safeguards detection system where only the risk to the producer is controlled explicitly. This must be corrected in view of the possible consequences of a diversion in terms of the possible threat to the national security. Optimizing risks and consequences only from the standpoint of the industry, obviously, is dangerous. It encourages the philosophy that safeguards efforts must be commensurate with the monetary worth of the material. This must not be the determining influence. In establishing the present system we anticipated that the product quality assurance-oriented industry would do its utmost to respond with a control scheme that would better satisfy its responsibility to the public. However, industry has responded with "good safeguards is good management - good management is what we are doing today."

A dilemma we face is that private industry has been trying to close balances without an accurate and precise ability to directly measure all material inventories and flows. The quality of material balances has been

limited largely by economic restraints on industry's resources. Most of these resources have been made available primarily to satisfy product quality assurance and material management requirements. Safeguards, then, has had to make do largely with plant layouts, which are difficult to safeguard; equipment that has been allocated for quality control and health and safety functions; measurements that are made generally for other purposes; and personnel who have been assigned materials management responsibility as a first consideration and a safeguards job as an afterthought.

This operating environment has contributed much to gaps in the closing of effective material balances. Let's explore some of them.

Present annual facility MUF's are:

1. too large absolutewise--reported in tens and even hundreds of kilograms of U-235.
2. dominated by receipt and shipment uncertainties, and these measurements are not readily verifiable at the time of inventory.
3. biased because of
 - a. inaccurate estimates of holdup or hidden inventory;
 - b. unidentified systematic errors due to facility sampling and analytical errors and acceptance of receipts without independent measurement;

- c. facility failure to directly measure all materials;
 - d. nominal values, that do not always accurately reflect the elemental and isotopic composition of material;
 - e. failure to assure the integrity of previously made measurements for inventory purposes;
 - f. unidentified significant shipper-receiver differences;
and
 - g. inaccurately determined measured discards.
4. imprecise because of random errors introduced by
- a. batch and lot sampling rates;
 - b. heterogeneity of material in containers, where replication sampling is necessary; and
 - c. analytical measurements, including laboratory sampling errors.

Limits of error associated with MUF:

- 1. are too large with generally poor probabilities for detecting
 - a. large single diversions less than the annual limit of error, and
 - b. large systematic or milling diversions that accumulate with other types of MUF to less than the annual limit of error.

2. are not statistically robust, that is they do not represent the true measurement error contribution to MUF because of
 - a. rigorously invalid error propagation models without proper identification and formulation of the interplay between sampling errors and covariances; and
 - b. a failure to identify their effect on the statistical power associated with the null hypothesis test on MUF, especially identifying the public's risk.

Annual facility material balances are:

- a. untimely in regard to critical time, and
- b. difficult to investigate and control.

As a result of these gaps, the valid but thus far poorly implemented concept of statistically evaluated, measured material balances has yielded a safeguards system that is neither sensitive to nor timely in the detection of significant losses of special nuclear material. Much remains to be done to improve the accuracy and precision, and therefore, the effectiveness of material balance parameters. Facilities must make more measurements and improve their quality; improve the collection, retrieval and analysis of data; preserve the integrity of special nuclear material data; improve the timeliness of detection; and interface all balance

information with the rest of the safeguards system in each facility and throughout the fuel cycle. Potential diverters will not, and we certainly cannot continue waiting for industry to develop and implement means to plug these gaps in their material balance systems.

Statistical power curves admittedly are complex to derive, but are the best criterion for industry to determine how many and what quality of measurements are necessary to account for nuclear materials. We need this information to converge on performance standards necessary for implementing an effective safeguards program.

To circumvent complex hypothesis testing difficulties, it is common practice to concentrate on minimizing the length of confidence intervals--in our case it means reducing the limits of error associated with MUF to acceptably low levels. The public's risk would not be identified, but it would be reduced. Let's briefly consider some possible ways of accomplishing this:

- Conduct more frequent and better inventories so as to provide for better timeliness in and a greater probability of detecting a diversion. We must also assure the quality of physical inventories, especially the integrity of previously made measurements, which should be either protected with

tamper-indicating devices or verified by acceptable remeasurement samples--weight, elemental and isotopic, if applicable--at the time of inventory. Holdup should also be measured and minimized.

2. Evaluate MUF on a cumulative basis, such as with a three to six-month moving total, to increase the probability of detecting systematic diversions.
3. Set action levels on the magnitudes of reported MUF's to trigger investigations necessary for ascertaining their causes. Constraints could be on both an absolute and a relative basis regardless of reported limits of error that exceed these action levels. A possible action level is 0.5% of the combined beginning inventory and receipts for a single month in a low enriched uranium facility. The establishment of any action levels will include grading by the strategic worth of the material; however, action levels in terms of throughput percentages must have meaningful time constraints. Low enriched uranium is certainly of secondary importance but still must be accounted for with effective material balances since it still represents a considerable strategic hazard which will increase as the AEC implements its newest policy of broadening the access to isotopic enrichment technology.

4. As the performance level of identifying, propagating and optimizing limits of error improves, constraints on the limits of error used for detecting significant MUF's should be reduced to acceptably low levels.
5. As an overcheck on the MUF action level efficiency, the limits of error of MUF, when an acceptable power curve is not available, could be used to test MUF at 20% to 33% risk to the facility. This would reduce the limits of error to 80% or one-sigma confidence intervals and in effect, reduce the public's risk.
6. Establish separate in-process and static inventory material balance areas. This would provide
 - a. a better allocation of measurement and other control efforts by facilities;
 - b. a better internal control system resulting in better localization of MUF and measurement uncertainties, stratified by enrichment; and
 - c. a better system to evaluate MUF relative to active throughput.

7. Facilities should participate in a continuing AEC program for probing the quality of facility main stream measurements, including those made on receipts and shipments. This might include a program requiring retention of samples of all special nuclear material receipts and shipments by each facility. These samples would comprise periodically defined lots subject to independent measurement by the AEC.

CONCLUSION

At present we are considering what additional measures should be taken to strengthen the AEC regulatory program and welcome possible alternatives. Whatever we do, we must never be lulled into a state of false security. All of us who are responsible for safeguarding special nuclear material, both in Government and private industry, must avoid using material balance accounting information as a dog uses a lamppost-- for relief rather than enlightenment. We should not feel relieved because more impressive statistics are being generated on an annual or sometimes semiannual basis. Instead, we must continually ask ourselves whether our system is capable of promptly detecting an actual diversion of material.

MORE AND BETTER MEASUREMENTS INCREASE DETECTION ABILITIES AND REDUCE RISKS

Probability of Detecting True MUF

Present Annual Facility MUF's Are:

- Too Large Absolutewise**
- Dominated by Receipt and Shipment Uncertainties**
- Biased Because of Holdup or Hidden Inventory, Unidentified Systematic Errors, Facility Failure to Directly Measure all Material in the Balance, Nominal Values, Failure to Protect the Integrity of Previously-Made Measurements, Unidentified Significant Shipper-Receiver Differences, and Inaccurately Determined Measured Discards.**

Limits of Error Associated With MUF:

- Are Too Large With Poor Probabilities for Detecting
 - Large Single Diversions
 - Large Systematic or Milling Diversions
- Are Not Statistically Robust Because of
 - Rigorously Invalid Error Propagation Models
 - Failure to Identify Their Statistical Power

MUF's Are Imprecise Because of Random Errors Introduced By:

- Batch and Lot Sampling Rates
- Heteorgeneity of Material in Containers
- Analytical Measurements

Annual Facility Material Balances Are:

- Untimely in Regard to Critical Time**
- Difficult to Investigate and Control**

Possible Ways of Improving the Effectiveness of Material Balance Accounting:

- Conduct More Frequent and Better Inventories
- Evaluate MUF on a Cumulative Basis
- Set Action Levels on the Magnitudes of Reported MUF's
- Limits of Error Should be Reduced to Acceptably Low Levels
- Test MUF at Between a 20% and 33% Risk to the Facility
- Establish Separate In-Process and Static Inventory Material Balance Areas
- Have AEC Program for Probing the Quality of Facility Main Stream Measurements