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Contact: S. D. Frattali (301)443-5976

PROPOSED REVISION 1 TO REGULATORY GUIDE 5.11

NONDESTRUCTIVE ASSAY OF SPECIAL NUCLEAR MATERIAL CONTAINED IN SCRAP AND WASTE

A. INTRODUCTION

Section 70.51, "Material Balance, Inventory, and Records Requirements," of 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material," requires licensees authorized to possess at any one time more than one effective kilogram of special nuclear material (SNM) to establish and maintain a system of control and accountability to ensure that the limit of error of any inventory difference (ID) ascertained as a result of a measured material balance meets established minimum standards. The selection and proper application of an adequate measurement method for each of the material forms in the fuel cycle is essential for the maintenance of these standards.

For some material categories, particularly scrap and waste, nondestructive assay (NDA) is the only practical, and sometimes the most accurate, means for measuring SNM content. This guide details procedures acceptable to the NRC staff to provide a framework for the utilization of NDA in the measurement of scrap and waste components generated in conjunction with the processing of special nuclear materials. Other guides detail procedures specific to the application of a selected technique to a particular problem.

B. DISCUSSION

1. APPLICABLE NONDESTRUCTIVE ASSAY PRINCIPLES

The nondestructive assay of the SNM content of heterogeneous material forms is usually achieved through observing either stimulated or spontaneously

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This regulatory guide and the associated value/impact statement are being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. They have not received complete staff review and do not represent an official NRC staff position.

Public comments are being solicited on both drafts, the guide (including any implementation schedule) and the value/impact statement. Comments on the value/impact statement should be accompanied by supporting data. Comments on both drafts should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch, by FEB 2 1983

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occurring radiations emitted from the isotopes of either plutonium or uranium, from their radioactive decay products, or from some combination thereof. Some nondestructive assay techniques such as absorption-edge densitometry and X-ray resonance fluorescence determine the elemental SNM concentration rather than the presence of specific isotopes. If isotopic radiation is measured, the isotopic composition of the material must be known or determined to permit a conversion of the amount of isotope measured to the amount of element present in the container. Assays are performed by isolating the container of interest to permit a measurement of its contents through a comparison with the response observed from known calibration standards. This technology permits quantitative assays of the SNM content of heterogeneous materials in short measurement times without sample preparation and without affecting the form of the material to be assayed. The proper application of this technology requires the understanding and control of factors influencing NDA measurements.

1.1 Passive NDA Techniques

Passive NDA is based on observing spontaneously emitted radiations created through the radioactive decay of plutonium or uranium isotopes or of their radioactive daughters. Radiations attributable to alpha (α) particle decay, to gamma ray transitions following α and beta (β) particle decay, and to spontaneous fission have served as the basis for practical passive NDA measurements.

1.1.1 NDA Techniques Based on Alpha Particle Decay

Alpha particle decay is indirectly detected using calorimetry measurements. (Note: additional contributions are attributable to the α decay of ^{241}Am and the β decay of ^{241}Pu in plutonium calorimetry applications.) The kinetic energy of the emitted α particle and the recoiling daughter nucleus is transformed into heat, together with some fraction of the gamma ray energies that may be emitted by the excited daughter nucleus in lowering its energy to a more stable nuclear configuration. The calorimetric measurement of the heat produced by a sample can be converted to the amount of α-particle-emitting nuclides present through the use of the isotopic abundance and the specific power (W/g-s) of

each nuclide (Refs. 1-3). Plutonium, because of the relatively high specific powers of ^{238}Pu and ^{240}Pu, is amenable to assay by calorimetry, with possible complication from the presence of alpha-active ^{241}Am.

Another technique based on alpha decay involves the interaction of high-energy α particles with some light nuclides (e.g., ^{7}Li, ^{9}Be, ^{10}B, ^{18}O, and ^{19}F) that may produce a neutron through an (α,n) reaction (Ref. 4). When the isotopic composition of the α-particle-emitting nuclides is known and the content of high-yield (α,n) targets is fixed, the observation of the neutron yield from a sample can be converted to the amount of SNM present.

1.1.2 NDA Techniques Based on Gamma Ray Analysis

The gamma ray transitions that reduce the excitation of a daughter nucleus following either α- or β-particle emission from an isotope of SNM occur at discrete energies (Refs. 5, 6). The known α- or β-particle-decay activity of the SNM parent isotope and the probability that a specific gamma ray will be emitted following the α- or β-particle decay can be used to convert the measurement of that gamma ray to a measurement of the amount of the SNM parent isotope present in the container being measured. High-resolution gamma ray spectroscopy is required when the gamma rays being measured are observed in the presence of other gamma rays or X-rays that, without being resolved, would interfere with the measurement of the desired gamma ray (Ref. 5).

1.1.3 NDA Techniques Based on Spontaneous Fission

A fission event is accompanied by the emission of an average of 2 to 3.5 neutrons (depending on the parent nucleus) and an average of about 7.5 gamma rays. A total of about 200 MeV of energy is released, distributed among the fission fragments, neutrons, gamma rays, beta particles, and neutrinos. Spontaneous fission occurs with sufficient frequency in ^{238}Pu, ^{240}Pu, ^{242}Pu, and marginally in ^{238}U to facilitate assay measurements through the observation of this reaction. Systems requiring the coincident observation of two or more of the prompt radiations associated with the spontaneous fission event provide the basis for available measurement systems (Ref. 7).

1.2 Active NDA Techniques

Most active NDA is based on the observation of radiations (gamma rays or neutrons) that are emitted from the isotope under investigation when that isotope undergoes a transformation resulting from an interaction with stimulating radiation provided by an appropriate external source. Isotopic (Refs. 8, 9) and accelerator (Ref. 7) sources of stimulating radiation have been investigated. For a thorough discussion of active NDA techniques, see Reference 10.

Stimulation with accelerator-generated high-energy neutrons or gamma rays is normally considered only after all other NDA methods have been evaluated and found to be inadequate. Operational requirements, including operator qualifications, maintenance, radiation shielding, and calibration considerations, normally require an inordinate level of support in comparison to the benefits of in-plant application.

Neutron bombardment readily induces fissions of ^{233}U, ^{235}U, ^{239}Pu, and ^{241}Pu. Active NDA systems have been developed using spontaneous fission (^{252}Cf) neutron sources, as well as (γ,n) (Sb-Be) sources and a variety of (α,n) (Am-Li, Pu-Li, Pu-Be) sources (Refs. 8, 9). Active techniques rely on one of the following three properties of the induced fission radiation to distinguish the induced radiation from the background and the stimulating radiation:

- High-energy radiation (neutrons with about 2 MeV energy and gamma rays with 1-2 MeV energy)
- Coincident radiation (simultaneous emission of two or more neutrons and about seven to eight gamma rays)
- Delayed radiation (neutrons emitted from certain fission products with half-lives ranging from 0.2 to 50 seconds and gamma rays emitted with half-lives ranging from submicroseconds to years. The usable delayed gamma rays are emitted with half-lives similar to those of delayed-neutron-emitting fission products.)

Examples of the use of these properties with the types of isotopic neutron sources listed above are: (1) fissions are induced by low-energy neutrons from a ^{124}Sb-Be source, and energetic fission neutrons are counted (Refs. 9, 11); (2) fissions are induced by an intense ^{252}Cf source, and delayed neutrons are counted after the source has been withdrawn (Refs. 9, 12-14); and (3) fissions

are induced by single emitted neutrons from an (α,n) source (Refs. 9, 15). Coincident gamma rays and neutrons resulting from the induced fission are counted by means of electronic timing gates (of less than 100 microseconds duration) that discriminate against noncoincident events (Refs. 9, 13).

2. FACTORS AFFECTING THE RESPONSE OF NDA SYSTEMS

Regardless of the technique selected, the observed NDA response depends on (1) the operational characteristics of the system, (2) the isotopic composition of the SNM, (3) the amount and distribution of SNM, (4) the amount and distribution of other materials within the container, and (5) the composition and dimensions of the container itself. Each of these variables increases the overall uncertainty associated with an NDA measurement.

The observed NDA response represents contributions from the different SNM isotopes present in the container. To determine the amount of SNM present, the isotopic composition of the SNM must be known (except for cases in which the NDA system measures the isotopic composition) and the variation in the observed response as a function of varying isotopic composition must be understood. The effects due to items (3), (4), and (5) on the observed response can be reduced through appropriate selection of containers, compatible segregation of scrap and waste categories, and consistent use of packaging procedures designed to improve the uniformity of container loadings.

2.1 Operational Characteristics

The operational characteristics of the NDA system, together with the ability of the system to resolve the desired response from a composite signal, determine the ultimate usefulness of the system. These operational characteristics include (1) operational stability, (2) uniform detection efficiency, (3) stimulating radiation uniformity (for active systems), and (4) energy of the stimulating radiation.

The impact of these operational characteristics on the uncertainty of the measured response can be reduced through the design of the system, the use of radiation shielding (where required), and standardized packaging and handling (as discussed below and in Reference 16).

2.1.1 Operational Stability

The ability of an NDA system to reproduce a given measurement may be sensitive to fluctuations in the operational environment. Temperature, humidity, line voltage variations, electromagnetic fields, and microphonics affect NDA systems to some extent. These effects may be manifested through the introduction of spurious electronic noise or changes in the high voltage applied to detectors or amplifiers, thereby changing the detection efficiency. To the extent that it is possible, a measurement technique and the hardware to implement that technique are selected to be insensitive to changes routinely expected in the operational environment. Accordingly, the instrument is designed to minimize environmental effects by placing components that operate at high voltages in hermetically sealed enclosures and shielding sensitive components from spurious noise pickup. In addition, electronic gain stabilization of the pulse-processing electronics may be advisable. As a final measure, the instrument environment can be controlled (e.g., through the use of a dedicated environmental enclosure for the instrument hardware) if expected environmental fluctuations result in severe NDA response variations that cannot be eliminated through calibration and operational procedures.

The sensitivity to background radiations can be monitored and controlled through proper location of the system and the utilization of radiation shielding, if required.

2.1.2 Uniform Detection Efficiency

For those NDA systems for which the sample or item to be counted is placed within a detection chamber, if the response throughout the detection chamber is not uniform, positioning guides or holders may be utilized to ensure consistent (reproducible) sample or item positioning. The residual geometric response dependence can be measured using an appropriate source that emits radiation of the type being measured. If the source is small with respect to the dimensions of the detection chamber, the system response can be measured with the source positioned in different locations to determine the volume of the detection chamber that can be reliably used.

An encapsulated plutonium source can be used to test gamma ray spectroscopic systems, active or passive NDA systems detecting neutrons or gamma rays, or calorimetry systems. Active NDA systems can be operated in a passive mode (stimulating source removed) to evaluate the magnitude of this effect. Rotating and scanning containers during assay is a recommended means of reducing the response uncertainties attributable to residual nonuniform geometric detection sensitivity.

2.1.3 Uniformity of Stimulating Radiation

The stimulating radiation field (i.e., interrogating neutron or gamma ray flux) in active NDA systems is designed to be uniform in intensity and energy spectrum throughout the volume of the irradiation chamber. The residual effect can be measured using an SNM sample that is small with respect to the dimensions of the irradiation chamber. The response can then be measured with the SNM sample positioned in different locations within the irradiation chamber. If the same chamber is employed for irradiation and detection, a single test for the combined geometric nonuniformity is recommended.

Having both a uniform detection efficiency and a uniform stimulating radiation field is the most direct approach and the recommended approach to obtaining a uniform response for the combined effects. However, it is possible in some cases either to tailor the stimulating radiation field to compensate for deficiencies in the detection uniformity or, conversely, to tailor the detection efficiency to compensate for deficiencies in the stimulating radiation field. An example of this combined approach is the use of interrogating sources on one side of the sample and placement of detectors on the other. A combined uniform response in this example relies both on material closer to the stimulating radiation source having a higher fission probability but a lower induced-radiation detection probability and on material closer to the detector having a lower stimulated fission probability but a higher induced-fission radiation detection probability. This type of approach may be necessary when there are spatial constraints. When the measurement system is optimized for these combined effects, a passive measurement with such a system will have a greater uncertainty than would be obtained with a system having a uniform detection efficiency.

Various methods have been used to reduce the response uncertainty attributable to a nonuniform stimulating radiation field, including rotating and scanning the container, source scanning, distributed sources, and combinations of these methods.

2.1.4 Energy of Stimulating Radiation

If the energy of the stimulating radiation is as high as practicable but below the threshold of any interfering reactions such as the neutron-induced fission in ^{238}U, the penetration of the stimulating radiation will be enhanced throughout the volume of the irradiation chamber. A high-energy source providing neutrons above the energy of the fission threshold for a fertile constituent such as ^{238}U or ^{232}Th can be employed to assay the fertile content of a container.

The presence of extraneous materials, particularly those of low atomic number, lowers the energy spectrum of the interrogating neutron flux in active neutron NDA systems. Incorporating a thermal neutron detector to monitor this effect and thereby provide a basis for a correction to reduce the response uncertainty caused by this variable effect is recommended.

Active neutron NDA systems with the capability to moderate the interrogating neutron spectrum can provide increased assay sensitivity for samples containing small amounts of fissile material (<100 grams). This moderation capability should be removable to enhance the range of usefulness of the system.

2.2 Response Dependence on SNM Isotopic Composition

The observed NDA response may be a composite of contributions from more than a single isotope of uranium or plutonium. Observed effects are generally attributable to one of the three sources described below.

2.2.1 Multiple Gamma Ray Sources

Plutonium contains the isotopes ^{238}Pu through ^{242}Pu in varying quantities. With the exception of ^{242}Pu, these isotopes emit many gamma rays (Refs. 5, 6). The observed plutonium gamma ray spectrum represents the contribution of all

gamma rays from each isotope, together with the gamma rays emitted in the decay of ^{241}Am, which may also be present.

Uranium-233 and -235 gamma rays are generally lower in energy than ^{239}Pu gamma rays. Uranium-232, occurring in combination with ^{233}U, has a series of prolific energetic-gamma-ray-emitting daughter products that include ^{228}Th, with the result that daughter products of ^{232}U and ^{232}Th are identical beyond ^{228}Th.

2.2.2 Multiple Spontaneously Fissioning Plutonium Isotopes

In addition to the spontaneous fission observed from ^{240}Pu, the minor isotopes ^{238}Pu and ^{242}Pu typically contribute a few percent to the total neutron rate observed (Refs. 17-19). In mixtures of uranium and plutonium blended for reactor fuel applications, the spontaneous fission yield from ^{238}U may approach one percent of the ^{240}Pu yield.

2.2.3 Multiple Fissile Isotopes

In active systems, the observed fission response may consist of contributions from more than one isotope. For uranium, if the energy spectrum of the stimulating radiation extends above the threshold for ^{238}U fission, that response contribution will be in addition to the induced ^{235}U fission response.

In plutonium, the observed response will be the sum of contributions from the variable content of ^{239}Pu and ^{241}Pu, with small contributions from the even plutonium isotopes.

When elements (e.g., plutonium and uranium) are mixed for reactor utilization, the uncertainty in the response is compounded by introducing additional fissile components in variable combinations.

2.3 Response Dependence on Amount and Distribution of SNM in a Container

If a system has a geometrically uniform detection sensitivity and a uniform field of stimulating radiation (where applicable), a variation in the response per gram of the isotope(s) being measured is generally attributable to one of the three causes described below.

2.3.1 Self-Absorption of the Emitted Radiation Within the SNM

For a fixed amount of SNM in a container, the probability that radiation emitted by the SNM nuclei will interact with other SNM atoms increases as the localized density of the SNM increases within the container. This is a primary source of uncertainty in gamma ray spectroscopy applications. It becomes increasingly important as the SNM aggregates into lumps and is more pronounced for low-energy gamma rays.

2.3.2 Multiplication of the Detected Radiation

The neutrons given off in either a spontaneous or an induced fission reaction can be absorbed in a fissile nucleus and subsequently induce that nucleus to fission, resulting in the emission of two or more neutrons. Multiplication affects the response of active NDA systems, passive coincidence neutron or gamma ray detection systems (used to detect spontaneous fission), and passive neutron systems used to count (α,n) neutrons. Multiplication becomes increasingly pronounced as the energy of the neutrons traversing the container becomes lower or as the density of SNM increases within the container. For further details on multiplication effects, see References 20 and 21.

2.3.3 Self-Shielding of the Stimulating Radiation

Attenuation of incident radiation by the SNM, or self-shielding, is particularly pronounced in active systems incorporating a neutron source to stimulate the fissile isotopes of the SNM to fission. More of the incident low-energy neutrons will be absorbed near the surface of a high-density lump of SNM, and fewer will penetrate deeper into the lump. Thus, the fissile nuclei located deep in the lump will not be stimulated to fission at the same rate as the fissile nuclei located near the surface, and a low assay content will be indicated. This effect is dependent on the energy spectrum of the incident neutrons and the density of fissile nuclei. It becomes increasingly pronounced as the energy of the incident neutrons is decreased or as the density of the SNM fissile content is increased. The density of fissile nuclei is increased when the SNM is lumped in aggregates or when the fissile enrichment of the SNM is increased.

2.4 Response Dependence on Amount and Distribution of Extraneous Materials within the Container

The presence of materials other than SNM within a container can affect the emitted radiations in passive and active NDA systems and can also affect the stimulating radiation in active assay systems. The presence of extraneous materials can result in either an increase or a decrease in the observed response.

Effects on the observed NDA response are generally attributable to one of the four causes described below.

2.4.1 Interfering Radiations

Interference arises when the material being assayed emits radiation that cannot be separated easily from the signal of interest. This problem is generally encountered in gamma ray spectroscopy and calorimetry applications. In gamma ray assays, the problem is manifest in the form of additional gamma rays that must be separated from the desired radiations, often with high-resolution detection systems. In calorimetry, the decay daughters of ^{241}Pu, ^{238}U, and ^{232}U contribute additional heat that cannot be corrected for without detailed knowledge of the isotopic composition of the sample.

2.4.2 Interference to Stimulating Radiation

Material lowers the energy of neutrons through collision processes. This lowering of the neutron energy is called moderation. Low-atomic-weight elements have greater moderating power than high-atomic-weight elements and thereby reduce energetic neutrons to thermal energies with fewer collisions. Hydrogen has the greatest moderating power. Hydrogenous materials such as water or plastics have a strong moderating power because of their hydrogen content.

Low-energy neutrons have interaction characteristics different from high-energy neutrons. If moderation of the stimulating neutron radiation occurs, the response will be altered and the assay value could be in error. Three effects arise from moderated neutrons. First, the fission probability for

fissile isotopes increases with decreasing neutron energy. In this case, the response increases and, correspondingly, so does self-shielding. Second, absorption by materials other than SNM also increases. This absorption decreases the response of the system. Third, if isotopes with a fission threshold such as ^{232}Th or ^{238}U are being assayed with high-energy neutrons, moderation can lower the energy of the stimulating neutrons below the fission threshold. In this case, the response by these isotopes can be sharply reduced.

Efforts to minimize moderation effects are particularly important if energetic neutrons are employed for the stimulating radiation. Segregation of waste categories according to their moderating characteristics and use of separate calibrations for each category are direct steps to minimize moderation effects. Another step that can be used with segregation, and sometimes independently, is to monitor the stimulating neutron radiation and then correct the assay result. Because several effects are associated with moderation, this latter step may be difficult to implement. In some cases, it may be impossible.

2.4.3 Attenuation of the Emitted Radiation

Attenuation may range from partial energy loss of the emitted radiation (through scattering processes) to complete absorption of the radiation by the sample material. This effect can be particularly severe for gamma ray assay systems; unless gamma ray attenuation is fully accounted for by measurement or calculation, the assay value assigned to an unknown sample may be underestimated (Refs. 4, 22). The attenuation of gamma radiation increases with atomic number and material density within the container. Also, systems that detect emitted neutrons above a given energy (threshold) will observe fewer neutrons above the detection threshold when low-atomic-number (i.e., highly moderating) material is added to the container and will thus produce a low assay.

The attenuation of the emitted radiation may be complete, as in the case of the absorption of neutrons in the nuclei of extraneous material. The probability for this absorption generally increases as the energy of the incident neutron decreases. Hence, this effect is further aggravated when low-atomic-number materials are present to reduce the energy of the emitted neutrons.

2.4.4 Attenuation of the Stimulating Radiation

This phenomenon is similar to the phenomenon of the preceding section. In this instance, some portion of the stimulating radiation does not penetrate to the SNM within the container and thus does not have the opportunity to induce fission. The presence of neutron poisons (e.g., lithium, boron, cadmium, gadolinium) may attenuate the stimulating radiation to the extent that the response is independent of the SNM fissile content. Most materials absorb neutrons. The severity of this absorption effect is dependent on the type of material, its distribution, the energy of the stimulating neutrons, and the relative neutron absorbing strength of the SNM compared to the combined effect of the remaining material.

The presence of extraneous material can thus alter the observed response, providing either a high or a low SNM content indication. This effect is further aggravated by nonuniformity within the container of either the SNM or the matrix in which it is contained. This dependence of response on material distributions and matrix variations is severe. Failure to attend to its ramifications through the segregation of scrap and waste categories and the utilization of representative* calibration standards may produce gross inaccuracies in NDA measurements.

2.5 Response Dependence on Container Dimensions and Composition

The items identified as potential sources of uncertainty in the observed response of an NDA system in Sections 2.1, 2.3, and 2.4 can be minimized or aggravated through the selection of containers to be employed when assaying SNM contained in scrap or waste.

*The term "representative" is taken to mean representative with respect to attenuation, moderation, multiplication, density, and any other properties to which the measurement technique is sensitive.

2.5.1 Container Dimensions

The practical limitation on container size for scrap and waste to be nondestructively assayed represents a compromise of throughput requirements and the increasing uncertainties in the observed NDA response incurred as a penalty for assaying large containers. Radiations emitted deep within the container must travel a greater distance to escape the confines of the container. Therefore, with increasing container size, the probability that radiations emitted near the center of the container will escape the container to the detectors decreases with respect to the radiations emitted near the surface of the container. This will result in large attenuation corrections that can cause added uncertainty in the assay result.

In active neutron NDA systems, a relatively uniform field of stimulating radiation must be provided throughout the volume of the container that is observed by the detection system. This criterion is required to obtain a uniform response from a lump of SNM positioned anywhere within a container. With increasing container size, it becomes increasingly difficult to satisfy this criterion and maintain a compact geometrically efficient system. For this reason, the assay of small-size containers is recommended for the highest accuracy.

If small containers are to be loaded into larger containers for storage or offsite shipment following assay, the size and shape of the inner and outer containers should be chosen to be compatible.

Packaging in small containers will produce more containers to be assayed for the same scrap and waste generation rates. An offsetting benefit, however, is that the assay accuracy of an individual container should be significantly improved over that of large containers.

2.5.2 Container Structural Composition

The structural composition of containers will affect the penetration of the incident or the emerging radiation. Provided all containers are uniform, their effect on the observed response can be factored into the calibration of the system. The attainable assay accuracy will be reduced when containers with poor penetrability or varying composition or dimensions are selected.

Uniform containers of the same composition, dimensions, and wall thickness provide improved or best accuracy (for a given material category). Variability in the wall thickness of nonhydrogenous containers usually is not critical for neutron assays, but it can be a significant factor for gamma spectroscopy applications when the container is constructed of relatively high-density material or when low-energy (less than approximately 200-keV) gamma rays are being measured. However, when hydrogenous materials (such as polyethylene) are used in containers, wall thickness variability can have a significant effect on neutron assay results.

3. NONDESTRUCTIVE ASSAY FOR SNM CONTAINED IN SCRAP AND WASTE

3.1 NDA Performance Objectives

The measurement accuracy objectives for any material balance component can be estimated by considering the amount of material typically contained in that component. The measurement performance required is such that, when the uncertainty corresponding to the scrap and waste material balance component is combined with the uncertainties corresponding to the other material components, the quality constraints on the total limit of error of the inventory difference (LEID) will be satisfied.

3.2 NDA Technique Selection

Factors that influence NDA technique selection are the accuracy requirements for the assay and the type and range of scrap and waste categories to be encountered. No single technique appears capable of meeting all requirements. When more than one type of information is required to separate a composite response, more than one NDA technique may be required to provide that information.

3.2.1 Plutonium Applications

Calorimetry determinations are the least sensitive to matrix effects, but rely on a detailed knowledge of the ^{241}Am content and the plutonium isotopic

composition to transform the measured heat flux to grams of plutonium (Ref. 1). In addition, a calorimetry measurement usually requires several hours in order to achieve or to carefully predict thermal equilibrium.

Gamma ray spectroscopy systems complement the potential of other assay methods by providing the capability to verify or determine nondestructively the ^{241}Am content and the plutonium isotopic composition (except ^{242}Pu). High-resolution gamma ray systems are capable of extracting the maximum amount of information (elemental content, isotopic distributions, presence of extraneous gamma ray sources) from an assay, but content density severely affects the accuracy of quantitative predictions based on that assay method in large samples.

Passive coincidence detection of the spontaneous fission yield of plutonium-bearing systems provides an indication of the combined ^{238}Pu, ^{240}Pu, and ^{242}Pu sample content. With known isotopic composition, the plutonium content can be computed (Ref. 17 and Regulatory Guide 5.34*). Neutron multiplication effects become severe at high plutonium sample loadings (Refs. 20, 21).

Combining passive and active measurements in a single system is a valuable approach for plutonium assay. Plastic scintillation coincidence detection systems have been designed in conjunction with active neutron interrogation source systems (Ref. 23). Delayed neutron counting systems have an inherent active-passive counting capability (Refs. 9, 13, 14). Operated in passive and active modes, such systems are able to provide an assay of both the spontaneously fissioning content and the fissile content of the sample. The spontaneous fission and (α,n) backgrounds can be subtracted from an active NDA response to provide a yield attributable to the fissile SNM content of the container.

3.2.2 Uranium Applications

Active neutron systems can provide both high-energy and moderated interrogation spectra. Operation with the high-energy neutron source will decrease

*Regulatory Guide 5.34, "Nondestructive Assay for Plutonium in Scrap Material by Spontaneous Fission Detection." A proposed revision to this guide has been issued for comment as Task SG 046-4.

the density dependence and neutron self-shielding effects, significantly enhancing the uniqueness of the observed response. To extend the applicability of such a system to small fissile loadings, a well-moderated interrogating spectrum can be used to take advantage of the increased ^{235}U fission probability for neutrons of low energy. In highly enriched uranium scrap and waste (>20% ^{235}U), active NDA featuring a high-energy stimulating neutron flux is recommended.

The 185-keV transition observed in the decay of ^{235}U is frequently employed in uranium applications. The penetration of this ^{235}U primary gamma ray is so poor that the gamma ray NDA technique is not applicable with high-density nonhomogeneous materials in large containers.

Occasions arise when a passive enrichment determination is practical through the measurement of the 185-keV gamma ray. Enrichment assay applications for uranium are the subject of Regulatory Guide 5.21, "Nondestructive Uranium-235 Enrichment Assay by Gamma Ray Spectrometry." A proposed revision to this guide has been issued for comment as Task SG 044-4.

Calorimetry is not applicable to the assay of uranium because of the low specific α activity. In ^{233}U applications, the intense activity of the daughter products of ^{232}U imposes a severe complication on the use of calorimetry.

3.3 Categorization and Segregation of Scrap and Waste for NDA

The range of variations in the observed response of an NDA system attributable to the effects noted in Sections 2.3 and 2.4 can be reduced or controlled. Following an analysis of the types of scrap and waste generated in conjunction with SNM processing, a plan to segregate scrap and waste at the generation points can be formulated. Recovery or disposal compatibility is important in determining the limits of each category. Limiting the variability of those extraneous NDA interference parameters discussed in Sections 2.3 and 2.4 is a primary means of improving the accuracy of the scrap and waste assay. Once the categories are established, it is important that steps be taken to ensure that segregation into separate uniquely identified containers occurs at the generation point.

Category limits can be established on the basis of measured variations observed in the NDA response of a container loaded with a known amount of SNM. The variation in extraneous parameters can then be mocked up and the resultant

effect measured. In establishing categories, the following specific items are significant sources of error.

3.3.1 Calorimetry

The presence of extraneous materials capable of absorbing heat (endothermic) or emitting heat (exothermic) will cause the observed response to be different from the correct response for the plutonium in the sample.

3.3.2 Neutron Measurements

The presence of high-yield (α,n) target material will increase the number of neutrons present in the sample. A fraction of these neutrons will induce fission in the fissile SNM isotopes and add another source of error to the measurement. These multiplication and self-multiplication effects are discussed thoroughly in References 4, 20, and 21.

3.3.3 Gamma Ray Measurements

Gamma rays are severely attenuated in interactions with heavy materials. Mixing contaminated combustibles with heavy, dense materials complicates the attenuation problem. Mixing of isotopic batches, mixing with radioactive materials other than SNM, or lumps of SNM can also add to the complexity of the response.

3.3.4 Fission Measurements

Scrap or waste having low-atomic-number materials will reduce the energy of the neutrons present in the container, which will significantly affect the probability of stimulating fission reactions.

Neutron-absorbing materials present in SNM scrap or waste may significantly affect the operation of NDA systems. Table 1 of this guide identifies neutron absorbers in the order of decreasing probability of absorption of thermal neutrons. An estimate of the significance of the presence of one of these materials may be obtained from the ratio of its absorption cross section to the absorption cross section of the SNM present in the container:

the density dependence and neutron self-shielding effects, significantly enhancing the uniqueness of the observed response. To extend the applicability of such a system to small fissile loadings, a well-moderated interrogating spectrum can be used to take advantage of the increased ^{235}U fission probability for neutrons of low energy. In highly enriched uranium scrap and waste (>20% ^{235}U), active NDA featuring a high-energy stimulating neutron flux is recommended.

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Occasions arise when a passive enrichment determination is practical through the measurement of the 185-keV gamma ray. Enrichment assay applications for uranium are the subject of Regulatory Guide 5.21, "Nondestructive Uranium-235 Enrichment Assay by Gamma Ray Spectrometry." A proposed revision to this guide has been issued for comment as Task SG 044-4.

Calorimetry is not applicable to the assay of uranium because of the low specific α activity. In ^{233}U applications, the intense activity of the daughter products of ^{232}U imposes a severe complication on the use of calorimetry.

3.3 Categorization and Segregation of Scrap and Waste for NDA

The range of variations in the observed response of an NDA system attributable to the effects noted in Sections 2.3 and 2.4 can be reduced or controlled. Following an analysis of the types of scrap and waste generated in conjunction with SNM processing, a plan to segregate scrap and waste at the generation points can be formulated. Recovery or disposal compatibility is important in determining the limits of each category. Limiting the variability of those extraneous NDA interference parameters discussed in Sections 2.3 and 2.4 is a primary means of improving the accuracy of the scrap and waste assay. Once the categories are established, it is important that steps be taken to ensure that segregation into separate uniquely identified containers occurs at the generation point.

Category limits can be established on the basis of measured variations observed in the NDA response of a container loaded with a known amount of SNM. The variation in extraneous parameters can then be mocked up and the resultant

effect measured. In establishing categories, the following specific items are significant sources of error.

3.3.1 Calorimetry

The presence of extraneous materials capable of absorbing heat (endothermic) or emitting heat (exothermic) will cause the observed response to be different from the correct response for the plutonium in the sample.

3.3.2 Neutron Measurements

The presence of high-yield (α,n) target material will increase the number of neutrons present in the sample. A fraction of these neutrons will induce fission in the fissile SNM isotopes and add another source of error to the measurement. These multiplication and self-multiplication effects are discussed thoroughly in References 4, 20, and 21.

3.3.3 Gamma Ray Measurements

Gamma rays are severely attenuated in interactions with heavy materials. Mixing contaminated combustibles with heavy, dense materials complicates the attenuation problem. Mixing of isotopic batches, mixing with radioactive materials other than SNM, or lumps of SNM can also add to the complexity of the response.

3.3.4 Fission Measurements

Scrap or waste having low-atomic-number materials will reduce the energy of the neutrons present in the container, which will significantly affect the probability of stimulating fission reactions.

Neutron-absorbing materials present in SNM scrap or waste may significantly affect the operation of NDA systems. Table 1 of this guide identifies neutron absorbers in the order of decreasing probability of absorption of thermal neutrons. An estimate of the significance of the presence of one of these materials may be obtained from the ratio of its absorption cross section to the absorption cross section of the SNM present in the container:

$$R = \frac{N_1 \sigma_{a_1}}{N_{SNM} \sigma_{a_{SNM}}}$$

where

N_1 = the number of atoms per cubic centimeter of material

σ_{a_1} = absorption cross section of the extraneous material (Table 1)

N_{SNM} = number of atoms of SNM present per cubic centimeter

$\sigma_{a_{SNM}}$ = absorption cross section of the SNM (includes both fission and neutron capture processes). Thermal neutron absorption cross sections of the following SNM isotopes of interest are: ^{233}U, 537 barns; ^{235}U, 678 barns; ^{239}Pu, 1015 barns; ^{241}Pu, 1375 barns.

The magnitude of this effect is dependent on the distribution of the materials and the energy of the neutrons present within the container. The relationship above is a gross approximation. For convenience in calculation, including only the primary fissile isotope is sufficient to determine which materials may constitute a problem requiring separate categorization for assay. In extreme cases, it will be necessary either to seek methods for measuring the content of the neutron absorber to provide a correction for the NDA response or to seek a different method for assay of that category.

3.4 Packaging for Nondestructive Assay

Nondestructive assay provides optimal accuracy when the packages to be assayed are essentially identical and when the calibration standards represent those packages in content and form. Containers for most scrap and waste can be loaded using procedures that will enhance the uniformity of the loading

Table 1

NATURALLY OCCURRING NEUTRON ABSORBERS (Ref. 24)

Naturally Occurring Element	Symbol	Absorption Cross Section (barns)*	Naturally Occurring Element	Symbol	Absorption Cross Section (barns)*
Gadolinium	Gd	46,000	Terbium	Tb	46
Samarium	Sm	5,600	Cobalt	Co	38
Europium	Eu	4,300	Ytterbium	Yb	37
Cadmium	Cd	2,450	Chlorine	Cl	34
Dysprosium	Dy	950	Cesium	Cs	28
Boron	B	755	Scandium	Sc	24
Actinium	Ac	510	Tantalum	Ta	21
Iridium	Ir	440	Radium	Ra	20
Mercury	Hg	380	Tungsten	W	19
Protactinium	Pa	200	Osmium	Os	15
Indium	In	191	Manganese	Mn	13
Erbium	Er	173	Selenium	Se	12
Rhodium	Rh	149	Praseodymium	Pr	11
Thulium	Tm	127	Lanthanum	La	9
Lutetium	Lu	112	Thorium	Th	8
Hafnium	Hf	105	Iodine	I	7
Rhenium	Re	86	Antimony	Sb	6
Lithium	Li	71	Vanadium	V	5
Holmium	Ho	65	Tellurium	Te	5
Neodymium	Nd	46	Nickel	Ni	5

*Cross section for thermal neutrons

within each container and from container to container. For further discussion and recommendations on container standardization, see Reference 16.

3.5 Calibration of NDA Systems for Scrap and Waste

To obtain an assay value on SNM in a container of scrap or waste with an associated limit of error, the observed NDA response or the predicted content must be corrected for background and for significant effects attributable to the factors described in the preceding parts of this discussion. Several approaches are available to correct an assay for effects that significantly perturb the assay result. The first approach is to use a separate calibration

for each material category that results in a different assay response. The second approach is to make auxiliary measurements as part of the assay. The assay is then corrected according to a procedure developed for interpreting each auxiliary measurement. A third possible calibration technique is one in which a random number of containers are assayed (by the NDA method to be used) a sufficient number of times (to minimize random error) and then destructively measured (in such a way that the entire container contents are measured). A calibration curve depicting the relationship between destructive assay values and NDA response can then be derived. This approach may give rise to relatively large (random) errors for individual items, but it can minimize the error associated with the total SNM quantity measured by the particular NDA method. This calibration procedure can also be used to confirm a calibration curve derived from calibration standards.

Each approach has its advantages and limitations. Separate calibrations are appropriate when (1) the perturbing effects are well characterized for each category, (2) there are relatively few categories, and (3) the instrument design will not allow collection of data suitable for making corrections. A calibration with auxiliary measurements for correction factors is appropriate when (1) the perturbing effects are variable within a material category, (2) the various categories are not reliably segregated, and (3) the measurement method facilitates the use of suitable auxiliary measurements. Calibration by comparison of NDA and destructive analyses on randomly selected actual samples may be useful in cases where well-characterized standards are not available or are not practical for the measurements involved. However, in view of the potential for greater errors with this calibration method, measurements based on this technique should be regarded as verifications rather than as careful quantitative assays.

The relative difficulty in implementing one calibration scheme over the other depends on the type of facility and available personnel. A steady operation with perhaps some initial set-up assistance might favor the correction factor approach because only one calibration is used. Often additional material categories can be assayed without preparing additional calibration standards. The separate calibration scheme might be favored by facilities that have well-characterized categories. A separate calibration is made for each category without the need for establishing relationships among the categories.

The calibration of radiometric nondestructive assay systems is the subject of Regulatory Guide 5.53, "Qualification, Calibration, and Error Estimation Methods for Nondestructive Assay,"* which endorses ANSI N15.20-1975, "Guide to Calibrating Nondestructive Assay Systems."**

C. REGULATORY POSITION

In the development of an acceptable framework for the incorporation of nondestructive assay for the measurement of SNM-bearing scrap and waste, strong consideration should be given to technique selection, calibration, and operational procedures; to the segregation of scrap and waste categories; and to the selection and packaging of containers. The guidelines presented below are generally acceptable to the NRC staff for use in developing such a framework that can serve to improve materials accountability.

1. ORIGIN OF SCRAP AND WASTE

The origin of scrap and waste generated in conjunction with SNM processing activities should be determined as follows:

a. Identify those operations that generate SNM-bearing scrap or waste as a normal adjunct of a process.

b. Identify those operations that occasionally generate SNM-bearing scrap or waste as the result of an abnormal operation that renders the product unacceptable for further processing or use without treatment.

c. Identify those scrap and waste items generated in conjunction with equipment cleanup, maintenance, or replacement.

The quantities of scrap and waste generated during normal operations in each category in terms of the total volume and SNM content should be estimated. Bulk measurement throughput requirements should be determined to ensure that such assay will not constitute an operational bottleneck.

*A proposed revision to this guide has been issued for comment as Task SG 049-4.

**Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, New York 10018.

2. NDA SELECTION

2.1 Technique

The performance objectives for the NDA system should be such that, when the uncertainty corresponding to the scrap and waste material balance component is combined with the uncertainties corresponding to the other material components, the quality constraints on the total limit of error of the inventory difference will be satisfied.

Techniques should be considered for implementation in the order of precedence established in Table 2 of this guide. Often, techniques within a given instrument category in Table 2 will have different accuracies, lower-limit sensitivities, costs, availabilities, and sizes. Selection should be based on attainable accuracy with due consideration of the characteristics of the scrap and waste categories as well as cost, availability, and size.

2.2 System Specifications

NDA systems for SNM accountability should be designed and shielding should be provided to meet the following objectives:

a. Performance characteristics should be essentially independent of fluctuations in the ambient operational environment, including:

(1) External background radiations,

(2) Temperature,

(3) Humidity, and

(4) Electric power.

b. Response should be essentially independent of positioning of SNM within the scrap or waste container, including effects attributable to:

(1) Detector geometrical efficiency and

(2) Stimulating source intensity and energy.

Techniques to achieve these objectives are discussed in Section B of this guide.

Table 2
NDA TECHNIQUE SELECTION GUIDELINES[a]

	Plutonium			^{233}U			≧ 20% ^{235}U			≦ 20% U^{235}		
Volume (liters)	2	20	200	2	20	200	2	20	200	2	20	200
Technique												
Calorimetry	1st*	3rd*	NR[b]	3rd	NR	NR	NA[b]	NA	NA	NA	NA	NA
	NR	NR	NR	NR	NR	NR	NA	NA	NA	NA	NA	NA
Gamma Ray	3rd	NR	NR	1st	NR	NR	4th	NR	NR	4th	NR	NR
	1st	1st	3rd	1st	1st	1st	1st	1st	2nd	1st	1st	2nd
Singles	SC[b]	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
Neutron	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
Coincidence	2nd*	1st*	2nd*	NA	NA	NA	NR	NR	NR	SC	SC	SC
Neutron	2nd*	2nd*	1st*	NA	NA	NA	NR	NR	NR	SC	SC	SC
Induced fission[c]												
Gamma ray	5th*	NR	NR	4th	NR	NR	2nd	NR	NR	2nd	NR	NR
	4th*	4th*	4th*	3rd	3rd	3rd	3rd	3rd	3rd	3rd	3rd	3rd
Neutron	4th*	2nd*	1st*	2nd	1st	1st	1st	1st	1st	1st	1st	1st
	3rd*	3rd*	2nd*	2nd	2nd	2nd	2nd	2nd	1st	2nd	2nd	1st
Both[d]	6th*	NR	NR	5th	NR	NR	3rd	NR	NR	3rd	NR	NR
	5th*	5th*	5th*	4th	4th	4th	4th	4th	4th	4th	4th	4th

[a]For each technique and type of SNM, recommendations are given for three sizes of containers and for low- and high-density samples. The upper recommendation is for high-density waste (>0.5 g/cm^3), the lower for low-density waste (<0.5 g/cm^3). Fissile loading is assumed to be above 0.5 g.

[b]Abbreviations: NR - Not recommended; NA - not applicable; SC - special case, use only well-characterized materials.

[c]Neutron-induced fission with methods subdivided by detected radiation.

[d]Neutrons and gamma rays are detected without distinguishing between two radiation types.

*Isotopic data required.

3. CATEGORIZATION AND SEGREGATION

Scrap and waste categories should be developed on the basis of NDA interference control, recovery or disposal compatibility (Ref. 3), and relevant safety considerations. Categorization for NDA interference control should be directed to limiting the range of variability in an interference. Items to be considered depend on the sensitivity of the specific NDA technique, as shown in Table 3.

The means through which these interferences are manifested are detailed in Section B. When such effects or contents are noted, separate categories should be established to isolate the materials.

4. CONTAINERS

4.1 Size Constraints

Scrap and waste should be packaged for assay in containers as small as practicable consistent with the capability and sensitivity of the NDA system. Discussion of container standardization and recommendations for NDA measurements can be found in Reference 16.

To enhance the penetration of stimulating or emitted radiations, containers should be cylindrical. If possible, the diameter should be less than 5 inches to provide for significant loading capability, ease in loading, reasonable penetrability characteristics, and where applicable, compatibility with criticality-safe geometry requirements for individual containers.

Containers having an outside diameter of 4-3/8 inches will permit 19 such containers to be arranged in a cross section of a 55-gallon drum, even when that drum contains a plastic liner. Containers having an overall length equal to some integral fraction of the length of a 55-gallon drum are further recommended when shipment or storage within such containers is to be considered. For normal operations, an overall length of either 16-1/2 inches (two layers or 38 containers per drum) or 11 inches (three layers or 57 containers per drum) is recommended.

Certain objectives may be inconsistent with the above size recommendations, such as the objective to limit handling, reduce cost, and keep waste volume to

Table 3

QUALITATIVE ASSESSMENT OF THE SENSITIVITY OF VARIOUS NDA TECHNIQUES TO INTERFERENCES

	Heat-Producing or Absorbing Processes	Mixed SNM	Mixed Isotopic Batches	Misc. Radiations[a]		Presence of High-Yield (α,n) Target Mat'l.	Gamma Ray Absorbers	Neutron Absorbers	Neutron Moderators	Combined Neutron Absorbers & Moderators	Lumped vs. Distr. SNM	Lumped vs. Distr. Matrix Mat'l.	SNM Chemical Form
				Gamma Ray	Neutron								
Calorimetry	3	3	3	1	1	0	0	0	0	0	0	0	0
Gamma Ray	0	1	1	3	1	0	3	0	0	0	3	2	0
Singles Neutron	0	3	3	1	3	3	0	1	1	3	1	0	3
Coincidence Neutron	0	3	3	1	2	1	1	0	1	2	3	1	0 0
Induced Neutron[b]													
(c)	0	3	2	1	1	1	0	1	2	3	1	0	0
(d)	0	3	1	1	1	1	0	3	1	3	3	0	0

[a] Effect depends on intensity of the radiation.

[b] If gamma rays are part of the detected signal, the gamma ray liabilities are in addition to those listed.

[c] High-energy (>1 Mev) neutron interrogation.

[d] Thermal-energy neutron interrogation.

Key: 0 - No sensitivity.
1 - Some sensitivity. Evaluate effect in extreme cases.
2 - Marked sensitivity. Categorize and calibrate according to magnitude of observed effect. Correction factors will be useful.
3 - Strong sensitivity. Requires tight control of material categories and correction factors. May render the technique unacceptable in some cases.

a minimum. It may therefore be necessary to package scrap and waste materials in containers of sizes that exceed these recommendations, and this may result in a significant impairment in the accuracy of NDA techniques on such samples. The relative merits of various NDA techniques with samples of different sizes are addressed in Table 2. With small containers (about 2 liters), an accuracy of 2 to 5 percent is routinely obtainable; with a 55-gallon (200-liter) drum a lower accuracy of 15 to 30 percent is to be expected. In cases of uniformly mixed well-characterized material, a better accuracy may be possible. On the other hand, certain combinations of adverse circumstances can lead to a considerably worse accuracy. The potential for an adverse measurement situation is greater with a larger container than with a smaller container, and the consequences of that situation can lead to a greater error with larger containers. Conditions leading to measurement errors are discussed in Section B.2, and they are listed as interferences in the column headings of Table 3.

If unusual container sizes are necessary, it is often useful to employ a second measurement method in a comparative analysis to obtain a comparison of results. The other measurement method should be more accurate and one that is not sensitive to the interferences affecting the first measurement method. For example, if the first measurement is one that measures neutrons and is affected by the amount of low-atomic-weight moderating material present (which is difficult to duplicate in the standards), the second method should be one insensitive to the amount of moderator present. Or, if uncertainty in the calibration of the first method is due to geometry effects, the second method should be one that is insensitive to those effects, e.g., through subdivision of the containers. Complete ashing, dissolution, sampling, and chemical and mass spectrometric analysis of waste containers constitutes a useful second measurement method in some cases.

The second, more accurate measurement method should be traceable to national standards* and should be employed to verify the calibration relationship of the primary method. Process items should be selected at random from the population of items being measured. A sufficient number of items analyzed by the first method should be selected to ensure, as a minimum, that a stable

*See Regulatory Guide 5.58, "Considerations for Establishing Traceability of Special Nuclear Material Accounting Measurements."

estimate of the population variance is obtained. If simple linear regression is applicable, the minimum number of items selected per material balance period should be 17 in order to provide 15 degrees of freedom for the standard error of estimate and test for a proportional bias (Ref. 25).

If a second NDA method is employed for comparative analysis, the container size for the second method analyses should be consistent with the recommendations in this guide.

4.2 Structural Features

Containers should be selected in accordance with normal safety considerations and should be:

a. Structurally identical for all samples to be assayed within each category,

b. Structurally identical for as many categories as practicable to facilitate loading into larger containers or storage facilities,

c. Uniform in wall thickness and material composition,

d. Fabricated of materials that do not significantly interfere with the radiations entering or leaving the sample,

e. Capable of being sealed to verify postassay integrity, and

f. Compatible with subsequent recovery, storage, and disposal requirements, as applicable.

In most NDA applications, uniformity of composition is more important than the specification of a particular material. Table 4 gives general recommendations in order of preference for container structural materials.

4.3 Container Identification

To facilitate loading and assay within the segregation categories, containers should either be color-coded or carry color-coded identification labels. Identification of categories should be documented, and operating personnel should be instructed to ensure compliance with established segregation objectives.

Table 4

SCRAP AND WASTE
CONTAINER COMPOSITION

NDA Technique	Container Composition
Calorimetry	metal (aluminum, brass)
Gamma Ray Analysis	cardboard, polyethylene bottle, thin metal
Spontaneous or Stimulated Fission	metal, cardboard, polyethylene bottle
Gross Neutron	metal, cardboard, polyethylene bottle

5. PACKAGING

Containers, where practicable, should be packaged with a quantity of material containing sufficient SNM to ensure that the measurement is not being made at the extremes of the performance bounds for that system. Packaging procedures should be consistent with relevant safety practices.

Containers should be packaged in as reproducible a manner as possible, with special attention to the maintenance of uniform fill heights. Low-density items should be compacted to reduce bulk volume and to increase the container SNM loading. Lowering the bulk volume reduces the number of containers to be assayed and generally improves the assay precision.

The sample containers should be loaded with SNM as uniformly as possible. If significant variability in the distribution of container contents is suspected, rotating or scanning the container during assay will aid in improving the accuracy of many NDA methods. An example of this approach is described in Reference 26.

6. CALIBRATION

The calibration should be verified for each material category. Within each category, the variation of interference effects should be measured within the boundaries defining the limits of that category. Calibration standards should employ containers identical to those to be employed for the scrap or waste. Their contents should be mocked up to represent the range of variations in the interferences to be encountered. To minimize the number of standards required, the calibration standards should permit the range of interference variations to be simulated over a range of SNM loadings.

Verification of the calibration should be made at the start of each assay section. If different calibrations are to be used, each calibration should be independently verified with material appropriate for that calibration. A record should be kept of the verification measurements for quality assurance and to identify long-term instrument drifts. Verification measurements should be used to periodically update the calibration data when the comparison with predicted quantities is satisfactory. Calibration of the system is not acceptable when the NDA predicted value (NDA) does not agree with the measured value (VER) to within the value of the combined limits of error (LE):

$$NDA - VER \leq (LE_{NDA}^2 + LE_{VER}^2)^{1/2}$$

Calibration data and hypotheses should be reinvestigated when this criterion is not satisfied. For detailed discussion of calibration and measurement control procedures, see Regulatory Guide 5.53, "Qualification, Calibration, and Error Estimation Methods for Nondestructive Assay,"* which endorses ANSI N15.20-1975, "Guide to Calibrating Nondestructive Assay Systems."

Assay values should be periodically checked through an independent measurement using a technique sufficiently accurate to resolve the assay uncertainty. Periodically, a container of scrap or waste should be randomly selected for verification. Once selected, the NDA analysis should be repeated a minimum of five times to determine the precision characteristics of the system. The contents of that container should then be independently measured using a technique sufficiently accurate to check the NDA.

*A proposed revision to this guide has been issued for comment as Task SG 049-4.

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Suggested Reading

American National Standards Institute and American Society of Testing Materials, "Standard Test Methods for Nondestructive Assay of Special Nuclear Materials Contained in Scrap and Waste," ANSI/ASTM C 853-79.

This document provides further details on procedures for assaying scrap and waste.

DRAFT VALUE/IMPACT STATEMENT

1. PROPOSED ACTION

1.1 Description

Licensees authorized to possess at any one time more than one effective kilogram of special nuclear material (SNM) are required in paragraph 70.58(f) of 10 CFR Part 70 to establish and maintain a system of control and accountability to ensure that the limit of error of any inventory difference (ID) ascertained as a result of a measured material balance meets established minimum standards. The selection and proper application of an adequate measurement method for each of the material forms in the fuel cycle are essential for the maintenance of these standards.

For some material categories, particularly scrap and waste, nondestructive assay (NDA) is the only practical, and sometimes the most accurate, means for measuring SNM content. This guide details procedures acceptable to the NRC staff to provide a framework for the utilization of NDA in the measurement of scrap and waste components generated in conjunction with the processing of special nuclear materials (SNM).

The proposed action is to revise Regulatory Guide 5.11, originally issued in October 1973, which is still basically sound.

1.2 Need for the Proposed Action

Regulatory Guide 5.11 was published in 1973. The proposed action is needed to bring the guide up to date with respect to advances in measurement methods, as well as changes in terminology.

1.3 Value/Impact of the Proposed Action

1.3.1 NRC Operations

The experience and improvements in technology that have occurred since the guide was issued will be made available for the regulatory procedure. Using these updated techniques should have no adverse impact.

1.3.2 Other Government Agencies

Not applicable.

1.3.3 Industry

Since industry is already applying the methods and procedures discussed in the guide, updating these should have no adverse impact.

1.3.4 Public

No impact on the public can be foreseen.

1.4 Decision on the Proposed Action

The guide should be revised.

2. TECHNICAL APPROACH

Not applicable.

3. PROCEDURAL APPROACH

3.1 Procedural Alternatives

Procedures that may be used for the proposed action include the following:

- Regulation
- Revision of a regulatory guide
- ANSI standard, endorsed by a regulatory guide
- Branch position
- NUREG-series report

3.2 Value/Impact of Procedural Alternatives

Since a regulatory guide already exists and modifications are minimal, the simplest procedure is to revise the guide.

3.3 Decision on Procedural Approach

A revised regulatory guide should be prepared.

4. STATUTORY CONSIDERATION

4.1 NRC Authority

The proposed action falls under the authority of the Atomic Energy Act through the Commission's regulations in § 70.51 of 10 CFR Part 70.

4.2 Need for NEPA Assessment

The proposed action is not a major action that may significantly affect the quality of the human environment and does not require an environmental impact statement.

5. RELATIONSHIP TO OTHER EXISTING OR PROPOSED REGULATIONS OR POLICIES

The proposed action is one of a series of revisions of existing regulatory guides on nondestructive assay techniques.

6. SUMMARY AND CONCLUSION

A revised guide should be prepared to bring Regulatory Guide 5.11 up to date.

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