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Standard Guide for the Selection, Training and Qualification of Nondestructive Assay (NDA) Personnel[1]

This standard is issued under the fixed designation C1490; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide contains good practices for the selection, training, qualification, and professional development of personnel performing analysis, calibration, physical measurements, or data review using nondestructive assay equipment, methods, results, or techniques. The guide also covers NDA personnel involved with NDA equipment setup, selection, diagnosis, troubleshooting, or repair. General guidelines for the selection, training, and qualification of NDA auditors are included as well, but at a lower level of detail due to the variability of the personnel's responsibilities performing this functions. Selection, training, and qualification programs based on this guide are intended to provide assurance that NDA personnel are suitably qualified and experienced personnel (SQEP) to perform their jobs competently. This guide presents a series of options but does not recommend a specific course of action.

This standard guide does not address the qualifications per se of an NDA Manager. However, it is expected that the NDA Manager is familiar with NDA techniques, and can make informed decisions on the acceptability of the assay results. If an NDA Manager does not have adequate technical qualifications in the NDA field, they are recommended to undergo training to gain familiarity in this area.

An NDA Manager with no relevant NDA experience should have access to a Senior NDA Professional who will give guidance for all technical decisions such as applicability and limitation of methods, reasonableness of results, needed upgrades and advantageous development investments.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1030 Test Method for Determination of Plutonium Isotopic Composition by Gamma-Ray Spectrometry

C1133 Test Method for Nondestructive Assay of Special Nuclear Material in Low-Density Scrap and Waste by Segmented Passive Gamma-Ray Scanning

C1207 Test Method for Nondestructive Assay of Plutonium in Scrap and Waste by Passive Neutron Coincidence Counting

C1221 Test Method for Nondestructive Analysis of Special Nuclear Materials in Homogeneous Solutions by Gamma-Ray Spectrometry

C1268 Test Method for Quantitative Determination of Americium 241 in Plutonium by Gamma-Ray Spectrometry

C1316 Test Method for Nondestructive Assay of Nuclear Material in Scrap and Waste by Passive-Active Neutron Counting Using ^{252}Cf Shuffler

C1455 Test Method for Nondestructive Assay of Special Nuclear Material Holdup Using Gamma-Ray Spectroscopic Methods

C1458 Test Method for Nondestructive Assay of Plutonium, Tritium and ^{241}Am by Calorimetric Assay

C1493 Test Method for Non-Destructive Assay of Nuclear Material in Waste by Passive and Active Neutron Counting Using a Differential Die-Away System

C1500 Test Method for Nondestructive Assay of Plutonium by Passive Neutron Multiplicity Counting

C1514 Test Method for Measurement of ^{235}U Fraction Using Enrichment Meter Principle

C1592 Guide for Nondestructive Assay Measurements

C1673 Terminology of C26.10 Nondestructive Assay Methods

C1718 Test Method for Nondestructive Assay of Radioactive Material by Tomographic Gamma Scanning

C1726 Guide for Use of Modeling for Passive Gamma Measurements

3. Terminology

3.1 Refer to Terminology C1673 for definitions used in this test method.

[1] This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.10 on Non Destructive Assay.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards*volume information, refer to the standard's Document Summary page on the ASTM website.

4. Significance and Use

4.1 The process of selection, training and qualification of personnel involved with NDA measurements is one of the quality assurance elements for an overall quality NDA measurement program.

4.2 This guide describes an approach to selection, qualification, and training of personnel that is to be used in conjunction with other NDA Quality Assurance (QA) program elements. The selection, qualification and training processes can vary and this guide provides one such approach.

4.3 The qualification activities described in this guide assume that NDA personnel are already proficient in general facility operations and safety procedures. The training and activities that developed this proficiency are not covered in this guide.

4.4 This guide describes a basic approach and principles for the qualification of NDA professionals and technical specialists and operators. A different approach may be adopted by the management organization based on its particular organization and facility specifics. However, if a variation of the approach of this guide is applied, the resulting selection, training, and qualification programs must meet the requirements of the facility quality assurance program and should provide all the applicable functions of Section 5.

4.5 This guide may be used as an aid in the preparation of a Training Implementation Plan (TIP) for the Transuranic Waste Characterization Program (TWCP).

4.6 This guide describes education and expertise guidance for NDA auditors due to the importance and complexity of proper oversight of NDA activities.

5. NDA Roles, Responsibilities, and Duties

5.1 The application and use of NDA techniques includes such diverse activities as data review and analysis; measurement control activities; equipment operation, troubleshooting and repair; all require different levels of education, expertise, and training. Therefore the implementation and continued successful application of an NDA measurement program requires a complex mixture of theory, experience, and professional judgement. For NDA professionals, a wide variety of skills and knowledge areas is required. These knowledge areas include: physics, chemistry, statistics, NDA modeling methods, electronics, engineering, health physics, quality assurance, nuclear safety, and appropriate regulatory requirements. For technical specialists and operators, less emphasis can be put on formal education, but would be compensated for by higher levels of job specific training.

5.2 Based on roles and responsibilities, NDA personnel can be broken into the following categories. These are not necessarily job titles and some facilities may combine one or more levels. The activities exist in a broader organizational context.

5.2.1 *Senior NDA Professional:*

5.2.1.1 *Education*—Advanced degree (M.S. or Ph.D.) in physics, chemistry, or nuclear engineering and five years NDA experience; or fifteen equivalent years of experience in the NDA field.

5.2.1.2 *Expertise*—Expertise in most or all NDA techniques. Recognized nationally as an expert in one or more NDA fields through publications, peer reviewed by other subject matter experts (SMEs), active participation in national NDA conferences or conducting NDA training courses. Knowledge areas cover most of those listed in 5.1. Core expertise in one or more of the following areas, and familiarity with the others: Test Methods C1030, C1133, C1207, C1221, C1268, C1316, C1455, C1458, C1493, C1500, C1514, Guide C1592, Terminology C1673, Test Method C1718, and Guide C1726 are applicable. The senior professional must adhere to t good practices for performing NDA measurements and data analysis to achieve quality results, as described in Guide C1592 (Standard Guide for Making Quality Nond-Destructive Assay Measurements). The senior professional must possess relevant technical knowledge of the physical and chemical properties of the materials being assayed, when available. In-depth knowledge of analysis algorithm's applicability to the assay conditions (and limitations) for the NDA methods used is required. . Knowledge of computational codes used for modeling, for example MCNP and MCNPX, may be necessary.

5.2.1.3 *Duties*—Designs NDA measurement programs, including method selection and instrument performance specification. Performs NDA technical oversight over the entire program. Performs initial calibrations, qualifications and certifications for instruments and methods. Provides expert technical data review. Provides consultation on NDA matters to various facility departments and organizations such as nuclear safety, safeguards, nuclear materials control and accountability, waste characterization, waste disposal and production operations. Provides mentoring to other job categories.

5.2.2 *NDA Professional:*

5.2.2.1 *Education*—Undergraduate degree in physical science or engineering and five years NDA experience; or ten equivalent years of experience in the NDA field.

5.2.2.2 *Expertise*—Expertise in one or more NDA techniques. Recognized in NDA field on a local or facility basis. Knowledge areas cover several of those listed in 5.1. Understanding of the NDA methods contained in one or more of the following: Test Methods C1030, C1133, C1207, C1221, C1268, C1316, C1455, C1458, C1493, C1500, C1514, Guide C1592, Terminology C1673, Test Method C1718, and Guide C1726, are essential. The professional must be a practitioner of good practices for performing NDA measurements and data analysis to achieve quality results, as described in Guide C1592 (Standard Guide for Making Quality Nondestructive Assay Measurements).

5.2.2.3 *Duties*—Provides expert technical data review, and NDA measurement oversight. Performs routine instrument qualification, calibration, and validation. Reviews and approves measurement control data. Provides consulting on NDA matters within his or her area of expertise to various facility departments and organizations such as nuclear safety, safeguards, nuclear materials control and accountability, waste characterization, waste disposal, production operations. Mentors technical specialists and operators.

5.2.3 *NDA Technical Specialist:*

5.2.3.1 *Education*—Undergraduate degree or equivalent with emphasis in the physical sciences and one year NDA experience or a 12–year General Education (High School) and two years NDA experience; or five equivalent years of experience in the NDA field.

5.2.3.2 *Expertise*—Knowledgeable in one or more NDA techniques. Knowledge areas may cover one or more of those listed in 5.1.

5.2.3.3 *Duties*—Independent technical data review; instrument calibration, and validation. Performs measurement control activities, instrument operation. Provides first response to instrument problems, upset conditions. Performs troubleshooting.

5.2.4 *NDA Qualified Instrument Operator:*

5.2.4.1 *Education*—a 12–year general education (high school) or equivalent technical training, or two years of experience in the nuclear facility field.

5.2.4.2 *Expertise*—Trained and qualified in operation of one or more NDA instruments.

5.2.4.3 *Duties*—Operation of NDA instrument. Recording of NDA data and other duties as qualified and assigned.

5.3 The hierarchy described above is only one set of possible tiers. Other tiered hierarchies providing equivalent functions are equally valid. The important consideration is the increasing level of required expertise and independence of action with increasing job level function. Based on site-specific practices and policies, the four levels presented above may be collapsed or expanded and the duties listed may move to other tiers in the hierarchy.

5.4 In addition to the NDA personnel described above, the services of other specialists are often required. These include statisticians to help establish measurement uncertainties, control limits, etc. Also, personnel trained in the maintenance and repair of electronic and mechanical systems may be required. In all cases, the value of the services provided by these specialists is enhanced if they have a basic understanding of NDA methods and instruments.

5.5 *Roles, Responsibilities, and Duties of NDA Auditors:*

5.5.1 *NDA Auditor:*

5.5.1.1 *Education*—Undergraduate degree or equivalent with emphasis in the physical sciences and two years experience in the nuclear facility field; or an under graduate degree in an unrelated field and four years experience in the nuclear facility field.

5.5.1.2 *Expertise*—Trained and qualified nuclear facility auditor. Demonstrated basic physics knowledge relevant to detection of neutrons and gamma rays. Familiarity with the NDA methods contained in those of the following that apply to personnel being audited: Test Methods C1030, C1133, C1207, C1221, C1268, C1316, C1455, C1458, C1493, C1500, C1514, Guide C1592, Terminology C1673, Test Method C1718, and Guide C1726; and the good practices for performing NDA measurements and data analysis to achieve quality results, as described in Guide C1592 (Standard Guide for Making Nondestructive Assay Measurements) is necessary.

5.5.1.3 *Duties*—Audits of NDA measurement process, application, results, and compliance typically related to, radioactive waste, safeguards or nuclear criticality.

6. Selection

6.1 The selection of NDA personnel should be a careful and thoughtful process that recognizes the responsibilities that are unique to the NDA position. The selection process should include an evaluation of the NDA candidate's technical skills, as well as the individual's experience and past performance relative to the position requirements.

6.2 The attributes, characteristics, and skills used as criteria for selecting NDA candidates or trainees should include demonstrated qualities such as: judgment, motivation, integrity, communication skills, teamwork skills, diagnostic skills, analytical ability, and strong technical competence.

6.3 The NDA organization should have a selection process for initial hiring and promoting of personnel. This process may involve a selection test, in addition to interviews. Selection should be based on the ability to meet position qualification criteria with reasonable amounts of training.

7. Training

7.1 A training program should be established to develop and enhance the skills, knowledge, and abilities of NDA trainees to perform their job assignments. The program should consist of a combination of classroom-type and on-the-job training (OJT) and should include laboratory training (for those facilities that have laboratory facilities), as it applies to the NDA position.

7.2 Full implementation of an NDA training program requires a long-term commitment from both the NDA personnel and management. Training activities should be carefully managed to produce effective results.

7.3 Each NDA organization should assess its training needs to develop a facility-specific training program. It is important to implement a systematic method to update training program content to incorporate facility modifications, operating experiences, procedure changes, and changes in job requirements.

7.4 The complete training program for NDA personnel may include courses offered by national laboratories, commercial vendors, universities, and other centers of excellence. The necessity for this type of training will depend on the roles and responsibilities of the NDA personnel.

7.5 Table 1 contains a list of training categories that are necessary for effective NDA application. Each training category includes a list of academic components for that training area. Table 1 is not intended to be comprehensive for all situations. Site-specific training plans shall be evaluated against the training categories listed in Table 1 and any academic content exclusion must be justified (for example, a site only stores sealed items so holdup measurements are never performed).

7.5.1 Different job responsibilities require different levels of understanding and mastery of the contents listed in Table 1. Recommended level of training for each training category are included in the last column of Table 1 for the six personnel categories listed in 4.2. Any requirement for advanced training within a training category presupposes basic knowledge or training has already been obtained.

TABLE 1 List of major training categories and academic components for each category. Due to the variability from site to site these listings are not intended to be comprehensive for all situations.

Training Category	Itemized Contents	Recommended Level of Training by NDA Personnel Category
Nuclear Theory	Radioactivity; Radiation Interactions	Basic: Specialist, Operator, Auditor Advanced: Senior Professional, Professional
NDA Measurement	Radiation Detectors & Counters; Spectroscopy; Energy Resolution; Collimation, Shielding, & Background; Spectrum Processing; Counting Statistics; Limits of Detectability; Measurement Control; Quality Assurance; Selection of Method	Basic: Specialist, Operator, Auditor Advanced: Senior Professional, Professional
Nondestructive Assay Methods	Gamma-Ray Spectrometry; Active & Passive Neutron Counting; X-Ray Fluorescence; Isotopic Composition; Solution Concentration; Generalized Geometry Holdup	Basic: Operator, Specialist, Auditor Advanced: Senior Professional, Professional
Instrument Calibration & Maintenance	Instrument Configuration & Setup; Calibration Schemes; Calibration Standards; Curve Fitting; Diagnostics	Basic: Specialist, Auditor Advanced: Senior Professional, Professional
Calculations & Correction Factors	Fundamental Equations & Relationships; Modeling & Sampling; Correction Factors; Measurement Uncertainty; MDA	Basic: Specialist, Auditor Advanced: Senior Professional, Professional
NDA Software[A]	Maestro; Gamma Vision; ISOTOPIC; ISOCS; HMS4; NaIGEM; WINU235, INCC, MultiCal, FRAM, MGA/U; Genie 2000 as examples	Basic: Specialist, Auditor Advanced: Senior Professional, Professional
ProcessFacility Knowledge[A]	Facility Process Flow; Process Chemistry; Packaging and Containers	Basic: Senior Professional, Professional, Auditor
Understanding of Customer Needs, Requirements, and Applications[A]	Nuclear Criticality Safety, Nuclear Material Accountability, Waste Management	Basic: Senior Professional, Professional Advanced: Auditor (at minimum site discipline being audited)

[A] Normally facility dependent.

7.5.2 Extensive relevant curriculum and course development has occurred throughout the Department of Energy (DOE) contractor sites for more than 40 years. Many of the DOE developed courses content has been replicated by numerous countries, commercial companies, and individual sites within countries. Independent development of relevant curriculum and courses throughout the world has also occurred.

7.5.2.1 Appendix X1 provides a crosswalk between existing DOE courses and meeting basic and advanced training requirements for each training category. Descriptions of the course content are also included. The level of availability of these courses is not addressed or implied by their inclusion in the listings.

7.6 Senior NDA Professionals should conduct mentoring sessions with NDA trainees to discuss and promote areas that include commitment to high standards of performance. These sessions may be conducted in either a one-on-one setting, or as small group activities, as appropriate. In addition, the Senior NDA Professional should demonstrate and maintain their expertise and leadership by participation in oral boards, annual performance evaluations, training plan and learning objectives development, interacting with peers in other institutions, attending technical conferences etc.

8. Qualification

8.1 Qualification is attained by demonstrating that an individual has satisfied the education, experience, training and other special requirements necessary for the performance of assigned responsibilities. Qualification is the result of the process of personnel selection and training required to effectively accomplish the duties of an NDA position or perform an NDA task.

8.2 Qualification for NDA personnel should be documented. The process for progressing through the levels of qualification, frequency for and renewal of qualification, and personnel record keeping should be defined and documented. NDA organizations should describe the authority, duties, and responsibilities of each NDA professional or technician as they apply to NDA activities.

8.3 Training should be conducted, evaluated, and documented through the use of qualification guides, discussion outlines, or checklists. Some portions of initial training may also be accomplished through the on-the-job instruction by an NDA professional. Training may also include specific training by other departments in associated knowledge areas such as safeguards, measurement control, material accountability, and nuclear safety.

8.4 Auditable records of each individual's participation and performance in, or exception(s) granted from, the training program(s) should be maintained. Training records should identify the qualification date and continuing training requirements to maintain qualification and should include the following (as appropriate):

NDA education, experience, employment history,

Training programs completed and qualification(s) achieved,

Correspondence relating to exceptions granted to training requirements (including justification and approval),

Attendance records for required training courses or sessions, and

Latest completed checklists, graded written examinations, and operational evaluations used for qualification.

9. Keywords

9.1 education; instruments; measurements; NDA auditor; NDA professional; software; training courses

APPENDIXES

X1. Basic and Advanced Training Course Curriculum Descriptions

X1.1 Content of the required basic and advanced training courses is critical to a successful training program. In this appendix course curriculum descriptions or existing courses meeting the curriculum needed will be provided. The details of the existing courses referenced in this Appendix are provided in Appendix X2.

X1.1.1 There exist numerous centers of excellence within the United States and throughout the world. The focus on available DOE training is justified by: the maturity of the course content, length of time many of the courses have been available, the number of US and foreign nationals that have taken the courses, the direct applicability of the courses to the training described in Table 1, and the number of replicate courses that have been developed based on the DOE courses. Only two sites within the DOE complex have a nearly comprehensive suite of courses that could fulfill a majority of the training categories. These sites are Los Alamos National Laboratory (LANL) and Oak Ridge National Laboratory (ORNL).

X1.2 Courses that could fulfill basic training requirements for the Nuclear Theory, NDA Measurement, NDA Assay Methods, and Calculations & Correction Factors Training Categories listed in Table 1 are noted below.

X1.2.1 Basic training requirements could be met by taking “Fundamentals of Nondestructive Assay” (LANL) or “Basic Non-destructive Assay (NDA)” (ORNL). Additional NDA technique specific course(s) may be required to meet the training requirements of NDA Assay Methods category.

X1.2.2 Advanced training requirements for gamma ray, neutron, or holdup NDA, respectively, could be met by taking courses such as “Advanced Hands-On Gamma-Ray Nondestructive Assay Techniques” (LANL), “Advanced Hands-On Neutron Nondestructive Assay Techniques” (LANL), or “Nondestructive Assay Holdup Measurements of Uranium and Plutonium Materials Training” (LANL) or “Principles of Nuclear Material Process Holdup” (ORNL). Other NDA technique specific course(s) may be required depending on the site specifics (that is, “Plutonium Calorimetric Assay” LANL would be adequate to meet any basic or advanced training requirement for a site using calorimetry). It is also recommended all NDA Professionals take one or more statistics courses such as “Statistical Concepts in Nuclear Safeguards” (LANL).

X1.3 *Instrument Calibration & Maintenance and NDA Software Training Categories:*

X1.3.1 Basic training requirements would be best met with site-specific training tailored to the instrumentation and software used by the site and/or site level training developed and presented by suitably qualified and experienced personnel (SQEP) provided by the site, another site, qualified private contractors, or commercial vendors. Basic operation, functionality, and proper applicability must be included in the curriculum, at a minimum.

X1.3.1.1 Training on a single version of software would not qualify the individual to operate additional versions of the software without additional training on what is different and what is the same in the two or more software versions. It is recommended the version of software most commonly used on site be used for training.

X1.3.2 Advanced training requirements could be met via the same methods described in X1.3.1 for the basic training but full functionality of the software and underlying mathematical equations used to calculate any values necessary for application of the given technique (for example, calibration constants, reported uncertainty values) must be included in the curriculum. It is recommended any calculations performed by the software be performed manually at least once.

X1.3.2.1 In the case that the mathematical calculations cannot be performed manually a suitable surrogate calculation should be performed.

X1.4 *Process/Facility Knowledge Training Category:*

X1.4.1 Basic training requirements would be best met with site-specific training tailored to the site and facilities that would be accessed. This basic training should include all of the information necessary to perform NDA measurements within the facility safely and securely. Additional information required to perform proper measurements could include information such as expected contaminates in the process, form and composition of process material streams, form and composition of waste streams, radioactive material storage locations, keeping in mind activities outside the building boundaries and on other floors of the building could affect measurement results.

X1.5 *Understanding of Customer Needs, Requirements, and Applications Training Category:*

X1.5.1 Basic training requirements would be best met with site-specific training tailored to the organizations being supported. "Facility Systems for Accounting and Control of Nuclear Materials‖ (ORNL) would be useful for those supporting MC" programs.

X1.5.2 Advanced training requirements would be best met with site-specific training. Training such as "Material Accounting for Nuclear Safeguards" (LANL) or "Waste and Residue Nondestructive Assay (NDA) Measurements" (LANL) would provide valuable advanced training if MC" or Waste Management was being supported by NDA or audited.

X2. Description of Courses Listed in Appendix X1

X2.1 By providing LANL and ORNL course descriptions and course objectives (when available) individuals or organization that do not have access to these courses can determine if other available courses contain the recommended content. The courses listed for both institutions are only those that are mentioned in Appendix X1, these are not comprehensive lists. All of the information contained in Appendix X2 is publically available information provide by the instutions.

X2.2 LANL Courses:

X2.2.1 *Fundamentals of Nondestructive Assay*

X2.2.1.1 *Course Content*—This course is an introduction to the NDA of uranium and plutonium-bearing materials using gamma-ray, neutron, and calorimetry measurement techniques. The course is intended to provide students with the knowledge needed to apply the appropriate measurement techniques to solve various NDA problems. A wide range of laboratory exercises are performed during the course to provide students with first hand experience with these techniques including: Uranium enrichment measurements; Transmission-corrected gamma-ray assay measurements of plutonium; Neutron singles counting; Active neutron coincidence counting of Uranium; and Passive neutron coincidence counting of Plutonium. Activities involve the use of radioactive materials.

X2.2.2 *Material Accounting for Nuclear Safeguards*

X2.2.2.1 *Course Description*—This course covers methods for designing and implementing conventional and near-real-time accounting systems for safeguarding nuclear material. Lecture topics include basic materials accounting concepts, the structure of safeguards systems, measurement technology, measurement control, statistical basis of materials accounting, nuclear material holdup, materials accounting at specific types of facilities, materials control and accountability MC&A system decision analysis and detection sensitivities, and international safeguards. Short workshops are conducted on topics such as NDA measurement technology, measurement statistics, simulation of materials accounting, measurement controls, and error propagation.

X2.2.3 *Statistical Concepts in Nuclear Safeguards*

X2.2.3.1 *Course Description*—This course is designed around a processing facility and a storage facility. Realistic data are used for the throughputs and inventories. The instruction emphasizes the proper statistical treatment of sampling plans and detection probability. Topics addressed for the processing facility include near-real-time accountancy with small and large balance areas, propagation and analysis of variance, quality control for measurements, sample exchange programs, shipper-receiver differences, measurement challenges with heterogeneous materials, and statistical concepts in designing NDA methods. Additional topics include statistical difficulties from poorly estimated error variances, fluctuating holdup, and assessment of the possibility of undeclared activities. There will be a brief review of basic statistical concepts including hypothesis testing, regression, and inferences about population parameters using sample statistics.

X2.2.3.2 *Course Objectives*—Describe a wide range of statistical techniques for analyzing materials accounting data. Prepare participants to apply statistical methods to evaluate materials accounting data. Identify procedures to ensure statistically sound and consistent materials accounting data. Describe the use of statistical techniques to address difficult measurement problems and to identify declared activities.

X2.2.4 *Plutonium Calorimetric Assay*

X2.2.4.1 *Course Description*—This course provides a comprehensive overview of the theory and application of calorimetric assay to plutonium bearing materials. Lectures and laboratory exercises provide individualized instruction and hands-on experience. Topics include principles and applications of heat-flow calorimeters for determining the thermal power emitted from plutonium and tritium, high-resolution gamma-ray measurements for calculating isotopic composition and specific power, the conversion of measured thermal power into an assay result, techniques to increase calorimeter throughput, and the development and application of heat standards and measurement control.

X2.2.4.2 *Course Objectives*—Establish familiarity with the basic concepts of calorimetric. Provide hands-on-experience with application of calorimetric measurements.

X2.2.5 *Advanced Hands-On Gamma-Ray Nondestructive Assay*

X2.2.5.1 *Instructional Scope*—This training course presents a wide range of gamma-ray measurement techniques that are used for a number of different purposes (that is, material safeguards, criticality safety, and waste segregation) domestically, within the DOE complex, and globally by the IAEA and other International nuclear regulatory agencies. The training course includes the following topics: Elements of Gamma-Ray Nondestructive Assay (NDA); Basics Concepts and Methods in Gamma-Ray Spectrometry and Spectroscopy; The Measurement of Uranium Enrichment; The Measurement of Plutonium Isotopic Composition; Transmission-Corrected Gamma-Ray Assay of Special Nuclear Materials; Gamma-Ray Assay of Inhomogeneous Nuclear Materials.

X2.2.5.2 *Curriculum Overview*—The overall goal of this training course is to provide students with an in-depth understanding of the use of gamma-ray spectrometry and spectroscopy to nondestructively measure and analyze primarily special nuclear materials and other radionuclides of interest. This includes an understanding of the calculations to convert raw detector data to mass values and the ability to set up, operate, and troubleshoot gamma-ray detector systems. Provide hands-on measurement experience with advanced, high-resolution gamma-ray assay systems. Demonstrate advanced NDA instrumentation and methodologies developed for critical Materials Control Protection & Accounting (MCP&A) applications. Provide an understanding of measurement physics and data analysis techniques for application to various NDA problems.

X2.2.6 *Advanced Hands-On Neutron Nondestructive Assay Techniques*

X2.2.6.1 *Course Description*—This course covers neutron-based methods for the NDA of nuclear materials. Topics include passive and active coincidence counting techniques and data corrections; passive multiplicity counting calibration and data correction procedures; californium shuffler-based delayed neutron counting; and neutron-generator-based multiplicity analysis and pulse-arrival-time recording electronics. Lectures cover the underlying principles of these techniques. Hands-on laboratory exercises illustrate the techniques with appropriate nuclear material samples in an interactive workshop format.

X2.2.7 *Waste and Residue Nondestructive Assay (NDA) Measurements*

X2.2.7.1 *Instructional Scope*—This course is designed to provide students with in-depth knowledge of waste and residue assay requirements for safeguards and waste characterization requirements to met waste acceptance criteria. Lectures and laboratory exercises will cover neutron and gamma-ray-based waste and residue NDA techniques.

X2.2.7.2 *Curriculum Overview*—The overall goal of this training course is to provide students with an in-depth knowledge of generic nondestructive assay techniques and instrumentation applicable to waste assay and categorization. Laboratory sessions are provided in which students will have the opportunity to gain hands-on experience in applying these techniques. Upon successful completion of this course students will: have a better understanding of current DOE safeguards and characterization issues associated with waste and residue measurements, have built a knowledge base to better choose between different waste and residue measurement techniques in the future, and have obtained the knowledge needed to select and apply appropriate measurement techniques to the waste and residue materials present in your facilities.

X2.2.8 *Nondestructive Assay Holdup Measurements of Uranium and Plutonium Materials Training*

X2.2.8.1 *Instructional Scope*—This course covers applying basic NDA techniques and field-portable instruments to measure nuclear material holdup deposits in process equipment and ductwork. Laboratory exercises emphasize procedures for measuring uranium and plutonium holdup, using calibrated gamma-ray instrumentation, and applying a generalized-geometry approach. Measurements are performed on simulated deposits using special nuclear material (SNM) standards inserted within items (pipes, ducts, tanks, blenders, etc.) that represent process equipment hardware. Equipment attenuation, geometric effects, and self-attenuation effects are also covered. Laboratory experiments are supplemented with lectures on topics related to holdup measurements. Activities involve the use of radioactive materials.

X2.2.8.2 *Curriculum Overview*—The overall goal of this training course is to provide students with an in-depth knowledge of generic nondestructive assay techniques and instrumentation used to assay uranium or plutonium holdup. This includes an understanding of the generalized-geometry approach for measuring and determining uranium and plutonium holdup. Laboratory sessions are provided in which you will have the opportunity to gain hands-on experience in applying these techniques through the use of portable, inspector-oriented instruments.

X2.3 ORNL Courses:

X2.3.1 *Facility Systems for Accounting and Control of Nuclear Materials*

X2.3.1.1 *Description*—Explains how to establish accounting and control systems at a facility to report to a national system. Includes demonstrations of accounting and control instruments and procedures.

X2.3.2 *Basic Non-destructive Assay (NDA)*

X2.3.2.1 *Description*—Basic NDA course for students who will be performing as NDA technicians or beginning to mid-level professionals. This course provides overviews of fundamentals of radiation physics (correction techniques, error propagation, measurement bias calculation). It also includes measurement and quantification of radionuclides by gamma-ray spectrometry and neutron coincidence counting.

X2.3.3 *Principles of Nuclear Material Process Holdup Description*

X2.3.3.1 *Description*—"Holdup" is the residual amount of Special Nuclear Material (SNM) remaining in a processing facility after the bulk materials have been cleaned out. Good accounting and control of materials in process streams is vital to prevent theft/diversion, loss to the environment, and unidentified/unmeasured waste and to minimize inventory differences in the process. This course applies and builds upon techniques covered in Basic NDA to perform accountability assays, taking into account material composition and distribution, intervening absorbers between source and detector, and interferences from background radiation.