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Criteria for the Operation of Federally-Owned Secondary Calibration Laboratories (Ionizing Radiation)

E. H. Eisenhower, Editor

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PREFACE

This document contains standards of performance for laboratories that calibrate instrumentation used to measure ionizing radiation. These standards may be used as criteria on which a decision is based regarding accreditation of a particular laboratory. Satisfaction of these criteria, along with any additional requirements imposed by an accrediting body, results in an accreditation that formally acknowledges a demonstrated high level of competence.

These criteria were developed by a group of representatives of federally-owned laboratories that perform the calibration functions addressed by this document. As presented here, the criteria represent a consensus of those knowledgeable individuals with regard to the actions and conditions necessary for the assurance of quality. Active participants in the preparation of these criteria, and the laboratory or agency each represented at the time of participation, were

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Although these criteria were developed by representatives of federally-owned calibration laboratories, they are not limited to application in the federal sector. Application in the state or private sectors is suitable also, and would result in achievement of a similar high level of performance by those laboratories.

The National Institute of Standards and Technology (formerly the National Bureau of Standards) is actively supporting the development of a secondary level of calibration laboratories for ionizing radiation measurements. Such laboratories can provide a high-quality link between the physical measurement standards maintained by NIST and those who make routine measurements at the field level. Since the criteria contained in this publication represent a significant step in the development of a national system of secondary laboratories, NIST is pleased to make them generally available for use.

NOTE REGARDING UNITS

It is the policy of NIST to use the modern metric system of measurement units (International System of Units: abbreviated as SI) in all publications. Units used with the International System and units in use temporarily, as recognized in NIST Special Publication 330, are acceptable. Included in those two categories are the following units in this document:

Quantity	Unit Name	Unit Symbol	Value in SI units
time	hour	h	1 h = 3600 seconds
energy	electronvolt	eV	1 eV = 1.602 $\times 10^{-19}$ joule (J)
exposure	roentgen	R	1 R = 2.58 $\times 10^{-4}$ coulomb/kilogram
absorbed dose	rad	rad	1 rad = 10^{-2} gray (Gy)
dose equivalent	rem	rem	1 rem = 10^{-2} sievert (Sv)

Although use of the roentgen, rad, and rem is temporarily acceptable, a timely transition to SI units is desirable. Therefore this document will show the SI equivalent in parentheses wherever feasible.

The SI units indicated above will be shown for the quantities absorbed dose and dose equivalent. However, since the quantity exposure is being phased out, the SI unit coulomb/kilogram will not be shown in this document. It has no special name, it is inconvenient (especially for exposure rate), and its definition is not consistent with other physical quantities. The quantity exposure will be replaced with the quantity air kerma, which has the SI unit joule/kilogram (J/kg) with the special name gray (Gy): 1 Gy = 1 J/kg.

Although the factor used for conversion from exposure in roentgens to air kerma in grays depends slightly on photon energy, that variation is insignificant for the purposes of this document and a single value will be used:

air kerma (in grays) = 0.00878 times exposure (in roentgens)

When a rounded value of exposure is given, the SI equivalent value of air kerma will be rounded also (e.g., 10 mR/h $\approx$ 90 μGy/h).

CRITERIA FOR THE OPERATION
OF FEDERALLY-OWNED SECONDARY CALIBRATION LABORATORIES

PART A - GENERAL CRITERIA

1. INTRODUCTION

This document contains the criteria for accreditation of federally-owned laboratories that calibrate ionizing radiation instrumentation (as defined in the glossary). Adherence to these criteria will assure that the laboratory is capable of high standards of performance in the calibration of instrumentation for use in various radiation environments.

The criteria contained in Part A of this document shall be satisfied by all laboratories seeking accreditation. In addition, each laboratory shall satisfy the specific criteria contained in other parts of this document for each category (radiation type and energy) for which accreditation is desired.

2. LABORATORY MANAGEMENT AND STAFF

2.1 Management

The technical director of the laboratory shall have a position in the organizational structure which assures the authority to conduct laboratory operations free from any influence that could adversely affect the quality or impartiality of the services offered. This individual shall have a minimum of a bachelor's degree in physics, engineering, health physics, or radiological physics, and should have a graduate degree in one of these or a closely related scientific field. This individual shall understand the laboratory protocol, be responsible for assuring that it is being followed, and shall at least annually evaluate staff competence and the need for training.

The laboratory technical director shall be responsible for verification at least annually that documented procedures are properly being followed and check the correctness of calibration of individual instruments. A complete record of such checks shall be maintained and available for audit.

The individual in charge of day-to-day operation of the laboratory shall have at least 3 years of practical experience in radiation measurement, including the calibration of radiation instrumentation.

2.2 Technical Staff

The technical staff employed in calibration work shall have appropriate training or experience, be adequately supervised and follow documented procedures. Each such individual shall understand that responsibility for the correctness of a calibration lies with the individual performing it.

3. PHYSICAL ASPECTS OF THE LABORATORY

3.1 Location

The effect of external conditions on the internal environment of the laboratory shall be considered in selection of the laboratory site. The laboratory should be sited away from, or otherwise isolated from, sources of mechanical vibration and shock, sources of electrical and electromagnetic interference, and other potential sources of interference with the proper calibration of instrumentation. If such potential sources exist, the laboratory shall have documentation that demonstrates no adverse effects on calibration accuracy.

3.2 Environment

Environmental monitoring equipment shall be provided for indicating the temperature, atmospheric pressure, and humidity within the laboratory at all times.

In general, strict temperature control is not essential for the calibration work covered by these criteria. It is, however, desirable that the laboratory be kept at reasonably uniform temperature so that the accuracy of calibration is not adversely affected and to ensure that an adequate level of stability is reached before the start of calibration measurements. The laboratory temperature should be maintained within the range of 20 to 24 °C. When using a vented ionization chamber, the temperature shall not vary more than ± 2 °C in any one hour during which a calibration is conducted.

The relative humidity should be within the range of 15 to 65 percent for routine laboratory operation.

The level of background radiation shall be maintained as low as practicable and not subject to variations that could significantly affect the accuracy of calibration work. Radiation sources not used for calibration should not be stored in the radiation room.

3.3 Services

The electrical power shall be appropriate to the equipment used, suitably stable, and free of switching surges and significant line noise. When necessary, local auxiliary voltage stabilizers and filters shall be provided.

The laboratory shall be provided with an adequate grounding system. Where there is a likelihood of interference arising from equipment connected to a single grounding system, separate grounding systems shall be provided and adequate precautions taken against any possible interconnection between systems.

If compressed air is used, a pressure regulator and means for removing moisture, dust, and oil from the compressed air should be provided.

4. CALIBRATION FACILITIES AND EQUIPMENT

4.1 Facilities

The laboratory shall have free-air conditions for all radiation beams used for calibrations.

The radiation room (or rooms) shall be of sufficient size and design that room-scattered radiation at the position where instrumentation is normally placed for calibration does not introduce an error inconsistent with overall accuracy goals. If necessary, proper scatter corrections shall be applied.

4.2 Equipment

The equipment available in the laboratory shall be appropriate to the calibration services offered and the procedures employed in the calibrations. Specific requirements for each service provided are given in appropriate parts of this document.

No new equipment shall be put into service until it has been properly checked and, where appropriate, calibrated.

The laboratory shall have secondary radiation measurement standards that cover the range of calibrations performed. The secondary standards should be used only for calibration of instruments and not for any other purpose. A working standard should be used in lieu of a secondary standard for routine reference.

The laboratory shall have a barometer capable of one percent accuracy and a thermometer capable of ± 1 °C accuracy. Each shall have been calibrated by comparison with a tertiary or higher-level standard. A hygrometer capable of monitoring over the range of relative humidity within which the laboratory operates shall be available.

The laboratory shall have an instrument and radiation source positioning system. The support shall be rigid and enable the reproduction of a desired source/detector geometry. It shall produce minimum scattered radiation.

All equipment used in the laboratory that was calibrated prior to the initial accreditation of the laboratory, and all subsequent replacements for those items of equipment, shall be subject to a documented program for quality control, and shall be recalibrated as necessary.

5. OPERATIONAL PROCEDURES

5.1 Laboratory Protocol

The laboratory shall have a written protocol. Each page of the protocol shall indicate the date of inception or revision. The protocol shall include the following:

1. A statement of the scope of the laboratory's work, including all of the radiation types, energies, and intensities for which calibrations are provided.

2. A statement of policy regarding acceptance of instrumentation for calibration. Examples are policy regarding instruments that are contaminated, in need of repair, or of a particular type not accepted. Restrictions on type of customer or liability for instrument damage should also be stated.

3. A statement of the laboratory's accuracy goals for the calibrations it performs. These accuracies shall be in terms of deviations from a national standard.

4. A method of documenting the model and serial number of each critical piece of equipment that is used in any calibration.

5. The procedure for calibrating each piece of laboratory support equipment and a statement of the conditions under which recalibration is to be performed.

6. A fully documented procedure for each type of instrumentation calibrated. The procedure shall provide the appropriate operational steps to permit a knowledgeable person to reproduce a particular calibration technique with a precision consistent with the accuracy goals of the laboratory. Each calibration procedure shall give the following information, as a minimum:

a. A concise but complete account of the procedure.

b. The scope and limitations of the procedure.

c. Any environmental constraints that must be met in calibrating the instrumentation, in addition to those stated in 3.2.

d. The sequence of the calibration procedure, drawing attention to special precautions.

e. The equipment and standards to be used in this calibration procedure.

f. An example of a completed data sheet (or computer record) for the calibrated instrumentation.

g. The method of data handling and reduction.

7. An assessment of the uncertainty associated with each calibration procedure. The total systematic and total random uncertainties shall be determined separately (at a specified confidence level) by combining the individual systematic or random uncertainties in quadrature. The total uncertainty shall be determined by combining the total systematic and total random uncertainties, and the method used for that combination shall be stated.

8. An example of a completed calibration report, including a statement of the accuracy to which the reference value of the radiation field is known.

9. The procedure or reference for auditing calibration data and approving reports.

10. The procedure to ensure the security of calibration records.

5.2 Amendments to Procedures and Protocol

Any new or amended calibration procedure that could have a significant effect on the accuracy of a calibration shall be evaluated by the accrediting body before it is adopted for routine use. A copy of the latest revision of the laboratory's protocol shall be available for audit at all times.

5.3 Notification of Mistakes

If the laboratory discovers a mistake in a calibration report that significantly affects the accuracy of the calibration, the person or institution that received the report shall be notified within 24 hours, if possible, and a written report of the mistake sent to that person or institution within 72 hours. The mistake shall be corrected as soon as possible by sending a corrected calibration report or recalibrating the instrumentation. The laboratory shall determine the reason for the mistake and take corrective action to prevent its reoccurrence.

If the laboratory discovers an apparent generic error in one of its procedures or in the design of an item of instrumentation that has or could lead to an erroneous calibration, it shall notify the accrediting body in writing within 10 days. Other accredited laboratories may then be notified of the problem, along with recommendations for remedial action.

6. ACCURACY AND QUALITY ASSURANCE

6.1 Calibration of Laboratory Standards

The standards or equipment originally calibrated by comparison with a higher-level standard shall be recalibrated when the need is demonstrated by the results of proficiency testing or routine quality control.

6.2 Accuracy of Services

The laboratory shall be capable of providing calibration services with accuracies as indicated in the appropriate parts of this document. Each accuracy shall be stated in terms of percent deviation from the national standard.

6.3 Quality Control

The laboratory's procedures shall be designed and operations conducted to discover undesired changes in the performance of equipment on which the quality of a calibration depends. Such quality control procedures, and the frequency of their use, shall be specified in the laboratory's protocol.

The laboratory's proficiency shall be tested annually by the National Institute of Standards and Technology (NIST) for those types of calibrations provided by the laboratory. Each proficiency test shall be representative of one or more types of calibration for which the laboratory is accredited (see Appendix A). If the test results indicate that corrective action is required, the laboratory shall take action to achieve the accuracy stated in the appropriate part of this document.

7. RECORDS AND REPORTS

7.1 Record System

A comprehensive and readily available record system shall be maintained by the laboratory and shall include at least the following:

1. A full history and calibration data, including certificates, for all standards and applicable calibration equipment.

2. An inventory of all standards and calibration equipment.

3. All procedures used for providing calibration services.

4. A bound day-book, or other equivalent record, in which is recorded a description, sufficient for identification, of every item of instrumentation for which a calibration service was provided and the date that the calibration was performed. The day-book or other record shall also include or reference a detailed report for that specific calibration.

5. Information essential to the analysis and reconstruction of the calibration of a specific item of instrumentation.

6. A record of routine quality control actions and any resultant control charts.

7. Copies of all calibration reports issued.

8. The results of all proficiency testing.

9. Records detailing the education, experience, and training of all operating staff and supervisory personnel.

All records of data shall identify the individual who collected the data on which the record is based. Records for all individual items of instrumentation calibrated shall be maintained for a period of at least five years. Records regarding calibration of standards used shall be maintained for a period of at least 50 years.

If calibration data are stored in a computer, the laboratory protocol shall specify how backup is provided (i.e., data protection procedures).

7.2 Calibration Reports

A calibration report shall be issued for each item of instrumentation calibrated under the scope of accreditation, including an appropriate statement clearly specifying the conditions (e.g., orientation of the detector) under which the calibration was performed. It should also state limitations to the calibration, i.e., maximum range calibrated if less than the indicated range of an instrument, scales not calibrated, application of correction factors, etc.

The uncertainty associated with the calibration shall be stated.

Calibration reports shall be reviewed for technical accuracy and shall be signed by the laboratory technical director or designated alternate.

CRITERIA FOR THE OPERATION
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PART B - CALIBRATION OF SURVEY INSTRUMENTS

PART B.1 - GAMMA-RAY CALIBRATION OF SURVEY INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of health physics instruments at radiation protection levels using one or more gamma-ray sources. These criteria are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if this gamma-ray calibration service is offered and its inclusion in the Scope of Accreditation is desired.

2. SOURCES OF GAMMA RADIATION

One or more of the following radiation sources shall be available for use in the calibration of health physics instruments:

Radionuclide	Nominal Energy
^{241}Am	60 keV
^{137}Cs	660 keV
^{60}Co	1.25 MeV

The radiation fields produced by the sources shall cover a range of exposure (air kerma) rates suitable for protection-level calibration. A minimal range is 1 mR/h to 5 R/h (9 μGy to 40 mGy/h); and, a more desirable range is 0.5 mR/h (4 μGy/h) to at least 100 R/h (0.9 Gy/h).

3. RADIATION CONTROL

3.1 Shielding

Radiation barriers and/or storage containers for sources shall provide sufficient shielding so that radiation added to natural background radiation in the calibration area is sufficiently low as to not interfere with ongoing calibration work. Added background radiation and leakage radiation from all sources in the calibration area should not contribute more than 1 percent of the total exposure (air kerma) rate at which an instrument is calibrated.

3.2 Beam Collimation

The gamma radiation beam emitted from a source that has been exposed for calibration shall be collimated so that its size is limited to an area consistent with calibration requirements. An exception to this requirement is calibration facilities sufficiently large to provide a low room-scatter radiation environment for instrument calibration, e.g., an uncollimated source in a low scatter room.

3.3 Source Exposure

The source storage container shall have a mechanism to control exposure in the gamma beam. If the radiation source is used for calibration of exposure (air kerma) measuring (as contrasted with exposure-rate (air kerma-rate) measuring) instruments, the shutter or source transit time and its effect on the total radiation exposure (air kerma) shall be known.

3.4 Exposure Control

If the radiation source is used for the calibration of exposure (air kerma) measuring instruments (see 3.3, above), the shutter or source transfer shall be initiated and terminated by a timer or the exposure (air kerma) shall be controlled by use of a transmission chamber. Any associated systematic timing uncertainties shall be documented and eliminated or compensated.

4. EQUIPMENT

In addition to one or more radiation sources and associated control devices, the laboratory shall have as a minimum the following equipment:

a. Secondary standard ionization chambers suitable for the photon energy and intensity ranges for which calibration services are offered.

b. An electrometer to measure the charge produced in the ionization chambers.

c. A voltage source suitable for chamber polarizing potential.

d. An independent measuring system for verification of the performance of the secondary standard ionization chambers and electrometer.

e. An instrument and ionization chamber support and positioning system. The system should provide for reproducible and accurate positioning of an instrument or chamber with respect to the radiation source. For beam type irradiation configurations, the positioning system should define the central axis of the gamma beam.

Additional equipment should include a pulse generator, oscilloscope, current source, precision capacitors and precision resistors.

5. CHARACTERIZATION OF THE RADIATION FIELD

5.1 Exposure Rate (Air Kerma Rate)

The gamma radiation field used for calibration shall be characterized in terms of exposure (air kerma) rate at a given position or distance from the source. The exposure (air kerma) rate shall be known at each distance used.

5.2 Scattered Radiation

The effect of room-scattered radiation (relative to a radiation field with minimal room scatter) on the accuracy of calibration of each instrument type shall be known at each location where a detector is placed for instrument calibration.

5.3 Attenuation

If an attenuator is used to reduce the exposure (air kerma) rate at any location in the radiation field, the effect of the altered radiation spectrum (relative to an unattenuated radiation spectrum) on the accuracy of calibration of each instrument type shall be known. The approximate energy spectrum of the attenuated radiation field should be known. Secondary electron equilibrium at the calibration position shall be documented.

5.4 Accuracy

The exposure (air kerma) rate specified by the laboratory as its reference value for each source of radiation shall be within 5 percent of the true value as defined by comparison with a national standard above 10 mR/h (90 μGy/h), and within 7 percent of the true value from 0.5 mR/h (4 μGy/h) to 10 mR/h (90 μGy/h). This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

6. CALIBRATION REPORT

An instrument calibration report shall include, as a minimum, the radionuclide or photon energy used, the reference exposure (air kerma) rate or rates at which the instrument was calibrated, the exposure (air kerma) rate indicated by the instrument, and the correction factor at each calibration point. In the case of integrating instruments, in addition to the radionuclide and exposure (air kerma) rate, the reference exposure (air kerma), instrument reading, and correction factor shall be included. At least one calibration point should be included for each range of the instrument, where applicable. The orientation of the instrument with respect to the radiation beam shall be described or illustrated in the calibration report, and the use of a build-up cap shall be noted. For instruments that use a vented ionization chamber, the reported values shall be referenced to a temperature of 22 °C and a barometric pressure of 760 mm Hg, and the equation needed to convert to other temperatures and pressures shall be provided.

CRITERIA FOR THE OPERATION
OF FEDERALLY-OWNED SECONDARY CALIBRATION LABORATORIES

PART B.2 — X-RAY CALIBRATION OF SURVEY INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of health physics instruments at radiation protection levels using an x-ray source. These criteria are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if this x-ray calibration service is offered and its inclusion in the Scope of Accreditation is desired.

Criteria for calibration of instruments for diagnostic levels using an x-ray source are contained in Part E.

2. SOURCE OF X RAYS

A constant potential x-ray generator shall be available for use in the calibration of health physics instruments. Its maximum ripple shall not exceed 2 percent and it should be operable over a minimum range of 30 to 150 kV, 1 to 10 mA.

3. CONTROL OF THE RADIATION BEAM

3.1 Radiation Production

The production of a useful beam of radiation may be by means of the application of high voltage to the x-ray tube or the opening of a mechanical shutter (which normally acts as a shield to the x-ray beam).

3.2 Beam Collimation

The x-ray beam emitted from the tube housing shall be collimated so that its size is limited to an area consistent with calibration requirements. Provision shall be made for identifying the central axis, and the boundaries of the useful area of the beam shall be known.

3.3 Exposure Control

If the radiation source is used for the calibration of exposure (air kerma) measuring instruments, the radiation beam shall be controlled by a timer or the exposure (air kerma) shall be controlled by use of a transmission chamber. The timing error due to the shutter transit times or high voltage ramping shall be known.

4. EQUIPMENT

In addition to one or more x-ray machines and associated control devices, the laboratory shall have the same minimum equipment as that required for gamma ray calibration (see Part B.1, Section 4) with the following exception - the secondary standard ionization chambers shall be appropriate to the energy and intensity of x rays for which calibration services are offered.

Additionally, the laboratory shall be equipped with filters to permit the production of a variety of x-ray beam qualities (see paragraph 5.3, below).

5. CHARACTERIZATION OF THE RADIATION FIELD

5.1 Exposure Rate (Air Kerma Rate)

The x-ray radiation field used for calibration shall be characterized in terms of exposure (air kerma) rate at a given position or distance from the anode of the x-ray tube. The exposure (air kerma) rate shall be known at each distance used. During calibration of an instrument, the exposure (air kerma) rate shall not vary by more than 2 percent from the nominal rate when it is 10 mR/h (90 μGy/h) or higher, and shall not vary by more than 4 percent from the nominal rate when it is below 10 mR/h (90 μGy/h).

5.2 Scattered Radiation

The effect of room-scattered radiation (relative to a radiation field with minimal room scatter) on the accuracy of calibration of each instrument type shall be known at each location where a detector is placed for instrument calibration.

5.3 Radiation Quality

The x-ray beam emitted from the tube housing shall be filtered before use to provide the appropriate radiation quality for calibration purposes. If a transmission chamber is used for routine beam monitoring, it shall be considered to be added filter material. Three or more of the beams shown in table 1 shall be available.

The first half-value layer and homogeneity coefficients for a given x-ray beam shall be within 5 percent, and 7 percent, respectively, of the values shown in table 1. If necessary the indicated tube voltage or added filter, or both, may be adjusted to achieve those values.

The intensity of the x-ray beam shall not vary more than 5 percent across the useful area of the beam.

The radiation quality shall be checked for stability at least annually. Whenever any part that could affect the beam quality is repaired or replaced the above requirements for radiation quality shall be met.

5.4 Accuracy

The exposure (air kerma) rate specified by the laboratory as its reference value for each x-ray beam shall be within 5 percent of the true value as defined by comparison with a national standard above 10 mR/h (90 μGy/h). and within 7 percent of the true value from 0.5 mR/h (4 μGy/h) to 10 mR/h (90 μGy/h). This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

6. CALIBRATION REPORT

An instrument calibration report shall include, as a minimum, the x-ray beam used for calibration, the reference exposure (air kerma) rate or rates at which the instrument was calibrated, the exposure (air kerma) rate indicated by the instrument, and correction factor at each calibration point. In the case of integrating instruments, in addition to the x-ray beam and exposure (air kerma) rate, the reference exposure (air kerma), instrument reading, and correction factor shall be included. At least one calibration point should be included for each range of the instrument, where possible. The orientation of the instrument with respect to the radiation beam shall be described or illustrated in the calibration report. For instruments that use a vented ionization chamber, the reported values shall be referenced to a temperature of 22 °C and a barometric pressure of 760 mm Hg, and the equation needed to convert to other temperatures and pressures shall be provided.

TABLE 1. Characteristics of X-Ray Beams

Beam Code	Critical Characteristics(1)				Relevant information(2)					
	Half-Value Layer		Homogeneity Coefficient		Added Filter				Effective Energy	Distance
	Al (mm)	Cu (mm)	Al	Cu	Al (mm)	Cu (mm)	Sn (mm)	Pb (mm)	(keV)	(cm)
L10	0.029		79		0.					25
L15	0.050		74		0.					25
L20	0.071		76		0.					50
L30	0.22		60		0.265					50
L40	0.49		57		0.50					50
L50	0.75		58		0.639					50
L80	1.83		58		1.284					50
L100	2.8		59		1.978					50
M20	0.152		79		0.230					50
M30	0.36		64		0.50					50
M40	0.73		66		0.786					50
M50	1.02	0.032	66	62	1.021					50
M60	1.68	0.052	68	64	1.51					
M100	5.0	0.20	72	55	5.0					
M150	10.2	0.67	87	62	5.0	0.25				
M200	14.9	1.69	95	69	4.1	1.12				
M250	18.5	3.2	98	86	5.0	3.2				
M300	22.	5.3	100	97	4.0		6.5			
H10	0.048		89		0.105					25
H15	0.152		87		0.500					25
H20	0.36		88		1.021					50
H30	1.23	0.038	93	94	4.13					50
H40	2.9	0.093	94	95	4.05	0.26				50
H50	4.2	0.142	92	90	4.0			0.10	38	
H60	6.0	0.24	94	89	4.0	0.61			46	
H100	13.5	1.14	100	94	4.0	5.2			80	
H150	17.0	2.5	100	95	4.0	4.0	1.51		120	
H200	19.8	4.1	100	99	4.0	0.60	4.16	0.77	166	
H250	22	5.2	100	98	4.0	0.60	1.04	2.72	211	
H300	23	6.2	99	98	4.1		3.0	5.0	252	

(1)The half-value layer and homogeneity coefficient shown for a beam shall be matched by the laboratory within limits prescribed by pertinent parts of these criteria. In the beam code, the letter indicates light, moderate, heavy filtration, and the number is the constant potential in kilovolts.

(2)This information relates specifically to the NIST beams, and may provide useful guidance to a laboratory that is seeking accreditation. The inherent filtration of the NIST beams is approximately

1.0 mm Be for beam codes L10-L100, M20-M50, H10-H40, and
3.0 mm Be for beam codes M60-M300, H50-H300.

PART B.3 — BETA-PARTICLE CALIBRATION OF SURVEY INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of health physics instruments at radiation protection levels using a beta particle source. These criteria are limited to the calibration of instruments used to measure dose rate from external beta sources and are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if this beta-particle calibration service is offered and its inclusion in the Scope of Accreditation is desired.

2. SOURCE OF BETA PARTICLES

The selection of a source for beta particle calibration of an instrument will depend both on the nature of the radiation field in which the instrument is to be used and the anticipated energy of the beta radiation. It is recommended that both point sources and distributed sources be available for instrument calibration since they represent the extremes of measurement geometry. The radionuclides listed in table 2 are recommended for use as reference sources for beta calibration; however, other sources may be used if they more accurately represent the beta energy spectrum in which the calibrated instrument is to be used.

The laboratory shall have at least the following radionuclide sources of beta particles:

^{147}Pm, ^{204}Tl, and ^{90}Sr/Y.

These sources shall comply with the ISO 6980 standard.

TABLE 2. Characteristics of Beta-Particle Sources

Radionuclide	E_{max} (keV)	Half-Life (years)
^{147}Pm (a)	225	2.62
^{99}Tc	290	~ 2×10^5
^{85}Kr	670	10.8
^{36}Cl	710	~ 3×10^5
^{204}Tl	763	3.8
^{90}Sr/Y (b)	2270	28.5
Natural U	2290	~ 4×10^9
Depleted U	2290	~ 4×10^9
^{106}Ru/Rh	3540	1.0

(a) ^{147}Pm usually also contains ^{146}Pm, which has an E_{max} = 780 keV.

(b) The source should be sealed with 100 mg/cm^2 (nominal) filtration to remove the ^{90}Sr beta component.

3. RADIATION BEAM CONTROL AND PARAMETERS

3.1 Radiation Production

The production of a beam (field) of beta radiation for instrument calibration may be achieved by means of a shutter exposing the source or by moving the source to an exposed position.

3.2 Beam Parameters

The physical size of the beta ray beam (field) shall have been predetermined to assure that it is sufficiently large to accommodate the instrument being calibrated. Provision shall be made for identifying the central axis, and the boundaries of the useful area of the beam shall be known. If necessary, beam flattening filters may be used to meet the requirements of paragraph 5.4.

3.3 Timer

If the radiation source is used for the calibration of fluence measuring instruments, the radiation beam shall be controlled by a timer. The timing error due to the shutter transit times shall be documented and eliminated or compensated.

4. EQUIPMENT

In addition to an appropriate selection of beta particle sources, the laboratory shall have the same minimum equipment as that required for gamma ray calibration (see Part B.1, Section 4); however, in this case the secondary standard ionization chamber shall be a thin-window fixed volume ionization chamber or an extrapolation chamber. The extrapolation chamber or thin-window ionization chamber response shall have been verified by the NIST or by comparison to NIST or PTB calibrated beta radiation sources and have an accuracy equivalent to that described in paragraph 5.5, below, over the anticipated range of irradiation conditions, i.e., beta energy and depth of dose measurement point.

5. CHARACTERIZATION OF THE BETA RADIATION FIELD

5.1 Dose Rate

The beta radiation fields used for calibration shall be characterized in terms of absorbed dose rate (at a depth in tissue of 7 mg/cm^2) at a given position or distance from the source. The dose rate shall be known at each distance used. Similarly, if calibrations are to be done at other tissue depths (for example, at 300 mg/cm^2 to simulate exposure of the lens of the eye, rather than 7 mg/cm^2 for the skin), then the dose rate at these depths shall be known.

5.2 Attenuation

In order to assure that the energy of the beta radiation that reaches the detector is similar to that originating from the radionuclide, certain limits on the calibration conditions are recommended. If E_{res} refers to the residual maximum energy of a beta particle reaching the detector of an instrument and E_{max} is the energy at which the beta particle originates, then the conditions shown in table 3 should be met.

TABLE 3. Limiting Conditions for Beta Particles

E_{max}	E_{res}/E_{max}
<100 keV	$\geqslant$ 0.6
100 - 800 keV	$\geqslant$ 0.7
>800 keV	$\geqslant$ 0.8

These conditions are recommended so that no undue attenuation from the source's self-absorption, containment, beam flattening filters, or air attenuation will significantly change the radionuclide's beta spectrum. The procedure for determining E_{res} is given in the ISO 6980 standard.

5.3 Contamination

In addition to the radiation quality considerations on which the preceding paragraphs impact, source contamination by other radionuclides may significantly change the beta or gamma radiation field from a source. Small levels of beta contamination are difficult to detect but fortunately are usually accompanied by gamma contamination. The beta spectral purity is considered adequate if the following hold:

1. The plot used to measure R_{res} has a linear section, and;

2. The E_{res} value meets the criteria in table 3.

For requirement 1 above, R_{res} is the range in an absorbing material of a beta spectrum of residual maximum energy, E_{res}. The procedure for measurement of R_{res} is given in the ISO 6980 standard.

Measurement to determine the adequacy of beta spectral purity shall be made every 2 years, or more often if needed.

Photon contamination of the beta field due to sources of gamma, x-ray, and bremsstrahlung radiation should contribute less than 5 percent of the total absorbed dose.

5.4 Uniformity of Beta Field

The beta dose rate should be uniform over the area of the detector face. The dose rate across the beam profile at a depth of 7 mg/cm^2 should not vary more than 5 percent from the mean dose rate for E_{res} greater than or equal to 300 keV, and not more than 10 percent for E_{res} less than 300 keV. The uniformity of the beta field shall be verified by measurement with a small area detector or film.

5.5 Accuracy

The dose rate specified by the laboratory as its reference value for each beta-particle beam shall be within 10 percent of the true value as defined by comparison with a national standard. This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

6. CALIBRATION REPORT

An instrument calibration report shall include, as a minimum, the radionuclide and radiation field type (point source or flat field) used for calibration, the reference dose rate or rates at which the instrument was calibrated, and the dose rate (or dose) indicated by the instrument at each calibration point. The orientation of the instrument with respect to the radiation beam shall be described or illustrated in the calibration report. The report should state whether the front face or the effective center of the detector was located at the point where the reference field was characterized.

PART B.4 - NEUTRON CALIBRATION OF SURVEY INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of health physics instruments at radiation protection levels using neutron radiation. These criteria are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if this neutron radiation calibration service is offered and its inclusion in the Scope of Accreditation is desired.

2. SOURCE OF NEUTRON RADIATION

The selection of a source for neutron radiation calibration of an instrument will depend on the nature of the radiation field in which the instrument is to be used, including the anticipated neutron energy spectrum. The neutron sources described in table 4 are frequently used for instrument calibration.

As a minimum, a laboratory shall have at least one of the sources shown in table 4 with appropriate strength for the dose equivalent or dose equivalent-rate range of the instruments to be calibrated. A minimum dose equivalent rate range is 10 mrem/h to 1 rem/h (0.1 to 10 mSv/h). The neutron source strength shall be certified by or traceable to the NIST. If a ^{252}Cf source is used, the laboratory shall be capable of calibrating an instrument using both the bare source and the moderated configuration.

TABLE 4. Characteristics of Commonly Used Fast Neutron Sources For Calibration of Neutron Survey Instruments (Lorenz, 1972)

Source	Method of Neutron Production	Half-life	Neutron Energy (MeV) Max.	Neutron Energy (MeV) Average
^{238}Pu (Be)	(α,n)	86.4 Y	11.3	5.0
^{239}Pu (Be)	(α,n)	24390 Y	10.74	4.5-5
^{241}Am (Be)	(α,n)	458 Y	11.5	5.0
^{252}Cf	SF	2.654 Y	15	2
^{252}Cf Moderated with 15 cm D_2O (e.g., Schwartz, 1980; Prevo, 1983)	SF	2.654 Y	15	0.54

The radiation field produced by a neutron source used for calibration shall provide an energy spectrum and dose equivalent rates appropriate for the instrument undergoing calibration.

3. RADIATION CONTROL AND PARAMETERS

3.1 Radiation Production

The production of a field of neutron radiation for instrument calibration should be achieved by moving the source from a shielded to an exposed position, preferably in a low-scatter environment in an open area or at the center of a large room (for example, 10×10 meters square with the source 4 m from both floor and ceiling). The neutron radiation field used for calibration shall be carefully monitored and controlled. The response due to room-scattered neutrons at the point of calibration should be less than 25 percent of the total instrument response, and the appropriate corrections shall be made.

3.2 Timer

If the neutron source is used for the calibration of integrated dose equivalent measuring instruments, the radiation field shall be controlled by a timer. Any associated systematic timing uncertainties shall be documented and eliminated or compensated.

4. EQUIPMENT

In addition to a selection of one or more neutron sources appropriate to the radiation field(s) for which instruments are being calibrated, the laboratory shall have the same minimum equipment as that required for gamma-ray calibration (see Part B.1, Section 4), with the exception of secondary standard ionization chambers and that equipment associated with their use. An instrument of each type calibrated should be available for the measurement of the contribution of scattered radiation to the total instrument response.

5. CHARACTERIZATION OF THE NEUTRON RADIATION FIELD

5.1 Dose Equivalent Rate

The neutron radiation field used for calibration shall be characterized in terms of the flux density (fluence rate) and spectral composition at the point of calibration. The dose equivalent rate shall be calculated on the basis of these characteristics (see table 5) as a means of setting calibration points for specific instrument types.

5.2 Radiation Quality

In addition to the radiation quality considerations on which the preceding paragraphs impact, contamination of the neutron field by other types of radiation may contribute to instrument response. If this is the case and the instrument is sensitive to photon and/or beta radiation as well as neutrons, the extent of this contamination shall be known and corrected for when calibrating a given instrument. Photon contamination of the neutron field shall be known and should be less than 20 percent of the total dose equivalent rate.

TABLE 5. Characterization of neutron sources in terms of dose equivalent

Radionuclide source	Mean neutron fluence to dose equivalent conversion factor[a]	Specific source strength	Specific neutron dose equivalent rate at 1 m[b]
	rem • cm^2	s^{-1} • Ci^{-1}	mrem • h^{-1} • Ci^{-1}
^{238}Pu(Be)		2.0×10^6	
^{239}Pu(Be)		1.5×10^6	
^{241}Am(Be)	3.8×10^{-8}	2.4×10^6	2.7
		s^{-1} • mg^{-1}	mrem • h^{-1} • mg^{-1}
^{252}Cf	3.4×10^{-8}	2.4×10^9	2.3×10^3
^{252}Cf moderated	9.1×10^{-9}	2.1×10^9	5.4×10^2

[a]The conversion factors were calculated from $\frac{1}{B}\int_0^\infty B_E\, h_\phi(E)dE$, where B is the neutron source strength, B_E is the spectral distribution of neutron source strength, and h_ϕ is the neutron fluence to dose equivalent conversion factor, i.e., the quotient of the dose equivalent and the neutron fluence, $\frac{H}{\phi}$ (Reference: ISO 8529 (1989)) (1 rem = 0.01 Sv).

[b]These are typical numbers. Dose equivalent rate from a particular source depends upon variable factors such as purity, internal absorption, construction details, and encapsulation (1 mrem = 0.01 mSv).

5.3 Accuracy

The dose equivalent rate specified by the laboratory as its reference value for each neutron field shall be within 10 percent of the true value as defined by comparison with a national standard. This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

6. CALIBRATION REPORT

An instrument calibration report shall include, as a minimum, the radionuclide and radiation field type (moderated or unmoderated) used for calibration, the free-field dose equivalent rate or rates at which the instrument was calibrated, the scatter-corrected instrument reading at each calibration point, and the basis for any calculation of dose equivalent rate from source emission rate. At least one calibration point should be included for each decade range of the instrument, where possible. The orientation of the instrument with respect to the radiation field shall be described or illustrated in the calibration report. The value of the scatter correction shall be provided.

PART B.5 - ALPHA-PARTICLE CALIBRATION OF SURVEY INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of survey instruments at radiation protection levels using alpha radiation sources. These criteria are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if this alpha-particle calibration service is offered and its inclusion in the Scope of Accreditation is desired.

2. SOURCE OF ALPHA RADIATION

Planar or pseudo planar alpha radiation sources shall be used for the purpose of calibrating instruments used for the detection of alpha contamination. A pseudo planar source is one made up of a closely spaced array of small sources. The combined thickness of the source media and overburden shall be less than one-tenth the range of the least energetic alpha particle in these media. Only the following thin sources of alpha radiation are acceptable provided their 2π alpha emission rate (per unit area) is known and traceable to a source calibrated by the National Institute of Standards and Technology.

1. Natural or depleted uranium.
2. Plutonium-238 or -239.
3. Natural thorium or thorium-230.

The radiation fields produced by the sources shall cover a range of at least three decades of alpha emission rates suitable for protection-level calibration. A recommended range is 100 alpha particles per minute (2π emission rate) to 10^6 alpha particles per minute.

3. RADIATION CONTROL

3.1 Source Exposure

Because of the short range of alpha particles in air, calibration measurements using an alpha source shall be made in such a way that the alpha radiation emitted from the source reaches the sensitive volume of the radiation detector. To assure that this is the case, there should be no shielding materials between the alpha source and the detector, other than that inherent to the detector or source itself. Additionally, the surface of the radiation detector should be no further than 3 mm from the surface of the alpha radiation source.

4. EQUIPMENT

In addition to radiation sources, the laboratory shall have as a minimum the following equipment:

(1) A source and detector support and positioning system. The system shall provide for reproducible and accurate positioning of a detector with respect to the radiation source.

(2) An independent measuring system used as a means of checking the sources for any degradation of their alpha emission rate.

5. CHARACTERIZATION OF THE RADIATION FIELD

5.1 Emission Rate

The source used for calibration shall be characterized in terms of the alpha emission rate per unit area. The boundary of the source shall be greater than that of the detector. The relative standard deviation of the emission rate averaged over every individual segment of the source shall be less than ± 6 percent. The maximum area of a segment shall be 10 cm^2, and a segment shall not exceed 10 percent of the total surface area of the source. The spacing of smaller sources to form a pseudo array shall be such that the point-to-point distance between sources is less than the range of alpha radiation in air.

5.2 Accuracy

The alpha emission rate specified by the laboratory as its reference value for each source of radiation shall be within 10 percent of the true value as defined by comparison with an appropriate standard traceable to the NIST. This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

6. CALIBRATION REPORT

An instrument calibration report shall include, as a minimum, the alpha radiation source used for calibration, the emission rate or rates at which the instrument was calibrated, and the instrument response at each calibration point. At least one calibration point and a linearity check should be included for each range of the instrument, where applicable.

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PART C - IRRADIATION OF PERSONNEL DOSIMETERS

PART C.1 - GAMMA-RAY IRRADIATION OF PERSONNEL DOSIMETERS

1. INTRODUCTION

The criteria contained in this part of the document apply to irradiation of dosimeters at radiation protection and accident levels (as defined in ANSI N13.11) using gamma-ray sources. These criteria are supplementary to the general criteria contained in Part A, and shall be followed if this specific irradiation service is offered and its inclusion in the Scope of Accreditation is desired. In that case, both the general criteria and these specific criteria shall be followed.

2. SCOPE

These criteria apply to irradiation of dosimeters used for personnel monitoring. They do not apply to dosimeters used for high-level dosimetry in applications such as radiation processing or sterilization.

3. SOURCE OF GAMMA RADIATION

One or more ^{137}Cs source(s) of gamma rays shall be available for irradiation services. The radiation fields produced by the sources shall cover a range of exposures (air kerma) suitable for protection-level irradiations. The range covered will be a function of the mission and requirements of the laboratory but 30 mR to 500 R (0.3 mGy to 4 Gy) will suffice for most radiation protection purposes.

4. CONTROL OF RADIATION BEAM

4.1 Shielding

Source storage containers shall provide sufficient shielding such that leakage radiation does not interfere with other uses of the radiation room by raising the background level. Background radiation and leakage radiation from all sources in the radiation room shall not contribute more than 0.1 percent of the total exposure (air kerma) to which dosimeters are irradiated.

4.2 Beam Size and Uniformity

The gamma beam emitted from the irradiator should be collimated so that its size is limited to the minimum area consistent with irradiation requirements. All dosimeters shall be irradiated with phantom backing, and the beam size shall be sufficient to irradiate the entire phantom surface that is facing the source. If several dosimeters are irradiated simultaneously, the beam shall be sufficiently uniform and characterized to satisfy the requirements of section 6.3.

4.3 Beam Emission Control

The irradiator shall have a built-in device to control emission of the gamma beam. It shall be possible to operate the emission control device with a timer. Any associated random timing uncertainties due to transit time of the device shall be known. Any associated systematic timing uncertainties shall be measured and eliminated or compensated.

5. EQUIPMENT

In addition to radiation source(s) and the associated beam control devices, the laboratory shall have the same minimum equipment as that required for gamma-ray calibration (see Part B.1, Section 4), plus the following:

(1) Secondary standard ionization chambers that are calibrated for ^{137}Cs gamma rays and that cover the exposure (air kerma) rate ranges used for irradiation services.

(2) A phantom consisting of a slab of polymethylmethacrylate with a minimum cross section of 30 × 30 cm and a thickness of 15 cm. The support system for the phantom shall be rigid and produce minimum scattered radiation at the dosimeter position(s).

6. CHARACTERIZATION OF THE RADIATION FIELD

6.1 Exposure Rate (Air Kerma Rate)

The gamma radiation field used for irradiation shall be characterized in terms of exposure (air kerma) rate in the absence of a phantom at the location where the center of the front surface of the phantom is placed for irradiation.

6.2 Scatter

The contribution from room-scattered radiation shall be determined with the phantom removed from the beam and shall not exceed 5 percent of the exposure (air kerma) rate at any location where a dosimeter is placed for irradiation. The approximate energy spectrum of room-scattered radiation should be known.

The relationship between shallow dose and deep dose shall be measured for each facility because the charged particle surplus or deficit is highly dependent on local scattering conditions.

6.3 Accuracy

The exposure (air kerma) rate specified by the laboratory as its reference value shall be within 3 percent of the actual value defined by comparison with the national standard. This level of agreement with the national standard shall be periodically verified through proficiency tests of the laboratory by NIST. A description of the proficiency test is given in Appendix A. The total uncertainty of the dose delivered to an irradiated dosimeter shall be less than or equal to 5 percent. To meet this criterion, it may be necessary to use position-specific correction factors when several dosimeters are irradiated simultaneously.

7. IRRADIATION CONDITIONS

7.1 Orientation

The dosimeters shall be attached to one of the two larger surfaces of the phantom, at least 5 cm from any edge of the surface, and that surface shall face the radiation source. The central axis of the collimated beam shall be perpendicular to that surface, and shall pass through its geometric center. The position and orientation of the phantom shall be reproducible and verifiable.

7.2 Distance

The distance between the radiation source and the phantom surface to which the dosimeters are attached shall be one meter or more. The distance shall be reproducible and verifiable.

8. VERIFICATION OF TOTAL EXPOSURE (AIR KERMA)

A method shall be used to verify the total exposure (air kerma) independent of the timer and known exposure (air kerma) rate.

9. CALIBRATION REPORT

The laboratory shall report to the customer the total exposure (air kerma) for each dosimeter irradiated. For conversion to deep dose or dose equivalent, the value of the exposure shall be multiplied by 1.03 for ^{137}Cs.

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PART C.2 - X-RAY IRRADIATION OF PERSONNEL DOSIMETERS

1. INTRODUCTION

The criteria contained in this part of the document apply to the irradiation of dosimeters at radiation protection levels using x-ray beam sources. These criteria are supplementary to the general criteria contained in Part A, and shall be followed if this specific irradiation service is offered and its inclusion in the Scope of Accreditation is desired. In that case, both the general criteria and these specific criteria shall be followed.

2. SCOPE

These criteria apply to the irradiation of dosimeters used for personnel monitoring.

3. SOURCE OF X-RAY IRRADIATION

At least one constant potential x-ray generator shall be available to cover a range of exposures (air kerma) for protection-level irradiations. The range covered will be a function of the mission and requirements of the laboratory but a minimal range is 30 mR to 500 R (0.3 mGy to 4 Gy). The laboratory shall be able to perform irradiations using three or more of the filtered beams described in ANSI N13.11 and DOE/EH-0027 by NIST beam codes.

4. CONTROL OF RADIATION BEAM

4.1 Shielding

Leakage radiation through a closed shutter or x-ray tubehead shielding shall be less than 0.1 percent of the open-shutter rates at the position of the dosimeters.

4.2 Beam Size and Uniformity

The x-ray beams shall be collimated and their size should be limited to an area consistent with the irradiation requirements. All dosimeters shall be irradiated with phantom backing, and the beam size shall be sufficient to irradiate the entire phantom surface that is facing the tube head. If several dosimeters are being irradiated simultaneously, the beam size and beam uniformity shall be sufficiently uniform and characterized to satisfy the requirements of section 6.4.

4.3 Exposure Control

If a shutter is used to control the beam the shutter transit time shall be known.

If a shutter is not used radiation produced prior to achieving beam stability shall be known in all cases and shall be compensated. The uncertainties associated with stabilization shall be known. Any associated systematic timing uncertainties shall be documented and eliminated or compensated.

5. EQUIPMENT

In addition to one or more x-ray machines and the associated beam control devices, the laboratory shall have the same minimum equipment as that required for gamma-ray calibration (see Part B.1, Section 4), plus the following:

(1) A phantom consisting of a slab of polymethylmethacrylate with a minimum cross section of 30 × 30 cm and a thickness of 15 cm. The support system for the phantom shall be rigid and produce minimum scattered radiation at the dosimeter position(s).

(2) Secondary standard ionization chambers appropriate to the energy and intensity of x rays for which irradiation services are offered.

6. CHARACTERIZATION OF THE RADIATION FIELD

6.1 Exposure Rate (Air Kerma Rate)

The radiation field shall be characterized in terms of exposure (air kerma) rate in the absence of a phantom at the location where the center of the front surface of the phantom is placed for irradiation.

6.2 Scatter

The contribution from room-scattered radiation shall be determined with the phantom removed from the beam and shall not exceed 5 percent of the exposure (air kerma) rate at any location where a dosimeter is placed for irradiation. The approximate energy spectrum of room-scattered radiation should be known.

6.3 Radiation Quality

The first half-value layer and homogeneity coefficients for a given x-ray beam shall be within 5 and 7 percent, respectively, of the values shown in table 1. If necessary the indicated tube voltage or added filter, or both, may be adjusted to achieve those values. If a transmission chamber is used for routine beam monitoring, it shall be considered to be added filter material.

The intensity of the x-ray beam shall not vary more than 5 percent across the useful area of the beam.

The radiation quality shall be checked for stability at least annually. Whenever any part that could affect the beam quality is repaired or replaced the above requirements for radiation quality shall be met.

6.4 Accuracy

The exposure (air kerma) rate specified by the laboratory as its reference value shall be within 3 percent of the actual value defined by comparison with the national standard. This level of agreement with the national standard shall be periodically verified through proficiency tests of the laboratory by NIST. A description of the proficiency test is given in Appendix A. The total uncertainty of the dose delivered to an irradiated dosimeter shall be less than or equal to 5 percent. To meet this criterion, it may be necessary to use position-specific correction factors when several dosimeters are irradiated simultaneously.

7. IRRADIATION CONDITIONS

7.1 Orientation

The dosimeters shall be attached to one of the two larger surfaces of the phantom, at least 5 cm from any edge of the surface, and that surface shall face the radiation source. The central axis of the collimated beam shall be perpendicular to the surface, and shall pass through its geometric center. The position and orientation of the phantom shall be reproducible and verifiable.

7.2 Distance

The distance between the radiation source and the phantom surface to which the dosimeters are attached shall be one meter or more. The distance shall be reproducible and verifiable.

8. VERIFICATION OF TOTAL EXPOSURE (AIR KERMA)

A method shall be used to verify the total exposure (air kerma) independent of the timer and known exposure (air kerma) rate.

9. CALIBRATION REPORT

The laboratory shall report to the customer the total exposure (air kerma) for each dosimeter irradiated. For conversion to dose or dose equivalent, the value of the exposure should be multiplied by the factors given in ANSI N13.11 or DOE/EH-0027. The reference(s) for the factor(s) used shall also be given.

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PART C.3 - NEUTRON IRRADIATION OF PERSONNEL DOSIMETERS

1. INTRODUCTION

The criteria contained in this part of the document apply to irradiation of dosimeters at radiation protection levels using neutron sources. These criteria are supplementary to the general criteria contained in Part A and shall be followed if this specific irradiation service is offered and its inclusion in the Scope of Accreditation is desired. In that case, both the general criteria and these specific criteria shall be followed.

2. SCOPE

These criteria apply to irradiation of dosimeters used for personnel monitoring. They do not apply to dosimeters that use neutron activation foils to determine accident level doses.

3. SOURCE OF NEUTRON RADIATION

These criteria apply to neutrons from radionuclide sources, including sources in a moderator. They do not apply to accelerator produced neutrons or neutrons from reactors. Neutron sources specified by ANSI N13.11 or DOE/EH-0027 shall be available. Additional sources may be used if their spectral distributions, neutron emission rates, and dose equivalent conversion factors are well documented. The range of dose equivalents covered will be a function of the mission and requirements of the laboratory, but 150 mrem to 5 rem (1.5 to 50 mSv) will suffice for most radiation protection purposes. All irradiations shall refer to free-field quantities and shall be performed with phantom backing.

4. CONTROL OF RADIATION FIELD

4.1 Shielding

The source storage container shall provide sufficient shielding such that leakage radiation does not interfere with other uses of the radiation room by raising the background level. Background radiation and leakage radiation from all sources in the radiation room shall not contribute more than 0.1 percent of the total dose equivalent to which dosimeters are irradiated.

4.2 Irradiation Control

A source transport system shall be provided to transport the source from the storage container to the irradiation position. Both the transit time from storage to irradiation position and the associated dose equivalent contribution to dosimeter irradiation shall be known.

It shall be possible to operate the source transport system with a timer. Any associated random timing uncertainties due to the transit time of the source shall be known. Any associated systematic timing uncertainties shall be measured and eliminated or compensated.

5. EQUIPMENT

In addition to one or more radiation sources and the associated source transport system, the laboratory shall have at least the following operable equipment available for calibration or irradiation use:

A phantom consisting of a slab of polymethylmethacrylate with a cross section of 40 × 40 cm and a thickness of 15 cm. The support system for the phantom shall be rigid and produce minimum scattered radiation at the dosimeter position(s). The system should provide for reproducible and accurate positioning of the phantom with respect to the radiation source.

6. CHARACTERIZATION OF THE RADIATION FIELD

6.1 Dose Equivalent Rates

The neutron radiation fields used for irradiation shall be characterized in terms of the free-field dose equivalent rate at the center of the front surface of the phantom. The neutron emission rate for each source shall be determined by the NIST. Procedures for determining the dose equivalent for dosimeters exposed to a ^{252}Cf source should follow Eisenhauer, Hunt, and Schwartz, "Calibration Techniques for Neutron Personnel Dosimetry," Radiat. Prot. Dosim. 10, 43 (1985). Procedures for other sources shall be documented. The contribution to the dose equivalent due to photon emission from the neutron source shall be measured and documented. There shall be verification of the expected dose-equivalent rate during irradiation.

6.2 Scatter

The contribution of air scattering, room return and source scattering shall be determined for all irradiation geometries and distances so that free-field dose equivalents can be determined. To minimize room scatter, the irradiation room should be as large as is practically possible and irradiations should be conducted near the center of the room.

6.3 Accuracy

The dose equivalent rate specified by the laboratory as its reference value shall be within 5 percent of the actual value defined by comparison with the national standard. This level of agreement with the national standard shall be periodically verified through proficiency tests of the laboratory by NIST. A description of the proficiency test is given in Appendix A. The total uncertainty in the assigned neutron dose equivalent for irradiated dosimeters shall be less than or equal to 5 percent, excluding uncertainties in the dose equivalent conversion factors and the photon component of the neutron irradiations. To meet this criterion, it may be necessary to use position-specific correction factors when several dosimeters are irradiated simultaneously.

7. IRRADIATION CONDITIONS

7.1 Orientation

The dosimeters shall be attached to one of the two larger surfaces of the phantom, at least 10 cm from any edge of the surface, and that surface shall face the radiation source. That surface shall be perpendicular to a radial line from the source center to the phantom center. The position and orientation of the phantom shall be reproducible and verifiable.

7.2 Distance

The distance between the center of the radiation source and the center of the phantom surface to which the dosimeters are attached shall be at least 50 cm. The dose equivalent shall be calculated at the location of each dosimeter. It shall be reproducible and verifiable.

8. VERIFICATION OF DELIVERED DOSE EQUIVALENT

A method shall be used to verify the delivered dose equivalent independent of the timer and known dose equivalent rate. Possible verification methods include an off-axis detector or a passive detector exposed with each irradiation.

9. CALIBRATION REPORT

The laboratory shall report to the customer the free-field dose equivalent for each dosimeter irradiated. The ratio of the dose equivalent arising from photon emission by the radiation source to the neutron dose equivalent should be reported.

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PART C.4 - BETA-PARTICLE IRRADIATION OF PERSONNEL DOSIMETERS

1. INTRODUCTION

The criteria contained in this part of the document apply to irradiation of dosimeters at radiation protection levels using beta-particle sources. These criteria are supplementary to the general criteria contained in Part A, and shall be followed if this specific irradiation service is offered and its inclusion in the Scope of Accreditation is desired. In that case, both the general criteria and these specific criteria shall be followed.

2. SCOPE

These criteria apply to irradiation of dosimeters used for personnel monitoring.

3. SOURCES OF BETA RADIATION

One or more sources of beta radiation shall be available for irradiation services. They may take the form of point sources or slab sources. The sources should meet the requirements of national or international standards (i.e., ANSI N13.11; DOE/EH-0027, ISO 6980). The dose range covered will be a function of the mission and requirements of the laboratory, but 150 mrad to 10 rad (1.5 to 100 mGy) should be sufficient for most radiation protection purposes.

4. EQUIPMENT

In addition to one or more radiation sources and the associated beam control devices, the laboratory shall have the same minimum equipment as that required for gamma-ray calibration (see Part B.1, Section 4), with the exception of secondary standard ionization chambers. They shall be replaced by an extrapolation chamber or thin-window fixed volume ionization chamber that covers the energy and intensity ranges used for irradiation services. The laboratory shall also have a phantom consisting of a slab of polymethylmethacrylate with a minimum cross section of 30 × 30 cm and a minimum thickness of 5 cm. The support system for the phantom shall be rigid and produce minimum scattered radiation at the dosimeter position(s).

5. POINT SOURCES

5.1 Control of Radiation Beam

5.1.1 Shielding

The source storage containers shall provide sufficient shielding such that leakage radiation does not interfere with other uses of the radiation room by raising the background level. Background and leakage radiation from all sources of radiation within the room shall not contribute more than 0.1 percent of the total dose to which dosimeters are irradiated.

5.1.2 Beam Size and Uniformity

The beam size shall be sufficient to irradiate the entire phantom surface that is facing the source. If several dosimeters are irradiated simultaneously the beam shall be sufficiently uniform and characterized to satisfy the requirements of section 5.2.2. The use of an appropriate flattening filter may be required to achieve this.

5.1.3 Beam Emission Control

The irradiator shall have a built-in device to control emission of the beta radiation. It shall be possible to operate the emission control device with a timer. Any associated random timing uncertainties due to transit time of the device shall be known. Any associated systematic timing uncertainties shall be measured and eliminated or compensated.

5.2 Characterization of Radiation Field

5.2.1 Dose Rate

The beta radiation field used for irradiation shall be characterized in terms of dose rate at a depth of 7 mg/cm^2 in tissue.

5.2.2 Accuracy

The dose rate specified by the laboratory as its reference value shall be within 3 percent of the actual value defined by comparison with the national standard. This level of agreement with the national standard shall be periodically verified through proficiency tests of the laboratory by NIST. A description of the proficiency test is given in Appendix A. The total uncertainty of the dose delivered to an irradiated dosimeter shall be less than or equal to 5 percent. To meet this criterion, the use of a flattening filter and/or position-specific correction factors may be required when several dosimeters are irradiated simultaneously.

5.3 Source Containment

Source containment must be sufficiently sturdy to permit its safe and routine use. At the same time, it shall be sufficiently thin to ensure the beta particle energy spectrum of sources specified in ISO 6980.

5.4 Irradiation Conditions

5.4.1 Orientation

The dosimeters shall be attached to one of the two larger surfaces of the phantom, at least 5 cm from any edge of the surface, and that surface shall face the radiation source. The central axis of the collimated beam shall be perpendicular to that surface, and shall pass through its geometric center. The position and orientation of the phantom shall be reproducible and verifiable.

5.4.2 Distance

The distance between the radiation source and the phantom surface to which the dosimeters are attached shall comply with requirements in ANSI N13.11 or DOE/EH-0027. It shall be reproducible and verifiable.

6. SLAB SOURCES

Slab sources may be used when such irradiation geometry is more appropriate than a point source irradiation geometry.

6.1 Slab Size

The dimensions of the source shall exceed the dimensions of the irradiated dosimeter including all radiation sensitive elements.

6.2 Source Characteristics

6.2.1 The slab shall have a protective covering in the range of 3 to 7 mg/cm^2 inclusive. For uranium, the dose rate at 100 mg/cm^2 divided by the dose rate at 7 mg/cm^2 shall be 0.58 ± 0.04. The in-phantom dose rate at 1000 mg/cm^2 shall be less than 3 percent of the dose rate at 7 mg/cm^2. Appropriate dosimeters shall be used to confirm these relative dose rates.

6.3 Dose Rate

The beta radiation field on or near (< 1 cm) the surface of the source shall be characterized in terms of absorbed dose rate in tissue at a depth of 7 mg/cm^2. An extrapolation ionization chamber or a thin fixed volume ionization chamber shall be used to determine the dose rate.

6.4 Accuracy

The dose rate specified by the laboratory as its reference value shall be within 3 percent of the actual value defined by comparison with the national standard. This level of agreement with the national standard shall be periodically verified through proficiency tests of the laboratory by NIST. A description of the proficiency test is given in Appendix A. The total uncertainty of the dose delivered to an irradiated dosimeter shall be less than or equal to 5 percent.

6.5 Orientation

Dosimeters shall lie flat on the source surface or be suspended parallel to the surface with a maximum source-to-dosimeter distance of 0.5 cm.

7. VERIFICATION OF DELIVERED DOSE

For point sources, a method shall be used to verify the delivered dose independent of the timer and known dose rate. Possible verification methods include an off-axis detector, a small detector embedded in a corner of the phantom or a passive detector exposed with each irradiation.

8. CALIBRATION REPORT

The laboratory shall report to the customer the total dose at 7 mg/cm^2 depth for each dosimeter irradiated.

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PART D - GAMMA-RAY SOURCE CALIBRATION FOR EXPOSURE (AIR KERMA) RATE

1. INTRODUCTION

The criteria contained in this part apply to the calibration of gamma-ray sources in terms of exposure (air kerma) rate in free air. These criteria are supplemental to the general criteria contained in Part A of this document, and are to be followed if this specific calibration service is offered and its inclusion in the Scope of Accreditation is desired. In that case, both the general and these specific criteria shall be met.

2. TYPES OF SOURCES CALIBRATED

These criteria are to allow sealed sources in transportable containers, which can be shipped easily, to be calibrated and shipped back to the user. The range of exposure (air kerma) rates shall be from 2 mR/h to 50 R/h (20 μGy/h to 0.4 Gy/h) measured at the 1 m point in free air. The following sources shall be allowed for this type of calibration: ^{241}Am, ^{137}Cs, or ^{60}Co.

3. EQUIPMENT

The laboratory shall have at least the equipment specified in Part B.1, Section 4, as well as the following equipment dedicated to calibration use:

> A source of gamma radiation greater than or equal to the activity of the radiation source to be calibrated. It shall have been calibrated in terms of exposure (air kerma) rate as a function of distance, and be subject to periodic quality assurance on at least an annual basis. Accreditation under Part B.1 precludes this requirement.

4. CONDITIONS OF CALIBRATION

4.1 Method

The calibration shall be performed by measurement of the source output using secondary standard ionization chambers or working standard ionization chambers that were calibrated against the secondary standards. The energy dependence of the standard chamber(s) shall be known over the range of photon energies to be measured.

4.2 Geometry

The source-detector geometry shall be carefully defined. Scattering (excluding that from the source and collimator) from the surroundings should be minimal and shall not exceed 10 percent of the exposure (air kerma) rate at any location where a detector is placed for source calibration. The approximate energy spectrum of scattered radiation should be known.

4.3 Attenuation

If an attenuator is used by the laboratory to deliberately reduce the exposure (air kerma) rate produced by the source, the effect of the attenuator on the energy spectrum of the gamma radiation should be known and the actual attenuation factor shall be determined by the laboratory. The effect of any electron fluence at the calibration position shall be considered.

5. SPECIFICATION OF SOURCE OUTPUT

5.1 Accuracy

The laboratory shall state the estimated uncertainty of the measured output of the source being calibrated, and this shall not exceed 5 percent total. This total uncertainty shall be calculated on the basis of a thorough analysis of possible errors. Accuracy shall be maintained through periodic intercomparison with a national standard.

5.2 Calibration Report

The calibration report shall include the following information for each source calibration:

(a) a complete description of the source-detector geometry used;

(b) the measured exposure (air kerma) rate at the distance(s) of calibration, with and without specified attenuators;

(c) a description of attenuator(s) used;

(d) the estimated uncertainty in the reported exposure (air kerma) rate.

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PART E - X-RAY CALIBRATION OF INSTRUMENTS FOR DIAGNOSTIC LEVELS

1. INTRODUCTION

The criteria contained in this part of the document apply to calibration of instruments at diagnostic radiology levels using an x-ray source. These criteria are supplementary to the general criteria and shall be followed if this specific calibration service is offered and its inclusion in the laboratory's Scope of Accreditation is desired. Both the general criteria and these specific criteria shall be followed in that case.

2. SOURCE OF X-RAYS

The laboratory shall have a constant potential x-ray machine available for calibration of instruments. It should operate at potentials from 30 to 150 kV as a minimum range. The radiation field produced shall cover, as a minimum range, exposure (air kerma) rates from 20 to 100 R/h (180 to 900 mGy/h), with a stability sufficient to calibrate instruments according to documented laboratory procedures. During calibration of an instrument, the exposure (air kerma) rate shall not vary by more than ± 1 percent.

3. CONTROL OF RADIATION BEAM

3.1 Beam Collimation

The x-ray beam emitted from the tube housing shall be collimated so that its size is limited to the minimum area consistent with calibration requirements. Provision shall be made for identifying the central axis, and the boundaries of the useful area of the beam shall be known.

3.2 Shutter

A shutter shall be used to control emission of the x-ray beam from the tube housing. If the beam is used for calibration of exposure-measuring instruments, the shutter transit time shall be known.

3.3 Exposure Control

If the x-ray beam is used for calibration of exposure (air kerma) measuring instruments, the shutter shall be operated by a timer or a suitable charge integrating device. Any associated errors due to shutter transit times shall be documented and eliminated or compensated.

4. EQUIPMENT

In addition to one or more x-ray machines and associated control devices, the laboratory shall have the same minimum equipment as that required for gamma ray calibration (see Part B.1, Section 4) with the following exception - the secondary standard ionization chambers shall be appropriate to the energy and intensity of x rays for which calibration services are offered.

Additionally, the laboratory shall be equipped with filters to permit the production of a variety of x-ray beam qualities (see paragraph 5.4, below).

5. CHARACTERIZATION OF THE RADIATION FIELD

5.1 Exposure Rate (Air Kerma Rate)

The x-ray field used for calibration shall be characterized in terms of exposure (air kerma) rate at the location where the effective center of the instrument's detector is placed for calibrations.

5.2 Scatter

The effect of room-scattered radiation (relative to a radiation field with minimal room scatter) on the accuracy of calibration of each instrument type shall be known at each location where a detector is placed for instrument calibration.

5.3 Accuracy

The exposure (air kerma) rate specified by the laboratory as its reference value shall be within ± 5 percent of the actual value defined by comparison with the national standard. This level of agreement with the national standard shall be demonstrated through periodic proficiency tests of the laboratory by the National Institute of Standards and Technology (NIST). A description of the proficiency test is given in Appendix A.

5.4 Radiation Quality

The x-ray beam emitted from the tube housing shall be filtered before use for calibration purposes. The laboratory shall provide calibration services using at least five of the following radiation qualities:

Beam Code	First Half-Value Layer Al (mm)	Cu (mm)	Homogeneity Coefficient Al	Cu	Added Filter[1] Al (mm)	Cu (mm)
M30	0.36		64		0.50	
M50	1.02	0.032	66	62	1.021	
L80	1.83		58		1.284	
L100	2.8		59		1.978	
M100	5.0	0.20	72	55	5.0	
M150	10.2	0.67	87	62	5.0	0.25

(1) The added filter thicknesses relate specifically to the NIST beams, and are provided for guidance only.

For either aluminum or copper, the first half-value layer and homogeneity coefficients for a given x-ray beam shall be within 5 percent and 7 percent, respectively, of the values shown in the above table. If necessary the indicated tube voltage or added filter, or both, may be adjusted to achieve those values. If a transmission chamber is used for routine beam monitoring, it shall be considered to be added filter material.

The intensity of the x-ray beam shall not vary more than 5 percent across the useful area of the beam.

The radiation quality shall be checked for stability at least annually. Whenever any part that could affect the beam quality is repaired or replaced the above requirements for radiation quality shall be met.

6. CALIBRATION REPORT

An instrument calibration report shall include, as a minimum, the x-ray beam used for calibration, the reference exposure (air kerma) rate or rates at which the instrument was calibrated, the exposure (air kerma) rate indicated by the instrument, and the correction factor at each calibration point. In the case of integrating instruments, in addition to the x-ray beam and exposure (air kerma) rate, the reference exposure (air kerma), instrument reading, and correction factor shall be included. One calibration point and a linearity check should be included for each range of the instrument, where possible. The orientation of the instrument with respect to the radiation beam shall be described or illustrated in the calibration report. For instruments that use a vented ionization chamber, the reported values shall be referenced to a temperature of 22 °C and a barometric pressure of 760 mm Hg, and the equation needed to convert to other temperatures and pressures shall be provided.

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PART F - CALIBRATION OF REFERENCE-CLASS INSTRUMENTS

PART F.1 - GAMMA-RAY CALIBRATION OF REFERENCE-CLASS INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of reference-class instruments at radiation protection levels using one or more gamma-ray sources. The reference-class instruments calibrated according to these criteria are intended for use by a customer and are not intended for use as working standards in the laboratory performing the calibration. These criteria are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if inclusion of this calibration service in the Scope of Accreditation is desired.

2. SOURCES OF GAMMA RADIATION

One or more of the following radiation sources shall be available for use in the calibration of reference-class instruments:

Radionuclide	Nominal Energy
^{137}Cs	660 keV
^{60}Co	1.25 MeV

The radiation fields produced by the sources should cover a range of exposure (air kerma) rates suitable for protection-level calibration.

3. RADIATION CONTROL

3.1 Shielding

Radiation barriers and/or storage containers for sources shall provide sufficient shielding so that background radiation in the calibration area is sufficiently low as to not interfere with ongoing calibration work.

3.2 Beam Collimation

The gamma radiation beam emitted from a source that is used for calibration shall be collimated so that its size is limited to an area consistent with calibration requirements. An exception to this requirement is a calibration facility sufficiently large to provide a low room-scatter radiation environment for instrument calibration, e.g., an uncollimated source in a low scatter room.

3.3 Source Exposure

The source storage container shall have a mechanism to control exposure in the gamma beam. If the radiation source is used for calibration of exposure (air kerma) measuring (as contrasted with exposure-rate (air kerma-rate) measuring) instruments, the shutter or source transit time and its effect on the total radiation exposure (air kerma) shall be known.

3.4 Exposure Control

If the radiation source is used for the calibration of exposure (air kerma) measuring instruments (see 3.3, above), the shutter or source transfer shall be initiated and terminated by a timer or the exposure (air kerma) shall be controlled by use of a transmission chamber. Any associated systematic timing uncertainties shall be documented and eliminated or compensated.

4. EQUIPMENT

In addition to one or more radiation sources and associated control devices, the laboratory shall have the same minimum equipment as that required for gamma-ray calibration (see Part B.1, Section 4).

5. CHARACTERIZATION OF THE RADIATION FIELD

5.1 Exposure Rate (Air Kerma Rate)

The gamma radiation field used for calibration shall be characterized in terms of exposure (air kerma) rate at a given position or distance from the source. The exposure (air kerma) rate shall be known at each distance used.

5.2 Scattered Radiation

The effect of room-scattered radiation (relative to a radiation field with minimal room scatter) on the accuracy of calibration of each instrument type shall be known at each location where a detector is placed for instrument calibration.

5.3 Attenuation

If an attenuator is used to reduce the exposure (air kerma) rate at any location in the radiation field, the effect of the altered radiation spectrum (relative to an unattenuated radiation spectrum) on the accuracy of calibration of each instrument type shall be known. The effect of any electron fluence at the calibration position shall be considered. The approximate energy spectrum of the attenuated radiation field should be known.

6. ACCURACY OF CALIBRATION

The chamber or instrument calibration factor specified by the laboratory for each source of radiation shall be within 3 percent of the true value as defined by comparison with a national standard. This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

7. CALIBRATION REPORT

An ionization-chamber calibration report shall include, as a minimum, the radionuclide or photon energy used, the reference exposure (air kerma) rate or rates at which the chamber was calibrated, and the calibration factor of the chamber at each calibration point in terms of exposure (air kerma) per unit charge. Orientation of the chamber with respect to the radiation beam shall be described, the polarity and magnitude of the polarizing potential shall be stated, and the use of a build-up cap shall be noted.

An instrument calibration report shall include, as a minimum, the radionuclide or photon energy used, the reference exposure (air kerma) rate or rates at which the instrument was calibrated, the exposure (air kerma) rate indicated by the instrument, and the correction factor at each calibration point. In the case of integrating instruments, in addition to the radionuclide and exposure (air kerma) rate, the reference exposure (air kerma), instrument reading, and correction factor shall be included. One calibration point and a linearity check should be included for each range of the instrument, where applicable. The orientation of the instrument with respect to the radiation beam shall be described or illustrated in the calibration report, and the use of a build-up cap shall be noted.

For a vented ionization chamber or an instrument that uses such a chamber, the reported values shall be referenced to a temperature of 22 °C and a barometric pressure of 760 mm Hg, and the equation needed to convert to other temperatures and pressures shall be provided.

PART F.2 — X-RAY CALIBRATION OF REFERENCE-CLASS INSTRUMENTS

1. INTRODUCTION

The criteria contained in this part apply to the calibration of reference-class instruments at radiation protection or diagnostic levels using an x-ray source. The reference-class instruments calibrated according to these criteria are intended for use by a customer and are not intended for use as working standards in the laboratory performing the calibration. These criteria are supplementary to the general criteria contained in Part A. Both the general criteria and these specific criteria shall be followed if inclusion of this calibration service in the Scope of Accreditation is desired.

2. SOURCE OF X RAYS

A constant potential x-ray generator shall be available for use in the calibration of reference-class instruments. Its maximum ripple shall not exceed 2 percent and it should be operable over a minimum range of 30 to 150 kV, 1 to 10 mA.

The radiation fields produced by the x-ray generator shall cover a range of exposure (air kerma) rates suitable for protection-level and diagnostic calibration. During calibration of an instrument, the exposure (air kerma) rate shall not vary by more than 1 percent from the nominal rate.

3. CONTROL OF THE RADIATION BEAM

3.1 Radiation Production

The production of a useful beam of radiation may be by means of the application of high voltage to the x-ray tube or the opening of a mechanical shutter (which normally acts as a shield to the x-ray beam).

3.2 Beam Collimation

The x-ray beam emitted from the tube housing shall be collimated so that its size is limited to an area consistent with calibration requirements. Provision shall be made for identifying the central axis, and the boundaries of the useful area of the beam shall be known.

3.3 Exposure Control

If the radiation source is used for the calibration of exposure (air kerma) measuring instruments, the radiation beam shall be controlled by a timer or the exposure (air kerma) shall be controlled by use of a transmission chamber. The timing error due to the shutter transit times or high voltage ramping shall be documented and eliminated or compensated.

4. EQUIPMENT

In addition to one or more x-ray machines and associated control devices, the laboratory shall have the same minimum equipment as that required for gamma ray calibration (see Part B.1, Section 4) with the following exception - the secondary standard ionization chambers shall be appropriate to the energy and intensity of x rays for which calibration services are offered.

Additionally, the laboratory shall be equipped with filters to permit the production of a variety of x-ray beam qualities (see paragraph 5.3, below).

5. CHARACTERIZATION OF THE RADIATION FIELD

5.1 Exposure Rate (Air Kerma Rate)

The x-ray radiation field used for calibration shall be characterized in terms of exposure (air kerma) rate at a given position or distance from the anode of the x-ray tube. The exposure (air kerma) rate shall be known at each distance used.

5.2 Scattered Radiation

The effect of room-scattered radiation (relative to a radiation field with minimal room scatter) on the accuracy of calibration of each instrument type shall be known at each location where a detector is placed for instrument calibration.

5.3 Radiation Quality

The x-ray beam emitted from the tube housing shall be filtered before use to provide the appropriate radiation quality for calibration purposes. If a transmission chamber is used for routine beam monitoring, it shall be considered to be added filter material. Three or more of the beams shown in table 1 (in Part B.2) shall be available.

The first half-value layer and homogeneity coefficients for a given x-ray beam shall be within 5 and 7 percent, respectively, of the values shown in table 1. If necessary the indicated tube voltage or added filter, or both, may be adjusted to achieve those values.

The intensity of the x-ray beam shall not vary more than 5 percent across the useful area of the beam.

The radiation quality shall be checked for stability at least annually. Whenever any part that could affect the beam quality is repaired or replaced the above requirements for radiation quality shall be met.

6. ACCURACY OF CALIBRATION

The chamber or instrument calibration factor specified by the laboratory for each x-ray beam shall be within 3 percent of the true value as defined by comparison with a national standard. This level of agreement with the standard shall be demonstrated through periodic proficiency testing by NIST. A description of the proficiency test is given in Appendix A.

7. CALIBRATION REPORT

An ionization-chamber calibration report shall include, as a minimum, a description of beam quality in terms of the codes in table 1 or an equivalent method, the reference exposure (air kerma) rate or rates at which the chamber was calibrated, and the calibration factor of the chamber at each calibration point in terms of exposure (air kerma) per unit charge. Orientation of the chamber with respect to the radiation beam shall be described, and the polarity and magnitude of the polarizing potential shall be stated.

An instrument calibration report shall include, as a minimum, the x-ray beam used for calibration, the reference exposure (air kerma) rate or rates at which the instrument was calibrated, the exposure (air kerma) rate indicated by the instrument, and the correction factor at each calibration point. In the case of integrating instruments, in addition to the x-ray beam and exposure (air kerma) rate, the reference exposure (air kerma), instrument reading, and correction factor shall be included. One calibration point and a linearity check should be included for each range of the instrument, where possible. The orientation of the instrument with respect to the radiation beam shall be described or illustrated in the calibration report.

For a vented ionization chamber or an instrument that uses such a chamber, the reported values shall be referenced to a temperature of 22 °C and a barometric pressure of 760 mm Hg, and the equation needed to convert to other temperatures and pressures shall be provided.

APPENDIX A - NIST PROFICIENCY TESTS

Section 6.3 of the General Criteria (Part A) requires that a laboratory's proficiency be tested annually by the National Institute of Standards and Technology (NIST). Each proficiency test shall be representative of one or more types of calibration for which the laboratory is accredited. This appendix provides descriptive information about those required tests.

Table A1 identifies an appropriate proficiency test for each radiation quantity addressed in the various specific criteria contained in Parts B through F. If the quantity of interest, for example, is gamma exposure (air kerma) rate, an appropriate method for conducting the test is that NIST will calibrate an ionization chamber using an identified photon source, that same chamber will be sent to the participating laboratory for its calibration, and the calibration factor obtained by the latter will be compared with that obtained by NIST. If the difference between the two results is within the limit set forth in the specific criteria (usually in the "accuracy" section), performance of the laboratory is considered to be satisfactory.

For a laboratory that is accredited under the criteria of Part C.1 for irradiation of dosimeters, the proficiency test method may involve irradiation of test dosimeters by the participating laboratory, for subsequent readout by NIST to determine whether the delivered dose was within prescribed limits, or it may involve an ionization chamber as described above.

The proficiency test method for x-ray exposure (air kerma) rate is similar to that for gamma exposure (air kerma) rate. For beta dose rate, NIST could calibrate either an appropriate source or instrument, send it to the participating laboratory for its calibration, and compare calibration results. For neutron fluence rate or dose equivalent rate an appropriate method involves calibration of a remmeter, and alpha emission rate may involve calibration of a suitable source.

One annual proficiency test may satisfy that requirement simultaneously for several specific criteria. If a laboratory is accredited, for example, to use a ^{137}Cs source for calibration of survey instruments (B.1), irradiation of personnel dosimeters (C.1), calibration of sources (D), and calibration of reference-class instruments (F.1), a single annual proficiency test could be sufficient for simultaneous satisfaction of the requirement for all four of those services. The most stringent performance level required in any one of these four specific criteria (3 percent) would, of course, have to be satisfied by the single proficiency test.

It is not feasible that an annual proficiency test for a particular radiation quantity should attempt to cover the entire range of exposure (air kerma) rates, dose rates, fluence rates, or emission rates of interest. Instead, each annual test will involve only a representative part of the possible range, with the intent of covering the complete range over a period of years.

Similarly, if a laboratory uses many of the x-ray beam codes, the annual proficiency test will not involve each code, but all codes will be covered in subsequent years.

There are a few cases where NIST does not have a radiation source similar to that used by a participating laboratory. In that case NIST may calibrate the proficiency test instrument with a surrogate source that has comparable characteristics. As an example, the ionization chamber used to test for gamma exposure (air kerma) rate may be calibrated by NIST with x rays instead of an ^{241}Am source if the participating laboratory wants to be accredited for using the latter. The energy spectrum of the x-ray beam used by NIST would approximate that from an ^{241}Am source.

The proficiency tests identified in table A1 are considered to be appropriate for their associated radiation quantities and the relevant criteria. They are not, however, intended to be an exclusive set. Proficiency tests not identified in the table may also be appropriate, and may be used when mutually acceptable to NIST and the participating laboratory.

TABLE A1. Appropriate NIST Proficiency Tests for Various Radiation Quantities

Radiation Quantity (rate)	Source	Relevant Criteria	Appropriate NIST Proficiency Test
gamma-ray exposure or air kerma	^{241}Am	B.1	ion chamber calibrated with x-rays
		D	ion chamber calibrated with x-rays
	^{137}Cs	B.1	ion chamber calibrated with ^{137}Cs
		C.1	dosimeter or ion chamber calibrated with ^{137}Cs
		D	ion chamber calibrated with ^{137}Cs
		F.1	ion chamber calibrated with ^{137}Cs
	^{60}Co	B.1	ion chamber calibrated with ^{60}Co
		D	ion chamber calibrated with ^{60}Co
		F.1	ion chamber calibrated with ^{60}Co
x-ray exposure or air kerma	NIST codes	B.2	ion chamber calibrated with appropriate beams
		C.2	dosimeter or ion chamber calibrated with appropriate beams
		E	ion chamber calibrated with appropriate beams
		F.2	ion chamber calibrated with appropriate beams
beta dose	^{147}Pm	B.3	calibrated ^{147}Pm source
	^{204}Tl	B.3	calibrated ^{204}Tl source
		C.4	calibrated ^{204}Tl source
	^{90}Sr/^{90}Y	B.3	calibrated ^{90}Sr/^{90}Y source
		C.4	dosimeter or calibrated ^{90}Sr/^{90}Y source
	^{99}Tc	B.3	calibrated ^{99}Tc source
	^{85}Kr	B.3	calibrated ^{85}Kr source
	U_{nat}	B.3	calibrated U_{nat} source
		C.4	calibrated U_{nat} source
	U_{dep}	B.3	calibrated U_{dep} source
		C.4	calibrated U_{dep} source
	^{106}Ru/^{106}Rh	B.3	calibrated ^{106}Ru/^{106}Rh source
neutron fluence or dose equivalent	^{238}Pu(Be)	B.4	remmeter calibrated with ^{241}Am(Be)
	^{239}Pu(Be)	B.4	remmeter calibrated with ^{241}Am(Be)
	^{241}Am(Be)	B.4	remmeter calibrated with ^{241}Am(Be)
	^{252}Cf	B.4	remmeter calibrated with ^{252}Cf, bare
		C.3	remmeter or dosimeter irradiated with ^{252}Cf, bare
	^{252}Cfmod	B.4	remmeter calibrated with ^{252}Cf, moderated
		C.3	remmeter or dosimeter irradiated with ^{252}Cf, moderated
alpha emission	U_{nat}	B.5	calibrated U_{nat} source
	U_{dep}	B.5	calibrated U_{dep} source
	^{238}Pu	B.5	calibrated ^{238}Pu source
	^{239}Pu	B.5	calibrated ^{239}Pu source
	Th_{nat}	B.5	calibrated Th_{nat} source
	^{230}Th	B.5	calibrated ^{230}Th source

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APPENDIX B - GLOSSARY OF TERMS

accreditation - recognition of a laboratory's competence to perform calibrations in accordance with established criteria.

accuracy - the degree of agreement of an observed value (i.e., the value indicated by a measurement process) with the true value of the quantity being measured. When expressed in percent it is calculated as

$$\text{accuracy} = \frac{\text{observed value} - \text{true value}}{\text{true value}} \times 100 \ .$$

attenuator - absorbing material intentionally placed in the path of a radiation beam to reduce its intensity.

calibration (instrument) - comparison of the response of a given instrument with the response of a standard instrument when both are exposed to the same radiation source under the same conditions; or the determination of the response of the given instrument when exposed to a known radiation field under well-defined conditions.

calibration (source) - determination of the output of a radiation source by comparison with the output of a standard source, or by the response of a standard instrument to the output of the source.

collimator - a device used to limit the size, shape, and direction of a radiation beam.

constant potential - a unidirectional voltage of essentially constant magnitude.

correction factor - the ratio of the reference value of a radiation quantity to the value indicated by an instrument, i.e., $\frac{\text{reference value}}{\text{indicated value}}$. Multiplication of the indicated value by the correction factor yields the reference value.

criteria - documented minimum performance characteristics that must be satisfied by a laboratory in order to achieve accreditation.

critical equipment - any piece of equipment that has a unique calibration (correction) factor and is used by the laboratory to provide a calibration service. Examples are a radiation source, secondary standard, and an electrometer.

error - for a particular measurement result, the difference between the measured value χ and the true value τ (i.e., $\chi - \tau$).

extrapolation chamber - an ionization chamber in which the separation of electrodes is variable, thereby enabling a series of measurements with decreasing separation so that the measured ion current per unit volume can be extrapolated to the case of infinitesimal volume.

free-air facility - a calibration facility in which the radiation emitted by the source reaches the instrument under calibration with minimal scatter from nearby structures.

free-field quantity - a radiation quantity, such as neutron dose equivalent, that has been corrected to remove contributions from scattered radiation (e.g., air scattering and room return).

half-value layer (HVL) - the thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the value of a specified radiation quantity upon transmission through the substance by one-half.

homogeneity coefficient - the ratio of the first half-value layer to the second half-value layer, multiplied by 100.

instrumentation - a generic term that includes radiation sources and instruments or devices used to measure radiation levels.

ionization chamber - a gas-filled enclosure in which ion pairs created by incident radiation are collected on electrodes.

leakage radiation - radiation other than the useful beam emitted from an x-ray tube housing or a source container.

point source - a radiation source whose maximum dimension is small compared with the source-to-detector distance used for irradiation of a dosimeter or instrument.

proficiency test - a test of the performance of a laboratory by intercomparison of the results obtained from calibration of a common instrument or radiation source by both the laboratory under test and the laboratory conducting the test.

protocol - the documented policies and procedures used by a laboratory in conduct of calibration.

quality assurance - the general program of actions taken to ensure a satisfactory level of quality in the services provided by a laboratory.

quality control - the specific, technical procedures followed routinely to detect and correct any problems that would cause a laboratory to provide services at an unacceptable level of quality.

reference-class instrument - an instrument or ionization chamber that is sufficiently precise and accurate to serve as a tertiary standard.

reference value - the value of a particular quantity (e.g., exposure or air kerma rate) that characterizes a laboratory's radiation field. It is the value to which the indicated value of an instrument under calibration is compared.

residual maximum beta energy, E_{res} - the maximum energy of the beta spectrum from all beta decay branches of a radionuclide at the calibration distance.

residual maximum beta range, R_{res} - the range in an absorbing material of a beta spectrum of residual maximum energy, E_{res}.

ripple - the periodic variation in the potential difference between the cathode and anode of an x-ray tube, resulting from rectification of an alternating current. As the ripple is decreased by the use of filtering circuits, a constant potential is more nearly approached.

scattered radiation - radiation that, as the result of interaction with matter, has had its direction changed and, for some interactions, its energy decreased.

room-scattered radiation - radiation that is scattered from the walls, floor, ceiling, or other structural part of the radiation room.

scope of accreditation - a document issued by an accrediting organization that specifies the radiation types, energies, and intensities for which a laboratory is accredited to calibrate a particular type of instrumentation.

shall - when "shall" is used in conjunction with an action or condition specified in this document, that action or condition is required to be implemented.

should - when "should" is used in conjunction with an action or condition specified in this document, that action or condition is not required to be implemented but is recommended as good practice.

slab source - a radiation source whose maximum dimension is large compared with the source-to-detector distance used for irradiation of a dosimeter or instrument.

standard - a physical realization of the unit of a quantity, used as a reference for the calibration of an instrument or a lower-level standard.

national standard - a standard that serves as the primary reference for a specified quantity in a particular country.

secondary standard - a standard that was calibrated by direct comparison with a pertinent national standard.

tertiary standard - a standard that was calibrated by direct comparison with a pertinent secondary standard.

working standard - a standard that is calibrated periodically by direct comparison with an appropriate secondary standard, and is only used for routine calibrations of instruments.

support equipment - any piece of equipment, including critical equipment, used by the laboratory to provide a calibration service.

survey instrument - a hand-held instrument used to measure ionizing radiation for purposes of radiation protection. It does not include instruments designed as area, portal, or personnel monitors, as monitors of radioactive gases or airborne particulates, or as dose or beam calibrators for medical diagnostic or therapeutic applications.

thin source - a radiation source consisting of alpha-emitting radioactive material uniformly distributed in a thin layer over the surface of a flat metallic backing plate so as to cause minimal degradation of the alpha energy spectrum.

transmission chamber - a thin-walled ionization chamber designed to monitor a radiation beam that is transmitted through the chamber with minimal attenuation or scatter.

uncertainty - the estimated limits of the error in a measurement result.

random uncertainty - that uncertainty associated with error components that can be and are estimated by a statistical analysis of repeated measurements, and which indicate the degree of precision.

systematic uncertainty - that uncertainty associated with error components that are biased, and those which may be due to random causes but cannot be or are not assessed by statistical methods.

total uncertainty - an estimate of the likely limits of the error in a measurement result, obtained by combining all of the random and systematic uncertainty components.

BIBLIOGRAPHY

American National Standards Institute (ANSI), Criteria for Testing Personnel Dosimetry Performance, ANSI N13.11-1983, American National Standards Institute, New York, NY (1983).

Eisenhauer, C. M., Hunt, J., and Schwartz, R. B., Calibration Techniques for Neutron Personnel Dosimetry, Radiat. Prot. Dosim. 10, 43 (1985).

International Organization for Standardization (ISO), Reference Beta Radiations for Calibrating Dosemeters and Doseratemeters and for Determining their Response as a Function of Beta Radiation Energy, ISO 6980-1984, International Organization for Standardization, Geneva (1984).

International Organization for Standardization (ISO), Neutron Reference Radiations for Calibrating Neutron-Measuring Devices Used for Radiation Protection Purposes and for Determining Their Response as a Function of Neutron Energy, ISO 8529-1989, International Organization for Standardization, Geneva (1989).

International Organization for Standardization (ISO), Procedures for Calibrating and Determining the Energy Response of Neutron Measuring Devices used for Radiation Protection, ISO/CD 10647, International Organization for Standardization, Geneva (1991).

Lorenz, A., A Survey of Neutron Sources and Their Applications, UCRL-51298, TID-4500, UC-34, Lawrence Livermore Laboratory (1972).

Prevo, C. T., Comparison of Calculated Neutron Spectrum and Dose Equivalent from NBS and LLNL 15-cm D_2O Spheres, Hazards Control Department Annual Technology Review, UCRL-50007-83, UC-41, Lawrence Livermore National Laboratory, 68 (1983)

Schwartz, R. B. and Eisenhauer, C. M., Procedures for Calibrating Neutron Personnel Dosimeters, National Bureau of Standards Special Publication 633, U.S. Government Printing Office (1985).

Schwartz, R. B. and Eisenhauer, C. M., The Design and Construction of a D_2O-Moderated ^{252}Cf source for Calibrating Neutron Personnel Dosimeters Used at Nuclear Power Reactors, NUREG/CR-1204, U.S. Nuclear Regulatory Commission, Washington, D.C. (1980).

U.S. Department of Energy, Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems, DOE/EH-0027, Washington, D.C. (1986).

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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This document contains standards of performance for laboratories that calibrate instrumentation used to measure ionizing radiation. Such standards are useful for the development of a secondary level of calibration laboratories that can provide a high-quality link between the National Institute of Standards and Technology and those who make routine measurements at the field level. These standards may also be used as criteria on which a decision is based regarding accreditation of a particular laboratory. They were developed by representatives of federally-owned laboratories that perform calibrations of the type addressed by the document. The first major part contains general criteria that must be satisfied by all laboratories seeking accreditation. It includes requirements relating to management and staff, physical aspects of the laboratory, calibrations facilities and equipment, operational procedures, accuracy and quality assurance, and records and reports. Five subsequent major parts establish criteria for calibration of survey instruments, irradiation of personnel dosimeters, calibration of sources, calibration of instruments for diagnostic levels, and calibration of reference-class instruments. The types of radiation covered include gamma rays, x rays, beta particles, neutrons, and alpha particles. An appendix describes the proficiency tests administered by NIST to secondary laboratories as a prerequisite for their accreditation.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

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