**Performance Specifications
for Health Physics
Instrumentation — Portable
Instrumentation for Use in
Normal Work Environments**

Part 2: Test Results

September 1986

Prepared for the U.S. Department of Energy
and the U.S. Nuclear Regulatory Commission
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Pacific Northwest Laboratory
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PERFORMANCE SPECIFICATIONS FOR HEALTH PHYSICS
INSTRUMENTATION - PORTABLE INSTRUMENTATION FOR
USE IN NORMAL WORK ENVIRONMENTS

PART 2: TEST RESULTS

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FOREWORD

In recent years, the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC) have jointly sponsored research to improve occupational radiation protection. Of common concern have been the accuracy and quality control of radiation survey instruments and bioassay measurements. A need was recognized for a standard that would specify performance requirements for health physics instrumentation to help ensure that the instrumentation would perform as the purchaser desired or as the instrument manufacturer advertised.

To meet this need, an ad hoc working group of representatives from industry and government with expertise in the design, testing, calibration, and use of health physics instrumentation was established to produce a comprehensive standard on performance specification. The working group included representatives from a diversity of sectors: users of instruments, manufacturers, regulatory personnel, the scientific community, and government laboratories. The working group was assembled in 1980; by the spring of 1981, it had prepared a draft standard that included broad performance requirements and evaluation procedures to determine if the specified requirements were in fact being met. This standard is designated ANSI N42.17, "Performance Specifications for Health Physics Instrumentation."

Recognizing that the draft standard goes far beyond specifications prescribed by existing standards and guidance, DOE and NRC requested the Pacific Northwest Laboratory to evaluate the applicability and practicality of the proposed standard. This included determining the degree of conformance of a cross section of contemporary instruments to the proposed performance specifications.

Testing results of this evaluation program have led to several changes in the proposed standard that have increased its practicality. After the standard

has been accepted and implemented, performance criteria for portable radiation protection instrumentation and procedures for testing instrumentation against those criteria will be readily available. This should improve the quality of instrumentation available to the health physics community.

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Thanks are given to Ronald L. Kathren and Dale M. Fleming for their assistance in reviewing this document and for their guidance in overall project direction and in interpretation of data, and to Albert M. Liebetrau for his assistance in the development of the statistical analysis methods used in the study.

We would also like to thank the nine instrument vendors, nine DOE contractors, the Hanford Calibration Facility, and one NRC licensee for the loan of portable instruments to be used in the testing program.

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Dr. Don Witters of the Center for Devices and Radiological Health provided the generation and monitoring equipment and his expertise for the exposure of instruments to microwave fields. Thanks are given to Richard J. Weigel, William T. Kaune, and Richard H. Lovely for assistance in the exposures of instruments to electric fields and to Dennis D. Mahlum and Ramona L. Rommereim for their help with magnetic field exposures.

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EXECUTIVE SUMMARY

The Pacific Northwest Laboratory has evaluated a draft American National Standards Institute Standard N42.17 (ANSI N42.17) during the past 3 years. The draft standard is entitled "Performance Specifications for Health Physics Instrumentation"; the second, third, and fourth drafts of the standard were included in the evaluation process. The project is jointly funded by the Office of Nuclear Safety of the U.S. Department of Energy (DOE) and by the Occupational and Radiation Protection Branch of the U.S. Nuclear Regulatory Commission (NRC).

The purpose of the project was to evaluate the draft standard in terms of its applicability and practicality and also to evaluate the performance of the instrumentation used in the study with respect to the requirements in the proposed standard. This report presents the results of the testing. Information on the specific testing procedures and requirements and the test equipment is included in "Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Normal Work Environments, Part I: Manual of Testing Procedures."

Health physics instruments that were evaluated with the testing procedures included alpha, beta, gamma, x-ray, and neutron devices used to detect radiation and radioactive contamination and to measure dose^(a) or dose rates. This included both battery- and ac/dc-powered handheld devices. Instruments that were not evaluated with these procedures include analytical laboratory counting equipment, thermoluminescent dosimeter readers, densitometers, hand and foot counters, portal monitors, thyroid or whole-body scanning devices, installed remote area monitoring systems, pocket ionization chambers, and instruments used to measure nonionizing radiation. Instruments were procured by three different methods: 1) by direct purchase from instrument manufacturers, 2) on loan from instrument manufacturers, and 3) on loan from DOE contractors and NRC licensees.

(a) Dose is used in this text as a generic term; that is, dose is to be interpreted as exposure, dose, or dose equivalent depending on the type of radiation being considered or measured.

Data has been generated with these instruments using procedures for the following tests: inspection (i.e., units of readout, scaling factors, ease of decontamination, moisture protection, alarm threshold, markings, battery status indication, protection of switches), zero set, ac power, battery power, latching and nonlatching alarm reset, alarm activation delay, alarm threshold drift, stability, geotropism, response time, coefficient of variation, line noise susceptibility, accuracy, photon energy dependence, beta energy dependence, neutron energy dependence, photon radiation overloads, angular dependence, extracameral response, radio frequency fields, microwave fields, electrostatic fields, magnetic fields, interfering ionizing radiations, temperature, temperature shock, humidity, mechanical shock, vibration, ambient pressure, and brief immersion.

Major conclusions about instrument performance based on the testing results include:

- A large variability in performance can be observed among instruments from different manufacturers.
- Variability can be observed between same manufacturer/same model instruments.
- Performance data supplied by many manufacturers are incomplete, unsatisfactory, and at times inaccurate.
- The response of most Geiger-Mueller (GM) type instruments currently available is highly dependent on the energy of the photons (i.e., they do not use energy-compensated GM tubes).
- The precision and the response time of the instruments need to be monitored during testing to ensure statistically reliable data.
- Ion chambers exhibit temperature-dependent responses (sometimes severe).
- High humidity can affect instrument performance; ion chambers and GM detectors usually recover when returned to low humidity, and some air proportional detectors fail permanently.
- Alpha-detection instruments are, in general, more fragile and more susceptible to environmental effects than GMs, ion chambers, or dose-equivalent monitors.

- For most tests, there were enough instruments passing to suggest that the standard as modified is achievable with state-of-the-art, off-the-shelf instruments.

Major changes that have been made in the proposed standard based on the findings of this testing program include:

- Statistically reliable data are required for each test (e.g., multiple instrument readings for each data point or high exposure rates so that statistical fluctuations are minimized).
- The coefficient of variation test requirement that the relative standard deviation (i.e., the coefficient of variation) be $\leq 2.5\%$ on all scales or decades was changed to 10% for exposure rate instruments, dose rate instruments, dose-equivalent rate instruments, and contamination monitors exposed to radiation intensities greater than or equal to 1 mR/h, 1 mrad/h, 10 mrem/h, and 500 cpm, respectively; when these instruments are exposed to radiation intensities less than those stated, the coefficient of variation shall not be more than 15%.
- The photon radiation energy dependence test requirement that the readings be $\pm 20\%$ over the range of 40 keV to 3 MeV was changed to $\pm 20\%$ over the range of 80 keV to 1.5 MeV, with a recommendation that it be $\pm 20\%$ over the 40 keV to 3 MeV range.
- The sources for the beta accuracy test were changed to those listed in ISO-6980 (i.e., Series 1 sources) (ISO 1983).
- The acceptable neutron sources were changed in the draft standard.
- An equilibration time was included in the temperature, humidity, and ambient pressure tests.
- Additional frequencies were added to the radio frequency test.
- The field intensity for the magnetic field test was increased to 10 oersteds.
- The acceleration level applied to instruments in the vibration test was decreased to 2 g from 5 g.

- The deceleration level applied to instruments in the mechanical shock test was increased to 50 g from 30 g.
- Additional requirements were added to the angular dependence test.
- Requirements for rechargeable battery units were added to the battery lifetime test.

ABSTRACT

The Pacific Northwest Laboratory evaluated a draft American National Standards Institute Standard N42.17 (ANSI N42.17) on performance specifications for health physics instrumentation through a project jointly funded by the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission. The evaluation involved testing a representative cross section of instruments against criteria in the standard.

This report presents results of the testing program. A brief history of the project is included in the introduction. The instrumentation tested is described in general terms (i.e., types, ranges); however, no direct relationship between the results and a specific instrument model is made in this report. Testing requirements in ANSI N42.17D4, Revision 1 (May 1985) are summarized and the methods by which the tests are performed are discussed. Brief descriptions of the testing equipment are included in the methods section of the report. More detailed information about the draft standard, testing requirements and procedures, and the test equipment is included in "Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Work Environments, Part 1: Manual of Testing Procedures."

Results of testing are given in two formats: test-by-test and instrument-by-instrument. Discussion is included on significant and interesting findings, on comparisons of results from the same type of instruments from same and different manufacturers, and on data grouped by manufacturer. Conclusions are made on the applicability and practicality of the proposed standard and on instrument performance. Changes that have been made to the proposed standard based on findings of the testing program are listed and discussed.

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1.0 INTRODUCTION

Pacific Northwest Laboratory (PNL) has evaluated a draft American National Standards Institute Standard N42.17 (ANSI N42.17) during the past 4 years. The draft standard is entitled "Performance Specifications for Health Physics Instrumentation"; the second, third, and fourth drafts of the standard were included in the evaluation process. The project is jointly funded by the Office of Nuclear Safety of the U.S. Department of Energy (DOE) and by the Occupational and Radiation Protection Branch of the U.S. Nuclear Regulatory Commission (NRC).

The purpose of the project was to evaluate the draft standard in terms of its applicability and practicality and also to evaluate the performance of the instrumentation used in the study with respect to the requirements in the proposed standard. This report presents the results of the testing. Information on the specific testing procedures and requirements and the test equipment is included in "Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Work Environments, Part 1: Manual of Testing Procedures."

Some guidance currently exists in American standards [e.g., American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM)] and European standards [e.g., International Electrotechnical Commission (IEC), Deutsches Institut für Normung (DIN)] on the performance of health physics instrumentation; however, the guidance is limited and frequently specific to a particular instrument classification or system. A broad specification of health physics instrumentation performance requirements is not currently available as a basis for evaluating health physics instruments and establishing minimum performance requirements.

To rectify this need, an ad hoc working group of representatives from industry and government with expertise in the design, testing, calibration, and use of health physics instrumentation was established to produce a comprehensive standard on performance specifications. The working group includes representatives from a diversity of sectors: users of instruments, manufacturers, regulatory personnel, the scientific community, and government laboratories. Specific members of the working group are listed in Table 1.1.

TABLE 1.1. ANSI N42.17 Working Group

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M. V. Federline,^(b) U.S. Nuclear Regulatory Commission
J. A. Flanigan, GPU Service Corporation
D. M. Fleming, Battelle, Pacific Northwest Laboratory
J. A. Jones,^(a) U.S. Nuclear Regulatory Commission
J. N. Little, Eberline Instrument Co.
R. B. Neel, U.S. Nuclear Regulatory Commission
G. J. Oliver, Carolina Power and Light
R. D. Terry, Bicron Corporation
R. P. Ulman, Victoreen Instrument Co.
C. K. Brown (Consultant), Consumers Power
L. M. Earls (Consultant), TVA
J. G. Flaherty (Consultant), EG&G, Idaho
R. L. Kathren (Consultant), Battelle, Pacific Northwest Laboratory
J. L. Kenoyer (Consultant), Battelle, Pacific Northwest Laboratory
K. L. Swinth (Consultant), Battelle, Pacific Northwest Laboratory

(a) Deceased.

(b) Replaced by another NRC representative.

The working group was assembled in 1980; by the spring of 1981, it had prepared a draft standard that included broad performance requirements and evaluation procedures to determine if the specified requirements were in fact being met. This standard has been designated as ANSI N42.17. Recognizing that the draft standard goes far beyond specifications prescribed by existing standards and guidance, DOE and NRC requested PNL to evaluate the applicability and practicality of the proposed standard (which by then had gone through a major revision and was designated ANSI N42.17D2, the D2 signifying second draft).

The Pacific Northwest Laboratory began its experimental evaluation of ANSI N42.17 based on this second draft. The purpose of this report is to describe testing results based on criteria in the ANSI N42.17 standard,

including drafts up through ANSI N42.17D4, Revision 1. The general performance of instruments is also described along with changes made in the standard based on the testing results. The March 1984 revision is ANSI N42.17D3; the next major revision was issued in December 1984 and was designated ANSI N42.17A D4, and the current revision was issued in May 1985 and is designated as ANSI N42.17A D4, Revision 1.

Results of earlier testing based on the third draft of the standard have been reported in the open literature in two reports, Swinth and Kenoyer (1985a) and Swinth and Kenoyer (1985b). The second report is included in the proceedings of a workshop held to discuss the calibration and testing of portable survey instruments. Representatives from a broad segment of the nuclear industry were present to discuss the standard and its impact on the nuclear industry. Subsequent changes in the standard and additional testing are reported in this document.

The evaluation program included determining the degree of conformance of a cross section of contemporary instruments to the proposed performance specifications. The evaluation will provide a basis for determining if the standard should be adopted as written or if it should be modified. To ensure that the testing of the standard would be a valid and appropriate indication of existing capabilities, instruments selected for the evaluation represent a cross section of models in current use at major DOE laboratories and at NRC licensee facilities. They include ionization chamber and Geiger-Mueller (GM) survey meters used for beta-photon monitoring, portable alpha-monitoring devices, and neutron monitors.

Two companion documents are currently in the development and testing phase. Requirements and testing criteria to be used for the evaluation of occupational-type air monitoring instrumentation are discussed in draft ANSI N42.17B, "Performance Specifications for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation." Requirements and testing criteria related to the evaluation of portable radiation protection instrumentation under extreme environmental conditions are covered in draft ANSI N42.17C, "Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Extreme Environmental Conditions."

This study is a test not only of the validity of the standard but also of health physics instrumentation in current use. The wisdom of evaluating this

draft standard before adoption became apparent as the content of the standard was reviewed. Many of the specifications and tests are unique in that they have never appeared in a U.S. standard. Many, however, are similar to or identical to the specifications and tests that are included in IEC standards.

The scope of the draft standard is broad, but the concept of it is simple. The draft standard basically establishes minimum acceptable performance criteria for health physics instrumentation, including testing methods to determine whether the instrument meets the required criteria. Included are both fixed and portable instruments for ambient beta-photon dose-rate measurement, contamination monitors, and dose-equivalent monitors. Personnel dosimeters and pocket alarming dosimeters and monitors such as chirpers are excluded. The draft standard does not recommend which instrument should be required at a facility or the numbers or locations of instruments.

Radiological, electrical, mechanical, safety, and environmental performance criteria are discussed in the proposed standard. Table 1.2 lists the specific tests in the draft standard and the sections in this report that discuss the methods and results for each of the tests.

Details on the instruments evaluated in the program, methods used to test the instruments, and results of testing are discussed in specific sections of this report. Several conclusions based on the testing results are made and are detailed thoroughly. Major changes that have been made to the proposed standard are identified and discussed.

TABLE 1.2. Tests in ANSI N42.17A D4 and Related Sections in This Report

ANSI Tests	Report Sections	
	Methods	Results
General Characteristics		
Inspection (8 tests)	2.2.1	3.1.1
Zero set	2.2.2	3.1.2
AC power	2.2.3	3.1.3
Battery power	2.2.4	3.1.4
Electronic and Mechanical		
Latching and nonlatching alarm reset	2.2.5	3.1.5
Alarm activation delay	2.2.6	3.1.6
Alarm threshold drift	2.2.7	3.1.7
Stability	2.2.8	3.1.8
Geotropism	2.2.9	3.1.9
Response time	2.2.10	3.1.10
Coefficient of variation	2.2.11	3.1.11
Line noise susceptibility	2.2.12	3.1.12
Radiation Response		
Accuracy	2.2.13	3.1.13
Photon energy dependence	2.2.14	3.1.14
Beta energy dependence	2.2.15	3.1.15
Neutron energy dependence	2.2.16	3.1.16
Photon radiation overloads	2.2.17	3.1.17
Angular dependence	2.2.18	3.1.18
Interfering Responses		
Extracameral response	2.2.19	3.1.19
Radio frequency fields	2.2.20	3.1.20
Microwave fields	2.2.21	3.1.21
Electrostatic fields	2.2.22	3.1.22
Magnetic fields	2.2.23	3.1.23
Interfering ionizing radiations	2.2.24	3.1.24
Environmental Factors		
Temperature	2.2.25	3.1.25
Temperature shock	2.2.26	3.1.26
Humidity	2.2.27	3.1.27
Mechanical shock	2.2.28	3.1.28
Vibration	2.2.29	3.1.29
Ambient pressure	2.2.30	3.1.30
Brief immersion	2.2.31	3.1.31

2.0 METHODS

In this section, two areas are discussed: 1) instrumentation evaluated during the study and 2) testing requirements and methods. The testing equipment used during the program (e.g., environmental chamber, vibration testing system, radio frequency generation and characterization system) will be referred to in the discussion on testing methods; however, more detailed information on that equipment is included in Appendix C of "Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Work Environments, Part 1: Manual of Testing Procedures." More detailed testing procedures are also included in Part 1; this report includes a generalized description of those methods.

2.1 INSTRUMENTATION

During the 2½-year period that procedure development and verification and instrument testing were performed, more than 100 instruments were obtained for evaluation. The three methods of procurement were: 1) direct purchase of instruments from the manufacturer, 2) the loan of instruments by manufacturers and vendors, and 3) the loan of instruments by DOE laboratories and an NRC licensee. Table 2.1 lists the manufacturers and vendors who either lent instruments to the study for evaluation or from whom instruments were purchased.

DOE laboratories that loaned instruments or detectors to the project were Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Pacific Northwest Laboratory, Rocky Flats Plant, Sandia National Laboratory, and Savannah River Plant. Southern California Edison, San Onofre Plant, also loaned instrumentation to the project for evaluation.

The instruments have been grouped into five categories: ionization chambers (IC), Geiger-Mueller (GM) detectors, alpha detectors, neutron monitors, and others (not covered by the preceding categories). Data on a total of 101 instruments are discussed in this report, including: 41 GM detectors, 21 ion chambers (i.e., 13 vented-type and 8 gas-filled, pressurized types that

TABLE 2.1. Manufacturers and Vendors of Instruments
Used in This Study

Baird Corporation
Bicron Corporation
Defense Apparel
Dosimeter Corporation of America
Eberline Instrument Corporation
G. E. Smith and Associates
Health Physics Instruments, Inc.
Johnson and Associates, Inc.
Keithley Instruments, Inc.
Ludlum Measurements, Inc.
Nuclear Research Corporation
Scintrex, Ltd.
Technical Associates
Victoreen, Inc.
Xetex, Inc.

are operated in the proportional region), 26 alpha detectors, 11 neutron monitors, and 2 "other" [both NaI(Tl) detectors]. Forty-five different instrument model numbers or types are represented in the cross section of instruments evaluated for the study. Table 2.2 lists the number of instruments and models for each type of instrument used in this study.

2.2 TESTING REQUIREMENTS AND METHODS

Test requirements and methods are presented here for the tests specified in ANSI N42.17D4, Revision 1. Included here are the general characteristics tests, electrical and mechanical tests, radiation response tests, interfering responses tests, and environmental factors tests.

2.2.1 Inspection Tests

The inspection tests in ANSI N42.17 include: units of readout, scaling factors, ease of decontamination, moisture protection, alarm threshold, markings, battery status indication, and protection of switches.

TABLE 2.2. Type and Number of Instruments Used in This Study

<u>Instrument Type</u>	<u>Number</u>	
	<u>Instruments</u>	<u>Models</u>
Ion chambers	21	10
(Vented)	13	8
(Closed)	8	2
GM detectors	41	20
Alpha detectors	26	9
(Gas flow)	8	3
(Scintillation)	6	2
(Air proportional)	12	4
Neutron	11	6
Other	2	1

For each of these tests, a single instrument of each type is examined carefully for compliance to applicable criteria in the standard. The results of the examination are marked directly on data sheets.

2.2.2 Zero Set Test

Requirements

If a control for setting zero or indication of zero is available to the operator, it shall be effective in the presence of radiation fields with intensities up to the limit of the range.

Test Method

The detector is exposed to a suitable source of radiation^(a) of sufficient intensity to produce a full-scale or full-decade reading on each scale or decade. An attempt is made to set the zero indication with the available control using the method recommended by the manufacturer on each scale or decade.

(a) The term "suitable source of radiation" denotes a source of radiation (e.g., ^{137}Cs , ^{60}Co , ^{239}Pu , ^{252}Cf , x-rays) that is used with an instrument designed to measure the emissions from that source. Some tests may require specific sources to be used.

2.2.3 AC Power Test

Requirements

The operating power requirements shall be stated for instruments and shall include the operating voltage range and current requirements. Instruments powered by ac shall operate at either 117 ± 15 V, single-phase ac or 230 ± 30 V single-phase ac at a nominal frequency of 60 Hz (i.e., 57 to 61 Hz).

Test Method

The detector shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The supply voltage is then varied in 5-volt increments over the applicable voltage range noted in the test requirements and a sufficient number of readings^(a) is recorded at each voltage. The response of the instrument over the voltage range shall not differ from the response observed at the reference operating voltage (specified by the manufacturer) by more than 5%.

2.2.4 Battery Power Test

Requirements

Instruments with a self-contained nonrechargeable power supply shall use readily available batteries with a continuous lifetime of 100 hours or more. Battery lifetimes and operating temperature ranges for continuous operation and normal storage under all conditions shall be stated by the instrument manufacturer. Instruments that use rechargeable batteries shall operate for a minimum of 8 hours with a maximum recharging time of 16 hours. The manufacturer shall state the minimum voltage required to produce satisfactory operation of the instrument. The low battery indication shall be no lower than the minimum voltage.

Test Method

The instrument shall be equipped with fresh batteries, as applicable. All functional circuits (alarms and speakers excluded) shall be switched on

(a) The term "a sufficient number of readings" indicates a series of readings are to be taken to calculate a mean and standard deviation useful in judging the performance of an instrument. Refer to Part 1 of this report for a more detailed description.

and shall remain on during the duration of the test. An exposure shall be made to a suitable source of ionizing radiation sufficient in strength to produce approximately a mid-scale or mid-decade reading on an appropriate scale or decade for at least 10 minutes and a sufficient number of readings taken initially and at approximately 24-hour intervals. Battery lifetime shall be considered to have been exceeded when the ratio of the mean reading at any time relative to the mean reading taken initially falls outside the range 0.9 to 1.1. The battery lifetime shall be stated as the longest time in hours during which the ratio of the mean reading at the sample time to the initial mean reading falls within this range.

2.2.5 Latching and Nonlatching Alarm Reset Test

Requirements

Instruments may be provided with various audible and/or visual alarms that operate in the following modes:

- latching alarms to stay on until manually reset (i.e., acknowledged)
- nonlatching alarms to clear automatically on reduction of exposure rate below the alarm level.

The alarms shall normally continue to operate in radiation fields greater than the selected alarm points; however, it should be possible to interrupt the audible alarm by deliberate action without interrupting the visual alarm.

Test Method

The detector shall be exposed to a suitable source of radiation with intensity sufficient to activate both audible and visual alarms and these shall be observed for at least 5 minutes in the alarm condition. If it is possible to interrupt the audible alarm by deliberate action without interrupting the visual alarm, this action shall be performed, and the result observed. The exposure shall then be terminated. Latching alarms shall remain activated for at least 5 minutes, and the meter indication or readout shall fall to background. The latching alarm shall be deactivated by the acknowledgment or reset switch. Nonlatching alarms shall deactivate and the readout shall fall to background.

2.2.6 Alarm Activation Delay Test

Requirements

The delay for activating the trip circuit shall be such that the calculated exposure, which may result from this delay and the level of alarm threshold, does not exceed 10 mrem. This delay shall not in any case exceed 1 minute and need not be less than 1 second.

Test Method

The detector shall be exposed to a suitable source of radiation with intensity sufficient to activate the alarm(s) with the alarm threshold set approximately mid-scale or mid-decade. The mean delay in time from when the alarm threshold is reached to when the alarm is activated shall be determined for each scale or decade and the exposures associated with the delays calculated.

2.2.7 Alarm Threshold Drift

Requirements

Under standard test conditions, the actual exposure rate trip level shall not deviate from the set point level by more than $\pm 1.0\%$ over a period of 500 hours or for the battery lifetime stated by the instrument manufacturer.

Test Method

The alarm threshold shall be set to approximately mid-scale or mid-decade and the detector shall be exposed to a suitable source of radiation with sufficient intensity to activate the alarm on an appropriate scale or decade. The mean exposure rate required to activate the alarm shall be determined initially, every hour for the first 8 hours, at the end of 24 hours, and then periodically for the next 20 days (e.g., at 100, 200, 300, 400, and 500 hours).

2.2.8 Stability Test

Requirements

Drift at constant temperature and pressure shall not be greater than 3% of the full-scale or full-decade value over a period of 24 hours for installed systems and 3 hours for survey meters after a 10-minute warmup period. A

maximum drift of no more than 10% of full scale or full decade over a period of 500 hours is allowed for installed systems.

Test Method

Instruments shall be switched on and allowed a 10-minute warmup. The detector shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. A sufficient number of readings shall be recorded every 30 minutes for 3 hours for survey meters. Readings shall be recorded every hour for the first 8 hours, at the end of 24 hours, and then periodically for the next 20 days (e.g., at 100, 200, 300, 400, and 500 hours) for installed systems.

2.2.9 Geotropism Test

Requirements

A change in instrument reading caused solely by change in spatial orientation of survey meters shall not be greater than 3% of the full-scale or full-decade value on which the reading is made.

Test Method

The survey instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The instrument shall be rotated through 3 mutually orthogonal planes. The radiation field to which the detector is exposed shall be constant throughout the test. The exposure geometry (i.e., relationship between the source and the effective center of the detector) shall not change. A sufficient number of readings shall be recorded at 90° increments and the means of readings calculated. These means shall be compared to the mean of a reference set of readings obtained in the orientation in which the instrument is normally used.

2.2.10 Response Time Test

Requirements

Instrument response time for increasing exposure rates for beta-photon and neutron rate readouts shall be in accordance with Table 2.3. Instruments suitable for both neutrons and photons or neutrons, beta, and photons shall meet the less restrictive value specified in Table 2.3.

Instrument response time for count rate readout (i.e., contamination monitors) should be less than 30 seconds.

Response times for increasing and decreasing exposure rates shall be stated by the manufacturer.

Test Method

An equilibrium reading of the instrument is established by exposing the detector to a suitable source of radiation of sufficient intensity to produce a mean reading between mid- and full-scale or decade. The source is removed instantaneously and the instrument is allowed to reequilibrate. The original radiation field is returned and the time for the instrument reading to move from 10% to 90% of the established equilibrium reading is recorded. The source is removed and the time for the instrument to move from 90% to 10% of the equilibrium reading is recorded. These two steps are repeated until a sufficient number of data points have been obtained. This test shall be done for all applicable scales or decades specified in Table 2.3.

TABLE 2.3. Instrument Response Time Versus Scale or Decade Maximum for Increasing Exposure Rates

Maximum Response Time, s	Scale or Decade Maximum	
	Beta-Photon Instruments, rad/h or rem/h	Neutron Instruments, rem/h
30	$>10^{-4}$ to $\leq 10^{-3}$	$<5 \times 10^{-2}$
10	$>10^{-3}$ to $\leq 10^{-2}$	5×10^{-2} to ≤ 1
5	$>10^{-2}$ to $\leq 10^{-1}$	>1
3	$>10^{-1}$ to ≤ 1	
1	>1	

2.2.11 Coefficient of Variation Test

Requirements

The coefficient of variation of a minimum of 20 instrument readings shall not be more than 10% for exposure rate instruments, dose rate instruments, dose-equivalent rate instruments, and contamination monitors exposed to radiation intensities greater than or equal to 1 mR/h, 1 mrad/h, 10 mrem/h, and

500 cpm, respectively. When these instruments are exposed to radiation intensities less than those stated, the relative standard deviation shall not be more than 15%. This test shall be performed on all scales or decades.

Test Method

The instrument shall be exposed to an acceptable source of sufficient intensity to produce a reading of between 25% to 75% of full-scale or full-decade for each scale or decade. Reference sources are specified in Table 2.4. A minimum of 20 successive readings is required on each scale or decade; the time interval between readings shall not be less than that corresponding to three times the response time for the scale or decade on which readings are made. The mean, standard deviation, and the coefficient of variation of the instrument readings shall be calculated for each scale or decade.

TABLE 2.4. Reference Sources for Coefficients of Variation and for Accuracy (ANSI 1985)

<u>Radiation Type</u>	<u>Acceptable Reference Source</u>
Alpha	^{230}Th , ^{239}Pu
Beta	^{90}Sr - ^{90}Y , ^{204}Tl Series 1 Sources, ISO-6980; Nat_U or depleted uranium in equilibrium with decay products filtered through 7 mg/cm ² of material with $Z \leq 13$; exposure to be made at a distance of ≤ 2 cm from the source to detector window
Photon	^{137}Cs filtered to remove $\geq 90\%$ of the betas and associated Ba x-rays
Neutron	^{252}Cf , $^{238}\text{PuBe}$, $^{239}\text{PuBe}$, D_2O -moderated ^{252}Cf , $^{241}\text{AmBe}$

2.2.12 Line Noise Susceptibility Test

Requirements

The mean instrument response of installed units shall not vary more than 15% from the mean of a set of reference readings while or after being subjected to voltage sags, surges, and transients on the power line.

Test Method

The detector shall be exposed to an acceptable source of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument response shall be determined. The power transients listed in Table 2.5 shall be randomly applied to the system (i.e., added to the ac voltage), and instrument readings shall be determined during and after each set of transients. The mean instrument responses shall be compared to the reference set of readings.

TABLE 2.5. Power Transients

<u>Number of Pulses</u>	<u>Rise Time, μs</u>	<u>Duration, μs</u>	<u>Decay, μs</u>	<u>Pulse Amplitude and Sign, RMS^(a) Voltage, % of Nominal</u>
10	1.2	50	12	+100
10	1.2	50	12	-100
10	1.2	50	12	+50
10	1.2	50	12	-50
20	1.2	100	12	+25
20	1.2	100	12	-25
20	1.2	500	12	+15
20	1.2	500	12	-15

(a) RMS = root mean square.

2.2.13 Accuracy Test

Requirements

The ratio of the mean indicated value to the conventionally true value shall fall within the range 0.85 to 1.15 at the 95% confidence level or

$$0.85 \leq \frac{\bar{r}_i}{r_t} \leq 1.15 \quad (2.1)$$

where $\bar{r}_i$ is the mean indicated value and r_t is the conventionally true value.

Test Method

The instrument is exposed to the appropriate reference energy or source of known intensity to produce a response of approximately 25% and 75% of each scale or decade. A sufficient number of readings is recorded and the ratios of the mean observed values to the conventionally true values are determined. The reference sources are specified in Table 2.4.

2.2.14 Photon Energy Dependence Test

Requirements

The range of photon energies over which the instrument response is 0.5 to 1.5 times the conventionally true value shall be stated or graphically indicated. Additionally, the useful energy range for photon-measuring instruments shall be stated and graphically indicated, and shall be the continuous range of photon energies over which the following condition is met:

$$0.8 \leq \frac{(\bar{r}_{en_i} / CTV_{en_i})}{(\bar{r}_{ref} / CTV_{ref})} \leq 1.2 \quad (2.2)$$

where

$\bar{r}_{en_i}$ = the mean indicated reading to photon energy i intensity

$\bar{r}_{ref}$ = the mean indicated reading to the reference photon energy

CTV_{en_i} = the conventionally true value of the photon of energy i

CTV_{ref} = the conventionally true value of the reference photon energy.

The useful energy range should be at least 40 keV to 3 MeV and shall be at least 80 keV to 1.25 MeV and shall be stated by the manufacturer. For instruments used in low-energy applications (e.g., x-ray exposures), the useful energy range shall be stated by the manufacturer and the instrument shall be clearly marked that it is to be used for this restricted application only.

Test Method

Photon energy dependence may be measured on any scale or decade providing a complete series of measurements is made for each detector in the instrument.

This test may be performed on a single unit or instrument. Photon energy response shall be determined by comparing the mean indicated value at a specific energy to that of the conventionally true value at that energy. Conventionally true values shall be determined from secondary or laboratory standard instruments or sources traceable to the U.S. National Bureau of Standards (NBS) or through measurement quality assurance with a national or qualified secondary laboratory. For quantum energies between 0.3 and 3.0 MeV, the response shall be determined to the following effective energies, obtainable with the nuclides shown:

<u>Nuclide</u>	<u>Effective Photon Energy</u>
^{60}Co	1.25 MeV
^{137}Cs	0.66 MeV

For energies below 300 keV, the exposure shall be made at a series of effective energies in approximately 40-keV increments ranging from approximately 250 keV_{eff} downward. The lower limit of the useful energy range of the instrument shall be determined by measurement and shall be equal to the lowest effective energy at which the response was measured, provided the response to all effective energies tested at and above this level fall within the test requirements. X-ray spectra used shall have a homogeneity coefficient of at least 0.8, where this coefficient is the ratio of the first half-value layer to the second. Suitable sources are described in Table 2.6. An energy dependence curve showing response as a function of energy and identifying clearly the measurement points shall be prepared.

TABLE 2.6. Acceptable X-Ray Sources for Photon Energy Dependence (ANSI 1985)

<u>Nominal Effective Energy, keV</u>	<u>NBS Technique</u>
40	H50
80	H100
120	H150
166	H200
210	H250
250	H300

2.2.15 Beta Energy Dependence Test

Requirements

The useful maximum energy range for beta dose or dose-rate monitoring instruments shall be stated and shall be at least 0.20 to 3.5 MeV. Within this stated range, the ratio of the indicated value to the conventionally true value shall fall within 0.5 to 1.5. The lower-level beta cutoff energy shall be stated along with the density thickness (e.g., mg/cm²) of the material through which the beta radiation must pass to reach the sensitive volume of the detector.

Test Method

Beta energy dependence may be measured on any scale or decade providing a complete series of measurements is made for each detector. This test may be performed on a single unit or instrument. The detector is exposed to each of the beta fields specified at an intensity sufficient to give approximately a mid-scale or mid-decade response. The indicated value is recorded, and the conventionally true value is divided into that value for each of the sources specified below:

⁹⁰Sr-⁹⁰Y, ²⁰⁴Tl, ¹⁴⁷Pm (Series 1 sources, ISO-6980)

The photon dose contribution from these sources shall be minimized during the measurement procedure and shall not exceed 10% of that from beta. Appropriate corrections should be made.

The lower-level beta cutoff energy shall be determined for each detector by reference to Figure 2.1 or by calculation from the following expressions:

$$\ln E_{\max} = 6.63 - 3.24 [10.215 - \ln R]^{0.5} \quad (0.01 \leq E_{\max} \leq 2.5 \text{ MeV}) \quad (2.3)$$

$$\text{and } R = 530E_{\max} - 106 \quad (E_{\max} \geq 2.5 \text{ MeV}) \quad (2.4)$$

where $E_{\max}$ is the cutoff energy in MeV and R is the thickness of the detector wall in mg/cm². In determining the wall thickness of the detector, the total

FIGURE 2.1. Lower-Level Beta Cutoff Energy as a Function of Detector Wall Thickness

mass of material (i.e., detector wall thickness, case, air, etc.) between the interior of the detector and the closest point of approach of the source shall be used.

2.2.16 Neutron Energy Dependence Test

Requirements

The useful energy interval for neutron dose equivalent and dose-equivalent rate instruments shall be stated. Within this stated interval, the ratio of the indicated to conventionally true value shall fall within 0.5 to 2.0 with the reference energy source specified by the instrument manufacturer as shown by the following equation:

$$0.5 \leq \frac{(\bar{r}_{n_i} / \text{CTV}_{n_i})}{(\bar{r}_{n_{\text{ref}}} / \text{CTV}_{n_{\text{ref}}})} \leq 2.0 \quad (2.5)$$

where

- $\bar{r}_{n_i}$ = the mean indicated reading to neutron reading of energy i
- $\bar{r}_{n_{ref}}$ = the mean indicated reading to the reference neutron radiation
- CTV_{n_i} = the conventionally true value of the neutron radiation of energy i
- $CTV_{n_{ref}}$ = the conventionally true value of the reference neutron radiation

Test Method

Neutron energy dependence may be performed on any scale or decade providing a complete series of measurements is made for each detector. This test may be performed on a single unit or instrument. The detector is exposed to each of the neutron fields specified in Table 2.7 at an intensity sufficient to provide an indicated value of approximately mid-scale or mid-decade. The mean indicated value is recorded for each of the specified energy spectra and is divided by the conventionally true value.

Neutron response shall be measured under low scatter conditions; the total neutron scatter contribution regardless of origin shall not exceed 15% of the dose-equivalent rate.

TABLE 2.7. Reference Sources for Neutron Energy Dependence

<u>Energy Range</u>	<u>Acceptable Reference Sources</u>
Thermal (0.025 eV)	Highly moderated sealed radionuclide source or reactor thermal column. Cd/In ratio ≥ 10
Intermediate (0.5 eV to 10 keV)	D ₂ O-moderated (15 cm) $^{238}\text{PuBe}$, $^{239}\text{PuBe}$, $^{241}\text{AmBe}$, or ^{252}Cf
Fast (10 keV to 10 MeV)	Unmoderated radionuclide sources ($^{238}\text{PuBe}$, $^{239}\text{PuBe}$, $^{241}\text{AmBe}$)
Fission Spectrum	Unmoderated ^{252}Cf
14 MeV	$^3\text{H}(0,n) ^4\text{He}$ reaction

2.2.17 Photon Radiation Overloads Test

Requirements

When exposed to a radiation level greater than that corresponding to the scale or decade maximum, the instrument shall continue to operate and the readout of an analog instrument shall remain off the scale or decade at the higher end until the radiation field is reduced to below the full-scale or full-decade value. Digital readouts shall convey that the radiation level exceeds the upper detection limit of the instrument in a manner described by the instrument manufacturer. When the field is removed, the instrument reading shall return to the expected value within 2 minutes. This requirement applies to all scales or decades of an instrument.

Test Method

The detector or instrument shall be placed in an appropriate radiation field(s) with a conventionally true value of 100 times the maximum instrument response value for values up to and including 10 rad/h (0.1 Gy/h) or of 10 times the maximum responses greater than 10 rad/h (0.1 Gy/h) with a minimum exposure rate of 1000 rad/h (10 Gy/h) to be used, and the response shall be observed for 5 minutes. The radiation field shall be removed and the instrument response shall be observed for 2 minutes. This procedure shall be repeated on all scales or decades.

2.2.18 Angular Dependence Test

Requirements

The response of an instrument to photon radiation incident at any angle not exceeding 45° from the direction of maximum response of the instrument shall not be less than 80% of this maximum response. At an angle of 90° from the direction of maximum response, the indication shall not be less than 50% of the maximum response. These requirements apply for at least two representative photon energies. The response of an instrument to beta radiation incident at any angle not exceeding 45° from the direction of maximum response of the instrument should not be less than 50% of this maximum response. The angular response of an instrument to neutron radiation shall be stated by the instrument manufacturer. The angular response of the detector or instrument,

as appropriate, shall be provided as a polar coordinate plot. These requirements apply to exposure and exposure rate, to dose and dose rate, and to dose equivalent and dose-equivalent rate instruments; no test is required for alpha or beta contamination monitoring instruments. The test for this requirement may be performed on a single instrument.

Test Method

The detector or instrument shall be placed in a suitable unidirectional parallel field such that approximately a mid-scale or mid-decade reading results; this may be done on any scale or decade on just one instrument. The instrument or field direction should be rotated in each of three mutually orthogonal planes around the effective center and the scale reading recorded at least at 45° increments in each plane with respect to the direction of maximum response.^(a) The results shall be plotted on polar coordinates. For photons, this test shall be made with at least the energies from a ¹³⁷Cs reference source (Table 2.4) and a source with an effective energy below 130 keV. For neutrons, at least an intermediate energy and fission energy source shall be used (Table 2.6). For betas, the reference source given in Table 2.3 shall be used. No test is required for alpha monitoring instruments.

2.2.19 Extracameral Response Test

Requirements

Extracameral response for photon or beta-photon dose rate instruments and neutron dose-equivalent rate instruments that have an external detector that can be considered separate from the rest of the unit shall not be greater than 5% (upscale or downscale) of the intensity of the exposing field to a maximum intensity equal to the scale or decade in use.

There shall be no detectable extracameral response in contamination survey instruments from external ambient beta-photon fields ≤ 1 rad/h.

-
- (a) To automate the testing, a stand with a stepping motor drive was built as described in Swinth et al. (1984). The stepping motor was geared 3.6:1 to provide two steps of the motor per degree of rotation. Rotation of the stand and reading of the instrument are controlled by software written in FORTRAN and implemented on a LeCroy 3500 multichannel analyzer with CAMAC control modules.

Test Method

For photon and beta-photon dose rate instruments and neutron dose-equivalent rate instruments, all portions of the instrument except the detector shall be exposed to fields equal to approximately full-scale of each scale or decade and the response observed. The detector shall remain in the circuit during this test, but it may be physically isolated or shielded such that the direct radiation level is ≤ 0.05 that of the remainder of the instrument. Surface contamination instruments shall be exposed in the same manner to photon fields of 1 rad/h from ^{137}Cs . Appropriate reference sources from Table 2.4 shall be used.

2.2.20 Radio Frequency Fields Test

Requirements

The mean instrument response, obtained when the instrument is exposed to a radio frequency (RF) field that is ≤ 100 V/m in intensity at 60 Hz, 400 Hz, or in the frequency range of 300 kHz to 35 MHz, and/or at a nominal 140 MHz,^(a) shall not vary more than 15% from the mean instrument response obtained with no RF field present, or, alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not operate properly in such fields.

Test Method

60-Hz and 400-Hz Electric Fields

The instrument shall be positioned in a 60-Hz electric field generation system with the field at zero intensity. The instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be exposed to an electric field that is 100 V/m in intensity and the mean instrument reading shall be determined again.

(a) Approximate frequency of most portable transceivers.

0.3-MHz to 35-MHz RF Field

The instrument shall be positioned in an RF field generation system with the field at zero intensity. The instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be exposed to an RF field that is 100 V/m in intensity and 300 kHz in frequency. The instrument reading shall be observed while the frequency is increased to 35 MHz at a rate not to exceed 10 kHz/s from 0.3 to 2 MHz and 100 kHz/s from 2 to 35 MHz. The field intensity is to be maintained at 100 V/m during this frequency scan.

If the RF exposure system is such that a zero-field intensity cannot be produced, the radiation exposure geometry shall be documented and reproduced later in another location, and the mean instrument reading without the field shall be determined after the exposure to the RF field.

Nominal 140-MHz RF Field

The instrument shall be positioned in an RF field generation system or near a portable communication transmission and receiving unit with the field at zero intensity. The instrument shall be exposed to an acceptable source of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be exposed to an RF field that is 100 V/m in intensity and a nominal 140 MHz in frequency (i.e., the most commonly used frequency for portable communication transmission and receiving units), and the mean instrument reading shall be determined again.

2.2.21 Microwave Fields Test

Requirements

The mean instrument response, obtained when the instrument is exposed to a microwave field that is $\leq 100 \text{ W/m}^2$ in intensity at 915 MHz or 2450 MHz, shall not vary more than 15% from the mean instrument response obtained with no microwave field present, or, alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not operate properly in such fields. The test may be performed on a single instrument.

Test Method

The instrument shall be positioned in a microwave field generation system with the field at zero intensity. The instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be exposed to a microwave field that is 100 W/m^2 in intensity and 2450 MHz in frequency and the mean instrument reading shall be determined again.

The instrument shall be exposed to a microwave field that is 100 W/m^2 in intensity and 915 MHz in frequency and the mean instrument reading determined and compared to a set of instrument readings obtained in a zero-intensity field.

2.2.22 Electrostatic Fields Test

Requirements

The mean instrument response, obtained when the instrument is exposed to an electrostatic field that is $\leq 5000 \text{ V/m}$ in intensity, shall not vary more than 15% from the mean instrument response obtained without an electrostatic field present, or, alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not operate properly in such fields. This test may be performed on a single instrument.

Test Method

The instrument shall be positioned in an electrostatic field generation system with the field at zero intensity. The instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be exposed to an electrostatic field that is 5000 V/m in intensity and the mean instrument reading shall be determined again.

If the electrostatic field exposure system is such that a zero-field intensity cannot be produced, the radiation exposure geometry shall be documented and reproduced later in another location, and the mean instrument reading without the field shall be determined after the exposure to the electrostatic field.

2.2.23 Magnetic Fields Test

Requirements

The mean instrument response, obtained when the instrument is exposed to a magnetic field that is ≤ 800 A/m (~ 10 oersteds), shall not vary more than 15% from the mean instrument response obtained with no magnetic field present, or, alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not operate properly in such fields.

Test Method

The instrument shall be positioned in a magnetic field generation system with the field at zero intensity. The instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be exposed to a magnetic field that is 800 A/m (~ 10 oersteds) in intensity and the mean instrument reading shall be determined again.

If the magnetic field exposure system is such that a zero-field intensity cannot be produced, the radiation exposure geometry shall be documented and reproduced later in another location, and the mean instrument reading without the field shall be determined after the exposure to the magnetic field.

2.2.24 Interfering Ionizing Radiations Test

Requirements

Instruments designed to measure one or more types of ionizing radiations shall not respond to other types of ionizing radiations at or below the levels shown in Table 2.8.

Test Method

These measurements shall be made with the instrument switched on and operating on its most sensitive scale. The instruments shall be exposed to an appropriate reference source (Table 2.9) at the levels specified in Table 2.8 and the response recorded.

TABLE 2.8. Response to Interfering Ionizing Radiations

Radiation(s) Measured by Instrument	Upper Limit to Interfering Ionizing Radiation to Which Instrument Shall Have No Response			
	α	$\beta^{(a)}$	IER ^(a)	Neutron ^(a)
α	---	1 rad/h	1 rad/h	1 rem/h
$\alpha + \beta^{(b)}$	---	---	1 rad/h	1 rem/h
$\alpha + \beta + \text{photon}^{(b)}$	---	---	---	1 rem/h
$\beta^{(c,d)}$	10^4 dpm/cm ²	---	10 rad/h	1 rem/h
$\beta + \text{photon}^{(b,c)}$	10^4 dpm/cm ²	---	---	1 rem/h
$\beta + \text{photon} + n^{(b)}$	10^4 dpm/cm ²	---	---	---
Photon	10^4 dpm/cm ²	10 rad/h	---	1 rem/h
Photon + n ^(b)	10^4 dpm/cm ²	10 rad/h	---	---
n	10^4 dpm/cm ²	10 rad/h	10 rad/h	---

(a) External ambient fields.

(b) Refers to measurement of these in combination; if instrument is claimed to measure one or more types of radiation, any or each singly, then the requirements specified in this table for an instrument measuring only that type of radiation apply.

(c) For thin window (i.e., ≤ 10 mg/cm²) detectors, some interference as specified by the instrument manufacturer from alpha particles is permitted.

(d) For beta scintillation detectors, some interference as specified by the instrument manufacturer from low-energy photons is permitted.

TABLE 2.9. Acceptable Sources for Interfering Ionizing Radiations

Radiation Type	Acceptable Reference Source
Alpha	^{230}Th
Beta	^{90}Sr - ^{90}Y (Series 1 source, ISO-6980)
Photon	^{137}Cs filtered to remove $\geq 90\%$ of the betas and associated Ba x-rays
Neutron	^{252}Cf (unmoderated)

2.2.25 Temperature Test

Requirements

The temperature range over which the mean instrument response does not vary more than 15% from the mean instrument response at 20°C shall be stated by the manufacturer. The mean instrument response shall not vary more than 15% from 0 to 40°C and shall not vary more than 20% from -10 to 50°C from the mean reference reading at 20°C. Corrections to instrument readings for air density changes are to be made when appropriate (e.g., for free-air ionization chambers).

Test Method

The instrument shall be exposed in an environmental chamber to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading at 20°C shall be determined. The temperature inside the chamber shall be raised or lowered at a rate of approximately 10°C/h until the temperature extremes have been reached. Sufficient data shall be recorded at least at 10°C increments; the instrument shall be permitted to come to thermal equilibrium at each temperature level before data are taken. The results should be plotted or stated as a temperature coefficient or inclusive range. Note: the rate of change of the temperature may have to be less than 10°C/h for some types of detectors to prevent damage [e.g., NaI(Tl) detectors].

Figure 2.2 represents the temperature exposure profile used for this study. On the first day of the exposure, data for most instruments was taken at 20°C, 30°C, 40°C, and 50°C. On the second day, data were obtained at 20°C, 10°C, 0°C, -10°C, and -20°C. This exposure profile allows one to obtain data from several different instruments in one group at the same temperature. Multiple readings were taken on each instrument at each temperature; readings were not "instantaneous." All instruments do not come to temperature at the same rate; this depends on the type of material of which the instrument is constructed, the amount of insulation, if any, and the quality of the construction. All instruments went through a minimum stabilization period of 30 minutes at a specific temperature before data acquisition so that data could be obtained with all instruments at the same temperature. Fresh batteries were checked for initial voltages before installation; batteries were replaced at the end

FIGURE 2.2. Temperature Exposure Profile

of the first day of testing when necessary. Data taken on the second day of the experiment were normalized to data obtained on the first day by comparing the data obtained at 20°C. This was done because of slightly different geometries that would occur on the two days when the instruments were removed from the chamber for the battery evaluation.

2.2.26 Temperature Shock Test

Requirements

The mean instrument response shall not vary more than 15% from a set of reference readings taken at a nominal temperature of 20°C when the instrument is taken from that environment of 20°C to one of 50°C or -10°C in less than 5 minutes. Note: this test should not be performed with detectors that may be damaged during the test [e.g., NaI(Tl) detectors].

The mean instrument response shall not vary more than 15% from a set of reference readings taken at a temperature of 50°C or -10°C when the instrument is taken from either one of those temperatures to one of a nominal 20°C.

Test Method

The instrument shall be placed in a controlled environment of approximately 20°C and allowed to stabilize for a minimum of 60 minutes. The

instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument and radioactive source shall be removed from this environment and placed directly into an environmental chamber such that the same exposure geometry is established and the temperature near the instrument is $50 \pm 5^\circ\text{C}$. This procedure shall be performed in less than 5 minutes. The mean instrument reading shall be determined then and every 15 minutes for 2 hours if the instrument fails the test within the first hour. If the instrument does not fail the test within the first hour, data does not need to be taken during the second hour; however, the instrument should remain in this environment during the period to reach temperature stabilization. The instrument and radioactive source shall be removed from the environmental chamber and returned to the first environment such that the same exposure geometry is established and the temperature near the instrument is approximately 20°C . This procedure shall be performed in less than 5 minutes. The mean instrument reading shall be determined then and every 15 minutes for 2 hours if the instrument fails the test within the first hour. If the instrument does not fail within the first hour, data does not need to be taken during the second hour; however, the instrument should remain in this environment during the period to reach temperature stabilization.

The test shall be repeated with the temperature inside the environmental chamber near the instrument at $-10 \pm 5^\circ\text{C}$.

2.2.27 Humidity Test

Requirements

The mean instrument response shall not vary more than 15% over the noncondensing relative humidity range of 40% to 95% and a temperature of $20 \pm 5^\circ\text{C}$ from the mean instrument response at 40% RH and $20 \pm 5^\circ\text{C}$. Response to high humidity and higher temperature is covered under extreme environmental conditions.

Test Method

The instrument shall be exposed in an environmental chamber to a suitable source or radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. Figure 2.3

FIGURE 2.3. Humidity Exposure Profile

represents the humidity exposure that was used for this study. The mean instrument reading at $40 \pm 5\%$ relative humidity and temperature of $20 \pm 5^\circ\text{C}$ shall be determined after a minimum exposure period of 4 hours in this atmosphere. The relative humidity inside the chamber shall be increased to $95 \pm 4\%$ while the temperature is kept at $20 \pm 5^\circ\text{C}$ and maintained at that level for a minimum of 8 hours. The mean instrument reading shall then be determined under these environmental conditions. The relative humidity shall be decreased to $40 \pm 5\%$ while the temperature is kept at $20 \pm 5^\circ\text{C}$ and then maintained at that level for a minimum of 4 hours. The mean instrument reading shall then be determined.

2.2.28 Mechanical Shock Test

Requirements

The mean instrument response for portable systems shall not vary more than 15% from a set of reference readings after being subjected to 10 shock pulses of 50 g peak acceleration applied for 18 milliseconds in each of three mutually orthogonal axes. This requirement applies to survey instruments only.

Test Method

The instrument shall be exposed in a reproducible geometry to a suitable

source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be subjected to 10 pulses of peak acceleration of 50 g (half-sine wave pulse) over a time interval of 18 milliseconds in 1 of 3 orthogonal directions. The mean instrument reading shall again be determined in the same exposure geometry as used initially. The instrument shall be subjected to similar shock pulses in the other 2 orthogonal directions and the mean instrument reading determined after each shock in the same exposure geometry.

2.2.29 Vibration Test

Requirements

The mean instrument response shall not vary more than 15% from a set of reference readings following harmonic loadings of 2 g applied for 15 minutes in the frequency range of 10 to 33 Hz.

Test Method

The instrument shall be exposed in a reproducible geometry to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be subjected to harmonic loadings of 2 g for 15 minutes in each of three orthogonal directions at one or more frequencies in each of the following ranges: 10 to 21 Hz and 22 to 33 Hz. After each 15-minute vibration interval, the mean instrument reading shall be determined in the same exposure geometry as used initially and compared to the previbration set of readings.

2.2.30 Ambient Pressure Test

Requirements

The mean instrument response shall not vary more than 15% from the mean instrument response at 101 kPa over the ambient pressure range of 70 to 106 kPa. Corrections to instrument readings for air density changes are to be made when appropriate (e.g., for free-air ionization chambers). This requirement does not apply to gas or air proportional instruments.

Test Method

The instrument shall be exposed to a suitable source of radiation of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading at 101 kPa shall be determined. The ambient pressure shall be changed at a rate not greater than 20 kPa/min. Sufficient data shall be obtained at 106, 100, 92, 84, 76, and 70 kPa; the instrument shall be permitted to equilibrate at each pressure before data are taken. Figure 2.4 represents the ambient pressure exposure profile that was used for this study. Pressure inside the chamber was changed at a maximum rate of 1.6 kPa/min. A temperature change of less than 1°C was observed during the pressure change level. A minimum equilibration time of 4 minutes at each pressure level was used to allow the temperature inside the chamber to return to its previously established value.

2.2.31 Brief Immersion Test

Requirements

The mean instrument response shall not vary more than 15% from a set of reference readings after being subjected to a brief immersion in a volume of water. This requirement does not apply to detectors open to the air, to detectors with thin windows, or to bench-top units.

FIGURE 2.4. Ambient Pressure Exposure Profile

Test Method

The instrument shall be exposed to an acceptable source of sufficient intensity to produce a response of approximately mid-scale or mid-decade on an appropriate scale or decade. The mean instrument reading shall be determined. The instrument shall then be turned off before immersion into a volume of water sufficient to cover the entire instrument. The temperatures of the water and the instrument shall both be nominal 20°C. The instrument shall be immersed in the volume of water for a brief period of time (e.g., 1 to 2 seconds). After the instrument is removed from the water, the exterior surface of the unit shall be dried. The instrument shall be opened and all parts shall be inspected for any signs of moisture. The instrument shall then be closed and turned on. The mean instrument reading shall again be determined in the same exposure geometry as used initially, and the mean instrument readings obtained before and after immersion shall be compared.

2.3 DESCRIPTION OF TESTING EQUIPMENT

Descriptions of the major pieces of equipment used in the testing program are included in this section. The calibration of this equipment and assurance of the continued performance of the equipment is described in Part 1 of this report. Specific model numbers or types, manufacturers, general system descriptions, and operating specifications if applicable are stated for the following: environmental chamber (2.3.1), vibration-testing system (2.3.2), shock-testing system (2.3.3), pressure/vacuum exposure chamber (2.3.4), radio frequency generation and characterization system (2.3.5), ^{137}Cs , ^{60}Co , and ^{252}Cf calibration wells (2.3.6), low-scatter exposure facility (2.3.7), high-level exposure facility (2.3.8), and x-ray exposure facility (2.3.9). In addition, test sources were used to obtain reference readings. These sources are described in Section 2.3.10.

Listing and describing the testing equipment used in this study in no way endorses the specific equipment. These are only examples of systems that can be used.

2.3.1 Environmental Chamber

General Description

The walk-in environmental chamber used for testing the performance of

instrumentation under the controlled temperature and humidity conditions that were considered to be in the normal range was a model WI-TR chamber manufactured by Tenney Engineering, Inc. This system is controlled by a microprocessor-based system that could also be used as a programmer and alarm system. Specific temperature and relative humidity set points could be manually entered into the controller, or programs could be read into the system by a touch sensitive keyboard or by tape cassette.

These specifications describe the environmental chamber:

- Internal dimensions: 5 ft wide x 5 ft 6 in. deep x 7 ft high
- Door: 3 ft wide x 6 ft 6 in. high
- Floor load: 600 lb/ft²
- Power: 230 Vac/3 phase/60 Hz
- Viewing window: 22 in. x 22 in.
- Perforated ceiling plenum
- Fluorescent lighting (4-ft lamps)
- 115-V electrical receptacles inside chamber (2)
- Manual window wiper
- 2-in. ports (2).

Operating Specifications

These operating specifications apply to the environmental chamber:

- Temperature Range: -20 to +60°C
- Humidity Range: 20% RH to 95% RH at any temperature in a range from +15 to +25°C
- Live energy load: 1000 watts
- Control stability: $\pm 0.5^{\circ}\text{C}$; $\pm 3\%$ RH
- Temperature uniformity: $\pm 0.5^{\circ}\text{C}$ (no load conditions at stabilized temperature; no closer than 4 in. to any interior wall surface)
- Temperature change rate: 20 to -20°C or vice versa within 1-hour period.

Manufacturer Information

Tenney Engineering, Inc.
1090 Springfield Road
Union, New Jersey 07083

2.3.2 Vibration-Testing System

General Description

Two vibration tables were used during this study to test the effects of vibration on the performance of the instrumentation. One table was fairly large (Model BRFCCD-48x66-1500) with a top surface area of approximately 22 ft², and the second table was smaller (Model BRVP-18-100) with a top surface area of approximately 2 ft². Both tables were manufactured by L.A.B., a division of Mechanical Technology Incorporated.

Before testing, the instruments were secured to the tops of the tables with clamps so that they would not move during the vibration period. The acceleration and frequency were measured with a vibration and frequency monitor manufactured by L.A.B. and an accelerometer manufactured by PCB Piezotronics.

Operating Specifications

Large Table (Model BRFCCD-48x66-1500)

- Maximum test load: 1500 lb
- Maximum acceleration (under full load): 3.2 g
- Maximum displacement (double amplitude): 0.07 in. at max. load
- Frequency range: 8 to 60 Hz
- Direction of vibration: vertical
- Motor size: 5 hp
- Power connections: 220 Vac, single phase, 60 Hz
- Table wt: 1110 lb

Small Table (Model BRVP-18-100)

- Maximum test load: 100 lb
- Maximum acceleration (under full load): 10 g
- Maximum displacement (double amplitude): 0.25 in. at max. load
- Frequency range: 10 to 60 Hz
- Direction of vibration: vertical
- Motor size: 2 hp
- Power connections: 115 Vac, single phase, 60 Hz
- Table wt: 105 lb

Vibration and Frequency Monitor (Model 9150)

- Maximum acceleration: 20 g
- Resolution: 0.01 g
- Accuracy: $\pm 2\%$
- Frequency: 2 to 2000 Hz
- Power: 115 Vac, 50 to 60 Hz, 0.5 A

Accelerometer (Model 308B)

- Maximum acceleration: 50 g
- Frequency range: 1 to 3000 Hz
- Nominal output: 100 mV/g

Manufacturer Information

Tables and Vibration/Frequency Monitor

L.A.B

Division of Mechanical Technology, Inc.

Onondaga Street

Skaneateles, New York 13152

Accelerometer

PCB Piezotronics, Inc.

3425 Walden Avenue

Depew, New York 14043

2.3.3 Shock-Testing System

General Description

A gravity-fall type system (Model SD-16-60-200) was used to evaluate the performance of instruments after they were subjected to a known size and shape shock pulse. An instrument would be secured to the top of a large base block, raised to a specific height, then the block would be dropped onto a predesigned surface in order to create a shock pulse of known intensity and width. The system was manufactured by L.A.B. Voltage signals from an accelerometer secured to the base were processed by an amplifier (Model 494A "Dial Cal"), and the output was observed with a calibrated oscilloscope.

Operating Specifications

Gravity-Fall System (Model SD-16-60-200)

- Carriage size: 16 in. x 16 in.
- Test load rating: 200 lb
- Carriage weight: 170 lb
- Standard carriage fall: 60 in.
- Maximum acceleration (for 50-lb load): 3000 g
- Hoist motor: 1/2 hp, single phase, 60 Hz, 120 Vac
- Base block: 2000 lb
- Floor space: 24 in. x 33 in. x 121 in. high
- Shipping weight: 3500 lb
- Decelerating device: 30 g, 18-millisecond half-sine-wave shock pad
- Overtravel safety limit switch
- Electrical interlocks
- Instrument trigger switch

Voltage Amplifier (Model 494 "Dial Cal")

- Adjustable gain: 0.1 to 100
- 1-kHz low pass filter
- Power: 105 to 125 Vac

Accelerometer (Model 305 A04)

- Maximum acceleration: 5000 g
- Nominal output: 1 mV/g

Manufacturer Information

Gravity-Fall System

L.A.B.

Division of Mechanical Technology, Inc.

Onondaga Street

Skaneateles, New York 13152

Amplifier and Accelerometer

PCB Piezotronics, Inc.

3425 Walden Avenue

Depew, New York 14043

2.3.4 Pressure/Vacuum Exposure Chamber

General Description

The pressure/vacuum exposure system used to evaluate the performance of instruments during changes in ambient pressure was a Model 48 system manufactured by Alpha Group, Inc. Two levels of instruments could be placed inside the chamber, the door secured, and the instrument readouts observed through the circular window in the door of the chamber.

Operating Specifications

- Unit capable of achieving a pressure range of 200 to 2800 mm Hg
- Transducer (0-100 psia)
- Digital readout
- Chamber volume: 324 gal = 1.43 m³
- Air pump of 11.2 scfm @ 80 psig
- Vacuum pump of 8 scfm @ 20 in. of Hg
- 2 shelves - midpoint of 48 in. x 36 in.
- midpoint of 18 in. x 36 in.
- Pump down time to 300 mm Hg is 5 minutes
- Pressurize time to 2000 mm Hg is 3 minutes
- Vent time from 300 mm Hg is 1 minute to atmospheric pressure
- Vent time from 2000 mm Hg is 1.5 minutes to atmospheric pressure
- Chamber weight: 2600 lb; Pumping station: 1200 lb; Total: 3800 lb

Manufacturer Information

Alpha Group, Inc.
14531 Griffith St.
San Leandro, California 94577

2.3.5 Radio Frequency Generation and Characterization System

General Description

The system used to measure the effects of radio frequency fields on the performance of portable health physics instruments consisted of four separate pieces of equipment: a power amplifier, a signal generator, an antenna, and a broadband meter. The antenna was designed to meet the specifications of MIL-STD-461B (DOD 1980).

Operating Specifications

Power Amplifier (Model A500)

- Frequency range: 0.3 to 35 MHz
- Gain: 60 dB
- Gain variation: ± 1 dB
- Maximum linear power output: 500 watts
- Noise: 10 dB maximum
- Output metering: RMS volts, watts
- Power: 208, 230, 245 Vac, tap selected, $\pm 5\%$, 50 to 60 Hz, 20 A
- Operating temperature: 0 to 40°C
- Weight: 165 lb

Signal Generator (Model 8656A)

- Frequency range: 0.1 to 999 MHz
- Frequency resolution: 100 Hz
- Output range: +13 to -127 dBm
- Output resolution: 0.1 dB
- Operating temperature range: 0 to 55°C
- Power: 220 Vac, 48 to 66 Hz

Antenna

- Uniform field established
- Parallel plate system
- Resistors: $\pm 1\%$ tolerance
- System approximately 12 ft long x 2 ft wide x 1 1/2 ft high
- Meets specifications in MIL-STD-461-B

Broadband Meter (Model HI-3001)

- Ranges: $100 \text{ V}^2/\text{m}^2$ to $10^7 \text{ V}^2/\text{m}^2$ full scale
- Frequency response: 0.5 MHz to 6 GHz: ± 2 dB
1 MHz to 1 GHz: ± 1 dB
3 to 500 MHz: ± 0.5 dB
- Accuracy: ± 0.5 dB at calibration frequencies
- Recorder output: 0 to 1 V

- Weight: 6.5 lb
- Operates on 14 C-size batteries

Manufacturer Information

Power Amplifier

Electronic Navigation Industries, Inc.
Rochester, New York

Signal Generator

Hewlett-Packard Company
1501 Page Mill Road
Palo Alto, California 94304

Antenna

Electro Mechanics Co.
Austin, Texas

Broadband Meter

Holaday Industries, Inc.
14825 Martin Drive
Eden Prairie, Minnesota 55344

2.3.6 ^{137}Cs , ^{60}Co , ^{252}Cf Calibration Wells

General Description

The calibration wells located in the 318 Building on the Hanford Site were used during several tests included in the draft standard. Two ^{137}Cs wells, one ^{60}Co well, and one ^{252}Cf (unmoderated) well were employed. Tests in which these sources were used include the following: accuracy, precision, response time, extracamerai response, photon radiation energy dependence, radiation overload, and interfering ionizing radiation.

Specifications

Table 2.10 lists the sources, the nominal activity of each source, and the approximate dose rate ranges achievable with each source.

TABLE 2.10. Calibration-Well Source Information

<u>Source</u>	<u>Nominal Activity</u>	<u>Approximate Dose Rate Range (4/85)</u>
^{137}Cs	1 Ci	0.1 mR/h to 200 mR/h
^{137}Cs	10 Ci	3 mR/h to 20 R/h
^{60}Co	1 Ci	50 mR/h to 3.5 R/h
^{252}Cf	100 μg	1 mrem/h to 600 mrem/h

2.3.7 Low-Scatter Exposure Facility

General Description

The low-scatter exposure facility is located in the 318 Building on the Hanford Site. The room in which the sources are used is approximately 40 ft wide, 60 ft long, and 25 ft high. Four sources were available for use in this room: two ^{137}Cs and two ^{252}Cf sources. The ^{252}Cf could be used as moderated or bare sources. The sources can be pneumatically controlled from outside the exposure room to go to one of three exposure locations in the room.

Specifications

Table 2.11 lists the sources, nominal activity of each source, and the dose rates achievable with each source.

TABLE 2.11. Low-Scatter Exposure Facility Source Information

<u>Source</u>	<u>Nominal Activity</u>	<u>Approximate Dose Rate (7/85)</u>
^{137}Cs	2 Ci	470 mR/h at 100 cm
^{137}Cs	10 Ci	2.5 R/h at 100 cm
^{252}Cf (bare)	80 μg	442 mrem/h at 50 cm
^{252}Cf (moderated)	80 μg	106 mrem/h at 50 cm
^{252}Cf (bare)	1 mg	5453 mrem/h at 50 cm
^{252}Cf (moderated)	1 mg	1312 mrem/h at 50 cm

2.3.8 High-Level Exposure Facility

General Description

The high-level exposure facility is located in the 318 Building on the Hanford Site. Four sources can be used in this facility: two ^{137}Cs sources and two ^{60}Co sources. The sources and distance from the source for the instruments can be controlled from outside the exposure room. Closed-circuit video systems and remote-readout systems are available.

Specifications

Table 2.12 lists the sources, the nominal activity of each source, and the approximate dose rate ranges achievable with each.

TABLE 2.12. High-Level Exposure Facility Source Information

<u>Source</u>	<u>Nominal Activity</u>	<u>Approximate Dose Rate Range (7/85)</u>
^{137}Cs	60 Ci	80 mR/h to 12 R/h
^{137}Cs	100 Ci	800 mR/h to 115 R/h
^{60}Co	500 Ci	15 R/h to 2,000 R/h
^{60}Co	4,500 Ci	130 R/h to 20,000 R/h

2.3.9 X-Ray Exposure Facility

General Description

The x-ray exposure facility is located in the 318 Building on the Hanford Site. The x-ray beams are generated using a 320 kV maximum constant potential machine manufactured by Picker Industrial. The beam is directed horizontally for heavily filtered (HF) techniques. After being filtered and collimated, the beam passes through an encompassing transmission ionization chamber used to monitor intensity.

Specifications

Only HF techniques are listed in the standard. Table 2.13 lists the techniques used in this study (i.e., referenced to the NBS notation).

TABLE 2.13. X-Ray Sources Used in This Study

<u>Nominal Effective Energy (keV)</u>	<u>NBS-Referenced Technique</u>
40	H50
80	H100
120	H150
166	H200
211	H250
252	H300

Exposure rates range from 16 mR/min to 1.2 R/min at 1 m depending on the technique used.

2.3.10 Test Sources

General Description

A number of different low-activity test sources (i.e., radioactive sources less than or equal to 10 mCi in total activity) were used for reference measurements during testing. Table 2.14 lists a number of these low-activity test sources. These sources were used in a number of different tests (e.g., stability, temperature, humidity, vibration, response time) where either the exposure geometry did not change during the test, reference readings were reproduced after the instrument was subjected to a specific type and level of stress, or the response of the instrument did not require a source where the activity was accurately known. These sources are available for purchase from a number of instrument manufacturers and radioisotope manufacturers and vendors.

TABLE 2.14. Low-Activity Test Sources

<u>Test Source</u>	<u>Nominal Activity</u>
^{137}Cs	8 μCi
^{137}Cs	100 μCi
^{137}Cs	1 mCi
^{137}Cs	10 mCi
^{241}Am	10 mCi
^{57}Co	10 mCi
^{230}Th	10 nCi
^{239}Pu	3 nCi
^{252}Cf	4.5 $\mu\text{g}^{(a)}$

(a) microgram

3.0 RESULTS AND DISCUSSION

Results of testing are discussed for the specific tests and also for the different types and models of instruments. The data are presented such that the bases for the conclusions can be easily derived.

3.1 TEST-BY-TEST RESULTS

3.1.1 Inspection Tests

Data in this section are summarized for the following inspection tests: units of readout, scaling factors, ease of decontamination, moisture protection, alarm threshold, markings, battery status indication, and protection of switches. A total of 46 instrument models have been evaluated using the inspection test procedures in ANSI N42.17A-D4, Rev. 1. These include 10 models of ion chambers, 21 models of GM detectors, 8 models of alpha detectors, 6 models of neutron detectors, and 1 model of NaI(Tl) detector.

Table 3.1 lists specific results for different types of instruments for each requirement under each inspection test. For each type of instrument [i.e., ion chamber, GM detector, alpha detector, neutron detector, or NaI(Tl) instrument], results are expressed in terms of whether the instrument passed or failed the requirement, and whether or not the requirement applied to the specific instrument model. These criteria are also discussed in "Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Work Environments, Part 1: Manual of Testing Procedures."

Table A.1 in Appendix A of this report lists data for each different instrument model in terms of the specific criteria each model failed. Listed in this table are the instrument identification (ID) numbers for each model and the criteria failed by each.

Specific criteria that a large number of instruments failed include the following: A.1.1.1, A.1.3.1, A.1.4.1, A.1.6.2(c), and A.1.8.1. Requirement A.1.1.1 states that readings of beta-photon dose and dose rate instruments shall be expressed in units of dose (e.g., rad, Gy) or dose rate (e.g., rad/h, Gy/h) in air. Some of the instruments tested that measure beta-photon dose rate express the readings only in R/h. Requirement A.1.3.1 states that an instrument should be constructed to facilitate decontamination; a smooth,

TABLE 3.1. Inspection Test Results

Requirements	Ion Chambers			GM			Alpha			Neutron			Other (NaI)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
A.1.1 Units of Readout															
1. Readings of beta-photon dose and dose rate instruments shall be expressed in units of dose (e.g., rad, Gy) or dose rate (e.g., rad/h, Gy/h) in air. Units of dose equivalent okay.	1	6	3	0	4	17	0	0	8	0	0	6	0	0	1
2. Readings of photon exposure and exposure rate instruments may be expressed in units of exposure (e.g., R) or exposure rate (e.g., R/h). Units of dose or dose equivalent okay.	10	0	0	17	0	4	0	0	8	0	0	6	1	0	0
3. Readings of contamination-monitoring instruments should be expressed in units of counts per unit time.	0	0	10	10	1	10	8	0	0	0	0	6	0	0	1
4. Readings of neutron-monitoring instrument shall be in units of dose equivalent (e.g., rem, Sv) or dose-equivalent rate (e.g., rem/h, Sv/h).	0	0	10	0	0	21	0	0	8	6	0	0	0	0	1

TABLE 3.1. (contd)

Requirements	Ion Chambers			GM			Alpha			Neutron			Other (NaI)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
A.1.2 Scaling Factors															
1. For an instrument with linear analog scales, the scaling factor between adjacent ranges shall not exceed ten.	5	0	5	15	0	6	7	0	1	3	0	3	1	0	0
2. If a logarithmic analog scale is provided with switched measurement ranges, there shall be an overlap between adjacent ranges.	0	2	8	1	1	19	0	0	8	0	1	5	0	0	1
3. Readouts shall clearly indicate the range or measurement units; if a floating decimal point is used, it should be clearly displayed.	2	1	7	3	0	18	5	0	3	3	0	3	1	0	0
4. Quasi-logarithmic or other nonlinear analog displays should be designed such that multiple ranges, if used, overlap.	0	0	10	1	0	20	1	0	7	1	0	5	0	0	1

TABLE 3.1. (contd)

Requirements	Ion Chambers			GM			Alpha			Neutron			Other (NaI)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
<u>A.1.3 Ease of Decontamination</u>															
1. The instrument should be constructed to facilitate decontamination. A smooth, nonporous external surface free of crevices is suggested.	8	2	0	18	3	0	2	6	0	5	1	0	0	1	0
<u>A.1.4 Moisture Protection</u>															
1. The manufacturer shall state the extent of protection from the effects of moisture and the design features or other precautions to prevent the ingress of moisture.	3	5	2	5	16	0	1	5	(a)	0	6	0	0	1	0
<u>A.1.5 Alarm Threshold</u>															
1. For instruments equipped with an alarm feature, the alarm threshold shall be capable of being adjusted to any point within the specified range.	0	0	10	2	3	16	0	0	8	0	0	6	0	0	1
2. The values of alarm threshold shall be given either as percentages of ranges of adjustment or in terms of the units of the display.	0	0	10	2	3	16	0	0	8	0	0	6	0	0	1

TABLE 3.1. (contd)

Requirements	Ion Chambers			GM			Alpha			Neutron			Other (NaI)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
A.1.5 Alarm Threshold (contd)															
3. Alarm threshold adjustments shall be protected from inadvertent adjustment.	0	0	10	2	3	16	0	0	8	0	0	6	0	0	1
A.1.6 Markings															
1. All external instrument controls, displays, and adjustments shall be clearly identified.	10	0	0	19	2	0	7	1	0	5	1	0	1	0	0
2. The following markings shall appear on the exterior of each major sub-assembly (e.g., detector probes) of the instrument as appropriate:															
(a) Manufacturer and model number	10	0	0	20	1	0	4	4	0	6	0	0	1	0	0
(b) Unique serial number	10	0	0	20	1	0	4	4	0	6	0	0	1	0	0
(c) Location of sensitive volume(s) or area(s) of detector(s)	1	9	0	2	19	0	0	8	0	0	6	0	0	1	0
(d) Function designation for controls, switches, and adjustments.	10	0	0	20	1	0	7	1	0	5	1	0	1	0	0

TABLE 3.1. (contd)

Requirements	Ion Chambers			GM			Alpha			Neutron			Other (NaI)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
A.1.6 Markings (contd)															
3. Markings shall be easily readable and permanently fixed under normal conditions of use, (including decontamination of instruments); markings of contrasting color, raised or recessed from the exterior surface, are recommended.	10	0	0	20	1	0	8	0	0	6	0	0	1	0	0
4. Displays shall be provided with clear markings.	6	0	4	18	0	3	8	0	0	4	1	1	1	0	0
5. For linear read-outs, major scale divisions shall be at zero and 100% of full-scale and at four or eight equally spaced points in between (e.g., 0.2, 0.4, 0.6, and 0.8 of full-scale).	4	1	5	13	2	6	5	2	1	3	0	3	0	1	0
6. Logarithmic scales shall have each decade clearly marked with at least four but not more than 12 approximately equally spaced (e.g., 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 10) major division markings between the limits of the decade.	2	0	8	3	1	17	0	0	8	2	0	4	0	0	1

TABLE 3.1. (contd)

Requirements	Ion Chambers			GM			Alpha			Neutron			Other (NaI)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
A.1.6 <u>Markings (contd)</u>															
7. Displays shall prominently show the readout units.	5	5	0	21	0	0	8	0	0	6	0	0	1	0	0
A.1.7 <u>Battery Status Indication</u>															
1. Battery-powered instruments shall be equipped with a visible test circuit or other direct indicators of battery condition.	10	0	0	20	0	1	7	1	0	6	0	0	1	0	0
A.1.8 <u>Protection of Switches</u>															
1. Switches and other controls shall be protected to prevent inadvertent deactivation or improper operation of system.	6	4	0	11	10	0	6	2	0	5	1	0	0	1	0

(a) Operation manuals not available to check.

nonporous external surface, free of crevices, is suggested. Many external probes, especially alpha contamination probes, do not meet this requirement. Requirement A.1.4.1 states that the manufacturer shall state the extent of protection from the effects of moisture and the design features or other precautions to prevent the ingress of moisture. This is rarely done. Requirement A.1.6.2(c) is the requirement that the most instruments failed; it requires that the location of the sensitive volume(s) or area(s) of the detector(s) be marked on the exterior of each major subassembly (e.g., detector probes). Only 1 model of ion chamber and 2 models of GM detectors met this criterion. Requirement A.1.8.1 states that switches and other controls shall be protected to prevent inadvertent deactivation or activation of the system. Many instruments do not use lock-type toggle switches or potentiometers. The high-voltage or zero-set controls on some instruments can be easily turned by accident.

3.1.2 Zero Set Test

A total of 7 instruments were tested using procedures based on the zero set requirements and methods in ANSI N42.17. These were all vented-type ion chambers; only the "current-reading" type of instruments have a zeroing circuit in the electronics. Four different models from 4 manufacturers are represented. All of the 7 instruments (4 models) tested passed the test.

Table A.2 in Appendix A represents detailed results for this test. Listed in this table are the instrument ID number, the highest exposure rate in which the instrument was tested, and whether or not the instrument passed or failed. The highest intensity radiation field in which instruments were tested was 2 R/h. Personnel would normally not be zeroing a meter while being exposed to levels greater than this.

3.1.3 AC Power Test

A total of 4 instruments were tested using procedures based on the ac voltage requirements and methods in ANSI N42.17. Each instrument was a different model; 3 different manufacturers were represented. All of the systems were bench-top units and were tested with GM-type detectors. All 4 of the instruments passed the test.

Table A.3 in Appendix A represents detailed results for this test. Listed in this table are the instrument ID numbers and whether the instruments passed or failed the test.

3.1.4 Battery Power Test

A total of 41 instruments were evaluated with procedures based on the requirements and methods stated in ANSI N42.17. Six of these instruments were ion chambers (vented), 28 were GM detectors, and 7 were alpha survey instruments. These included 3 different models of ion chambers, 16 different models of GM detectors, and 4 models of alpha meters, for a total of 23 different instrument models tested.

Table 3.2 summarizes the battery power test results in terms of the number of failures observed for instruments and models and the total number of each tested for the different types of instruments. None of the ion chambers tested failed this test. Twelve of the 28 GM detectors (4 of the 16 different models) failed the test, and 3 of the 7 alpha detectors (1 of 4 models) failed the test.

TABLE 3.2. Battery Power Test Results

<u>Instrument Type</u>	<u>Number of Failures/ Number Tested</u>	
	<u>Instrument</u>	<u>Model</u>
Ion chamber	0/6	0/3
GM detector	12/28	4/16
Alpha detector	3/7	1/4

Table A.4 in Appendix A represents more detailed results for this test. Listed in this table are the instrument ID number, the approximate battery lifetime, whether the instrument passed or failed the test, and specific comments for an instrument.

3.1.5 Latching and Nonlatching Alarm Reset Test

A total of 3 instruments were tested using procedures based on the latching and nonlatching alarm reset requirements and methods in ANSI N42.17. Each instrument was a different model from a different manufacturer. Two of the instruments had nonlatching alarms while the third instrument had a latching alarm. All 3 systems were bench-top units and were tested with GM-type detectors.

Table 3.3 summarizes the results of the latching and nonlatching alarm reset test in terms of the number of failures observed for instruments and models. One of the 3 instruments failed this test. The instrument that failed would alarm (visible and audible) at the established set point; however, when the alarms were activated, the meter indication would decrease substantially below the set point and the alarm condition would be eliminated. When this occurred, the audible and visible alarms deactivated and the meter indication would increase until the alarm set point was reached again. This routine was repeated throughout the 5-minute evaluation interval.

TABLE 3.3. Latching and Nonlatching Alarm Reset Test Results

<u>Instrument Type</u>	<u>Number of Failures/ Number Tested</u>	
	<u>Instrument</u>	<u>Model</u>
GM detector	1/3	1/3

Table A.5 in Appendix A represents more detailed results for this test. Listed in this table are the instrument ID number and whether the instrument passed or failed the test. The latching type alarm is identified by an "L" after the identification number.

3.1.6 Alarm Activation Delay Test

A total of 3 instruments were tested using procedures based on the alarm activation delay requirements and methods in ANSI N42.17. Each instrument was a different model from a different manufacturer. These bench-top systems were tested with GM-type detectors. No instruments failed this test.

Table A.6 in Appendix A represents detailed results for this test. Listed in this table are the instrument ID number and whether or not the instrument passed or failed the test.

3.1.7 Alarm Threshold Drift Test

A total of 3 instruments were tested using procedures based on the alarm threshold drift requirements and methods in ANSI N42.17. Each instrument was a different model from a different manufacturer. These bench-top systems were tested with GM-type detectors. No instruments failed this test.

Table A.7 in Appendix A represents detailed results for this test. Listed in this table are the instrument ID number and whether or not the instrument passed or failed the test.

3.1.8 Stability Test

A total of 63 instruments were tested using procedures based on the stability requirements and methods discussed in ANSI N42.17. Thirty-five of these were GM detectors, 9 were ion chambers (all vented type), 15 were alpha detectors, and 4 were neutron detectors. These included 6 different models of ion chambers, 20 different models of GM detectors, 7 different models of alpha detectors, and 3 different models of neutron detectors. Several instruments were evaluated more than once, with the instrument being operated on different ranges or decades for each evaluation.

Table 3.4 summarizes the results of the stability test in terms of the number of failures observed for instruments and models and the total number of each tested for the different types of instruments. One of the 35 GM detectors failed the test (1 of the 20 different models), 1 of the 9 ion chambers failed (none of the 6 different models), 2 of the 15 alpha detectors failed (none of the 7 different models), and none of the 4 neutron detectors failed the test. All of the failures with GM detectors and ion chambers were on the lowest scale or decade; 2 of the 4 failures of the gas flow alpha detectors were also on the lowest scale or decade. It is quite possible that if these instruments were tested on higher scales or decades the instruments could have passed the test. Three of the 5 gas flow alpha detectors and 3 of the 4 neutron detectors that passed were marginal decisions.

Table A.8 in Appendix A represents more detailed results for this test. Listed in this table are the instrument ID number, the maximum percentage of change from the reference data with respect to the full-scale or full-decade value plus or minus one standard deviation, the full-scale or full-decade reading, the time at which the maximum change occurred, and whether or not the instrument failed the requirement in the draft standard. Data from all of the runs performed on the instruments are not listed in this table, only the best

TABLE 3.4. Stability Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Ion chamber (Vented)	1/9	0/6
GM detector	1/35	1/20
Alpha detector	2/15	0/7
(Gas flow)	1/6	0/3
(Scintillation)	0/5	0/2
(Air proportional)	1/4	0/3
Neutron detector	0/4	0/3

data (i.e., the most statistically reliable data) are listed for each instrument. The overall results showed that the results were affected by the exposure rate at which the instruments were exposed. More statistically reliable data were obtained with higher exposure rates. Initial drafts (1 and 2) of the standard required testing on the most sensitive scale. Because of the difficulty in obtaining statistically reliable data, later drafts were changed to read "appropriate scale or decade" to permit use of the instrument on a scale showing less statistical variation. Data are shown for instrument 129 where a source was used for one run and a pulser for another. The pulser produced data that showed no change in the instrument readings over the 3-hour period. The data obtained with this instrument and a radioactive source still passed the test; however, a change in response was measured. This change could be due to only the random fluctuations in the data. The use of a pulser in this test may result in data that are more statistically reliable.

3.1.9 Geotropism Test

A total of 48 instruments were tested using procedures based on the requirements of ANSI N42.17. Ten of these were ion chambers (9 vented-type and 1 closed, pressurized-type), 24 instruments were GM detectors, and 14 were alpha detectors (5 gas flow, 5 scintillators, and 4 air proportional). These included 6 different models of ion chambers (vented), 1 model of ion chamber (open), 12 different models of GM detectors, and 6 different models of alpha detectors. No neutron detection instruments were evaluated.

Table 3.5 summarizes the geotropism test results in terms of the number of failures observed for instruments and models and the total number of each tested for different types of instruments. None of the ion chambers or GM

TABLE 3.5. Geotropism Test Results

<u>Instrument Type</u>	<u>Number of Failures/ Number Tested</u>	
	<u>Instrument</u>	<u>Model</u>
Ion chamber	0/10	0/7
(Vented)	0/9	0/6
(Closed)	0/1	0/1
GM detector	0/24	0/12
Alpha detector	8/14	3/6
(Gas flow)	4/5	1/2
• Probe	1/5	0/2
• Instrument	4/5	1/2
(Scintillation)	0/5	0/2
(Air proportional)	4/4	2/2
Neutron detector	NT	NT

detectors failed the test. Of the 14 alpha detection instruments, 8 failed the test (3 of the 6 different models); deviations of 3.5% to 43% were observed with these failed instruments. All scintillation detectors passed the test while all the gas flow proportional counters and air proportional detectors failed. Gas flow instruments were tested for both probe orientation and instrument orientation. Of the 5 gas flow instruments, 4 instruments failed the instrument orientation test and only 1 instrument failed the probe orientation test, indicating probe orientation is not a significant problem. For gas flow proportional counters, there does not appear to be any one orientation that fails more often than another. However, 3 out of 4 air proportional detectors failed the test in the 270° x-axis position, indicating the reading indicator may be influenced by gravitational forces.

Table A.9 of Appendix A represents more detailed geotropism data. Listed are the instrument ID number, maximum percentage of change from reference, the

full-scale or full-decade reading, the axis and angle of maximum change, and whether the instrument passed or failed the test. Several runs were made with a number of the instruments employing different exposure rates. Eighty-two runs are listed in this table. If an instrument was observed to pass the test on any scale, it was considered to have passed the test overall. With some of the instruments, it was very difficult to obtain statistically reliable data on the lower scales.

3.1.10 Response Time Test

A total of 47 instruments were evaluated with procedures based on the requirements and methods stated in ANSI N42.17. Ten of these instruments were ion chambers (vented), 5 were ion chambers (closed), 22 were GM detectors, 7 were alpha survey instruments, and 3 were neutron detectors. These included 7 different models of ion chambers (vented), 2 different models of ion chambers (closed), 13 different models of GM detectors, and 4 different models of alpha survey instruments, and 1 model of neutron detectors.

Table 3.6 summarizes the response time test results in terms of the number of failures observed for instruments and models and the total number of each tested for the different types of instruments. An instrument was considered to have failed the test if it failed to meet the ANSI N42.17 requirement on any range tested. Seven of the 10 ion chambers (vented) (4 of the 7 different models) tested failed this test while only 1 of 5 ion chambers (closed) (none of the 2 different models) failed. Ten of the 22 GM detectors (6 of the 13 different models) failed the test; none of the 7 alpha survey instruments failed; and all 3 of the neutron detectors failed.

Table 3.7 summarizes response time test results for each of the ranges defined in ANSI N42.17. Ion chambers (vented) failed the test at approximately the same rate over all the ranges tested. Ion chambers (closed) only failed the test at the highest range (>1 rem, rad/h). All GM detectors passed the test on the two lowest ranges with an increasing number of failures at the higher ranges (i.e., all instruments failed on the highest range, >1 rem, rad/h). Testing of a limited number of neutron detectors showed all

TABLE 3.6. Response Time Test Results (Overall)

<u>Instrument Type</u>	<u>Number of Failures/Number Tested</u> ^(a)	
	<u>Instrument</u>	<u>Model</u>
Ion chamber	8/15	4/9
(Vented)	7/10	4/7
(Closed)	1/5	0/2
GM detector	10/22	6/13
Alpha detector	0/7	0/4
Neutron detector	3/3	1/1

(a) Instruments that failed on at least one range.

instruments failed at the lowest range ($\leq 5 \times 10^{-2}$ rem/h) and highest range (>1 rem/h), while all passed in the middle range (5×10^{-2} to ≤ 1 rem/h).

Table A.10 in Appendix A presents more detailed results for this test. Listed in this table are the instrument IO number, the response time in seconds plus or minus one standard deviation for each scale or decade tested, and whether the instrument passed or failed the test.

3.1.11 Coefficient of Variation Test

A total of 54 instruments were tested using procedures based on the requirements and methods stated in ANSI N42.17. Twelve of these instruments were ion chambers (vented), 8 were ion chambers (closed), 21 were GM detectors, 3 were gas flow alpha survey instruments, 5 were scintillation-type alpha survey instruments, 2 were air proportional alpha survey instruments, and 3 were neutron detectors. These included 8 different models of ion chambers (vented), 2 different models of ion chambers (closed), 13 different models of GM detectors, 5 different models of alpha survey instruments (1 gas-flow and 2 each scintillation and air proportional), and 1 model of neutron detector.

Table 3.8 summarizes the coefficient of variation test results in terms of the number of failures observed for instruments and models and the total number of each tested for the different types of instruments. An instrument was considered to have failed the test if it failed to meet the ANSI N42.17

TABLE 3.7. Response Time Test Results by Range

Instrument Type	Number of Failures/Number Tested									
	$>10^{-4}$ to $\leq 10^{-3}$ rem,rad/h		$>10^{-3}$ to $\leq 10^{-2}$ rem,rad/h		$>10^{-2}$ to $\leq 10^{-1}$ rem,rad/h		$>10^{-1}$ to ≤ 1 rem,rad/h		>1 rem,rad/h	
	Instrument	Model	Instrument	Model	Instrument	Model	Instrument	Model	Instrument	Model
Ion chamber	---	---	2/10	0/6	2/11	0/6	3/10	1/6	5/11	3/7
(Vented)	---	---	2/6	0/4	2/7	0/4	3/7	1/4	4/7	3/5
(Closed)	---	---	0/4	0/2	0/4	0/2	0/3	0/2	1/4	0/2
GM detector	0/12	0/9	0/17	0/11	4/20	2/12	5/9	2/6	5/5	3/3
Neutron detector	$\leq 5 \times 10^{-2}$ rem/h		5×10^{-2} to ≤ 1 rem/h		>1 rem/h					
	Instrument	Model	Instrument	Model	Instrument	Model				
	2/2	1/1	0/2	0/1	3/3	1/1				
Alpha detector (a)	Instrument	Model								
	0/7	0/4								

(a) Response time for count rate readout (i.e., alpha monitors) should be less than 30 seconds on any scale as defined in ANSI N42.17.

TABLE 3.8. Coefficient of Variation Test Results (Overall)

Instrument Type	Number of Failures/Number Tested ^(a)	
	Instrument	Model
Ion chamber	1/20	0/10
(Vented)	0/12	0/8
(Closed)	1/8	0/2
GM detector	11/21	5/13
Alpha detector	7/10	3/5
(Gas flow)	3/3	1/1
(Scintillation)	2/5	0/2
(Air proportional)	2/2	2/2
Neutron detector	0/3	0/1

(a) Instruments that failed on at least one scale or decade.

requirement on any scale or decade tested. None of the ion chambers (vented) failed the test, and only 1 of 8 ion chambers (closed) (none of the 2 different models) failed. Eleven of the 21 GM detectors (5 of the 13 different models) failed the test. All of the gas flow and air proportional alpha survey instruments failed while 2 of the 5 scintillation alpha survey instruments (none of the 2 different models) failed. None of the neutron detectors failed the test.

Table 3.9 summarizes coefficient of variation test results for the 2 exposure ranges [≤ 1 mR/h (≤ 500 cpm) and > 1 mR/h (> 500 cpm)] defined in ANSI N42.17. Results are presented for both instruments and models. For both GM detectors and gas flow alpha survey instruments, a higher proportion of failures were observed for testing done on ranges ≤ 1 mR/h (≤ 500 cpm). Five of 10 GM detectors failed on ranges ≤ 1 mR/h, while only 6 of 21 GM detectors failed on ranges > 1 mR/h. Similarly, all 3 of the gas flow alpha survey instruments failed on ranges ≤ 500 cpm, while none failed on ranges > 500 cpm.

Table A.11 in Appendix A presents more detailed results for this test. Listed in the table are the instrument ID number, the relative standard deviation of reading (in percent) for each scale or decade tested, and whether the instrument passed or failed the test.

TABLE 3.9. Coefficient of Variation Test Results by Range

Instrument Type	Number of Failures/Number Tested			
	≤ 1 mR/h (≤ 500 cpm)		> 1 mR/h (> 500 cpm)	
	Instrument	Model	Instrument	Model
Ion chamber (Vented) (Closed)	0/1	0/1	1/20	0/10
	0/1	0/1	0/12	0/8
	---	---	1/8	0/2
GM detector	5/10	2/7	6/21	3/13
Alpha detector (Gas flow) (Scintillation) (Air proportional)	5/7	3/3	2/10	2/5
	3/3	1/1	0/3	0/1
	1/3	0/1	1/5	0/2
	1/1	1/1	1/2	1/2
Neutron detector	---	---	0/3	0/1

3.1.12 Line Noise Susceptibility Test

The requirements for this test are still being evaluated. Testing results will be reported after the requirements and testing procedures have been finalized.

3.1.13 Accuracy Test

Photon, beta, and neutron accuracy tests were performed with procedures based on the requirements and methods stated in ANSI N42.17. A total of 28 instruments were evaluated for the photon accuracy test including 9 vented ion chambers (6 different models) and 19 GM detectors (11 different models). Ten vented ion chambers (6 different models) were evaluated for the beta accuracy test. A total of 6 neutron detectors (6 different models) were evaluated for the neutron accuracy test. The accuracy test was not performed on any alpha survey instruments.

Table 3.10 summarizes accuracy test results in terms of the number of failures observed for instruments and models and the total number of each tested. Only 1 of the 9 vented ion chamber (1 of the 6 different models) failed the photon accuracy test while 7 of the 19 GM detectors (3 of the 11 different models) failed. Six of the 10 vented ion chambers tested (3 of the 6 different models) failed the beta accuracy test.

TABLE 3.10. Accuracy Test Results

<u>Instrument Type</u>	<u>Number of Failures/ Number Tested</u>	
	<u>Instrument</u>	<u>Model</u>
<u>Photon Accuracy</u>		
Ion chamber (Vented)	1/9	1/6
GM detector	7/19	3/11
<u>Beta Accuracy</u>		
Ion chamber (Vented)	6/10	3/6
<u>Neutron Accuracy</u>		
Neutron detector	4/6	4/6

It should be noted that correction factors have not been applied to the beta instrument readings and in most cases a scale calibrated in exposure dose (R/h) is compared with absorbed dose (rad/h) at a depth of 7 mg/cm². Four of the 6 neutron detectors (4 of the 6 different models) failed the neutron accuracy test.

Table A.12 in Appendix A presents more detailed results for this test. Listed in this table are the instrument ID numbers, maximum percent change between the conventionally true value and the mean indicated value for the different scales and decades tested, the number of scales or decades that the test was performed on, and whether the instrument passed or failed the test. Not all scales and decades were tested on every instrument, because appropriate source strengths to test lowest and highest scales were not always available.

3.1.14 Photon Radiation Energy Dependence Test

A total of 29 instruments were tested using procedures based on the requirements and methods stated in ANSI N42.17. Nine of these were ion chambers (6 vented and 3 closed, pressurized), and 20 were GM detectors. These included 7 different models of ion chambers (5 vented and 2 closed,

pressurized) an 14 different models of GM detectors. All of the ion chambers were exposed to x-rays of 6 different energies and to known intensities from ^{137}Cs and ^{60}Co sources. All but 4 of the GM detectors were exposed to the same sources; these 4 instruments were exposed only to x-rays. The x-ray energies were nominally 40, 80, 120, 165, 210, and 250 keV.

Table 3.11 summarizes the photon energy dependence test results in terms of the number of failures observed for instruments and models and the total number of each tested for the different types of instruments. The quantities of instruments and models tested are shown as well as the number of failures in the 40 to 1250 keV range, 80 to 1250 keV range, and 80 to 250 keV range. Of the 9 ion chambers, 5 of the 9 failed the testing criteria from 40 to 1250 keV while only 3 of the 9 failed the criteria from 80 to 1250 keV. These 3 instruments failed in the 80 to 250 keV energy range. All 3 of the closed, pressurized-type ion chambers failed in the 40 to 1250 keV range, but only 1 of these 3 instruments failed in the 80 to 1250 keV range. Of the 16 GM type instruments that were evaluated from 40 to 1250 keV, all 16 failed the criteria from 40 to 1250 keV while 12 of them failed the criteria from 80 to 1250 keV. Four GM-type instruments were exposed only to the 5 different energies of x-rays; 3 out of these 4 instruments failed the requirements between 80 to 250 keV. When combined with the data from the other GM detectors, the results show that 12 of 20 GM-type instruments and 9 of 14 different models of GM detectors failed in this range.

TABLE 3.11. Photon Energy Dependence Test Results

Instrument Type	Number of Failures/Number Tested					
	40 to 1250 keV		80 to 1250 keV		80 to 250 keV	
	Instrument	Model	Instrument	Model	Instrument	Model
Ion chamber	5/9	4/7	3/9	2/7	3/9	2/7
(Vented)	2/6	2/5	2/6	2/5	2/6	2/5
(Closed)	3/3	2/2	1/3	0/2	1/3	0/2
GM detector	16/16	11/11	12/16	8/11	12/20	9/14

Table A.13 in Appendix A represents more detailed results for this test. Listed in this table are the instrument ID number and the ratio of the instrument response to the conventionally true value for each instrument for different photon energies. These results show that, in general, instruments of the same model type respond similarly. Many of the GM detectors are highly energy dependent; most of the ion chambers (vented and closed, pressurized) are not highly energy dependent between 80 and 1250 keV. Unless GM-type instruments are "energy compensated," they should not be used for dose rate determinations.

3.1.15 Beta Energy Dependence Test

A total of 8 instruments, all vented ion chambers, were evaluated with procedures based on the requirements and methods stated in ANSI N42.17. Six different models of vented ion chambers were tested.

Table 3.12 summarizes beta energy dependence test results in terms of the number of failures observed for both instruments and models. Five out of the 8 vented ion chambers (4 of the 6 different models) failed the test. Figure 3.1 presents the beta energy response (ratio of the mean indicated reading to beta radiation of energy i and the conventionally true value of the beta radiation of energy i) versus beta energy for ^{147}Pm , ^{204}Tl , and ^{90}Sr , ^{90}Y .

TABLE 3.12. Beta Energy Dependence Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Ion chamber (Vented)	5/8	4/6

Table A.14 in Appendix A presents more detailed results for this test. Listed in the table are the instrument ID numbers, ratio of mean indicated reading to beta radiation energy i and the conventionally true value of the beta radiation of energy i ($\bar{r}_i/\text{CTV}$) for ^{147}Pm , ^{204}Tl , and ^{90}Sr - ^{90}Y sources, ratio of $(\bar{r}_i/\text{CTV})_{\text{max}}$ to $(\bar{r}_i/\text{CTV})_{\text{min}}$, minimum beta cutoff energy, and whether the instrument passed or failed the test. For the requirements in the standard to be met, the ratio

FIGURE 3.1. Beta Energy Response

of $(\bar{r}_{\beta_i}/CTV_{\beta_i}) / (\bar{r}_{\beta_{ref}}/CTV_{\beta_{ref}})$ must be greater than or equal to 0.5 and less than or equal to 1.5 with the reference source specified by the instrument manufacturer. If the reference source for the test is not specified (as is the case with the testing results presented here), one can look at the ratio of $(\bar{r}_{\beta_i}/CTV_{\beta_i})_{max} / (\bar{r}_{\beta_i}/CTV_{\beta_i})_{min}$. This ratio must be ≤ 3 for the instrument to pass the test.

3.1.16 Neutron Energy Dependence Test

Cosack and Lesiecki (1981) evaluated the energy dependence of 8 different neutron survey meter instruments, all different models. Instrument response was tested at 9 energies (0.026, 0.11, 0.25, 0.57, 1.0, 2.5, 5.0, 15.5, and 19 MeV). These neutron energies were produced by bombarding different targets with protons and deuterons from a Van de Graaff accelerator. The dose-equivalent response (R_H) was determined for each energy:

$$R_H = \frac{M}{h_\phi \cdot \phi}$$

where

M = evaluated survey meter reading for a given energy (mrem/h)

ϕ = neutron fluence (neutrons/cm²·s) at the effective center of the survey meter assuming meter is not there

h_ϕ = neutron fluence-to-dose-equivalent conversion factor from ICRP 21 (1973) [(mrem/h)/(neutrons/cm²·s)]

Table 3.13 summarizes the neutron energy dependence test results in terms of the number of failures observed per number of instruments and models tested. Seven out of the 8 instruments failed the test. The one instrument that passed the test was not tested at the lowest energy (0.026 MeV). All instruments showed a decreasing relative response with increasing energies. Figure 3.2 shows this relationship. Dose-equivalent response values were normalized to the value at 1 MeV for each instrument.

TABLE 3.13. Neutron Energy Dependence Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Neutron detector	7/8	7/8

Table A.15 in Appendix A presents more detailed results for this test. Listed in the table are the instrument ID numbers, dose-equivalent response (R_H) values for the different energies tested, ratio of (R_H) max to (R_H) min, and whether the instrument passed or failed the test. For the requirements in the standard to be met, the ratio of (r_{n_i}/CTV_{n_i}) / ($r_{n_{ref}}/CTV_{n_{ref}}$) must be

^(a) Two instruments had identical responses

FIGURE 3.2. Dose-Equivalent Response Versus Neutron Energy
(Instrument ID numbers in parentheses)

greater than or equal to 0.5 and less than or equal to 2.0 with the reference source specified by the instrument manufacturer. In the testing results, the reference source is not specified; therefore, one can look at the ratio of $(r_{n_i}/CTV_{n_i})_{\max} / (r_{n_i}/CTV_{n_i})_{\min}$ as in the beta energy response test. This ratio must be ≤ 4 for the instrument to pass the test.

3.1.17 Photon Radiation Overloads Test

A total of 27 instruments were tested using procedures based on the radiation overload requirements and methods discussed in ANSI N42.17. Sixteen of these were GM detectors, 9 were ion chambers (vented-type), and 2 were NaI(Tl) detectors. These represented 13 different models of GM detectors, 6 models of ion chambers, and 1 model of NaI(Tl) detector.

Table 3.14 summarizes the results of the photon radiation overloads test in terms of the number of failures for instruments and models and the total number of each tested. Seven of the 9 ion chambers tested (4 of 6 models) failed the test, 1 of 16 GM detectors failed (1 of 13 models) and neither NaI(Tl) detector failed the test.

TABLE 3.14. Photon Radiation Overloads Test Results

<u>Instrument Type</u>	<u>Number of Failures/ Number Tested</u>	
	<u>Instrument</u>	<u>Model</u>
Ion chamber		
(Vented)	7/9	4/6
GM detector	1/16	1/13
NaI(Tl) detector	0/2	0/1

Table A.16 in Appendix A represents more detailed results for this test. Listed in this table are the instrument ID number, the level of the exposure rate to the instrument (i.e., 2X, 10X, or 100X the upper detection limit of the instrument), and whether or not the instrument passed or failed the test at each exposure rate level. All of the ion chambers tested remained off-scale high during the high-level exposures; the ion chambers that failed the test did so because they did not return to background within 2 minutes after the

exposure was completed. The failure observed for the GM detectors was at 100X the upper detection level of the instrument and was because of detector saturation; the instrument response went to zero above a specific exposure rate.

3.1.18 Angular Dependence Test

Photon

A total of 23 instruments were evaluated with procedures based on the requirements and methods stated in ANSI N42.17. Three of these instruments were ion chambers (vented), 2 were ion chambers (closed), and 18 were GM detectors. These included 2 different models of ion chambers (vented), 1 model of ion chambers (closed), and 11 different models of GM detectors.

Table 3.15 summarizes the photon angular dependence test results in terms of the number of failures observed for instruments and models and the total number of each tested. An instrument was considered to have failed if it failed to meet the ANSI N42.17 requirement for at least the high-energy source (^{137}Cs) and a representative low-photon-energy source (^{57}Co , ^{241}Am , or 120-keV x-ray).

TABLE 3.15. Photon Angular Dependence Test Results

<u>Instrument Type</u>	<u>Number of Failures/Number Tested</u> ^(a)	
	<u>Instrument</u>	<u>Model</u>
Ion chamber	2/5	1/3
(Vented)	1/3	1/2
(Closed)	1/2	0/1
GM detector	15/18	9/11

(a) An instrument was considered to have failed if it did not meet the standard's requirement for each orientation and source tested. If an instrument passed at least one high-energy source test and one low-energy source test for each orientation, it was considered to have passed the test.

One of the 3 ion chambers (vented) (1 of 2 models) failed the test, and 1 of 2 ion chambers (closed) (0 of 1 model) failed. Fifteen of the 18 GM detectors (9 of 11 models) failed the test.

Table 3.16 summarizes photon angular dependence test results based on photon energies used in the testing. Results are presented for high photon energy (^{137}Cs) and low photon energies (^{57}Co , ^{241}Am , and 120-keV x-rays). For the limited number of ion chambers tested, more failures were observed at the low photon energies (2 of 5 instruments) compared to the high photon energy (none of 2 instruments). A similar trend was observed for GM detectors where 13 of 17 instruments (9 of 11 models) failed at low photon energies while only 8 of 18 instruments (3 of 11 models) failed at the high photon energy.

TABLE 3.16. Photon Angular Dependence Test Results, Photon Energy Effect

Instrument Type	Number of Failures/Number Tested			
	^{137}Cs		Effective Energy (<130 keV)	
	(high photon energy)		(low photon energies)	
	Instrument	Model	Instrument	Model
Ion chamber	0/2	0/2	2/5	1/3
(Vented)	0/2	0/2	1/3	1/2
(Closed)	NT ^(a)	NT	1/2	0/1
GM detector	8/18	3/11	13/17	9/11

(a) NT = none tested.

Table 3.17 summarizes photon angular dependence test results based on angle from the direction of maximum response of the instrument. Results are presented for 45° and 90° from the direction of maximum instrument response. For the limited number of ion chambers tested, more failures were observed at 90° (1 of 5 instruments) than at 45° (0 of 5 instruments). The GM detectors had the same number of instrument failures at 45° and at 90° (13 of 18 instruments). Eight of the 11 models of GM detectors failed at 90° and 7 of 11 models failed at 45°.

TABLE 3.17. Photon Angular Dependence Test Results, Degrees from Maximum Response

Instrument Type	Number of Failures/Number Tested			
	45° from		90° from	
	Maximum Response		Maximum Response	
	Instrument	Model	Instrument	Model
Ion chamber	0/5	0/3	1/5	0/3
(Vented)	0/3	0/2	0/3	0/2
(Closed)	0/2	0/1	1/2	0/1
GM detector	13/18	7/11	13/18	8/11

Table A.17 in Appendix A presents more detailed results for this test. Listed in the table are instrument ID numbers, the radiation source used in the testing, the maximum percentage of change from the maximum instrument response, orientation(s) where the instrument failed, and whether the instrument passed or failed the test.

Beta

A total of 11 instruments were evaluated with procedures based on the requirements and methods stated in ANSI N42.17. Seven vented ion chambers (6 different models) and 4 GM detectors (3 different models) were tested.

Table 3.18 summarizes the beta angular dependence test results in terms of failures observed for instruments and models and the total number of each tested. Three out of the 7 vented ion chamber (2 of the 6 different models) failed the test while 1 of the 4 GM detectors failed (1 of 3 models).

TABLE 3.18. Beta Angular Dependence Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Ion chamber		
(Vented)	3/7	2/6
GM Detector	1/4	1/3

Table A.18 in Appendix A presents more detailed test results. Listed in the table are instrument ID numbers, the radiation source used in testing, the maximum percent change from the maximum instrument response, orientation(s) where the instrument failed, and whether the instrument passed or failed the test.

Neutron

A total of 2 neutron detectors (2 different models) were evaluated with procedures based on the requirements and methods stated in ANSI N42.17. Neither of the two instruments (neither model) failed the test. An instrument would have been considered to fail if it had failed to meet the ANSI N42.17 requirements for the orientation and source tested.

Table A.19 in Appendix A presents detailed results for this test. Listed in the table are the instrument ID numbers, the radiation source used in the testing, the maximum percentage of change from the maximum instrument response, and whether the instrument passed or failed the test.

3.1.19 Extracameral Response Test

A total of 12 exposures were performed using procedures based on the requirements and methods discussed in ANSI N42.17. Eight different instruments and 9 different probes were tested. All of the probes were GM detectors. No failures were observed. However, one of the instruments with an internal probe (for high exposure rates) had a higher than normal reading when the instrument alone was positioned in the radiation field. Some feedback from the internal probe was observed even though the external probe was in use. Table A.20 lists the instruments and probes evaluated for this test.

3.1.20 Radio Frequency Fields Test

This test includes 2 different exposure protocols; instruments were exposed to a 60-Hz electric field and also to a field whose frequency was varied from 300 kHz to 35 MHz. The intensity of both fields was maintained at 100 V/m while the instrument readings were observed.

Table 3.19 summarizes the test results in terms of the number of failures for instruments and models and the total number of each tested. A total of 20 instruments, each a different model, were exposed to a 60-Hz electric field.

TABLE 3.19. Radio Frequency Fields Test Results

Instrument Type	Number of Failures/Number Tested			
	60 Hz		300 kHz to 35 MHz	
	Instrument	Model	Instrument	Model
Ion chamber	0/7	0/7	3/8	2/7
(Vented)	0/6	0/6	3/7	2/6
(Closed)	0/1	0/1	0/1	0/1
GM detector	0/13	0/13	4/11	2/5
Alpha detector	NT ^(a)	NT	0/5	0/5
Neutron detector	NT	NT	1/5	1/5

(a) NT = not tested.

Seven of these were ion chambers (6 vented-type and 1 closed, pressurized-type) and 13 were GM detectors. Alpha and neutron detectors were not exposed to the 60-Hz field. A total of 29 instruments were tested in the 300-kHz to 35-MHz RF field. Eight of these were ion chambers (7 were vented-types and 1 was a closed, pressurized-type), 11 were GM detectors, 5 were alpha detectors, and 5 were neutron detectors.

None of the instruments failed the 60-Hz test. Seven instruments failed during the exposure to the 300-kHz to 35-MHz field. Three of the instruments that failed were ion chambers; 2 of these were same model/same manufacturer instruments. Four of the instruments that failed were GM detectors; 3 of these were same model/same manufacturer instruments. All of the instruments that failed had plastic housings that did not provide shielding from the RF field. Figure 3.3 illustrates the responses of 2 of these instruments, 1 ion chamber and 1 GM detector. The lines connecting the data points in the 2 graphs in Figure 3.3 do not represent the best fit to the data but do represent the general trends of the instrument responses. Multiple instrument readings were taken only at the indicated frequencies. The reference exposure rate for each curve is the one related to the first data point of the curve (i.e., the instrument reading at 300 kHz). One of 5 neutron instruments failed.

FIGURE 3.3. Radio Frequency Interferences (field intensity: 100 V/m) for One GM Detector and One Ion Chamber

Table A.21 in Appendix A presents more detailed data for this test. Listed are the instrument ID number, the type of instrument, and whether or not the instrument passed, failed, or was not tested for the 60-Hz and 300-kHz to 35-MHz exposures.

3.1.21 Microwave Fields Test

Table 3.20 lists results of the microwave susceptibility test. The instruments were exposed to microwave fields (915 and 2450 MHz) at the Center for Devices and Radiological Health in Rockville, Maryland. Table A.22 in Appendix A represents more detailed data for the test. Of the 15 instruments studied, 9 instruments were affected by a microwave field either at the frequency of 915 MHz or at both 915 and 2450 MHz with the field intensity established at 100 W/m^2 . Seven of the instruments were GM-type detectors, 4 were vented-type ion chambers, 1 was a closed-type ion chamber, and 3 were alpha-survey instruments. There were 4 different models of vented-type ion chambers, one model of closed-type ion chamber, 7 different models of GM detectors, and 3 different models of alpha-survey instruments. Four GM detectors passed the test, 3 failed only at 915 MHz, and 1 failed the test at both frequencies. Four vented-type ion chambers failed the test; 3 of them failed at both frequencies and the other failed at only 915 MHz. The one pressurized ion chamber passed the test at both frequencies. Two air proportional alpha detectors failed the test; 1 failed at both frequencies and the other only at 915 MHz. The one alpha scintillation detector passed the test.

Results from this test show that many different types of instruments can be affected by microwaves. Effects were observed with readings going off-scale high and off-scale low depending on the direction of the field. Different effects were observed on different scales. Some digital displays flickered off in the presence of a microwave field. Some alarm thresholds were also affected. In general, however, if the instrument was constructed

TABLE 3.20. Microwave Fields Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Ion chamber	4/5	4/5
	(Vented)	4/4
	(Closed)	0/1
GM detector	3/7	3/7
Alpha detector	2/3	2/3

well (e.g., rugged, metal case, good seals around instrument case, good connectors), the effects of microwave fields were minimized.

3.1.22 Electrostatic Fields Test

Twenty instruments representing 20 different models were exposed to an electrostatic field using procedures based on the requirements and methods in ANSI N42.17. Seven of these instruments were ion chambers (6 vented-type and 1 closed, pressurized-type) and 13 of the instruments were GM detectors. Instruments were positioned in an electrostatic field that was 5000 V/m in intensity. All of the instruments passed this test. Table A.23 in Appendix A represents detailed data for the test.

3.1.23 Magnetic Fields Test

Nineteen instruments representing 19 different models were exposed to magnetic fields using procedures based on the requirements and methods in ANSI N42.17. Six of these instruments were ion chambers (5 vented-type and 1 closed, pressurized-type) and 13 were GM detectors. Alpha and neutron detectors were not tested with these procedures. All instruments were exposed to a magnetic field that was 3 oersteds in intensity; 6 of these instruments (4 ion chambers and 2 GM detectors) were also exposed to higher intensity fields.

Table 3.21 represents the results of this test in terms of the number of failures per the number of instruments tested at a specified magnetic field intensity. All instruments passed at the intensity level of 3 oersteds. Table A.24 in Appendix A represents more detailed data for these instruments. The data in these tables show that failures were indeed observed at field intensities higher than those required by the draft standard. One of the ion chambers tested at these higher field intensities failed at 45 oersteds, two ion chambers failed at approximately 250 oersteds, and the last one tested failed at 600 oersteds. One of the GM detectors failed at 250 oersteds and the other GM-type instrument did not fail in fields up to 1000 oersteds. In these cases, the meter indication went to zero when the instrument failed.

TABLE 3.21. Magnetic Fields Test Results

Instrument Type	Magnetic Field Intensity (Oersteds)				
	3 ^(a)	45	250	600	1000
Ion chamber (Vented) (Closed)	0/5 ^(b)	1/4	3/4	4/4	NT ^(c)
	0/1	NT	NT	NT	NT
GM detector	0/13	0/2	1/2	1/2	1/2

(a) ANSI N42.17D3 requirement.

(b) Number of failures/number tested.

(c) NT = none tested

3.1.24 Interfering Ionizing Radiation Test

Thirty-four instruments including 26 different models were used to evaluate this test. Seven ion chambers (5 vented- and 2 closed, pressurized-type), 18 GM detectors, 5 alpha detectors and 4 neutron detectors were used. These included 6 different models of ion chambers and 11 different models of GM detectors; each alpha and neutron detector represented a different model instrument.

Table 3.22 lists some of the test results. The instrument type, number of instruments and models tested, and range of instrument responses to each interfering radiation applicable to the instrument type are listed.

The levels of interfering radiations are listed in Table 2.8. Ion chambers and GM detectors were exposed to 1 rem/h neutron radiation (i.e., ^{252}Cf). Alpha detectors were exposed to 1 rad/h beta radiation (^{90}Sr - ^{90}Y), 1 rad/h photon radiation (^{137}Cs), and 1 rem/h neutron radiation. Neutron detectors were exposed to 10^4 dpm/cm² alpha radiation (^{230}Th), 10 rad/h beta radiation (^{90}Sr - ^{90}Y), and 10 rad/h photon radiation (^{137}Cs).

Table A.25 in Appendix A lists more detailed test results in terms of the specific instruments tested and the responses of those instruments to the interfering radiations. The responses of the ion chambers and GM detectors are responses to the photon radiation emitted by ^{252}Cf . Some interfering responses were seen in alpha detectors from beta, photon, and especially

TABLE 3.22. Interfering Ionizing Radiation Test Results

Instrument Type	Number Evaluated		Range of Response ^(a) to Interfering Radiation			
	Instrument	Model	Alpha	Beta	Photon	Neutron
Ion chamber	7	6	---	---	---	45.5-80 mR/h
(Vented)	5	5	---	---	---	46-60 mR/h
(Closed)	2	1	---	---	---	45.5-80 mR/h
GM detector	18	11	---	---	---	20-60 mR/h
Alpha detector	5	5	---	0-100 cpm	0-9800 cpm	0-45,350 cpm
Neutron detector	4	4	0	0	0-0.6 mrem/h	

(a) Levels of interfering radiations listed in Table 2.8.

neutron radiation. Some low-level interferences were seen with neutron detectors from photon radiation.

3.1.25 Temperature Test

A total of 57 instruments were tested using procedures based on the requirements and methods in ANSI N42.17. Twenty-three were GM detectors, 17 were ion chambers (11 vented-type and six closed, pressurized-type), 13 were alpha detectors, and 4 were neutron detectors. These included 12 different models of GM detectors, 7 models of ion chambers (6 vented-type and 1 closed, pressurized-type), 6 models of alpha detectors, and 3 models of neutron detectors. All instruments were exposed to -20, -10, 0, 10, 20, 30, 40, and 50°C according to the exposure profile shown in Figure 2.2.

Table 3.23 summarizes the temperature test results in terms of failures for all of the instruments. The quantities of instruments and models tested are shown as well as the number of failures in the 0 to 40°C range and the -10 to 50°C range. Of the 17 ion chamber instruments, 9 failed in the 0 to 40°C range and 10 failed in the -10 to 50°C range. Three of 7 models failed in each temperature range. Most of the failures of the ion chambers were observed at high temperatures. Two of the failures of the vented-type ion chambers in the 0 to 40°C range were 2 instruments of the same model. Three of the failures of this type of instrument in the -10 to 50°C range were instruments produced by the same manufacturer. All 6 of the closed, pressurized ion chambers failed this test; these were all of the same model. Of the 23 GM detectors, none failed in the 0 to 40°C range and 1 failed in the -10 to 50°C range. Ten of the 13 alpha-detection instruments failed in the 0 to 40°C range, and 10 of the 13 instruments failed in the -10 to 50°C range. All the gas flow and air proportional instruments tested failed. As noted in manufacturer's instrument specifications, gas flow instruments may require resetting of the high voltage control to achieve <10% meter reading error over the temperature range of -40 to 60°C. Manufacturers also indicated that meter errors are greater at the lower temperatures (<20°C) than at the higher temperatures (>20°C); this was confirmed by greater reading fluctuations and more instrument failures at the lower temperatures. Voltage adjustments are necessary because of a) plateau shift of the detector, b) sensitivity shift of

TABLE 3.23. Temperature Test Results, Failures in the 0 to 40°C and -10 to 50°C Temperature Ranges

Instrument Type	Number of Failures/Number Tested				Comments
	0 to 40°C		-10 to 50°C		
	Instrument	Model	Instrument	Model	
Ion chamber	9/17	3/7	10/17	3/7	Most failures were at high temperatures
(Vented)	3/11	2/6	4/11	2/6	
(Closed)	6/6	1/1	6/6	1/1	
GM detector	0/23	0/12	1/23	0/12	
Alpha detector	10/13	4/6	10/13	4/6	
(Gas flow)	4/4	2/2	4/4	2/2	
(Scintillation)	2/5	0/2	2/5	0/2	
(Air proportional)	4/4	2/2	4/4	2/2	
Neutron detector	0/4	0/3	0/4	0/3	One passed marginally

the electronics, or c) shift of the high voltage output itself. Manufacturer's specifications for air proportional instruments indicated reading changes should be <5% from -15 to 49°C. However, >15% changes were noted over this range for all instruments tested. Failures occurred about equally at both ends of the temperature range, 0 and 40°C.

Table A.26 in Appendix A lists more detailed temperature data for the instruments tested. In this table, the percentage of change from the mean reading obtained at 20°C is listed for observations made at -10, 0, 40, and 50°C. Data for vented-type ion chambers have been corrected for air density changes. Temperature dependence was observed in a large number of instruments; it was quite severe in a number of ion chambers. Significant differences in performance were observed among instruments from different manufacturers, among the same manufacturer/same model instruments, and between two runs with the same instrument. Figure 3.4 represents curves from same manufacturer/same model instruments.

3.1.26 Temperature Shock Test

A total of 27 instruments were tested using procedures based on the requirements in ANSI N42.17. Seven of the instruments were ion chambers

FIGURE 3.4. Temperature Response Curves for Three Identical Ion Chambers from the Same Manufacturer

(4 vented-type and 3 closed, pressurized-type), 9 were GM detectors, 6 were alpha detectors, and 5 were neutron detectors. These included 4 different models of vented ion chambers, 2 different models of closed ion chambers, 9 different models of GM detectors, 3 different models of alpha detectors, and 5 different models of neutron detectors. All but one of the instruments were tested at both 40°C and 0°C.

Table 3.24 summarizes the temperature shock results in terms of the number of failures for each type of instrument and model for the test at 40°C and 0°C. The results are shown for 4 different exposure profiles: 23 to 40°C, 40 to 23°C, 23 to 0°C, and 0 to 23°C. When the instruments were moved from a 23°C environment to one of 40°C, none of the 7 ion chambers failed, 2 of the 9 GM detectors failed, 2 of the 6 alpha detectors (1 of 2 gas flow units, 0 of 2 scintillators, and 1 of 2 air proportional instruments) failed, and none of the 5 neutron detectors failed. When these instruments were returned quickly to room temperature, none of the 7 ion chambers failed, the same 2 GM detectors failed, no alpha detectors failed, and no neutron instruments failed. Three of these 5 neutron detectors passed marginally; that is, the mean change in each of the instrument responses exceeded the test requirement, but was not

TABLE 3.24. Temperature Shock Test Results

Instrument Type	Number of Failures/Number Tested							
	40°C				0°C			
	23 to 40°C		40 to 23°C		23 to 0°C		0°C to 23°C	
	Instrument	Model	Instrument	Model	Instrument	Model	Instrument	Model
Ion chamber	0/7	0/6	0/7	0/6	2/7	1/6	1/7	1/6
(Vented)	0/4	0/4	0/4	0/4	1/4	1/4	0/4	1/4
(Closed)	0/3	0/2	0/3	0/2	1/3	0/2	1/3	0/2
GM detector	2/9	2/9	2/9	2/9	3/9	3/9	0/9	0/9
Alpha detector	2/6	0/3	0/6	0/3	3/5	2/3	3/5	2/3
(Gas flow)	1/2	0/1	0/2	0/1	2/2	1/1	2/2	1/1
(Scintillation)	0/2	0/1	0/2	0/1	0/2	0/1	0/2	0/1
(Air proportional)	1/2	0/1	0/2	0/1	1/1	1/1	1/1	1/1
Neutron detector	0/5	0/5	0/5	0/5	1/5	1/5	0/5	0/5

significant at the 95% confidence level. When the instruments were moved from room temperature to a 0°C environment, 2 of the 7 ion chambers (1 vented-type and 1 closed, pressurized-type) failed, 3 of the 9 GM detectors failed, 3 of the 5 alpha detectors (both gas flow units, zero scintillators, and the 1 air-proportional unit) failed, and 1 of 5 neutron detectors failed. When these instruments were returned to room temperature, one of the same ion chambers failed, none of the GM detectors failed, the same alpha detectors failed, and none of the 5 neutron instruments failed.

When an instrument was moved into the environment of the temperature to be studied, the reference reading used was the last mean reading obtained in the previous atmosphere. For example, when an instrument was moved to a room temperature environment from one of 40°C in which the instrument had been positioned for 2 hours, the last mean reading taken in that 40°C environment was used as the reference reading for the room temperature readings. The effect of temperature alone has not been considered for the temperature shock results listed in Table 3.24 for the determination of passage and failure of the instruments.

Table A.27 of Appendix A lists more detailed temperature shock data for these instruments. In this table, the instrument identification number, the

maximum percentage of change (plus or minus one standard deviation) from a reference set of readings, and whether or not the instrument passed or failed for each of the high- and low-temperature shock profiles.

3.1.27 Humidity Test Results

A total of 46 instruments were tested using procedures based on requirements and methods in ANSI N42.17. Seven of these instruments were ion chambers (5 vented-type and 2 closed, pressurized-type), 18 were GM detectors, 15 were alpha detectors, and 6 instruments were neutron detectors. These included 3 different models of vented ion chambers, 2 different models of closed ion chambers, 14 different models of GM detectors, 4 different models of alpha detectors and 3 different models of neutron detectors. Exposure profiles differed for this test between the second and third versions of the draft standard. In the second draft, instruments were exposed for a total of 72 hours at 40°C and 72 hours at approximately 0°C with the relative humidity being established at 40% for 24 hours, 95% for 24 hours, and then again at 40% for 24 hours at each temperature. Twenty-one instruments were exposed using this procedure. In the third draft of the standard, the procedure was changed to require a total of 20 hours of exposure at 30°C, a minimum of 4 hours at 40% RH, 8 hours at 95% RH, and then another 4 hours at 40% with 2 hours for transition between the relative humidity levels. This represented the exposure profile employed for 27 instruments. Two instruments were exposed using both profiles.

Table 3.25 summarizes the humidity test results in terms of number of failures for instruments and models and the total number of each tested. One of the 7 ion chambers failed at high humidity levels (1 of 5 models); 3 of 18 GM detectors (2 of 14 models) failed either at high humidity or after being exposed to high humidity. The ion chamber and GM detectors that failed at high humidity levels all recovered after the relative humidity was lowered back to 40%. Ten of the 15 alpha instruments (2 of 4 models) failed the test; all 10 of the air proportional instruments failed (both models). None of the neutron detectors failed the test.

Table A.28 in Appendix A represents more detailed results for this test. Listed in this table are instrument ID number, instrument type, exposure duration, the maximum percentage difference (plus or minus one standard

TABLE 3.25. Humidity Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Ion chamber	1/7	1/5
(Vented)	1/5	1/3
(Closed)	0/2	0/2
GM detector	3/18	2/14
Alpha detector	10/15	2/4
(Gas flow)	0/3	0/1
(Scintillation)	0/2	0/1
(Air proportional)	10/10	2/2
Neutron detector	0/6	0/3

deviation) from a reference reading, whether or not the instrument passed or failed the test, and specific comments on most of the failures. A large variability exists between instruments from different manufacturers, between same model/same manufacturer instruments, and between instruments of the same type. Figure 3.5 shows responses from 3 different air proportional alpha detection instruments; a large variability is evident.

3.1.28 Mechanical Shock Test

Nineteen instruments representing 18 different models were tested using procedures based on the requirements and methods in ANSI N42.17. Three of the instruments were ion chambers (2 vented-type and 1 closed, pressurized-type), 8 of the instruments were GM detectors, 7 were alpha detectors (6 models) and 1 instrument was an NaI detector. No neutron instruments were evaluated with the mechanical shock test procedures due to the concern of causing damage to these very expensive instruments. Six of the instruments were subjected to a 30-g shock pulse that was approximately 18 milliseconds in duration one time in each of 3 orthogonal axes. The other 5 instruments were subjected to 10 shock pulses in each of 3 orthogonal axes that were 50 g in intensity and approximately 18 milliseconds in duration.

FIGURE 3.5. Effect of Relative Humidity on Selected Air-Proportional Instruments

It is stated in ANSI N42.17D3 that a shock pulse of 30 g in intensity and 18 milliseconds in duration be used for this test. After performing the test using procedures based on these requirements, it was decided that the test may be too lax; that is, that the intensity of deceleration of 30 g may not represent the level of stress to which instruments may realistically be subjected. ANSI C39.3 (1976), "American National Standard Shock Testing for Electrical Indicating Instruments," includes information on shock levels that may be expected. A 3-lb instrument that was dropped from a height of 3 ft could easily be subjected to a deceleration of 50 g. The type of surface on which the instrument landed would affect the level of deceleration and the duration of the shock pulse. ANSI N42.17D4 requires 10 shock pulses of 50 g peak acceleration each applied for a nominal 18 milliseconds.

All of the instruments tested passed this test. Table A.29 represents detailed results for this test. Listed in this table are instrument ID number,

instrument type, the level of deceleration and the number of times the instrument was subjected to the shock pulse in each of 3 orthogonal axes, and whether or not the instrument passed or failed the test.

3.1.29 Vibration Test

Nineteen instruments representing 18 different models were tested using procedures based on the requirements and methods in ANSI N42.17. Four of the instruments were ion chambers (3 vented-type and 1 closed, pressurized-type), 7 were GM detectors, 7 were alpha detectors, and 1 instrument was a NaI detector. No neutron instruments were evaluated with the vibration test procedures due to the concern of causing damage to these very expensive instruments. Six of the instruments were subjected to 5 g of acceleration for a duration of 5 minutes and 13 instruments were subjected to 2 g of acceleration for 15 minutes; in both cases, vibrations were produced in each of 3 orthogonal axes.

It is stated in ANSI N42.17D3 that instruments will be subjected to accelerations of 5 g for 15 minutes in each of 3 mutually orthogonal planes. After several instruments had been tested using procedures based on these requirements, it was decided that the test may be too severe in terms of the level of acceleration and that the 15-minute exposure time may be too short. One instrument was physically damaged and had to be sent to the factory for repair. ANSI C39.1 (1981), American National Standard Requirements for Electrical Analog Indicating Instruments, includes information on vibration testing. Acceleration levels of 2 g are referred to in this document with testing periods up to 20 minutes. ANSI N42.17D4 requires harmonic loadings of 2 g for 15 minutes.

Table 3.26 summarizes the vibration test results in terms of the number of failures for instruments and models and the total number of each tested. Table A.30 represents more detailed results for this test in terms of pass or fail for each of the instruments tested. Listed are the instrument ID number, instrument type, level of acceleration and duration of the test, and whether or not the instrument passed or failed the test. Four of the instruments failed this test; 1 ion chamber was physically damaged, 1 GM detector passed marginally, and 3 alpha detectors failed.

TABLE 3.26. Vibration Test Results

Instrument Type	Number of Failures/ Number Tested	
	Instrument	Model
Ion chamber	1/4	1/4
(Vented)	1/3	1/3
(Closed)	0/1	0/1
GM detector	0/7	0/7
Alpha detector	3/7	2/6
NaI detector	0/1	0/1

3.1.30 Ambient Pressure Test

Thirty-six instruments were evaluated using procedures based on the requirements and methods in ANSI N42.17. Ten of these were ion chambers (6 vented-type and 4 closed, pressurized-type), 5 instruments were GM-type detectors, 15 were alpha detectors, and 6 were neutron detectors. These included 4 different models of vented ion chambers, 2 different models of closed ion chambers, 4 different models of GM detectors, 8 different models of alpha detectors, and 6 different models of neutron detectors. All of these instruments were exposed according to the exposure profile shown in Figure 2.4. The pressure change rate was approximately 1.5 kPa/min for these experiments.

Table 3.27 summarizes the ambient pressure test results in terms of number of failures for instruments and models and the total number of each tested. Data has been corrected for changes in air density for the vented-type ion chambers. All of the ion chambers, GM detectors, and neutron detectors passed the requirements of the standard; only 2 instruments produced data that differed from the reference data by more than 5%.

Results of the ambient pressure testing for alpha survey instruments are shown in Table 3.28 where it shows that data was obtained at 3 different pressure change rates. Although the standard permits a pressure change rate of 20 kPa/min, to determine if the rate of change affected instrument response a few instruments were tested at slower rates of change. It appears that the rate of pressure change does affect scintillation instruments, but an explanation cannot be given at this time. Twelve of the 15 instruments (6 of 8 models)

TABLE 3.27. Ambient Pressure Results, Pressure Change Rate of 1.5 kPa/min

<u>Instrument Type</u>	<u>Number of Failures/ Number Tested</u>	
	<u>Instrument</u>	<u>Model</u>
Ion chamber	0/10	0/6
(Vented)	0/6	0/4
(Closed)	0/4	0/2
GM detector	0/5	0/4
Alpha detector	12/15	6/8
(Gas flow)	4/5	2/3
(Scintillation)	3/5	1/2
(Air proportional)	5/5	3/3
Neutron detector	0/6	0/6

TABLE 3.28. Results of Ambient Pressure Testing for Alpha Detectors Using Different Pressure Change Rates

<u>Instrument Type</u>	<u>Number of Failures/Number Tested</u>		
	<u>1.5 kPa/min</u>	<u>0.5 kPa/min</u>	<u>0.125 kPa/min</u>
Gas flow	4/5	1/2	0/1
Scintillation	3/5	0/3	NT
Air proportional	<u>5/5</u>	<u>2/2</u>	<u>4/4</u>
TOTAL	12/15	3/7	4/5

failed the fast pressure drop rate test (approximately 1.5 kPa/min). Two scintillation detector instruments passed the test. As 3 of 5 scintillation types failed during the fast pressure rate test but zero out of 3 failed during the slower change rate test, the pressure drop rate appears to be an important factor. Figure 3.6 presents data for 1 air proportional-type instrument that was tested at 3 different pressure change rates. It failed the test each time; however, as shown in this figure, the pressure change rate does affect the response of the instrument. All of the air proportional instruments

FIGURE 3.6. Air Proportional Instrument Response to Pressure Change Rates

failed the tests both at fast and slow pressure drop rates. Four out of five gas flow instruments failed the test at 1.5 kPa/min, 1 of the 2 instruments tested at 0.5 kPa/min failed (the one that passed, passed marginally), and the one unit tested at 0.125 kPa/min passed. The one unit that passed was a newer instrument than those that failed. The general trend was for readings to decrease as pressure increased from 101 to 106 kPa and to increase as pressure was decreased from 101 to 70 kPa. In many cases, readings were offscale (low) at 106 kPa and offscale (high) at 70 kPa. Figure 3.7 is a graphic representation of selected data.

Table A.31 in Appendix A lists more detailed data for the ambient pressure test. Listed in this table are instrument identification number, percentage of change (plus or minus one standard deviation) of the instrument readings taken at different ambient pressure levels from readings taken at 101 kPa (1 atmosphere), and whether the instrument passed or failed the test.

FIGURE 3.7. Effect of Pressure on Selected Alpha Instruments

3.1.31 Brief Immersion Test

The requirements for this test are still being evaluated. Testing results will be reported after the requirements and testing procedures have been finalized.

3.1.32 Summarized Test Results

Table 3.29 summarizes the test results discussed in Section 3.1 of this report. Listed are the tests and the number of failures per the number of instruments tested for each type of instrument. Results are shown in relation to instruments and models of each instrument type.

3.2 INSTRUMENT-BY-INSTRUMENT RESULTS

3.2.1 General

Table B.1 in Appendix B lists all of the instruments tested, the type of each instrument, and whether the instrument passed a test, the instrument failed a test, or the change in instrument response was not significantly different from the requirement in draft ANSI N42.17A at the 95% confidence level.

Using Table B.1, one can easily determine the tests that were performed on a specific instrument or look under a specific test to see how many instruments were evaluated with those test procedures. A total of 112 instruments are listed. Ninety-seven instruments were tested with more than one set of testing procedures, 32 instruments went through 10 or more tests, 12 instruments were tested with 15 or more sets of testing procedures, and 2 instruments went through a total of 20 tests. For the 97 instruments that were tested with more than one set of testing procedures, an average of 8 tests were performed on each instrument. Twenty-eight different tests are listed; of course, not all tests are applicable to each instrument. Twenty sets of test procedures were evaluated with 10 or more instruments; 16 test procedures were used with 20 or more instruments; 12 test procedures were evaluated with 30 or more instruments; 8 tests were used with 40 or more instruments; and 4 tests were evaluated with 50 or more instruments.

TABLE 3.29. Summarized Test Results

Test	Number of Failures/Number Tested							
	Ion Chamber		GM Detector		Alpha Detector		Neutron Detector	
	Instrument	Model	Instrument	Model	Instrument	Model	Instrument	Model
Inspection	NA ^(a,b)	10/10	NA ^(a)	21/21	NA ^(a)	8/8	NA ^(a)	6/6
Zero set	0/7	0/4	NA	NA	NA	NA	NA	NA
AC voltage	NT ^(c)	NT	0/4	0/3	NT	NT	NT	NT
Battery lifetime	0/6	0/3	12/28	4/16	3/7	1/4	NT	NT
Latching and non-latching alarm reset	NT	NT	1/3	1/3	NT	NT	NT	NT
Alarm activation delay	NT	NT	0/3	0/3	NT	NT	NT	NT
Alarm threshold drift	NT	NT	0/3	0/3	NT	NT	NT	NT
Stability	1/9	0/6	1/35	1/20	2/15	0/7	0/4	0/3
Geotropism	0/10	0/7	0/24	0/12	8/14	3/6	NT	NT
Response time	8/15	4/9	10/22	6/13	0/7	0/4	3/3	1/1
Coefficient of variation	1/20	0/10	11/21	5/13	7/10	3/5	0/3	0/1
Accuracy (photon)	1/9	1/6	7/19	3/11	NA	NA	NA	NA
Accuracy (beta)	6/10	3/6	NT	NT	NA	NA	NA	NA
Accuracy (neutron)	NA	NA	NA	NA	NA	NA	4/6	4/6
Photon radiation energy dependence	3/9	1/7	14/20	9/14	NA	NA	NA	NA

TABLE 3.29. (contd)

Test	Number of Failures/Number Tested							
	Ion Chamber		GM Detector		Alpha Detector		Neutron Detector	
	Instrument	Model	Instrument	Model	Instrument	Model	Instrument	Model
Beta energy dependence	5/8	4/6	NT	NT	NA	NA	NA	NA
Neutron energy dependence	NA	NA	NA	NA	NA	NA	7/8	7/8
Photon radiation overloads	7/9	4/6	1/16	1/13	NA	NA	NA	NA
Photon angular dependence	2/5	1/3	15/18	9/11	NA	NA	NA	NA
Beta angular dependence	3/7	2/6	1/4	1/3	NA	NA	NA	NA
Extracameral	NA	NA	0/12	0/10	NA	NA	NT	NT
Radio frequency field susceptibility	3/8	2/7	4/11	2/5	0/5	0/5	1/5	1/5
Microwave field susceptibility	4/5	4/5	3/7	3/7	2/3	2/3	NT	NT
Electrostatic field susceptibility	0/7	0/7	0/13	0/13	NT	NT	NT	NT
Magnetic field susceptibility	0/6	0/6	0/13	0/13	NT	NT	NT	NT
Temperature	10/17	3/7	1/23	0/12	10/13	4/6	0/4	0/3
Temperature shock	2/7	1/6	3/9	3/9	3/6	1/3	1/5	1/5
Humidity	1/7	1/5	3/18	2/14	10/15	2/4	0/6	0/3

TABLE 3.29. (contd)

Test	Number of Failures/Number Tested							
	Ion Chamber		GM Detector		Alpha Detector		Neutron Detector	
	Instrument	Model	Instrument	Model	Instrument	Model	Instrument	Model
Mechanical shock	0/3	0/3	0/8	0/8	0/7	0/6	NT	NT
Vibration	1/4	1/4	0/7	0/7	3/7	2/6	NT	NT
Ambient pressure	0/10	0/6	0/5	0/4	12/14	6/7	0/6	0/6

- (a) Only one instrument per model was inspected; it was assumed that all instruments of the same model were identical.
 (b) NA: Not applicable.
 (c) NT: None tested.

One can look at a specific instrument or type of instrument (e.g., GM, ion chamber, alpha detector) in Table B.1 to see how it performed in each test or group of tests. When the overall performance of GM detectors, ion chambers, alpha detectors, and neutron monitors are compared, the following observations can be made: 1) ion chambers and GM detectors passed a higher percentage of the tests than alpha detectors and neutron monitors (i.e., normalized to the number of tests performed on each instrument), 2) ion chambers performed slightly better than GM detectors, 3) neutron monitors and alpha detectors performed similarly in terms of the percentage of tests passed, and 4) alpha scintillator-type detectors performed much better than alpha air proportional or gas flow detectors. These observations are, of course, generalized because all instruments were not tested with the procedures for all tests. Some instruments were tested with more test procedures than others.

3.2.2 Specific Details

Some of the information in Table B.1 can be misleading. A failure symbol (●) is used if any portion of a test is failed. For example, not one instrument is shown to have passed the inspection test. Depending on the type of instrument and its use, the number of inspection criteria can range from 15 to 19. The fewest criteria failed by any instrument was 2; the most was 9. The 2 criteria that most instruments did not meet were the requirement that the manufacturer state the extent of moisture protection and the requirement that the location of the sensitive volume be marked on the detector. (More detailed testing results are listed in Appendix A).

A few of the tests had a large percentage of instruments fail; this may mean that some of the requirements are too severe or, alternatively, that some of the instruments should be upgraded so that they will pass the requirements in the draft standard. Results from 13 tests will be discussed briefly; detailed results can be found in Appendix A.

A large number of GM detectors failed the battery lifetime test. The requirement for a 100-hour battery lifetime for an instrument was not considered excessive by the authors of ANSI N42.17A and since over one half of the instruments passed, it appears that well-designed instruments can meet this requirement.

A number of GM detectors, ion chambers, and neutron monitors failed to meet the requirements of the response time test; GM detectors and ion chambers failed mostly on the highest scales, while neutron monitors failed on both low and high scales. The requirements of the draft standard may be too restrictive in this test.

Approximately 40% of all of the instruments tested failed the coefficient of variation test; most of these were GM detectors being tested on the lowest scale. The draft standard may be too restrictive in this case.

A fairly high percentage of GM detectors failed the photon accuracy test, several ion chambers failed the beta accuracy test, and a number of neutron monitors failed the neutron accuracy test. The accuracy test combines the instrument linearity with the accuracy of the calibration set point against the conventionally true value of a calibration source. Since this is fundamental in determining the accuracy of field readings to be made with the instrument a 15% accuracy is considered basic to monitoring requirements.

A large percentage of GM detectors failed the photon energy dependence test; these were not energy-compensated detectors, and most of them failed at the nominal x-ray energies of 80 keV and 120 keV. The 20% requirement in this test is not considered to be too restrictive. A paper published by Barclay (1986), showed that GM detectors could be properly compensated to meet the energy response and angular response criteria in ANSI N42.17A.

A large number of beta and neutron detectors failed their energy-dependence tests; the requirements in the draft standard may be too severe for these instruments. However, new beta instruments are being developed that will readily pass the test.

A large number of ion chambers failed the radiation overload test; all of these instruments remained off-scale at the high end of the scale during the high-level exposures but failed the test when the response did not return to the reference reading after the high-level exposure. In most cases, the zero-set had drifted or the instrument response was changed because of a failed transistor or other component. In an emergency (i.e., high-level exposure) the instruments would have stayed off-scale high and the instrument user would be adequately warned. The fact that the instrument did not come back to

a reference reading (e.g., in some cases it was only 15% to 20% off) would have been an inconvenience rather than a reason to reject the instrument. The second requirement of the test should perhaps be reduced to a recommendation (a "should" statement). For example, "The components of an instrument should be protected from damage caused by high exposure rates."

A high percentage of GM detectors and ion chambers failed the photon and beta angular dependence. The requirements for the low-energy photon angular dependence test and the beta angular dependence test may be too restrictive.

A number of instruments (GM detectors, ion chambers, and alpha detectors) failed the microwave susceptibility test. These failures identify the need for the instrument manufacturer to state whether or not the instrument may be susceptible to interferences caused by the presence of microwave fields.

A large number of ion chambers failed the temperature test. The requirement of a maximum 15% change over the temperature range when the instrument response is compared to the response at 20°C is not considered too severe; these environmental conditions represent field conditions one is likely to encounter. A higher percentage of these units should have passed the test.

A large number of alpha detectors failed both the humidity and ambient pressure tests. The instruments can be improved to meet the humidity requirements, and the testing procedure for the ambient pressure test may need to be revised for air proportional alpha detectors. This would permit high-voltage adjustments to compensate for pressure changes.

3.2.3 Summary

Table B.1 is a useful generalized summary of the testing results discussed in detail in other sections of this report. Instruments are grouped by instrument type; the identification numbers are sequential within a group. Some numbers are missing because the numbers were assigned randomly from a pool of 200 numbers. One can look at the pass/fail decision made for each instrument or types of instruments for a specific test or series of tests. The details of the testing results are discussed in Section 3.1 of this report and are summarized in Appendix A.

4.0 CONCLUSIONS

During the testing phase of this project a large amount of data on the performance of different types of instruments under different testing conditions was obtained. Instruments were evaluated under the categories of ion chambers, GM detectors, alpha detectors, neutron monitors, and "others."

Major conclusions about instrument performance based on the testing results include:

- A large variability in performance can be observed among instruments from different manufacturers.
- Variability can be observed between same manufacturer/same model instruments.
- Performance data supplied by many manufacturers are incomplete, unsatisfactory, and at times inaccurate.
- The response of most Geiger-Mueller (GM) type instruments currently available is highly dependent on the energy of the photons (i.e., they do not use energy-compensated GM tubes).
- The precision and the response time of the instruments need to be monitored during testing to ensure statistically reliable data.
- Ion chambers exhibit temperature-dependent responses (sometimes severe).
- High humidity can affect instrument performance; ion chambers and GM detectors usually recover when returned to low humidity, and some air proportional detectors fail permanently.
- Alpha-detection instruments are, in general, more fragile and more susceptible to environmental effects than GMs, ion chambers, or dose-equivalent monitors.
- For most tests, there were enough instruments passing to suggest that the standard as modified is achievable with state-of-the-art, off-the-shelf instruments.

5.0 CHANGES TO THE PROPOSED ANSI STANDARD

A number of recommendations have been made to the ANSI N42.17 working group over the last three years regarding the contents of the draft ANSI standard on performance specifications for health physics instrumentation. Major changes that have been made in the proposed standard based on the findings in the testing program include:

- Statistically reliable data are required for each test (e.g., multiple instrument readings for each data point or data from using high exposure rates so that statistical fluctuations are minimized).
- The coefficient of variation test requirement that the relative standard deviation (i.e., coefficient of variation) be $\leq 2.5\%$ on all scales or decades was changed to $\leq 10\%$ for exposure rate instruments, dose rate instruments, dose-equivalent rate instruments, and contamination monitors exposed to radiation intensities greater than or equal to 1 mR/h, 1 mrad/h, 10 mrem/h, and 500 cpm, respectively. When these instruments are exposed to radiation intensities less than those stated, the coefficient of variation shall not be more than 15%.
- The photon-radiation energy dependence test requirement that the readings be $\pm 20\%$ over the range of 40 keV to 3 MeV was changed to $\pm 20\%$ over the range of 80 keV to 1.5 MeV, with a recommendation that it be $\pm 20\%$ over the 40 keV to 3 MeV range.
- The sources for the beta accuracy test were changed to those listed in ISO-6980 (i.e., Series 1 sources) (ISO 1983).
- The acceptable neutron sources were changed in the draft standard.
- An equilibration time was included in the temperature, humidity, and ambient pressure tests.
- Additional frequencies were added to the radio frequency test.
- The field intensity for the magnetic field test was increased from 3 to 10 oersteds.
- The acceleration level applied to instruments in the vibration test was decreased to 2 g from 5 g.

- The deceleration level applied to instruments in the mechanical shock test was increased to 50 g from 30 g.
- Additional requirements were added to the angular dependence test.
- Requirements for rechargeable battery units were added to the battery lifetime test.

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APPENDIX A

TEST-BY-TEST SUMMARY OF DATA
FOR EACH INSTRUMENT

TABLE A.1. Inspection Test Results

<u>Instrument ID Number</u>	<u>Criteria Failed (Refer to Section 3.1.1)</u>
<u>Ion Chambers (Vented)</u>	
18, 96	A.1.1.1, A.1.6.2(c), A.1.6.7, A.1.8.1
47, 60	A.1.1.1, A.1.3.1, A.1.6.2(c), A.1.8.1
51, 68	A.1.1.1, A.1.6.7
62, 112, 156	A.1.1.1, A.1.2.3, A.1.4.1, A.1.6.2(c), A.1.6.7, A.1.8.1
144	A.1.4.1, A.1.6.2(c)
154	A.1.1.1, A.1.6.2(c)
165	A.1.4.1, A.1.6.2(c), A.1.6.7
196	A.1.1.1, A.1.4.1, A.1.6.2(c), A.1.6.5, A.1.6.7, A.1.8.1
<u>Ion Chambers (Closed)</u>	
34, 95	A.1.2.2, A.1.4.1, A.1.6.2(c)
36, 65, 73, 103, 104, 182	A.1.2.2, A.1.4.1, A.1.6.2(c)
<u>GM Detectors</u>	
3, 15, 130	A.1.1.1, A.1.1.3, A.1.4.1, A.1.6.1, A.1.6.2(c), A.1.8.1
4, 9, 128	A.1.4.1, A.1.5.1, A.1.5.3, A.1.6.1, A.1.6.2(a,c,d), A.1.6.6, A.1.8.1
13, 52	A.1.1.1, A.1.6.5, A.1.6.2(c)
14, 26, 187	A.1.4.1, A.1.6.5
24, 120, 175	A.1.1.2, A.1.4.1
35	A.1.5.1, A.1.5.2, A.1.6.2(c)
40, 56	A.1.4.1, A.1.6.2(c), A.1.8.1
41, 57	A.1.4.1, A.1.6.2(c), A.1.8.1
50	A.1.4.1, A.1.3.1, A.1.6.2(c)
75	A.1.1.1, A.1.4.1, A.1.6.2(c)
78, 142, 180	A.1.6.2(c), A.1.8.1
81	A.1.4.1, A.1.6.2(c)
89, 94, 173	A.1.6.2(c)
100	A.1.4.1, A.1.6.2(b,c), A.1.8.1
118, 125, 155	A.1.4.1, A.1.6.2(c), A.1.8.1
127	A.1.4.1, A.1.6.2(c)
129	A.1.1.1, A.1.4.1, A.1.6.2(c)
137	A.1.5.1, A.1.5.2, A.1.6.2(c)
149, 198	A.1.4.1, A.1.6.2(c), A.1.8.1
158	A.1.3.1, A.1.4.1, A.1.5.3, A.1.6.2(c), A.1.8.1
191	A.1.3.1 A.1.4.1, A.1.5.2, A.1.5.3, A.1.6.2(c), A.1.6.3, A.1.8.1

TABLE A.1. (contd)

<u>Instrument ID Number</u>	<u>Criteria Failed (Refer to Section 3.1.1)</u>
<u>Alpha Detectors</u>	
10, 38, 124	A.1.3.1, A.1.6.2(a,b,c)
17, 29, 32, 152	A.1.3.1, A.1.4.1, A.1.6.2(c)
27	A.1.3.1, A.1.4.1, A.1.6.2(c), A.1.8.1
39, 64, 174	A.1.4.1, A.1.6.2(c)
43, 87, 90	A.1.6.2(a,b,c), A.1.6.5
44, 54	A.1.3.1, A.1.4.1, A.1.6.2(a,b,c), A.1.6.5, A.1.7.1
114, 168, 193	A.1.3.1, A.1.4.1, A.1.6.2(a,b,c)
133	A.1.3.1, A.1.6.1, A.1.6.2(a,b,c), A.1.8.1
<u>Neutron Detectors</u>	
12, 42, 59, 77, 141	A.1.4.1, A.1.6.2(c)
22	A.1.1.5, A.1.3.1, A.1.4.1, A.1.6.1, A.1.6.2(c,d), A.1.8.1
23, 178	A.1.4.1, A.1.6.2(c)
48	A.1.2.2, A.1.4.1, A.1.6.2(c)
172	A.1.4.1, A.1.6.2(c)
189	A.1.1.5, A.1.4.1, A.1.6.2(c), A.1.6.4
<u>NaI(Tl) Detectors</u>	
135	A.1.3.1, A.1.4.1, A.1.6.2(c), A.1.8.1

TABLE A.2. Zero Set Test Results

<u>Instrument ID Number</u>	<u>Highest Exposure Rate Tested</u>	<u>Pass/Fail</u>
<u>Ion Chambers (Vented)</u>		
18	500 mR/h	P
51	500 mR/h	P
62	2 R/h	P
96	500 mR/h	P
112	2 R/h	P
156	2 R/h	P
196	1 R/h	P

TABLE A.3. AC Power Test Results

<u>Instrument ID Number</u>	<u>Pass/Fail</u>
<u>GM Detectors</u>	
50	P
132	P
158	P
191	P

TABLE A.4. Battery Power Test Results

<u>Instrument ID Number</u>	<u>Approximate Battery Lifetime, h</u>	<u>Pass/Fail</u>	<u>Comments</u>
<u>Ion Chambers (Vented)</u>			
18	120+	P	
51	120+	P	
62	120+	P	
68	120+	P	
96	47	F	Passed during second run
96	120+	P	
112	120+	P	
<u>GM Detectors</u>			
13	48-72	F	
14	75-96	F	
24	120+	P	
26	75-96	F	
26	95	F	
35	64	F	
35	1-2	F	Alarm on
35	26-47	F	Carbon-zinc battery
40	32	F	
41	120+	P	
52	120+	P	
56	32	F	
57	110-114	P	
75	120+	P	
78	120+	P	
81	120+	P	
100	120+	P	
118	3-6	F	
120	120+	P	
125	4-5	F	
127	120+	P	
129	120+	P	
137	90-100	P(M) ^(a)	
137	98-112	P	
142	52	F	
149	120+	P	
155	5-6	F	
175	1	F	
180	120+	P	
187	72-96	F	
191	22-42	P	Rechargeable batteries
198	120+	P	

TABLE A.4. (contd)

<u>Instrument ID Number</u>	<u>Approximate Battery Lifetime, h</u>	<u>Pass/Fail</u>	<u>Comments</u>
<u>Alpha Detectors</u>			
17	10-20	F	
27	100	P	
32	50	F	
38	120+	P	
87	120+	P	
124	120+	P	
152	50-59	F	

(a) P(M) = pass marginally.

TABLE A.5. Latching and Nonlatching Alarm Reset Test Results

<u>Instrument ID Number</u>	<u>Pass/Fail</u>
<u>GM Detectors</u>	
85	P
158(L) ^(a)	P
191	F

(a) L = latching alarm.

TABLE A.6. Alarm Activation Delay Test Results

<u>Instrument ID Number</u>	<u>Pass/Fail</u>
<u>GM Detectors</u>	
85	P
158	P
191	P

TABLE A.7. Alarm Threshold Drift Test Results

<u>Instrument ID Number</u>	<u>Pass/Fail</u>
<u>GM Detectors</u>	
85	P
158	P
191	P

TABLE A.8. Stability Test Results

Instrument ID Number	Maximum % Change from Reference with Respect to Full Scale or Full Decade $\pm$ SD	Full-Scale or Full-Decade Reading	Time at Which Maximum Change Occurred, min	Pass/Fail
<u>Ion Chambers (Vented)</u>				
18	-2.0 ± 0.3	5 mR/h	180	P
51	0	50 mR/h	---	P
62	-0.3 ± 0.1	200 mR/h	180	P
68	-0.6 ± 0.02	50 mR/h	150	P
96	-3.9 ± 0.3	5 mR/h	180	F
154	-0.01 ± 0.01	2,000 mR/h	60	P
156	-0.1 ± 0.1	200 mR/h	150	P
165 (γ only)	0.02 ± 0.03	2,000 mR/h	60	P
196	-0.3 ± 0.5	3 mR/h	180	P
<u>GM Detectors</u>				
3	0.8 ± 0.8	99.9 mR/h	90	P
4	5.3 ± 1.8	10 mrad/h	150	P(M) ^(a)
9	3.0 ± 1.2	10 mrad/h	120	P
13	-1.3 ± 0.9	2,500 cpm	120	P
14	1.6 ± 0.6	100 mR/h	180	P
15	0.6 ± 0.5	99.9 mR/h	60	P
24	4.0 ± 3.1	10 mR/h	30	P(M)
26	-1.6 ± 0.6	100 mR/h	30	P
35	2.60 ± 2.0	5,000 cpm	120	P
40	-2.40 ± 0.8	5,000 cpm	150	P
41	0.97 ± 0.7	100 mR/h	60	P
50 ^(b)	-3.1 ± 0.5	30,000 cpm	26 days	P
52	-1.3 ± 1.6	250,000 cpm	120	P
56	-1.4 ± 1.1	5,000 cpm	180	P
57	-2.2 ± 0.8	100 mR/h	60	P
75	-0.7 ± 0.6	60,000 cpm	150	P
78	-0.2 ± 0.1	2,000 mR/h	60	P
81	7.7 ± 2.2	10 mR/h	150	F
89	-1.8 ± 1.6	100 mR/h	60	P
94	2.75 ± 1.3	100 mR/h	120	P
100	1.50 ± 0.7	10,000 cpm	120	P
118	-1.8 ± 1.1	99.9 mR/h	30	P
120	6.8 ± 4.9	10 mR/h	150	P(M)
125	2.2 ± 0.8	99.9 mR/h	180	P
129 ^(c)	0	600 cpm	---	P
129	-2.3 ± 0.8	6,000 cpm	180	P

TABLE A.8. (contd)

Instrument ID Number	Maximum % Change from Reference with Respect to Full Scale or Full Decade $\pm$ SD	Full-Scale or Full-Decade Reading	Time at Which Maximum Change Occurred, Min	Pass/Fail
<u>GM Detectors (contd)</u>				
130	0.7 ± 0.5	99.9 mR/h	120	P
132 ^(b)	-2.3 ± 0.3	50,000 cpm	25 days	P
142	0.4 ± 0.3	2,000 mR/h	30	P
149	4.4 ± 5.6	500 cpm	90	P(M)
155	-2.3 ± 1.0	99.9 mR/h	120	P
158 ^(b)	-1.0 ± 0.6	30,000 cpm	8 h	P
173	2.5 ± 1.7	100 mR/h	90	P
180	0.1 ± 0.1	2,000 mR/h	150	P
191 ^(b)	-4.4 ± 0.3	50,000 cpm	22 days	P
198	6.35 ± 2.4	500 cpm	180	P(M)
<u>Alpha Detectors (Gas flow)</u>				
39	-10.5 ± 0.8	50,000 cpm	180	F
44	5.4 ± 2.0	1,000 cpm	30	P(M)
114	3.6 ± 0.7	5,000 cpm	90	P(M)
168	-3.8 ± 1.7	500 cpm	120	P(M)
174	1.1 ± 0.6	50,000 cpm	120	P
193	-1.6 ± 0.5	5,000 cpm	30	P
<u>Alpha Detectors (Air proportional)</u>				
17	-3.9 ± 1.2	10,000 cpm	120	P(M)
27	-2.8 ± 0.8	5,000 cpm	120	P
32	-2.0 ± 1.0	10,000 cpm	150	P
152	7.62 ± 2.1	10,000 cpm	180	F
<u>Alpha Detectors (Scintillation)</u>				
10	-3.0 ± 0.4	5,000 cpm	150	P
38	-1.8 ± 0.3	5,000 cpm	150	P
43	-0.1 ± 0.1	2,000 cpm	60	P
87	2.0 ± 0.2	2,000 cpm	90	P
124	1.4 ± 0.5	5,000 cpm	30	P
<u>Neutron Detectors</u>				
12	4.4 ± 0.9	20 mrem/h	150	P(M)
23	-3.74 ± 1.6	50 mrem/h	120	P(M)
48	-3.50 ± 1.0	50 mrem/h	60	P(M)
178	-0.9 ± 1.3	50 mrem/h	90	P

(a) P(M) = pass marginally.

(b) Benchtop system.

(c) Data from testing with a pulser.

TABLE A.9. Geotropism Test Results

<u>Instrument ID Number</u>	<u>Maximum % Change</u>	<u>Full-Decade or Full-Scale Reading</u>	<u>Axis & Angle of Maximum Change</u>	<u>Pass/Fail</u>
<u>Ion Chambers (Vented)</u>				
18	1.2 ± 0.1	50 mR/h	X-180°, X-270°	P
18	-6.4 ± 0.2	5 mR/h	X-270°	F
18	-8.2 ± 0.2	5 mR/h	Y-270°	F
51	-3.0 ± 0	5,000 mR/h	X-270°, Y-270°	P
51	-4.1 ± 0.4	5 mR/h	Y-90°	F
62	-2.7 ± 0.06	200 mR/h	Y-90°	P
96	-1.0 ± 0	5 R/h	X-180°	P
96	-4.7 ± 0.4	5 mR/h	X-180°	F
112	0.2 ± 0.05	200 mR/h	Y-270°	P
154	-0.7 ± 0.03	2 R/h	Y-90°	P
156	-4.9 ± 0.06	200 mR/h	Y-90°	F
156	-0.10 ± 0.02	20 R/h	X-180°	P
165	-0.1 ± 0.01	2 R/h	Y-90°	P
196	0.83 ± 0.9	3 mR/h	X-270°	P
<u>Ion Chambers (Closed, pressurized)</u>				
65	-4.2 ± 0.8	10 mR/h	X-270°	P(M) (a)
65	0	1,000 mR/h	---	P
65	-4.3 ± 0.5	100 mR/h	Y-90°	F
<u>GM Detectors</u>				
3	1.2 ± 0.7	99.9 mR/h	Y-90°	P
4	0	100 mR/h	---	P
4	5.0 ± 2.1	1 mR/h	X-180°	P(M)
4	4.0 ± 1.5	10 mR/h	X-180°	P(M)
4	10.0 ± 0	100 mR/h	X-180°	F
9	-0.50 ± 0.3	500 mR/h	X-270°	P
9	-7.0 ± 2.6	1 mR/h	Y-270°	P(M)
9	-11.5 ± 1.5	10 mR/h	Y-270°	F
13	0	0.2 mR/h	---	P
13	-0.50 ± 0.5	2 mR/h	Y-90°	P
13	-0.6 ± 0.7	200 mR/h	Y-270°	P
13	-2.4 ± 1.1	20 mR/h	Y-90°	P
15	-2.3 ± 0.7	99.9 mR/h	Y-90°	P
35	2.1 ± 1.3	5,000 cpm	X-90°	P
35	5.7 ± 1.4	500 cpm	Y-270°	P(M)
35	0	500 cpm	---	P
35	-1.0 ± 0	5,000 cpm	X-180°	P
40	1.9 ± 1.1	5,000 cpm	Y-270°	P
41	2.2 ± 2.0	10 mR/h	X-270°	P
52	0.50 ± 0.3	0.2 mR/h	X-270°, Y-270°	P

TABLE A.9. (contd)

<u>Instrument ID Number</u>	<u>Maximum % Change</u>	<u>Full-Decade or Full-Scale Reading</u>	<u>Axis & Angle of Maximum Change</u>	<u>Pass/Fail</u>
<u>GM Detectors (contd)</u>				
52	-2.4 ± 0.8	20,000 cpm	Y-270°	P
52	-2.5 ± 0.0	2 mR/h	X-270°	P
56	-0.5 ± 0.9	5,000 cpm	Y-90°	P
57	-1.6 ± 1.7	10 mR/h	X-180°	P
78	-0.1 ± 0.06	2,000 mR/h	X-90°	P
81	-1.1 ± 0.3	1,000 mR/h	X-270°	P
81	4.3 ± 1.8	10 mR/h	X-90°	P(M)
89	4.3 ± 0.7	500 mR/h	X-180°	P(M)
89	4.3 ± 1.2	100 mR/h	X-90°	P(M)
89	9.0 ± 2.9	10 mR/h	X-180°	F
94	2.5 ± 1.3	100 mR/h	Y-90°	P
94	5.20 ± 3.5	10 mR/h	X-270°	P(M)
100	-1.4 ± 1.5	100 cpm	Y-90°	P
100	0.4 ± 0.3	100 cpm	Y-90°	P
100	0	1,000 cpm	---	P
128	-0.3 ± 0.1	500 mR/h	X-270°	P
128	10.0 ± 0	100 mR/h	X-180°, Y-270°	F
128	-7.0 ± 3.0	1 mR/h	X-90°, X-270°	P(M)
128	-7.5 ± 1.7	10 mR/h	X-270°	F
130	1.0 ± 0.6	99.9 mR/h	Y-90°	P
137	-2.3 ± 1.8	600 cpm	X-270°	P
137	0	600 cpm	---	P
137	0	6,000 cpm	---	P
142	0.1 ± 0.2	2,000 mR/h	Y-90°	P
149	-1.5 ± 1.0	5,000 cpm	X-90°	P
173	-2.0 ± 1.3	100 mR/h	Y-90°	P
173	-7.7 ± 2.9	10 mR/h	X-270°	P(M)
180	0.1 ± 0.07	2,000 mR/h	X-270°	P
198	-1.2 ± 0.2	50,000 cpm	X-90°	P
<u>Alpha Detectors (Gas flow)</u>				
39				
(probe)	-0.6 ± 0.7	50,000 cpm	X-90°	P
(instr.)	-5.9 ± 0.7	50,000 cpm	X-270°	F
114				
(probe)	5.8 ± 0.5	5,000 cpm	Y-270°	F
(instr.)	42.8 ± 1.1	5,000 cpm	Y-270°	F
168				
(probe)	1.8 ± 0.4	5,000 cpm	Y-270°	P
(instr.)	5.8 ± 0.5	5,000 cpm	X-180°	F

TABLE A.9. (contd)

<u>Instrument ID Number</u>	<u>Maximum % Change</u>	<u>Full-Decade or Full-Scale Reading</u>	<u>Axis & Angle of Maximum Change</u>	<u>Pass/Fail</u>
<u>Alpha Detectors (Gas flow) (contd)</u>				
174				
(probe)	-0.8 $\pm$ 0.6	50,000 cpm	X-180°	P
(instr.)	4.0 $\pm$ 0.7	50,000 cpm	Y-90°	P(M)
193				
(probe)	-2.2 $\pm$ 0.6	5,000 cpm	Y-270°	P
(instr.)	-34.2 $\pm$ 0.5	5,000 cpm	Y-90°	F
<u>Alpha Detectors (Air proportional)</u>				
17	7.5 $\pm$ 0.5	100,000 cpm	Y-90°	F
27	5.2 $\pm$ 0.7	5,000 cpm	Y-90°	F
32	-7.6 $\pm$ 0.7	10,000 cpm	Y-90°	F
152	10.0 $\pm$ 0.7	100,000 cpm	X-90°	F
<u>Alpha Detectors (Scintillation)</u>				
10	-0.8 $\pm$ 0.4	5,000 cpm	X-180°	P
38	2.20 $\pm$ 0.4	5,000 cpm	Y-90°	P
43	-2.6 $\pm$ 0.4	20,000 cpm	X-270°	P
87	-2.8 $\pm$ 0.4	20,000 cpm	X-270°	P
124	1.4 $\pm$ 0.5	5,000 cpm	X-90°	P

(a) P(M) = pass marginally.

TABLE A.10. Response Time Test Results

Instrument ID Number	Response Time, s					Pass/Fail
	$>10^{-4}$ to $\leq 10^{-3}$ rem,rad/h (30-s requirement)	$>10^{-3}$ to $\leq 10^{-2}$ rem,rad/h (10-s requirement)	$>10^{-2}$ to $\leq 10^{-1}$ rem,rad/h (5-s requirement)	$>10^{-1}$ to ≤ 1 rem,rad/h (3-s requirement)	>1 rem,rad/h (1-s requirement)	
Ion Chambers (Vented)						
18	---(a)	$18.7 \pm 1.7^{(b)}$	$8.2 \pm 0.6^{(b)}$	$5.6 \pm 0.4^{(b)}$	0.2 ± 0 (5 R scale) 0.2 ± 0 (50 R scale)	F
47	---	$13.3 \pm 0.9^{(b)}$	$5.7 \pm 0.3^{(b)}$	$4.1 \pm 0.3^{(b)}$	---	F
51	---	4.8 ± 0.6	4.5 ± 0.5	2.1 ± 0.2	$1.2 \pm 0.1^{(b)}$ (5 R)	F
60	---	10.0 ± 0.7	4.9 ± 0.2	$4.0 \pm 0.4^{(b)}$	---	F
68	---	NT	2.0 ± 0.2	2.2 ± 0.1	$1.2 \pm 0.1^{(b)}$ (5 R) $1.1 \pm 0.1^{(b)}$ (50 R)	F
96	---	7.4 ± 0.6	3.4 ± 0.5	2.9 ± 0.3	0.3 ± 0.1 (5 R) 0.2 ± 0 (50 R) 0.2 ± 0 (500 R)	P
154	---	---	---	---	0.8 ± 0.3 (2 R) $1.4 \pm 0.2^{(b)}$ (200 R)	F
156	---	---	---	NT ^(c)	0.5 ± 0.1 (2 R scale) 0.6 ± 0.1 (20 R scale)	P
165	---	---	---	---	$2.4 \pm 0.2^{(b)}$ (2 R) 0.4 ± 0 (20 R) 0.3 ± 0.1 (200 R)	F
196	---	2.8 ± 0.2	1.8 ± 0.2	2.4 ± 0.2	---	P

TABLE A.10. (contd)

Response Time, s						
Instrument ID Number	$>10^{-4}$ to $\leq 10^{-3}$ rem,rad/h (30-s requirement)	$>10^{-3}$ to $\leq 10^{-2}$ rem,rad/h (10-s requirement)	$>10^{-2}$ to $\leq 10^{-1}$ rem,rad/h (5-s requirement)	$>10^{-1}$ to ≤ 1 rem,rad/h (3-s requirement)	>1 rem,rad/h (1-s requirement)	Pass/Fail
<u>Ion Chambers (Closed)</u>						
34	---	0.7 ± 0.1	0.9 ± 1.1	1.3 ± 0.2	0.6 ± 0.1 (10 R) 0.9 ± 0.1 (100 R) 0.9 ± 0.1 (1000 R)	P
65	---	2.8 ± 0.4	1.3 ± 0.2	2.3 ± 0.1	0.2 ± 0 (10 R) 0.3 ± 0.1 (100 R) 0.2 ± 0.1 (1000 R)	P
95	---	0.7 ± 0.1	1.3 ± 0.2	NT	NT	P
103	---	0.6 ± 0.1	1.2 ± 0.1	1.2 ± 0.2	0.5 ± 0.1 (10 R) 1.0 ± 0.2 (100 R)	P
104	---	NT	NT	NT	0.5 ± 0.1 (10 R) 0.9 ± 0.1 (100 R) $2.0 \pm 0.2^{(b)}$ (1000 R)	F
<u>GM Detectors</u>						
3	---	---	$2.9 \pm 0^{(d)}$	---	NT	P
4	3.3 ± 0.6	4.5 ± 0.7	5.0 ± 0.6	---	---	P
9	4.6 ± 1.4	5.4 ± 0.7	4.9 ± 0.3	---	---	P
13	$2.7 \pm 0^{(d)}$	$2.5 \pm 0^{(d)}$	$1.9 \pm 0^{(d)}$	$2.1 \pm 0^{(d)}$	$1.9 \pm 0^{(d)}$ (2 R) ^(b)	F
14	---	9.5 ± 3.1	$7.9 \pm 1.1^{(b)}$	$8.3 \pm 0.5^{(b)}$	---	F
15	---	---	$3.2 \pm 0^{(d)}$	---	NT	P
26	---	3.4 ± 0.7	2.2 ± 0.4	0.8 ± 0.2	---	P

TABLE A.10. (contd)

Instrument ID Number	Response Time, s					Pass/Fail
	$>10^{-4}$ to $\leq 10^{-3}$ rem,rad/h (30-s requirement)	$>10^{-3}$ to $\leq 10^{-2}$ rem,rad/h (10-s requirement)	$>10^{-2}$ to $\leq 10^{-1}$ rem,rad/h (5-s requirement)	$>10^{-1}$ to ≤ 1 rem,rad/h (3-s requirement)	>1 rem,rad/h (1-s requirement)	
<u>GM Detectors (contd)</u>						
35	11.5 ± 3.1	2.9 ± 1.4	1.1 ± 0.4	0.6 ± 0.2	---	P
41	11.1 ± 4.3	10.0 ± 1.5	3.6 ± 0.6	2.3 ± 0.3	$2.5 \pm 0.3^{(b)}$ (10 R)	F
52	NT	3.1 ± 0.8	$5.3 \pm 0.2^{(b)}$	$8.8 \pm 0.3^{(b)}$	$2.0 \pm 0.1^{(b)}$ (2 R)	F
56	$3.1 \pm 0^{(d)}$	$3.3 \pm 0^{(d)}$	$3.3 \pm 0^{(d)}$	---	---	P
75	2.6 ± 1.1	8.8 ± 1.3	$8.2 \pm 0.8^{(b)}$	---	---	F
78	---	---	---	---	$3.1 \pm 0^{(b,d)}$ (2 R)	F
81	---	$4.1 \pm 0^{(d)}$	$5.1 \pm 0^{(b,d,e)}$	$6.1 \pm 0^{(b,d)}$	---	F
95	$12.4 \pm 0^{(d)}$	$3.6 \pm 0^{(d)}$	$3.8 \pm 0^{(d)}$	---	---	P
100	$16.2 \pm 0^{(d)}$	$4.5 \pm 0^{(d)}$	$4.3 \pm 0^{(d)}$	$4.1 \pm 0^{(b,d)}$	---	F
128	3.4 ± 0.7	4.1 ± 0.7	5.0 ± 0.7	---	---	P
129	1.6 ± 0.4	2.4 ± 1.1	2.0 ± 0.1	---	---	P
130	---	---	$3.3 \pm 0^{(d)}$	---	NT	P
137	8.0 ± 2.1	5.8 ± 0.6	2.6 ± 0.3	---	---	P
180	---	---	---	---	$2.8 \pm 0^{(b,d)}$ (2 R)	F
187	---	4.6 ± 1.6	4.8 ± 0.6	$7.5 \pm 1.0^{(b)}$	---	F
<u>Neutron Detectors</u>						
	<5 to 10^{-2} rem/h (30-s requirement)	5×10^{-2} to ≤ 1 rem/h (10-s requirement)	>1 rem/h (5-s requirement)			
12	NT	NT	$7.4 \pm 0.3^{(b)}$ (2 rem)	F		
42	$49.3 \pm 17^{(b)}$ (2 mrem)	8.4 ± 0.8	$6.5 \pm 0.3^{(b)}$	F		
	17.4 ± 2.6 (20 mrem)					

TABLE A.10. (contd)

Instrument ID Number	Response Time, s			Pass/Fail
<u>Neutron Detectors (contd)</u>				
	<5 to 10^{-2} rem/h (30-s requirement)	5×10^{-2} to ≤ 1 rem/h (10-s requirement)	>1 rem/h (5-s requirement)	
77	$48.6 \pm 7.1^{(b)}$ (2 mrem)	8.0 ± 1.4	$10.3 \pm 0.4^{(b)}$	F
	22.8 ± 4.8 (20 mrem)			
<u>Alpha Detectors</u>				
	<u>Most Sensitive Scale</u>	<u>Second Scale</u>	<u>Third Scale</u>	<u>Fourth Scale</u>
114 (Gf) ^(f)	19.7 ± 6.3	16.1 ± 2.0	NT	NT
193 (Gf)	21.3 ± 4.2	20.5 ± 1.3	NT	NT
27 (Ap) ^(g)	---	2.3 ± 0.6	1.8 ± 0.2	NT
32 (Ap)	5.0 ± 3.4	4.2 ± 1.5	NT	NT
10 (S) ^(h)	7.5 ± 3.3	4.7 ± 0.8	NT	NT
38 (S)	5.7 ± 2.2	5.7 ± 1.3	NT	NT
124 (S)	8.8 ± 4.3	4.2 ± 0.8	NT	NT

(a) Readings were too variable on the most sensitive scale to allow testing.

(b) Failed test.

(c) NT = not tested.

(d) Only one reading done.

(e) M = marginal.

(f) Gf = gas flow.

(g) Ap = air proportional.

(h) S = scintillation.

TABLE A.11. Coefficient of Variation Test Results

Instrument ID Number	Relative Standard Deviation (%)		Pass/Fail
	≤ 1 mR/h (≤ 500 cpm)	> 1 mR/h (> 500 cpm)	
<u>Ion Chambers (Vented)</u>			
18	---	0.8 (5 mR/h) 1.0 (50 mR/h) 2.2 (500 mR/h) 0.4 (5,000 mR/h)	P
51	---	1.5 (5 mR/h) 1.0 (50 mR/h) 1.6 (500 mR/h) 0 (5,000 mR/h)	P
60	---	0 (500 R/h)	P
62	---	0.9 (200 mR/h) 0.5 (2,000 mR/h) 0.1 (20,000 mR/h)	P
68	---	1.1 (50 mR/h) 1.6 (500 mR/h) 0 (5,000 mR/h)	P
96	---	1.7 (5 mR/h) 1.4 (50 mR/h) 0.4 (500 mR/h) 0.3 (5,000 mR/h) 0.5 (50,000 mR/h)	P
112	---	1.9 (200 mR/h) 0.4 (2,000 mR/h) 0.3 (20,000 mR/h)	P
144	2.9 (1 mR/h)	1.5 (10 mR/h) 0.8 (100 mR/h)	P
154	---	0.4 (2 R/h)	P
156	---	0.6 (200 mR/h) 0.5 (2,000 mR/h) 0.3 (20,000 mR/h)	P
165	---	0.2 (2 R/h) 0.1 (20 R/h)	P
196	---	2.3 (3 mR/h) 3.0 (30 mR/h) 0.4 (300 mR/h)	P
<u>Ion Chambers (Closed)</u>			
34	---	0 (1 R/h) 0 (10 R/h) 0 (100 R/h) 2.7 (1,000 R/h)	P
36	---	4.4 (10 mR/h) 0 (100 mR/h) 0 (1 R/h) 0 (10 R/h) 2.3 (100 R/h) 3.1 (1,000 R/h)	P

TABLE A.11. (contd)

Instrument ID Number	Relative Standard Deviation (%)		Pass/Fail
	≤ 1 mR/h (≤ 500 cpm)	> 1 mR/h (> 500 cpm)	
<u>Ion Chambers (Closed) (contd)</u>			
65	---	3.3 (1 R/h) 0 (10 R/h) 73 (100 R/h) (a,b)	F
73	---	5.6 (10 mR/h) 0 (100 mR/h) 0 (1 R/h) 0 (10 R/h) 0 (100 R/h) 0.8 (1,000 R/h)	P
95	---	0 (1 R/h) 0 (10 R/h) 0 (100 R/h) 2.6 (1,000 R/h)	P
103	---	0 (1 R/h) 0 (10 R/h) 0 (100 R/h) 3.0 (1,000 R/h)	P
104	---	5.1 (10 mR/h) 0 (100 mR/h) 1.9 (1 R/h) 0 (10 R/h) 3.6 (100 R/h) 1.3 (1,000 R/h)	P
182	---	4.6 (10 mR/h) 0 (100 mR/h) 4.0 (1 R/h) 0 (10 R/h) 0 (100 R/h) 3.1 (1,000 R/h)	P
<u>GM Detectors</u>			
3	---	2.7 (100 mR/h) 2.6 (9.99 R/h)	P
13	8.3 (0.2 mR/h)	5.2 (2 mR/h) 4.0 (20 mR/h) 1.3 (200 mR/h) 1.9 (2,000 mR/h)	P
14	---	11.1 (10 mR/h) (a) 2.9 (100 mR/h) 0.7 (1,000 mR/h)	F
15	---	3.0 (100 mR/h) 2.7 (9.99 R/h)	P
26	---	8.1 (10 mR/h) 4.0 (100 mR/h) 0.7 (1,000 mR/h)	P

TABLE A.11. (contd)

Instrument ID Number	Relative Standard Deviation (%)		Pass/Fail
	≤1 mR/h (≤500 cpm)	>1 mR/h (>500 cpm)	
GM Detectors (contd)			
35	8.6 (0.5 mR/h)	4.8 (5 mR/h) 2.8 (50 mR/h) 1.2 (500 mR/h)	P
40	18.8 (0.15 mR/h) ^(a)	7.3 (1.5 mR/h) 3.8 (15 mR/h)	F
41	9.8 (1 mR/h)	3.7 (10 mR/h) 1.3 (100 mR/h) 1.6 (1,000 mR/h)	P
52	17.8 (0.2 mR/h) ^(a)	6.7 (2 mR/h) 1.9 (20 mR/h) 1.2 (200 mR/h) 2.0 (2,000 mR/h)	F
56	16.6 (0.15 mR/h) ^(a)	9.5 (1.5 mR/h) 3.6 (15 mR/h)	F
57	15.6 (1 mR/h) ^(a)	4.0 (10 mR/h) 1.5 (100 mR/h)	F
75	9.3 (0.5 mR/h)	5.7 (5 mR/h) 2.1 (50 mR/h)	P
81	---	14.6 (10 mR/h) ^(a) 3.5 (100 mR/h) 2.2 (1,000 mR/h)	F
89	---	26.6 (10 mR/h) ^(a) 10.4 (100 mR/h) ^(a) 4.4 (1,000 mR/h)	F
94	---	22.6 (10 mR/h) ^(a) 9.8 (100 mR/h) 6.6 (1,000 mR/h)	F
129	16.0 (0.5 mR/h) ^(a)	3.6 (5 mR/h) 1.3 (50 mR/h)	F
130	---	3.7 (100 mR/h) 2.4 (9.99 R/h)	P
137	11.0 (0.5 mR/h)	5.3 (5, 50 mR/h) 1.6 (5, 50 mR/h)	P
149	NT ^(c)	11.6 (10 mR/h) ^(a) 7.4 (100 mR/h) 2.4 (1,000 mR/h)	F
180	---	4.4 (999 mR/h) 1.9 (2,000 mR/h)	P
187	---	12.2 (10 mR/h) ^(a) 2.9 (100 mR/h) 2.6 (1,000 mR/h)	F

TABLE A.11. (contd)

Instrument ID Number	Relative Standard Deviation (%)		Pass/Fail
	≤1 mR/h (≤500 cpm)	>1 mR/h (>500 cpm)	
<u>Alpha Detectors (Gas flow)</u>			
114	27.1 (500 cpm) ^(a)	5.0 (5,000 cpm) 4.5 (50,000 cpm)	F
168	22.0 (500 cpm) ^(a)	5.3 (5,000 cpm) 2.5 (50,000 cpm)	F
193	15.3 (500 cpm) ^(a)	3.1 (5,000 cpm) 3.9 (50,000 cpm)	F
<u>Alpha Detectors (Air proportional)</u>			
27	18.6 (500 cpm) ^(a)	4.2 (5,000 cpm) 1.5 (50,000 cpm)	F
32	---	16.3 (1,000 cpm) ^(a) 5.7 (10,000 cpm) 4.1 (100,000 cpm)	F
<u>Alpha Detectors (Scintillation)</u>			
10	11.2 (500 cpm)	3.5 (5,000 cpm) 0 (50,000 cpm)	P
38	9.5 (500 cpm)	3.7 (5,000 cpm) 0 (50,000 cpm)	P
43		5.8 (2,000 cpm) 3.8 (20,000 cpm)	P
87		14.3 (2,000 cpm) ^(a) 3.5 (20,000 cpm)	F
124	18.1 (500 cpm) ^(a)	3.0 (5,000 cpm) 2.2 (50,000 cpm)	F
<u>Neutron Detectors</u>			
12	---	1.2 (2,000 mrem/h)	P
77	---	2.5 (2 mrem/h) 4.0 (20 mrem/h) 2.9 (200 mrem/h) 1.2 (2,000 mrem/h)	P
141	---	4.3 (2 mrem/h) 2.8 (20 mrem/h) 5.3 (200 mrem/h) 1.8 (2,000 mrem/h)	P

(a) Failed test.

(b) Meter malfunction.

(c) NT = not tested.

TABLE A.12. Accuracy Test Results

<u>Instrument ID Number</u>	<u>Maximum % Change^(a)</u>	<u>Number of Ranges Tested</u>	<u>Pass/Fail</u>
<u>I. Photon Accuracy</u>			
<u>Ion Chambers (Vented)</u>			
51	-1.3	4	P
62	10.2	3	P
68	-0.7	4	P
96	103.2	6	F
112	11.5	3	P
154	-5.8	2	P
156	11.6	3	P
165	-5.7	3	P
196	6.1	6	P
<u>GM Detectors</u>			
3	12.1	2	P
15	9.9	2	P
24	-1.0	2	P
40	-12.5	1	P
41	13.8	4	P
52	6.0	1	P
56	4.0	1	P
57	15.8	4	P(M) ^(b)
64	-5.0	3	P
75	11.5	2	P
89	44.3	2	F
94	56	2	F
118	17.8	2	F
125	31.8	2	F
130	13.4	2	P
142	2.0	2	P
149	-32.0	2	F
173	32.8	2	F
198	28	1	F

TABLE A.12. (contd)

<u>Instrument ID Number</u>	<u>Maximum % Change^(a)</u>	<u>Number of Ranges Tested</u>	<u>Pass/Fail</u>
<u>II. Beta Accuracy</u>			
<u>Ion Chambers (Vented)</u>			
18	-29	1	F
51	7.9	1	P
61	23	1	F
62	-29.8	1	F
68	-10.3	1	P
96	1.2	1	P
112	-31.2	1	F
156	-35	1	F
165	3.0	1	P
196	-18.3	1	F
<u>III. Neutron Accuracy</u>			
<u>Neutron Detectors</u>			
12	33.8	3	F
22	1,100	4	F
48	-50.0	2	F
172	-6.8	3	P
178	-11.4	1	P
189	35.6	3	F

(a) Maximum percent change between the conventionally true value and the mean indicated value for the different ranges tested. Values $\leq 15\%$ met the requirements of the standard.

(b) P(M) = pass marginally.

TABLE A.13. Photon Energy Dependence Test Results

Instrument Response/Conventionally True Value									
Instrument ID Number	X-Rays						¹³⁷ Cs	⁶⁰ Co	P/F
	38 keV	83 keV	120 keV	166 keV	210 keV	248 keV	661 keV	1250 keV	
<u>Ion Chambers (Vented)</u>									
51	1.08	1.41	1.26	1.14	1.13	1.15	1.04	1.00	P
60	0.95	2.44	1.82	1.51	1.30	1.00	1.06	0.93	F
62	0.91	1.21	1.18	1.16	1.14	1.21	0.98	0.95	P
68	1.03	1.28	1.05	1.13	1.06	1.09	1.12	1.05	P
96	1.04	0.93	1.03	1.03	0.92	0.35	0.85	1.0	F
196	0.93	1.17	1.10	1.06	1.01	1.04	1.04	0.98	P
<u>Ion Chambers (Closed)</u>									
65	0.56	0.99	0.99	0.99	0.97	0.99	1.10	1.05	P
95	0.36	0.79	0.75	0.74	0.64	0.77	0.90	0.80	P
103	0.18	0.27	0.47	0.33	0.29	0.29	0.40	0.35	F
<u>GM Detectors</u>									
9	0.02	1.2	1.09	1.09	0.99	0.92	---	---	P
13	0.33	0.44	0.60	0.52	0.51	0.52	---	---	P
14	0.02	0.87	0.66	0.80	0.78	0.87	0.99	1.17	F
24	0.01	0.88	1.01	0.94	1.14	1.00	1.09	1.28	P
26	0.04	0.84	0.59	0.71	0.69	0.78	0.96	1.07	F
40	3.42	2.86	1.50	1.04	0.91	0.71	0.85	1.04	F
41	1.61	4.67	2.65	2.06	1.46	1.58	1.18	0.98	F
56	3.42	2.64	1.64	0.98	0.91	0.66	0.83	1.01	F
78	0.01	0.81	0.80	1.08	1.04	1.05	1.11	1.16	P
81	0.99	1.00	1.53	1.59	1.47	1.44	---	---	F
100	0.17	4.76	5.43	4.87	3.52	2.92	2.36	4.00	F
120	0.01	0.41	0.66	0.59	0.72	0.68	0.86	1.01	F
127	0.41	0.89	0.95	0.91	0.81	0.87	1.03	1.16	P
128	0.07	0.37	0.36	0.42	0.23	0.28	1.00	1.00	F
129	4.42	4.92	3.72	2.67	2.27	2.29	---	---	F
130	0.83	3.26	3.41	2.85	2.06	1.66	1.09	1.17	F
137	0.19	3.36	2.84	1.91	1.39	1.11	0.97	1.14	F
180	0.01	1.03	1.17	1.46	1.46	1.35	1.20	1.21	P
187	0.03	0.65	0.46	0.63	0.62	0.69	0.95	1.05	F
198	0.47	1.82	1.51	1.20	1.09	1.11	0.82	0.93	F

TABLE A.14. Beta Energy Dependence Test Results

Instrument ID Number	$\bar{r}_i/\text{CTV}^{(a)}$	Ratio of $(\bar{r}_i/\text{CTV})_{\text{max}}^{(b)}$ to $(\bar{r}_i/\text{CTV})_{\text{min}}$	Beta Cutoff Energy (MeV)	P/F
51	$^{147}\text{Pm} - 0.45$ $^{204}\text{Tl} - 0.39$ $^{90}\text{Sr}-^{90}\text{Y} - 1.08$	2.8	0.068	P
61	$^{147}\text{Pm} - 0.07$ $^{204}\text{Tl} - 0.45$ $^{90}\text{Sr}-^{90}\text{Y} - 1.23$	17.6	0.068	F
62	$^{147}\text{Pm} - 0.07$ $^{204}\text{Tl} - 0.25$ $^{90}\text{Sr}-^{90}\text{Y} - 0.70$	10.0	0.23	F
68	$^{147}\text{Pm} - 0.82$ $^{204}\text{Tl} - 0.63$ $^{90}\text{Sr}-^{90}\text{Y} - 0.90$	1.4	0.068	P
96	$^{147}\text{Pm} - 0.28$ $^{204}\text{Tl} - 0.57$ $^{90}\text{Sr}-^{90}\text{Y} - 1.01$	3.6	0.017	F
112	$^{147}\text{Pm} - 0.05$ $^{204}\text{Tl} - 0.25$ $^{90}\text{Sr}-^{90}\text{Y} - 0.69$	13.8	0.23	F
165	$^{147}\text{Pm} - 0.96$ $^{204}\text{Tl} - 1.00$ $^{90}\text{Sr}-^{90}\text{Y} - 1.03$	1.1	0.068	P
196	$^{147}\text{Pm} - 0.10$ $^{204}\text{Tl} - 0.50$ $^{90}\text{Sr}-^{90}\text{Y} - 0.82$	8.2	0.11	F

(a) $\bar{r}_i/\text{CTV}$ is the ratio of mean indicated reading to beta radiation of energy i and the conventionally true value of the beta radiation of energy i .

(b) To meet the requirements of the standard, the ratio of $(\bar{r}_i/\text{CTV})_{\text{max}}$ to $(\bar{r}_i/\text{CTV})_{\text{min}}$ for and instrument must be ≤ 3 to pass the test.

TABLE A.15. Neutron Energy Dependence Test Results

Instrument ID Number	R_H (a)	Ratio of $\frac{(R_H)_{\max}}{(R_H)_{\min}}$ to (b)	P/F
6, 141	3.2 (0.026 MeV)	10.7	F,F
	1.9 (0.11 MeV)		
	1.5 (0.25 MeV)		
	1.2 (0.57 MeV)		
	1.0 (1.0 MeV)		
	0.9 (2.5 MeV)		
	0.8 (5.0 MeV)		
	0.3 (15.5 MeV)		
21, 151	2.5 (0.026 MeV)	6.3	F,F
	1.5 (0.11 MeV)		
	1.2 (0.25 MeV)		
	1.1 (0.57 MeV)		
	1.0 (1.0 MeV)		
	1.0 (2.5 MeV)		
	0.8 (5.0 MeV)		
	0.4 (15.5 MeV)		
119	NT (0.026 MeV)	3.6	P
	1.8 (0.11 MeV)		
	1.2 (0.25 MeV)		
	1.1 (0.57 MeV)		
	1.0 (1.0 MeV)		
	1.0 (2.5 MeV)		
	0.9 (5.0 MeV)		
	0.5 (15.5 MeV)		
121	2.9 (0.026 MeV)	6.4	F
	1.7 (0.11 MeV)		
	1.3 (0.25 MeV)		
	1.1 (0.57 MeV)		
	1.0 (1.0 MeV)		
	0.9 (2.5 MeV)		
	0.8 (5.0 MeV)		
	0.45 (15.5 MeV)		

TABLE A.15. (contd)

Instrument ID Number	R_H (a)	Ratio of $(R_H)_{\max}$ to $(R_H)_{\min}$ (b)	P/F
179	3.3 (0.026 MeV)	8.3	F
	1.8 (0.11 MeV)		
	1.5 (0.25 MeV)		
	1.2 (0.57 MeV)		
	1.0 (1.0 MeV)		
	1.0 (2.5 MeV)		
	0.8 (5.0 MeV)		
	0.4 (15.5 MeV)		
199	2.7 (0.026 MeV)	6.8	F
	1.3 (0.11 MeV)		
	1.2 (0.25 MeV)		
	1.1 (0.57 MeV)		
	1.0 (1.0 MeV)		
	1.0 (2.5 MeV)		
	0.8 (5.0 MeV)		
	0.4 (15.5 MeV)		

(a) R_H is the dose-equivalent response.

$$R_H = \frac{M}{h_\phi \cdot \phi}$$

where:

M = evaluated survey meter reading for a given energy (mrem/h)

ϕ = neutron fluence (neutrons/cm² · s) at the effective center of the survey meter assuming meter is not there.

h_ϕ = neutron fluence to dose equivalent conversion factor from ICRP 21 (1973) [(mrem/h)/(neutrons/cm²·s)].

R_H values were taken from work by Cosack and Lesiecki (1981).

All R_H values in this table were normalized to the R_H value at 1 MeV.

(b) To meet the requirements of the standard, the ratio of $(R_H)_{\max}$ to $(R_H)_{\min}$ for an instrument must be ≤ 4 to pass the test.

TABLE A.16. Radiation Overloads Test Results

Instrument ID Number	Pass/Fail			Comments
	2X UDL ^(a)	10X UDL	100X UDL	
<u>Ion Chambers (Vented)</u>				
18	NT ^(b)	NT	F	Did not return to background
51	NT	NT	F	Did not return to background
61	NT	NT	P	
62	NT	NT	F	Did not return to background
68	NT	NT	F	Did not return to background
96	NT	NT	F	Did not return to background
154	NT	NT	F	Did not return to background
156	NT	NT	P	
165	NT	NT	F	Did not return to background
<u>GM Detectors</u>				
4	NT	NT	P	
13	NT	NT	P	
14	NT	NT	P	
40	P	P	P	
52	NT	P	P	
56	P	P	P	
75	NT	NT	F	Saturation
100	P	P	P	
129	P	P	NT	
137	P	P	NT	
148	NT	NT	P	
149	NT	P	P	
150	NT	NT	P	
153	NT	NT	P	
166	NT	NT	P	
198	NT	P	P	
<u>NaI(Tl) Detectors</u>				
28	NT	NT	P	
135	NT	NT	P	

(a) UDL = upper detection limit.

(b) NT = not tested.

TABLE A.17. Angular Dependence Test Results

Instrument ID Number	Radiation Source	Maximum % Change From Maximum Response		Orientations ^(a) Failed	Pass/Fail	
		45°(b)	90°		Individual Run	Overall
<u>Photon Angular Dependence Data</u>						
<u>Ion Chambers (Vented)</u>						
51	¹³⁷ Cs (d,e)	0.8	2.2	---	P	P
	⁵⁷ Co (d,e)	13.5	15.2	---	P	
68	120 keV x-ray ^(c,e)	1.7, 6.1	16.7	---	P	P
196	¹³⁷ Cs	11.2, 31.0	36.0	---	P(M)	F
	⁵⁷ Co	5.0, 21.0	67.7*	a, c	F	
<u>Ion Chambers (Closed)</u>						
34	120 keV x-ray ^(c,f)	0.7, 2.4	3.6	---	P	P
	120 keV x-ray ^(d,f)	83.5,* 83.7*	83.7*	f	F	
95	120 keV x-ray ^(c,f)	12.9, 36.0	67.8*	f	F	F
<u>GM Detectors</u>						
9	¹³⁷ Co	6.4, 13.9	48.9	---	P	F
	⁵⁷ Co	57.3,* 80*	78.7*	f, g	F	
13	¹³⁷ Cs (c)	6.5, 51.6	17.9	---	P(M)	P(M)
	²⁴¹ Am (d)	18.3, 74.2	51.6*	e	F	
	⁵⁷ Co (c)	14.6, 78.6	44.0	---	P(M)	
	¹³⁷ Cs (g)	33.3,* 39.3*	51.2*	d	F	
	120 keV x-ray ^(c,i)	13.7, 39.7	71.2*	d	F	
	120 keV x-ray ^(d,i)	61.5,* 28.6*	22.0	d	F	
14	¹³⁷ Cs	29.8,* 47.5*	23.6	h	F	F
	¹³⁷ Cs	21.9,* 37.2*	40.9	f	F	
	¹³⁷ Cs	17.8, 17.2	61.5*	h	F	
	⁵⁷ Co	74.3,* 84.3*	75.1*	f, g, h	F	
26	¹³⁷ Cs	41.3,* 70.2*	41.8	f, g, h	F	F
	¹³⁷ Cs	41.2,* 47.7*	75.5*	f, g, h	F	
	⁵⁷ Co	43.0,* 60.3*	89.6*	f, g, h	F	
40	¹³⁷ Cs	19.1, 52.3	54.8*	g, h	F	F
	⁵⁷ Co	29.0, 41.7	77.8*	g, h	F	

TABLE A.17. (contd)

Instrument ID Number	Radiation Source	Maximum % Change From Maximum Response		Orientations ^(a) Failed	Pass/Fail	
		45°(b)	90°		Individual Run	Overall
Photon Angular Dependence Data (contd)						
GM Detectors (contd)						
41	⁵⁷ Co	31.4,* 79.6*	79.3*	f, g, h	F	F
	¹³⁷ Cs	32.4,* 56.1*	65.0*	f, h	F	
	²⁴¹ Am	93.6,* 91.9*	90.2*	f, g, h	F	
52	¹³⁷ Cs(d,f)	3.2	6.5	---	P	P
	⁵⁷ Co(d,f)	12.6	7.5	---	P	
56	¹³⁷ Cs	14.3, 20.2	61.8*	g, h	F	F
57	¹³⁷ Cs	32.2,* 39.4*	30.3	f	F	F
	²⁴¹ Am	74.4,* 89.2*	92.3*	f, g, h	F	
75	⁵⁷ Co(h)	21.2,* 49.5*	68.4*	e	F	F
	²⁴¹ Am(h)	71.0,* 72.0*	75.1*	e	F	
	²⁴¹ Am(h)	57.5,* 77.5*	76.3*	e	F	
	¹³⁷ Cs(h)	6.1, 11.1	29.3	---	P	
	¹³⁷ Cs(h)	6.0, 11.5	56.2*	e	F	
78	¹³⁷ Cs	16.2, 22.9	22.9	---	P	F
	⁵⁷ Co	46.0,* 43.0*	82.3*	f, g	F	
81	¹³⁷ Cs(h)	13.1, 21.1	28.3	---	P(M)	F
	⁵⁷ Co(h)	71.0,* 94.0*	97.1*	f, g, h	F	
	⁵⁷ Co(h)	66.5,* 90.1*	96.0*	f, g, h	F	
129	¹³⁷ Cs(g)	9.1, 27.3	45.5	---	P(M)	F
	²⁴¹ Am(g)	28.4,* 55.3*	91.2*	d, e	F	
	⁵⁷ Co(g)	56.6,* 49.4*	41.3	d	F	
	¹³⁷ Cs(g)	9.1, 20.9	33.6	---	P	

TABLE A.17. (contd)

Instrument ID Number	Radiation Source	Maximum % Change From Maximum Response		Orientations ^(a) Failed	Pass/Fail	
		45° ^(b)	90°		Individual Run	Overall
Photon Angular Dependence Data (contd)						
GM Detectors (contd)						
137	¹³⁷ Cs	15.1, 25.1	41.9	---	P(M)	F
	¹³⁷ Cs	62.9*	28.1	e	F	
	¹³⁷ Cs(j)	17.4, 9.4	13.6	---	P	
	⁵⁷ Co	8.8, 50.2	86.8*	e	F	
	⁵⁷ Co(j)	8.4, 25.8	72.9*	e	F	
	x-ray ⁽ⁱ⁾	10.4, 59.8	74.9*	d	F	
	x-ray ⁽ⁱ⁾	5.2, 50.7	76.9*	d	F	
149	¹³⁷ Cs(h)	0, 0	0	---	P	P
	²⁴¹ Am(h)	52.5,* 80.0*	87.5*	e	F	
	x-ray ^(c,i)	47.2,* 34.7*	11.1	d	F	
	x-ray ^(d,i)	11.1, 11.1	11.1	---	P	
180	⁵⁷ Co	53.2,* 58.5*	86.5*	f, g	F	F
	¹³⁷ Cs	10.8, 25.0	20.0	---	P(M)	
187	¹³⁷ Cs	63.4,* 43.0*	48.0	f, h	F	F
	¹³⁷ Cs	42.0,* 59.2*	64.5*	f, g, h	F	
	¹³⁷ Cs	28.2*, 46.2*	40.4	f, h	F	
	⁵⁷ Co	69.0,* 91.1*	75.0*	f, g, h	F	
198	⁵⁷ Co	8.1, 7.5	6.7	---	P	F
	¹³⁷ Cs	54.9,* 16.3	15.4	e	F	
	²⁴¹ Am	68.5,* 85.3*	89.6*	e	F	

* Failed test.

P(M): Pass marginally.

(a) Instrument orientations are defined by the following key:

- (b) Testing done before the most recent revision of the standard (5/85) was done in 30° increments (specified in the 3/84 version) and thus did not include 45° (specified in the most recent standard). Therefore, if an instrument was within 20% of the maximum response at 30° and not at 60°, it was assumed to marginally pass the test at 45°. When two numbers are listed, the first is the percentage of change at 30° and the second is the percentage of change at 60°.
- (c) Tested with window closed.
 - (d) Tested with window open.
 - (e) Only tested in position g.
 - (f) Only tested in position f.
 - (g) Pancake-type probe.
 - (h) Cylindrically shaped probe.
 - (i) Only tested in position d.
 - (j) Only tested in position e.

TABLE A.18. Beta Angular Dependence Test Results

Instrument ID Number	Radiation Source	Maximum % Change from Maximum Response		Orientations Failed (b)	P/F (c)
		45° (a)	90°		
Ion Chambers (Vented)					
18	⁹⁰ Sr- ⁹⁰ Y	66.8*	98.5	a	F
51	⁹⁰ Sr- ⁹⁰ Y	40.1, 70.2	86.8	Tested in g	P(M)
61	⁹⁰ Sr- ⁹⁰ Y	47.7	98.7	Tested in g	P
	²⁰⁴ Tl	50.3*	92.0	g	F
68	⁹⁰ Sr- ⁹⁰ Y	51.2*	96.3	h	F
165	⁹⁰ Sr- ⁹⁰ Y	10.5	30.2	Tested in a	P
	²⁰⁴ Tl	5.1	17.9	Tested in a	P
156	⁹⁰ Sr- ⁹⁰ Y	50.2	98.5	c	F
196	⁹⁰ Sr- ⁹⁰ Y	0	21.3	Tested in a	P
GM Detectors					
13	²⁰⁴ Tl	30.2	88.8	d	P
	⁹⁰ Sr-Y	65.7*	89.0	d,e	F
Probe #131					
137	⁹⁰ Sr- ⁹⁰ Y	34.8, 67.2	85.2	Tested in d	P(M)
149	⁹⁰ Sr- ⁹⁰ Y	46.2, 72.5	90.2	Tested in d	P(M)
198	²⁰⁴ Tl	35.9	87.8	Tested in e	P

Probe #171

(a) Testing done before the most recent revision of the standard (1/85) was done in 30° increments and thus did not include 45° as specified in the standard. Therefore if two values appear in this column, they represent values for 30° and 60°.

(b) Instruments orientations are defined by the following key:

(c) Based on results at 45° with $^{90}\text{Sr}-^{90}\text{Y}$ source.
* Failed test.

TABLE A.19. Neutron Angular Dependence Test Results

Instrument ID Number	Radiation Source	Maximum % Change From Maximum Response		Pass/Fail	
		45° (a)	90°	Individual Run	Overall
<u>Neutron Angular Dependence Data</u>					
<u>Neutron Detectors</u> (b)					
12	²⁵² Cf	11.7, 25.0	38.8	P(M)	P
22	²⁵² Cf	11.1, 33.3	49.2	P(M)	P

(a) Testing done before the most recent revision of the standard (5/85) was done in 30° increments (specified in the 3/84 version) and thus did not include 45° (specified in the most recent standard). Therefore, if an instrument was within 20% of the maximum response at 30° and not at 60°, it was assumed to marginally pass the test at 45°.

(b) The instruments were tested in only one orientation to the source:

TABLE A.20. Combinations of Instruments and Probes Used for the Extracameral Response Test

Instrument ID Number	Probe ID Number	Pass/Fail
<u>GM Detectors</u>		
13	122-P	P
35	117-P	P
52	122-P	P
52	183-P	P
75	122-P	P
75	186-P	P
129	102-P	P
137	58-P	P
149	93-P	P
149	169-P	P
198	93-P	P
198	88-P	P

TABLE A.21. Radio Frequency Fields Test Results

Instrument ID Number	Pass/Fail	
	60 Hz	0.3 to 35 MHz

Ion Chambers (Vented)

18	P	P
51	P	NT ^(a)
62	P	F
68	NT	P
112	NT	F
144	P	P
165	P	P
196	P	F

Ion Chambers (Closed, pressurized)

73	P	NT
182	NT	P

GM Detectors

4	NT	F
9	NT	F
13	NT	P
14	P	NT
40	NT	P
41	P	NT
52	P	P
56	P	P
78	P	P
81	P	NT
100	P	NT
127	P	NT
128	P	F
129	P	NT
130	P	F
137	P	NT
142	NT	P
180	NT	P
198	P	NT

TABLE A.21. (contd)

Instrument ID Number	Pass/Fail	
	60 Hz	0.3 to 35 MHz
<u>Alpha Detectors</u>		
174(Gf) ^(b)	NT	P
27(Ap) ^(c)	NT	P
32(Ap)	NT	P
133(Ap)	NT	P
10(S) ^(d)	NT	P

Neutron Detectors

12	NT	P
22	NT	F
172	NT	P
178	NT	P
189	NT	P

- (a) NT = not tested.
 (b) Gf = gas flow.
 (c) Ap = air proportional.
 (d) S = scintillation.

TABLE A.22. Microwave Fields Test Results

<u>Instrument ID Number</u>	<u>915 MHz</u>	<u>2450 MHz</u>	<u>Comments</u>
<u>Ion Chambers (Vented)</u>			
62	F	F	
96	F	F	
196	F	F	Range and direction effects
<u>Ion Chambers (Closed, pressurized)</u>			
34	P	P	
<u>GM Detectors</u>			
9	F	F	Alarm also affected
13	P	P	
24	P	P	
75	P	P	
130	F	P	Display flickers off
137	F	P	
198	P	P	
<u>Alpha Detectors</u>			
27(Ap) ^(a)	F	P	Meter direction effect only
152(Ap)	F	F	
124(S) ^(b)	P	P	

(a) Ap = air proportional.

(b) S = scintillation.

TABLE A.23. Electrostatic Fields Test Results

<u>Instrument ID Number</u>	<u>Pass/Fail</u>
<u>Ion Chambers (Vented)</u>	
18	P
51	P
62	P
144	P
165	P
196	P
<u>GM Detectors</u>	
14	P
41	P
52	P
56	P
78	P
81	P
100	P
127	P
128	P
129	P
130	P
137	P
198	P
<u>Ion Chambers (Closed, pressurized)</u>	
73	P

TABLE A.24. Magnetic Fields Test Results

<u>Instrument ID Number</u>	<u>Field Intensity at Which Instrument Failed, Oersteds</u>	<u>Pass/Fail at 3 Oersteds</u>
<u>Ion Chambers (Vented)</u>		
47	NT(a)	P
51	600	P
62	45	P
144	250	P
196	250	P
<u>Ion Chambers (Closed, pressurized)</u>		
73	NT	P
<u>GM Detectors</u>		
26	250	P
41	NT	P
52	NT	P
56	NT	P
78	NT	P
81	NT	P
100	NT	P
127	NT	P
128	NT	P
129	NT	P
130	Passed at 1000 oersteds	P
137	NT	P
198	NT	P

(a) NT = No testing above 3 oersteds.

TABLE A.25. Interfering Ionizing Radiations Test Results

<u>Instrument ID Number</u>	<u>Instrument Response (mR/h) to 1 rem/h Neutron Radiation (^{252}Cf)</u>
<u>Ion Chambers (Vented)</u>	
47	48.8 ± 0.4
68	60.0 ± 0
96	46.0 ± 1.1
112	63.0 ± 1.1
165	58.0 ± 2.0
<u>Ion Chambers (Closed)</u>	
34	80.0 ± 0
95	45.5 ± 3.9
<u>GM Detectors</u>	
	<u>Instrument Response (mR/h) to 1 rem/h Neutron Radiation (^{252}Cf)</u>
4	50.0 ± 0
9	20.0 ± 0
14	26.1 ± 1.0
15	24.6 ± 2
24	43.0 ± 4.7
26	23.9 ± 1.8
40	40.2 ± 1.7
41	41.6 ± 1.5
52	60.0 ± 0
78	41.1 ± 3.7
120	44.0 ± 5.0
127	41.1 ± 1.9
128	20.0 ± 0
130	38.6 ± 2.0
137	34.7 ± 0.9
180	38.0 ± 4.6
187	25.0 ± 1.8
100	$63,200 \pm 951 \text{ cpm}^{(a)}$

TABLE A.25. (contd)

Alpha Detectors

Instrument ID Number	Instrument Response, cpm		
	1 rad/h Beta	1 rad/h Photon	1 rem/h Neutron
114 (Gf) ^(b)	0 ± 0	0 ± 0	0 ± 0
174 (Gf) ^(c)	0-100	2,005 ± 147	45,350 ± 933
152 (Ap) ^(d)	0 ± 0	0 ± 0	5,050 ± 759
38 (S)	34 ± 18	9,800 ± 523	8,950 ± 224
87 (S)	0 ± 0	0 ± 0	94 ± 31

Neutron Detectors

Instrument ID Number	Instrument Response, nrem/h		
	10 ⁴ dpm/cm ² Alpha	10 rad/h Beta	10 rad/h Photon
12	0 ± 0	0 ± 0	0 ± 0
22	0 ± 0	0 ± 0	0 ± 0
48	NT	NT	0.2 ± 0.04
172	0 ± 0	0 ± 0	0.6 ± 0.2

(a) Readout was in cpm only, not mR/h.

(b) Gf = gas flow.

(c) Ap = air proportional.

(d) S = scintillation.

TABLE A.26. Temperature Test Results

Instrument ID Number	% Change ($\pm$ SD) From Mean Reading at 20°C				Pass/Fail	
	-10°C	0°C	40°C	50°C	0 to 40°C	-10 to 50°C
<u>Ion Chambers (Vented) (Readings corrected for air density changes)</u>						
18	27.3 $\pm$ 0	17.5 $\pm$ 0.1	-15.4 $\pm$ 0.1	-21.3 $\pm$ 0.1	F	F
47	23.2 $\pm$ 0.4	14.5 $\pm$ 0.3	-10.9 $\pm$ 0.3	-28.5 $\pm$ 0.4	P	F
51	-1.4 $\pm$ 1.1	-4.8 $\pm$ 1.1	0 $\pm$ 0.8	-2.6 $\pm$ 0.8	P	P
60	11.2 $\pm$ 0.3	7.9 $\pm$ 0.3	6.0 $\pm$ 0.4	8.6 $\pm$ 0.4	P	P
62	2.2 $\pm$ 0.1	0.9 $\pm$ 0.1	-0.5 $\pm$ 0.2	-2.0 $\pm$ 0.2	P	P
68	4.0 $\pm$ 0.5	2.7 $\pm$ 0.4	-1.7 $\pm$ 0.4	-3.4 $\pm$ 0.5	P	P
68	2.9 $\pm$ 0.6	1.4 $\pm$ 0.6	-1.0 $\pm$ 0.5	-2.5 $\pm$ 0.6	P	P
96	0 $\pm$ 1.4	0 $\pm$ 0.8	-18.2 $\pm$ 1.3	-31.8 $\pm$ 1.2	F	F
112	7.6 $\pm$ 0.3	5.3 $\pm$ 0.3	-6.7 $\pm$ 0.3	-14.1 $\pm$ 0.3	P	P
156	7.9 $\pm$ 0.1	5.3 $\pm$ 0.1	-5.3 $\pm$ 0.1	-9.2 $\pm$ 0.1	P	P
156	20.5 $\pm$ 0.5	13.0 $\pm$ 0.5	-16.2 $\pm$ 0.2	-30.1 $\pm$ 0.2	F	F
156	12.2 $\pm$ 0.3	7.6 $\pm$ 0.2	-13.4 $\pm$ 0.3	-23.8 $\pm$ 0.3	P	F
165	4.4 $\pm$ 1.5	4.8 $\pm$ 2.0	-6.1 $\pm$ 1.0	-9.9 $\pm$ 0.9	P	P
196	17.8 $\pm$ 0.9	9.8 $\pm$ 0.8	-17.1 $\pm$ 0.8	-28.6 $\pm$ 0.8	F	F
<u>Ion Chambers (Closed, pressurized)</u>						
36	-4.6 $\pm$ 0.3	-2.4 $\pm$ 0.2	17.0 $\pm$ 0.2	30.5 $\pm$ 0.4	F	F
65	42.5 $\pm$ 1.2	31.7 $\pm$ 1.1	-87.4 $\pm$ 0.1	Zero reading	F	F
73	-16.5 $\pm$ 0.8	-8.1 $\pm$ 0.8	22.3 $\pm$ 2.2	40.9 $\pm$ 1.9	F	F
103	-72.8 $\pm$ 0.2	-61.5 $\pm$ 0.3	-9.0 $\pm$ 0.8	-18.0 $\pm$ 0.6	F	F
104	-7.7 $\pm$ 0	-4.6 $\pm$ 0	24.8 $\pm$ 0.5	35.7 $\pm$ 0.4	F	F
182	-7.7 $\pm$ 0.9	-3.2 $\pm$ 0.6	107.3 $\pm$ 1.7	273.8 $\pm$ 2.1	F	F
182	-9.4 $\pm$ 0.7	-9.2 $\pm$ 0.7	208.9 $\pm$ 0.8	325 $\pm$ 1.1	F	F
<u>GM Detectors</u>						
3	-0.8 $\pm$ 1.9	-6.1 $\pm$ 1.9	0.4 $\pm$ 2.4	3.7 $\pm$ 2.0	P	P
14	1.2 $\pm$ 0.9	1.9 $\pm$ 1.0	2.6 $\pm$ 0.9	2.3 $\pm$ 0.8	P	P
15	0.8 $\pm$ 1.9	-0.4 $\pm$ 1.8	-1.4 $\pm$ 2.1	-0.5 $\pm$ 2.1	P	P
24	-10.7 $\pm$ 3.1	-8.6 $\pm$ 3.9	-1.0 $\pm$ 5.7	12.6 $\pm$ 5.7	P	P
26	-1.1 $\pm$ 1.4	0.4 $\pm$ 1.8	-0.6 $\pm$ 1.8	-2.5 $\pm$ 1.6	P	P
40	-8.5 $\pm$ 0.5	-5.9 $\pm$ 0.5	3.3 $\pm$ 0.6	3.5 $\pm$ 0.7	P	P
52	-2.4 $\pm$ 0.3	-2.0 $\pm$ 0.4	-8.9 $\pm$ 0.4	-12.5 $\pm$ 0.3	P	P
56	-12.6 $\pm$ 0.5	-8.4 $\pm$ 0.5	5.2 $\pm$ 0.8	7.4 $\pm$ 0.8	P	P
75	1.8 $\pm$ 1.0	0.9 $\pm$ 1.3	-0.8 $\pm$ 1.3	-2.0 $\pm$ 1.2	P	P
78	-2.0 $\pm$ 5.2	3.4 $\pm$ 5.3	14.5 $\pm$ 8.8	6.0 $\pm$ 7.0	P	P
89	-4.0 $\pm$ 4.2	-6.7 $\pm$ 5.0	-6.6 $\pm$ 4.7	-3.3 $\pm$ 5.5	P	P
94	-2.1 $\pm$ 3.8	-0.3 $\pm$ 4.3	-1.2 $\pm$ 3.7	-5.2 $\pm$ 3.4	P	P
118	-3.1 $\pm$ 1.3	-0.7 $\pm$ 1.6	1.8 $\pm$ 1.5	2.3 $\pm$ 1.3	P	P
120	-8.4 $\pm$ 3.0	-4.0 $\pm$ 2.8	8.9 $\pm$ 4.3	33.0 $\pm$ 5.1	P	F
125	1.8 $\pm$ 1.7	-0.8 $\pm$ 1.6	1.4 $\pm$ 1.8	2.3 $\pm$ 1.3	P	P

TABLE A.26. (contd)

Instrument ID Number	% Change ($\pm$ SD) From Mean Reading at 20°C				Pass/Fail	
	-10°C	0°C	40°C	50°C	0 to 40°C	-10 to 50°C
GM Detectors (contd)						
127	2.8 $\pm$ 0.7	1.6 $\pm$ 0.7	9.8 $\pm$ 0.8	19.5 $\pm$ 0.8	P	P
129	-3.7 $\pm$ 1.3	-2.2 $\pm$ 1.7	-3.2 $\pm$ 1.1	-3.6 $\pm$ 0.9	P	P
130	1.7 $\pm$ 2.3	1.0 $\pm$ 2.5	2.6 $\pm$ 2.5	-0.5 $\pm$ 2.3	P	P
142	8.7 $\pm$ 9.5	1.9 $\pm$ 10.6	10.1 $\pm$ 13.6	6.1 $\pm$ 12.4	P	P
173	4.4 $\pm$ 4.2	7.0 $\pm$ 4.0	-0.5 $\pm$ 3.9	-3.8 $\pm$ 3.6	P	P
180	5.9 $\pm$ 3.4	2.3 $\pm$ 3.2	-0.9 $\pm$ 3.0	1.5 $\pm$ 3.1	P	P
187	0.4 $\pm$ 1.2	2.5 $\pm$ 1.1	0.6 $\pm$ 1.2	-1.7 $\pm$ 0.9	P	P
191	-0.7 $\pm$ 1.5	-1.5 $\pm$ 1.2	-3.9 $\pm$ 1.2	-2.0 $\pm$ 1.2	P	P
Alpha Detectors						
44 (Gf) ^(a)	Zero reading	Zero reading	313 $\pm$ 12.7	387 $\pm$ 12.9	F	F
114 (Gf)	Zero reading	-98.6 $\pm$ 0.1	370 $\pm$ 24.8	434 $\pm$ 28.0	F	F
168 (Gf)	-94.6 $\pm$ 0.4	-47.5 $\pm$ 2.3	6.8 $\pm$ 3.9	12.5 $\pm$ 4.2	F	F
193 (Gf)	-34.6 $\pm$ 0.7	-17.9 $\pm$ 0.9	97.2 $\pm$ 6.9	102 $\pm$ 7.3	F	F
17 (Ap) ^(b)	-84.5 $\pm$ 0.4	-81.3 $\pm$ 0.4	37.8 $\pm$ 2.0	0.4 $\pm$ 1.3	F	F
27 (Ap)	Offscale high	4.7 $\pm$ 1.3	480 $\pm$ 8.1	-8.4 $\pm$ 0.7	F	F
32 (Ap)	-55.3 $\pm$ 3.0	-48.3 $\pm$ 3.5	Offscale high	164.3 $\pm$ 17.5	F	F
152 (A)	-78.4 $\pm$ 0.5	-43.1 $\pm$ 0.6	-1.8 $\pm$ 1.1	-4.0 $\pm$ 1.0	F	F
10 (S) ^(c)	-56.9 $\pm$ 1.2	-34.3 $\pm$ 2.0	16.9 $\pm$ 2.1	45.3 $\pm$ 3.1	F	F
38 (S)	1.0 $\pm$ 3.6	10.4 $\pm$ 3.9	7.1 $\pm$ 3.0	19.9 $\pm$ 3.5	P	P
43 (S)	7.8 $\pm$ 0.2	7.0 $\pm$ 0	-6.8 $\pm$ 0.1	-7.3 $\pm$ 0.2	P	P
87 (S)	7.7 $\pm$ 0.3	Offscale low	-4.8 $\pm$ 0	-7.5 $\pm$ 0.2	F	F
124 (S)	-2.1 $\pm$ 2.1	-2.5 $\pm$ 2.3	-9.7 $\pm$ 2.4	-7.8 $\pm$ 2.7	P	P
Neutron Detectors						
12	-17.2 $\pm$ 1.3	-9.0 $\pm$ 1.2	11.2 $\pm$ 1.8	12.1 $\pm$ 1.9	P	P
23	3.9 $\pm$ 4.1	-2.3 $\pm$ 2.8	-1.5 $\pm$ 3.2	2.4 $\pm$ 3.5	P	P
48	-7.2 $\pm$ 1.5	-2.4 $\pm$ 1.8	0.7 $\pm$ 1.8	7.7 $\pm$ 1.7	P	P
178	-1.3 $\pm$ 3.9	-2.1 $\pm$ 3.7	8.5 $\pm$ 2.9	20.8 $\pm$ 3.4	P	P(M) ^(d)

(a) Gf = gas flow.

(b) Ap = air proportional.

(c) S = scintillation.

(d) P(M) = mean of readings outside the requirement but not significant at the 95% confidence level.

TABLE A.27. Temperature Shock Test Results

Instrument ID Number	40°C			0°C		
	Maximum % Change ± SD		Pass/Fail	Maximum % Change ± SD		Pass/Fail
	23 to 40°C	40 to 23°C		23 to 0°C	0 to 23°C	
Ion Chambers (Vented) (Readings corrected for air density changes)						
51	-2.6 ± 0.6	-9.4 ± 0.5	P	-40.6 ± 0.7	16.1 ± 0.7	F
60	-7.5 ± 0.2	0 ± 0.5	P	0.9 ± 0.5	-6.3 ± 0.4	P
156	-1.6 ± 0.2	2.2 ± 0.2	P	2.9 ± 0.2	-1.6 ± 0.2	P
196	-6.6 ± 0.2	1.5 ± 0.2	P	7.8 ± 0.1	-3.4 ± 0.2	P
Ion Chambers (Closed, pressurized)						
95	0.5 ± 1.0	13.5 ± 0.9	P	-9.6 ± 1.2	4.8 ± 1.4	P
104	13.5 ± 1.0	-6.7 ± 1.5	P	-18.9 ± 1.6	27.4 ± 1.9	F
182	-16.7 ± 1.3	13.9 ± 1.0	P(M) ^(a)	-6.3 ± 1.2	3.7 ± 1.2	P
GM Detectors						
15	4.2 ± 3.2	2.5 ± 2.8	P	-4.1 ± 4.9	-7.5 ± 4.1	P
35	5.8 ± 0.6	1.0 ± 0.4	P	3.4 ± 0.5	4.3 ± 0.4	P
78	3.7 ± 2.5	-3.9 ± 2.9	P	2.0 ± 3.3	-2.9 ± 3.2	P
81	-3.5 ± 3.3	14.5 ± 3.1	P	7.3 ± 4.4	11.9 ± 3.5	P
100	-3.4 ± 0.5	6.1 ± 0.8	P	-7.8 ± 0.6	10.1 ± 0.6	P
128	33.3 ± 0	-18.8 ± 0	F	-23.1 ± 0	0 ± 0	F
129	1.3 ± 0.4	0.4 ± 0.2	P	-1.7 ± 1.1	2.1 ± 1.2	P
137	0 ± 1.1	-6.3 ± 1.9	P	-18.8 ± 1.8	-14.3 ± 0.9	F
198	32.4 ± 0.8	-21.8 ± 0.5	F	-18.6 ± 0.6	16.4 ± 0.8	F
Alpha Detectors						
168 (Gf) ^(b)	-7.5 ± 1.3	-7.8 ± 1.1	P	-27.6 ± 0.8	27.4 ± 1.2	F
193 (Gf)	22.5 ± 1.2	-15.0 ± 0.8	F	-18.6 ± 0.8	25.4 ± 1.2	F
32 (Ap) ^(c)	-28.6 ± 1.3	11.3 ± 2.0	F	-30.0 ± 1.6	42.4 ± 2.9	F
152 (Ap)	-6.2 ± 3.3	12.3 ± 3.8	P	NT ^(d)	NT	
10 (S) ^(e)	2.3 ± 0.9	4.7 ± 0.9	P	1.6 ± 0.7	3.5 ± 0.8	P
124 (S)	-2.4 ± 0.9	4.0 ± 1.0	P	-3.8 ± 0.9	6.5 ± 1.2	P
Neutron Detectors						
12	4.5 ± 0.9	-2.5 ± 0.7	P	-6.6 ± 0.7	9.4 ± 1.2	P
22	-8.3 ± 4.7	-4.8 ± 2.4	P	11.9 ± 2.6	3.5 ± 2.2	P
172	-8.0 ± 2.5	-15.2 ± 2.4	P(M)	15.1 ± 4.1	-7.7 ± 2.5	P(M)
178	-12.2 ± 9.7	41.0 ± 17.3	P(M)	139 ± 20.7	16.5 ± 19.3	F
189	-12.6 ± 2.6	21.5 ± 3.8	P(M)	-1.0 ± 3.1	-3.2 ± 3.0	P

(a) P(M) = mean of readings outside the requirement but not at the 95% confidence level.

(b) Gf = gas flow.

(c) Ap = air proportional.

(d) NT = not tested.

(e) S = scintillation.

TABLE A.28. Humidity Test Results

Instrument ID Number	Exposure Duration, h	Maximum % Difference ($\pm$ SD) from Reference	Pass/Fail	Comments
<u>Ion Chambers (Vented) (readings corrected for air density changes)</u>				
18	20	10.7 ± 1.0	P	
62	144	-3.0 ± 0.25	P	
112	144	7.0 ± 0.18	P	
156	144	-4.4 ± 0.25	P	
196	144	924 ± 6.6	F	Failed at 95% RH, 40°C
<u>Ion Chambers (Closed, pressurized)</u>				
95	20	5.4 ± 2.0	P	
104	20	14.1 ± 1.7	P	
<u>GM Detectors</u>				
3	144	1.2 ± 1.2	P	
13	144	-17.3 ± 7.4	P(M) ^(a)	Failed at 95% RH, 5°C
15	144	-2.3 ± 2.0	P	
40	144	-7.7 ± 1.6	P	
41	144	-2.8 ± 1.3	P	
50	144	7.9 ± 0.5	P	
50	20	-6.8 ± 1.5	P	
52	144	19.1 ± 0.6	F	Failed at 40%, 40°C after 95% RH
56	144	16.8 ± 3.0	P(M)	Failed at 40% RH, 40°C after 95% RH
75	144	9.3 ± 2.7	P	
89	144	8.7 ± 2.7	P	
129	144	3.4 ± 0.4	P	
137	144	3.0 ± 1.0	P	
158	20	-3.1 ± 0.9	P	
173	144	7.5 ± 2.6	P	
175	144	Zero reading	F	Failed at 95% RH, 40°C and 5°C
180	144	79.5 ± 5.1	F	Failed at 95% RH, 40°C
187	144	-2.6 ± 1.0	P	
191	144	7.2 ± 0.5	P	
191	20	5.3 ± 0.4	P	

TABLE A.28. (contd)

Instrument ID Number	Exposure Duration, h	Maximum % Difference ($\pm$ SD) from Reference	Pass/Fail	Comments
<u>Alpha Detectors</u>				
114 (Gf) ^(b)	20	6.8 ± 1.1	P	
168 (Gf)	20	2.6 ± 1.1	P	
193 (Gf)	20	5.6 ± 1.0	P	
1 (Ap) ^(c)	20	49.0 ± 1.7	F	Maximum change after 3.5 h in 95% RH
17 (Ap)	20	Offscale high	F	
29 (Ap)	20	Offscale high	F	
32 (Ap)	20	Offscale high	F	
37 (Ap)	20	-19.5 ± 0.7	F	Maximum change after 8.5 h in 95% RH
55 (Ap)	20	-16.7 ± 0.8	F	Maximum change after 5.5 h in 95% RH
97 (Ap)	20	-20.7 ± 0.8	F	Maximum change after 7.5 h in 95% RH
152 (Ap)	20	Offscale high	F	
160 (Ap)	20	-23.8 ± 1.1	F	Maximum change after 4.5 h in 95% RH
185 (Ap)	20	-19.9 ± 0.8	F	Maximum change after 4.5 h in 95% RH
10 (S) ^(d)	20	-7.4 ± 0.8	P	
124 (S)	20	4.3 ± 0.8	P	
<u>Neutron Detectors</u>				
12	20	3.4 ± 0.9	P	
23	20	7.6 ± 3.3	P	
42	20	-4.3 ± 0.8	P	
59	20	4.9 ± 0.8	P	
172	20	-5.0 ± 3.8	P	
178	20	13.9 ± 2.6	P	

(a) P(M) = mean of readings outside the requirement but not significant at the 95% confidence level.

(b) Gf = gas flow.

(c) Ap = air proportional.

(d) S = scintillation.

TABLE A.29. Mechanical Shock Test Results

<u>Instrument ID Number</u>	<u>Deceleration/ No. of Cycles</u>	<u>Pass/Fail</u>
<u>Ion Chambers (Vented)</u>		
60	50 g/10	P
156	50 g/10	P
<u>Ion Chambers (Closed, pressurized)</u>		
36	30 g/1	P
<u>GM Detectors</u>		
3	30 g/1	P
4	30 g/1	P
14	50 g/10	P
75	50 g/10	P
81	30 g/1	P
127	50 g/10	P
142	30 g/1	P
175	30 g/1	P
<u>Alpha Detectors</u>		
44 (Gf) ^(a)	50 g/10	P
114 (Gf)	50 g/10	P
32 (Ap) ^(b)	50 g/10	P
97 (Ap)	50 g/10	P
185 (Ap)	50 g/10	P
38 (S) ^(c)	50 g/10	P
87 (S)	50 g/10	P
<u>Nai Instruments</u>		
28	50 G/10	P

(a) Gf = gas flow.

(b) Ap = air proportional.

(c) S = scintillation.

TABLE A.30. Vibration Test Results

<u>Instrument ID Number</u>	<u>Acceleration/Duration</u>	<u>Pass/Fail</u>
<u>Ion Chambers (Vented)</u>		
60	2 g/15 min	P
156	2 g/15 min	P
196	5 g/5 min	F
<u>Ion Chambers (Closed, pressurized)</u>		
36	5 g/5 min	P
<u>GM Detectors</u>		
3	5 g/5 min	P
4	5 g/5 min	P
14	2 g/15 min	P
75	2 g/15 min	P
127	2 g/15 min	P
142	5 g/5 min	P(M) (a)
175	5 g/5 min	P
<u>Alpha Detectors</u>		
44 (Gf) (b)	2 g/15 min	P
114 (Gf)	2 g/15 min	F
32 (Ap) (c)	2 g/15 min	P
97 (Ap)	2 g/15 min	P
185 (Ap)	2 g/15 min	F
38 (S) (d)	2 g/15 min	P
87 (S)	2 g/15 min	F
<u>Nal Instrument</u>		
28	2 g/15 min	P

- (a) P(M) = pass marginally.
 (b) Gf = gas flow.
 (c) Ap = air proportional.
 (d) S = scintillator.

TABLE A.31. Ambient Pressure Test Results

<u>Instrument ID Number</u>	<u>Pressure Change Rate, kPa/min</u>	<u>Maximum % Change ($\pm$ SD) from Reference Pressure</u>	<u>Pressure at Which Maximum Change Occurred, kPa</u>	<u>Pass/Fail</u>
<u>Ion Chambers (Vented) (readings corrected for air density changes)</u>				
18	1.5	-2.6 ± 0.8	106	P
51	1.5	4.9 ± 0.8	70	P
60	1.5	-5.3 ± 0.3	70	P
62	1.5	0.7 ± 0.2	84	P
96	1.5	7.9 ± 0.9	70	P
156	1.5	-0.8 ± 0.2	100	P
<u>Ion Chambers (Closed, pressurized)</u>				
36	1.5	0 ± 0	A11	P
73	1.5	3.4 ± 2.7	92	P
95	1.5	1.8 ± 1.7	106	P
104	1.5	-1.3 ± 1.0	106	P
<u>GM Detectors</u>				
40	1.5	2.6 ± 0.6	84	P
52	1.5	4.7 ± 0.3	76	P
56	1.5	3.3 ± 0.8	84	P
75	1.5	0 ± 0.7	A11	P
129	1.5	3.2 ± 0.4	70	P
<u>Alpha Detectors (Gas flow)</u>				
44	1.5	Offscale low	106	F
114	1.5	Offscale low & 581 ± 16.1	106 & 70, respectively	F
114	0.5	Offscale high	92 and lower	F
168	1.5	63.1 ± 5.2	76	F
174	1.5	14.2 ± 2.2	70	P
174	0.5	16.7 ± 2.5	70	P(M) ^(a)
174	0.125	7.0 ± 1.8	70	P
193	1.5	22.6 ± 1.7	70	F
<u>Alpha Detectors (Air proportional)</u>				
1	1.5	Offscale high	76 and lower	F
17	0.125	Offscale high	84 and lower	F
27	1.5	Offscale high	76 and lower	F
27	0.5	Offscale high	70	F
27	0.125	33.5 ± 0.9	70	F
32	1.5	Offscale high	76 and lower	F
32	0.5	Offscale high	70	F
32	0.125	59.8 ± 1.6	70	F
97	1.5	Offscale high	70	F
152	0.125	Offscale high	84 and lower	F
185	1.5	Offscale high	84 and lower	F

TABLE A.31. (contd)

<u>Instrument ID Number</u>	<u>Pressure Change Rate, kPa/min</u>	<u>Maximum % Change ($\pm$ SD) from Reference Pressure</u>	<u>Pressure at Which Maximum Change Occurred, kPa</u>	<u>Pass/Fail</u>
<u>Alpha Detectors (Scintillation)</u>				
10	1.5	22.6 ± 1.7	70	F
10	0.5	5.4 ± 0.8	70	P
38	1.5	19.2 ± 1.6	70	F
38	0.5	9.1 ± 1.2	70	P
43	1.5	14.6 ± 4.0	70	P
87	1.5	16.0 ± 3.7	70	P(M)
124	1.5	30.2 ± 3.2	76	F
124	0.5	14.5 ± 1.1	70	P
<u>Neutron Detectors</u>				
12	1.5	-4.3 ± 1.7	100	P
22	1.5	-1.5 ± 1.2	70	P
48	1.5	17.6 ± 5.1	70	P(M)
172	1.5	-7.1 ± 1.8	70	P
178	1.5	2.7 ± 2.7	70	P
189	1.5	0.9 ± 0.7	84	P

(a) P(M) = pass marginally.

APPENDIX B

INSTRUMENT-BY-INSTRUMENT SUMMARY OF DATA FOR EACH TEST

TABLE B.1. Instrument-by-Instrument Test Results

Instrument Type	Instrument Number	Inspection	Zero Set	AC Voltage	Battery Lifetime	Alarm Reset	Alarm Act. Delay	Alarm Th. Drift	Stability	Geotropism	Response Time	Coefficient of Var.	Accuracy	Photon Energy Dep.	Beta Energy Dep.	Neutron Energy Dep.	Radiation Energy Dep.	Angular Dependence	Extracameral Response	Radio Frequency Int.	Microwave Int.	Electrostatic Int.	Magnetic Int.	Temperature	Temperature Shock	Humidity	Mechanical Shock	Vibration	Ambient Pressure
IC	18	●	○	○				○	○	●	○	●			●	●	○	○	○	○	○	○	○					○	
IC	47	●								●										○	●								
IC	51	●	○	○				○	○	●	○	○	○		●	○	○	○	○	○	○	○	○					○	
IC	60	●								●	○		●								○	○			○	○	○		
IC	61																○												
IC	62	●	○	○				○	○		○	○	○	○	●	○	○	○	○	○	○	○	○	○				○	
IC	68	●		○				○		●	○	○	○		○	○	○	○	○	○	○	○	○	○					
IC	96	●	○	○				●	○	○	○	○	○		○					○		○	○					○	
IC	112	●	○	○					○		○	○	○		○				○		○	○	○	○					
IC	144	●									○								○		○	○							
IC	154	●						○	○	●	○	○	○		○														
IC	156	●	○					○	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	
IC	165	●						○	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	
IC	196	●	○					○	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	
IC (C)	34	●								○	○						○			○									
IC (C)	36	●									○											○			○	○	○		
IC (C)	65	●							○	○	●	○	○									○							
IC (C)	73	●									○		○						○		○	○	○	○				○	
IC (C)	95	●								○	○		○			○						○	○					○	
IC (C)	103	●									○		○									○	○						
IC (C)	104	●								●	○											○	○	○				○	
IC (C)	182	●									○							○			○	○	○	○					
GM	3	●						○	○	○	○	○	○									○			○	○	○	○	
GM	4	●						○	○	○					○			○							○	○			
GM	9	●						○	○	○			○			○	○	○	○										
GM	13	●		●				○	○	○	○	○	○		○	○	○	○	○					○					
GM	14	●		●				○		○	○	○	○		○	○	○	○	○		○	○		○	○				
GM	15	●						○	○	○	○	○	○									○	○	○	○				
GM	24	●		○				○			○	○	○						○		○	○							
GM	26	●		●				○		○	○	○	○			○					○	○							

○ Pass

● Fail

○ Mean test response exceeds evaluation criteria but not significant at the 95% confidence level

Accuracy and angular dependence tests for ICs and GMs list results for photon (i.e., upper, left half of square) and beta (i.e., lower, right half of square) exposures.

TABLE B.1. (contd)

			Instrument Type	Instrument Number	Inspection	Zero Set	AC Voltage	Battery Lifetime	Alarm Reset	Alarm Act. Delay	Alarm Th. Drift	Stability	Geotropism	Response Time	Coefficient of Var.	Accuracy	Photon Energy Dep.	Beta Energy Dep.	Neutron Energy Dep.	Radiation Energy Dep.	Angular Dependence	Extrac-ameral Response	Radio Frequency Int.	Microwave Int.	Electrostatic Int.	Magnetic Int.	Temperature	Temperature Shock	Humidity	Mechanical Shock	Vibration	Ambient Pressure
GM	35	●			●					○	○	○	○							○					○							
GM	40	●			●					○	○		●	○		●		○	●		○				○		○				○	
GM	41	●			○						○	○	●	○		●			●			○	○				○					
GM	50	●		○						○																	○					
GM	52	●			○					○	○	●	●	○				○	○		○	○	○	○	○		●			○		
GM	56	●			●					○	○	○	●	○		●		○	●		○		○	○	○		○			○		
GM	57	●			○					○	○		●	○				○	○				○	○	○		○			○		
GM	75	●			○					○		●	○	○				●	○		○		○		○		○	○	○	○	○	
GM	78	●			○					○		●				○			○			○		○	○	○						
GM	81	●			○					●	○	●	●			●			○			○		○	○		○					
GM	85					○	○	○																								
GM	89	●								○	○		●	○											○		○					
GM	94	●								○	○	○	●	○											○							
GM	100	●			○					○	○	●				●		○			○		○	○		○						
GM	118	●			●					○				○												○						
GM	120	●			○					○						●									○							
GM	125	●			●					○				○											○							
GM	127	●			○											○					○		○	○	○				○	○		
GM	128	●									○	○				●					○		○	○		○						
GM	129	●			○					○		○	○		○	○		○	○		○	○	○	○	○	○	○	○			○	
GM	130	●								○		○	○	○		○					○	○	○	○	○							
GM	132				○					○																						
GM	137	●			○						○	○	○		○	○		○	○	○	○	○	○			○	○					
GM	142	●			●					○	○			○								○				○		○	○			
GM	148																															
GM	149	●			○					○	○		●	○				○	○		○											
GM	150																	○														
GM	155	●			●					○																						
GM	158	●			○			○	○	○	○																○					

○ Pass

● Fail

◐ Mean test response exceeds evaluation criteria but not significant at the 95% confidence level

Accuracy and angular dependence tests for ICs and GMs list results for photon (i.e., upper, left half of square) and beta (i.e., lower, right half of square) exposures.

TABLE B.1. (contd)

Instrument Type		Instrument Number	Inspection	Zero Set	AC Voltage	Battery Lifetime	Alarm Reset	Alarm Act. Delay	Alarm Th. Drift	Stability	Geotropism	Response Time	Coefficient of Var.	Accuracy	Photon Energy Dep.	Beta Energy Dep.	Neutron Energy Dep.	Radiation Energy Dep.	Angular Dependence	Extracameratal Response	Radio Frequency Int.	Microwave Int.	Electrostatic Int.	Magnetic Int.	Temperature	Temperature Shock	Humidity	Mechanical Shock	Vibration	Ambient Pressure
GM	166	●														○														
GM	173	●						○	○			●											○		○					
GM	175	●		●																					●	○	○			
GM	180	●		○				○	○	●	○		○				●		○				○		●					
GM	187	●		●							●	●		●			●						○		○					
GM	191	●	○	○	●	○	○	○															○		○					
GM	198	●		○				●	○			●	●			○	●	○	○	○	○	○		●						
AL, AP	1																								●				●	
AL, AP	17	●		●				●	●														●		●				●	
AL, AP	27	●		○				○	●	○	●								○	●			●						●	
AL, AP	29	●																							●					
AL, AP	32	●		●				○	●	○	●								○				●	●	●	○	○	●		
AL, AP	37																								●					
AL, AP	55																								●					
AL, AP	97																								●	○	○	●		
AL, AP	133	●																	○											
AL, AP	152	●		●				●	●											●			●	○	●				●	
AL, AP	160																								●					
AL, AP	185																								●	○	●	●		
AL, GF	39	●						●	○																					
AL, GF	44	●						●															●			○	○	●		
AL, GF	54	●																												
AL, GF	64	●											○																	
AL, GF	114	●						●	●	○	●													●		○	○	●	●	
AL, GF	168	●						●	○		●													●	●	○		●		
AL, GF	174	●						○	○															●				○		
AL, GF	193	●						○	○	○	●													●	●	○		●		
AL, S	10	●						○	○	○	○									○				●	○	○			○	
AL, S	38	●		○				○	○	○	○													○			○		○	
AL, S	43	●						○	○		○													○					○	
AL, S	87	●		○				○	○		●													●			○	●	○	

○ Pass

● Fail

◐ Mean test response exceeds evaluation criteria but not significant at the 95% confidence level

Accuracy and angular dependence tests for ICs and GMs list results for photon (i.e., upper, left half of square) and beta (i.e., lower, right half of square) exposures.

TABLE B.1. (contd)

		Instrument Type	Instrument Number	Inspection	Zero Set	AC Voltage	Battery Lifetime	Alarm Reset	Alarm Act. Delay	Alarm Th. Drift	Stability	Geotropism	Response Time	Coefficient of Var.	Accuracy	Photon Energy Dep.	Beta Energy Dep.	Neutron Energy Dep.	Radiation Overload	Angular Dependence	Extracamer. Response	Radio Frequency Int.	Microwave Int.	Electrostatic Int.	Magnetic Int.	Temperature	Temperature Shock	Humidity	Mechanical Shock	Vibration	Ambient Pressure
AL, S	90	●																													
AL, S	124	●		○					○	○	○	●									○			○	○	○		○	○		
N	6																●														
N	12	●							◐		●	○	●						○		○			○	○	○			○		
N	21																●														
N	22	●												●					○		●				○				○		
N	23	●							◐															○		○					
N	42	●										●														○					
N	48	●							◐					●										○					◐		
N	59	●																								○					
N	77	●										●	○																		
N	119																○														
N	121																●														
N	141	●										●					●														
N	151																●														
N	172	●												○						○					◐	○			○		
N	178	●							○					○						○				◐	●	○			○		
N	179																●														
N	189	●												●						○					◐				○		
N	199																●														
Nal	28																	○										○	○		
Nal	135	●															○						○								

Abbreviations: AL Alpha Detector
 AP Air Proportional
 GF Gas Flow
 S Scintillation

GM Geiger-Mueller Detector
 IC Ion Chamber
 (C) Closed, Pressurized
 N Neutron Detector
 Nal Nal Detector

○ Pass

● Fail

● Mean test response exceeds evaluation criteria but not significant at the 95% confidence level

Accuracy and angular dependence tests for ICs and GMs list results for photon (i.e., upper, left half of square) and beta (i.e., lower, right half of square) exposures.

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