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The Development of RADIATION SHIELDING STANDARDS in the American Nuclear Society

RADIATION SHIELDING INFORMATION CENTER

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy $4.00; Microfiche $2.25

ORNL-RSIC-39

Contract No. W-7405-eng-26

THE DEVELOPMENT of RADIATION SHIELDING STANDARDS in the American Nuclear Society[1]

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presented to
American Nuclear Society
San Francisco, California
November 16-21, 1975

NOVEMBER 1975

1. Research sponsored jointly by the U. S. Energy Research and Development Administration, the Defense Nuclear Agency, and the Electric Power Research Institute, under contract with Union Carbide Corp.
2. Chairman Shielding Standards Subcommittee, ANS-6, Standards Committee, American Nuclear Society.

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Acknowledgment

Obviously the development of worthwhile standards depends on a great deal of technical skill, hard work, and financial outlay. All of us who benefit from modern technology are indebted to those who, often at great sacrifice, voluntarily contribute in this way to advancing the state-of-the-art. In particular, the author is grateful to the ANS-6 working group leaders who are leading the effort for each standard and all the members who really get the job done through hard work. The author is especially grateful to the working group leaders who presented reports at the November 1975 ANS meeting in San Francisco and allowed the author to use some of their presentation in this report.

The roster of ANS-6 (as of September 1975) is as follows:

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Ad Hoc Committee on SI Units: J. H. Hubbell, Group Leader, National Bureau of Standards; D. J. Dudziak, Los Alamos Scientific Laboratory; and W. G. Price, Jr., Princeton Plasma Physics Laboratory.

Liaison Representative—ANS-19: C. R. Weisbin, Oak Ridge National Laboratory.

Abstract

The American Nuclear Society (ANS) is a standards-writing organization-member of the American National Standards Institute (ANSI). The ANS Standards Committee has a subcommittee denoted ANS-6, Shielding, whose charge is to establish standards in connection with radiation protection and shielding, to provide shielding information to other standards writing groups, and to prepare recommended sets of shielding data and test problems. This paper is a progress report of this subcommittee.

By Standards, we mean voluntary Standards - sometimes called industry Standards - promulgated through the American National Standards Institute (ANSI) consensus procedure whereby all interested parties have an opportunity to comment on and contribute to the content in a manner avoiding any conflict of interest.

The purpose of a Standard is to set forth acceptable practices, procedures, dimensions, material properties, specifications, or other criteria, which have been agreed upon by representatives of a broad segment of the subject activity.

The management organization of Nuclear Standards has accepted a definition propounded by an international standards organization as, first,

> Standardization: The process of formulating and applying rules for an orderly approach to a specific activity for the benefit and with the cooperation of all concerned and in particular for the promotion of optimum overall economy taking due account of functional conditions and safety requirements.
>
> It is based on the consolidated results of science, technique, and experience.
>
> It determines not only the basis for the present but also for future development and it should keep pace with progress.
>
> and a Standard is "The result of a particular standardization effort approved by a recognized authority." It is an established criterion of effective performance.

The organization responsible for promulgating voluntary standards is ANSI. The Institute, a nonprofit corpora-tion, is a federation of leading trade, technical and professional organizations, government agencies, and consumer groups. ANSI's principle functions are to coordinate standards development, minimize duplication and overlap, and provide a neutral forum to consider and identify standards needs.

The Institute does not develop standards. It makes use of the combined technical talent and expertise of its member bodies: technical, professional, and trade organizations together with the companies and industrial firms that comprise the institute. A standards writing organization, such as a technical society, having developed a standard and seeking approval by ANSI, prepares a list of the organizations, companies, and other groups with substantial concern and competence in the scope of the standard and then conducts a canvass of them on approval of the proposed standard. The final results are reported to the ANSI Board of Standards Review for determination that a consensus exists and declaration of the proposed standard as a voluntary American National Standard. Further information on the ANSI nuclear standards program can be found in Ref. [1].

The standards-writing organization of interest here is the American Nuclear Society (ANS). Among its several administrative committees is one on Standards composed of 18 Subcommittees.

ANS-1	Performance of Critical Experiments
ANS-2	Site Evaluation
ANS-3	Reactor Operations
ANS-4	Reactor Dynamics and Control
ANS-5	Energy and Fission Product Release
ANS-6	Shielding
ANS-8	Fissionable Materials Outside Reactors
ANS-9	Nuclear Terminology and Units
ANS-10	Mathematics and Computation
ANS-11	Radioactive Materials Handling Facility and Specialized Equipment
ANS-13	Fuel Assemblies Criteria
ANS-14	Operation of Fast Pulse Reactors
ANS-15	Operation of Research Reactors
ANS-16	Isotopes and Radiation
ANS-18	Environmental Impact Evaluation
ANS-19	Physics of Reactor Design
ANS-40	Radioactive Waste Management
ANS-50	Nuclear Power Plant Systems Engineering

The subcommittee on shielding standards, ANS-6, now composed of eight working groups, was established in 1964 with the sponsorship of what is now the Shielding and Dosimetry Division of the Society [2]. The standards development of the subcommittee is carried on within working groups composed of members from reactor vendors, architect-engineers, national laboratories, the Energy Research and Development Administration, Nuclear Regulatory Commission, and Universities. The goals and accomplishments of the working groups are briefly described below.

ANS-6.1: Shielding Cross Section Standards

Because of the changing state of knowledge of neutron cross sections, no standard is possible with anything near the time constant of the usual standard such as, for example, the classical ASTM code for unfired pressure vessels. At present it is better to think of recommended cross-section sets as *reference* sets rather than standards. Within ANS-6, "Shielding Cross Sections" has a broad interpretation, which includes neutron interaction cross sections for all common reactions, photon-production cross sections, photon interaction cross sections, and secondary angular and energy distributions for all these interactions. Since the Evaluated Nuclear Data File (ENDF) represents current reference data, no action in this area seems to be required. The group did recommend in 1970 that the Lawrence Livermore Laboratory evaluated photon interaction cross section set be accepted as reference data and be distributed with the ENDF neutron data. This was accomplished in the release of ENDF/B-IV.

Current projects include standard flux-to-dose rate conversion factors and reference coupled neutron-gamma-ray multigroup cross sections for the elements normally found in concrete.

The draft standard N666, "Neutron and Gamma-Ray Flux-to-Dose Rate Factors," was transmitted to ANSI in August of 1975. Also, about that time, a working group began to consider seriously the possibility of selecting multigroup cross sections as reference data to be used in solving an important class of problems.

ANS-6.2: Benchmark Problems

The primary objective of the benchmark problems effort is to compile in convenient form a limited number of well-documented problems in radiation transport which will be useful in testing computational methods used in shielding.

The compilation and publication of solutions to benchmark problems are expected to accomplish several things: (1) attention will be focused on typical problems where careful work should produce solutions which are representative of the state-of-the-art in solving radiation transport problems, (2) specifications of standard configurations and data will make comparisons of different computational methods and theory-experiment comparisons more meaningful, (3) discrepancies between calculation and experiment may suggest refinements in the numerical approximations or nuclear data, or may suggest new experiments to resolve the disagreement, (4) reliable solutions by several methods will be made available to help judge the precision and efficiency of different computer codes, and to suggest if new codes ought to be developed, (5) newly acquired codes and codes converted to new machines may be verified by duplication of the benchmark problem solution, and (6) mistakes in existing or new codes, or their options, can probably be detected by independent calculations of the benchmark problems.

Four problem solutions were published in 1969 in loose-leaf form in Ref. [3] by the Radiation Shielding Information Center. Revisions and a new problem were issued as a revision in 1970. Two new problems were recently issued as Suppl. 2 of Ref. [3] and are available from RSIC upon request. They are *Neutron and Secondary Gamma Ray Fluence Transmitted Through a Slab of Borated Polyethylene* by C. E. Burgart and *A Benchmark Experiment and Calculation for Neutron Transport in Thick Sodium* by R. E. Maerker *et al.* The work slowed for a period but now additional problems are being developed, including several for typical reactor configurations.

ANS-6.3: Shield Performance Evaluation

The initial goal of this group was attained in 1972 with the publication of Ref. [4]. Shortly after publication, the U. S. Atomic Energy Commission issued a Regulatory Guide [5] based on this standard for research and training reactors. The current goal of the committee is to completely revise Ref. [4] to make it more applicable to current practices in the nuclear power industry.

The objective of this standard is to describe a radiation shield test and surveillance program that can be used to verify that sufficient radiation shielding has been provided throughout the plant and during the lifetime of the plant. For this verification the test program must provide data that demonstrate the following: (1) the shielding will reduce the dose equivalent rate to below specified levels at all locations outside the shield walls when shield design level sources are present; (2) the design of the shielding has considered all source terms that need to be taken into account; and (3) the shielding design level sources have not been exceeded.

The standard has been structured into three major areas: (a) Radiation Shielding Testing Program; (b) Instrumentation and Methods; and (c) Administrative Practice. The detailed considerations involved in each of the above areas are included in the following outline:

A. Radiation Shield Testing Program
   General
   Selection of Radiation Base Points Locations
      Selection Criteria
      Radiation Base Points
      Vertical Shields
      Penetrations
   Methods of Measurements
      Vertical Shields
      Horizontal Shields
      Penetrations
   Shield Testing Phases
      Construction Phase Examination
      Preoperational Shield Examination and Tests
      Initial Startup Survey
      Operating Phase
         Primary Shielding
         Auxiliary Shielding Required During Power Operations
         Auxiliary Shielding Required Only During Reactor Shutdown
         Shielding Modifications
B. Instrumentation and Methods
   General Characteristics
   Gamma Radiation
   Neutron Radiation
C. Administrative Practices
   General
      Administration
      Personnel Safety
   Data Collection
      Personnel
      Shield Test Data Sheets
      Gamma-Ray and Neutron Data Sheets
      Data Sheets and Work Packages
      Additional RBP
   Data Analysis
      Data Analysis Sheet for Gamma-Ray and Neutron Measurements
      Recording of Normalized Radiation Levels
      Composite Survey Diagram
   Records
   Program Feedback and Comparison
      Utilization of the Shield Test Program
      Records of Design Assumptions
      Design Information

ANS-6.4: Shield Materials

Initial efforts involving materials *per se*, e.g., lead as a shielding material, have failed. The current work has produced the draft of a standard, ANSI N403, on the *Analysis and Design of Concrete Radiation Shielding for Nuclear Plants*. The standard is much more general, in many respects, than required for designing concrete shields only. That is, the approach to radiation analysis and the methods recommended can be applied to many shielding analysis problems.

The ANS-6.4 working group was originally staffed to represent a cross section of nuclear power plant vendors, architect-engineers, and shielding specialists. By late 1972, an outline of the proposed standard had been drafted and writing assignments made. The first draft was completed in late 1973 and submitted to ANS-6 for review and comments.

It developed by the November 1974 ANS meeting that the required 80% affirmative vote would not be achieved, since the ballots appeared to be 6 to 2 in favor. Exchanges of correspondence followed during the ensuing months in an effort to resolve the objections. Unfortunately, one of the basic ground rules for the standard that it be a "guide to good practice" was a main point of contention, some thinking the document should be entirely rewritten into a short list of requirements, others favoring retention of the second draft with no significant change.

A roundtable decision reviewing the original aims and ground rules of ANS-6.4 was held at the ANS-6 meeting in New Orleans in June 1975. It was decided to resubmit the document with only minor changes for a second vote. Thereupon the second draft was formally submitted to ANS-6 for a vote in July 1974.

Much of the work of ANS-6.4 has been done by mail, phone, and independently. The group's experience with group meetings has been favorable except that members now feel these meetings should not be held concurrently with national ANS meetings. Most important, there should be a very clear understanding between the parent committee and its working group regarding the purpose, philosophy, format, and contents of the proposed standard so that expeditious processing through to the appropriate ANSI N Committee is possible. Progress in the nuclear field is still rapid enough to deprecate long processing times for standards documents.

The standard treats the following topics:

- Characterization of Concrete
  - Introduction
  - Concrete Placement
  - Water Content
  - Heating Effects
  - Reinforcing Steel
  - Aggregates
- Calculation Methods
  - Introduction
  - Point Kernel Methods
  - Discrete Ordinates Method
  - Monte Carlo Method
  - Other Methods
- Concrete Shielding Data
  - Introduction
  - Gamma-Ray Attenuation Coefficients
  - Gamma-Ray Buildup Factors
  - Secondary Gamma-Ray Production
  - Neutron Cross Sections
  - Neutron Attenuation Curves
- Applications
  - Radiation Effects
  - Minimum Water Content
  - Bulk Transport
  - Radiation Streaming through Penetrations
  - Reflection
- Standards of Documentation

ANS-6.5: Shielding Nomenclature

The effort of this group is directed to the preparation of a glossary of shielding terms and definitions and maintaining liaison with the Nuclear Terminology and Units Subcommittee (ANS-9).

The latter subcommittee is assisting the Nuclear Terminology, Units, Symbols, Identification, and Signals Committee of the American National Standards Institute in the preparation of definitions for the ANSI *Glossary of Terms in Nuclear Science and Technology*. It is possible that the special shielding terms and definitions prepared by the ANS-6.5 working group will be published separately since the list is sufficiently long and specialized to not be included in the glossary covering all of nuclear science.

The glossary is the outgrowth of a need recognized by the shielding community in the late 1960s for a list of proper definitions of shielding and dosimetry terms not found in the *Glossary of Terms in Nuclear Science and Technology*, N1.1—1967, published by United States of America Standards Institute (USASI), predecessor of ANSI. During this time a revision of N1.1—1967 was announced, and the responsible American Nuclear Society standards subcommittee, ANS-9 (Units and Terminology), was approached with a list of shielding terms, with a request that the subcommittee prepare definitions and include them in the revision. This request was rejected on the basis that there was not enough time to prepare definitions consistent with the required schedule.

As a consequence, ANS-6 created a new subcommittee, ANS-6.5. A first draft of the glossary was prepared and submitted to ANS-6 for review late in 1973. In early 1974 comments received from the ANS-6 members were collated and reviewed, and as a result the present (second) draft of the glossary was undertaken, in the main a cut-and-paste job, with new definitions inserted, and the old definitions revised as necessary. The draft glossary contains 492 words, one hundred more than the first draft. It was under review by ANS-6 and ANS-9 in August, 1975.

ANS-6.6: Calculation and Measurement of Direct and Scattered Radiation from Nuclear Power Plants

The group had its first meeting in November 1973. A first working draft of the standard, N346, was prepared in June 1975. Extensive revisions to this working draft are currently in progress and the document should be available for public comment by June 1976.

This standard defines calculational requirements and techniques for estimates of exposures near nuclear power plants due to direct and scattered gamma radiation from contained sources on site. On-site locations outside plant buildings and locations in the off-site unrestricted area are considered. The standard reviews the considerations necessary to compute exposures, including component self-shielding, shielding afforded by walls and structures, and scattered radiation. The requirements for measurements and data interpretation of measurements are given.

A number of reference calculations are included based on solutions contributed by the working group members. These include point kernel, Monte Carlo, and discrete ordinates solutions of sample problems. It is intended that users of the standard would compare their analytical methods with the results of the reference calculations as a confirmatory check of the analytical procedures being employed.

Appendices to the standard include examples of the calculation of ^{16}N source terms for typical Boiling Water Reactor (BWR) turbine buildings. Appendices also present the inferred annual absorbed doses in free air (rads) for ^{16}N gamma radiation fields in the environs of three large boiling water reactors. These data are based on measurements of the total gamma radiation dose rates with pressurized argon ionization chambers and of the background gamma radiation contributions from natural and fallout radionuclides with NaI(Tl) and Ge(Li) spectrometers.

The purpose of the standard is to provide a uniform approach to (a) the determination of expected levels of direct and scattered radiation and (b) the delineation of the requirements for measurements thereof. It should provide a consistent approach for the assessment of direct and scattered radiation for those persons involved in the design, licensing and operation of nuclear power plants.

ANS-6.7: Radiation Zoning for Design of Nuclear Power Plants

This group was organized in early 1974 to standardize radiation level zoning in power plants. Since proper zoning of a nuclear plant is one of the most important concerns of the nuclear engineer, there has long existed a need for a standard which would serve as a guide in the design of nuclear power plants. The proposed standard ANSI N651 is intended to fill that need and will be of use to both the designer and the shielding engineer, and of benefit to the entire nuclear industry.

Radiation zoning inside nuclear plant buildings has a high priority because well planned zoning assures that: (a) personnel exposures will be "as low as practicable"; (b) the plant will be readily accessible for inspection and maintenance; and (c) unexpected events can be handled without unscheduled shutdown.

Though it seems simple, zoning is a highly controversial concept for utilities, reactor manufacturers, and architect-engineers, who incessantly play a numbers game with maximum dose rates and allowed access times for the zones, and often fix a maximum dose rate so low, in cubicles housing radioactive equipment, that it is impossible to avoid violation.

The proposed standard will alleviate the problem by a new functional approach. The goal is not only to give a base to the plant designer in implementing design criteria for the various zones, considering expected occupancy and operation, space utilization, and traffic patterns, but also to be instrumental in keeping maximum expected doses to individuals and total doses to all radiation workers "as low as reasonably possible" (ALARP). Secondly, the standard will aid the shielding engineer in calculating shield thicknesses for a given layout, so that the principle of ALARP can be implemented in future plant operation.

In view of the need for such a document and its anticipated usefulness, a preliminary draft of ANSI N651 was prepared in May, 1975. The draft was further elaborated during and after the ANS New Orleans meeting in June, 1975. The final draft of the proposed standard is expected to be available in November 1975.

This standard addresses all known and expected contained radiation sources, but does not consider radiation dose resulting from the release of radioactive materials into the working environment.

Instead of quantizing dose-time, a functional subdivision of the plant will be ensured by assigning zones for people and zones primarily for equipment. The plant will be subdivided into two regions: unrestricted and restricted areas. Unrestricted areas are occupied by personnel not involved in radiation work. The restricted area will be limited to radiation workers and equipment, and will be subdivided into four zones: two zones for people, and two zones for equipment. The zones for people include one used for routine work requiring unlimited access during the normal work week, and one zone designated for work which requires limited access time. There are two zones utilized for locating radioactive equipment: one is reserved to those components, which may require limited access time for inspection or minor maintenance while the plant is at power, such as for valves, pumps and similar components; and another zone for equipment which does not require access when in operation. Such equipment includes large radioactive tanks, heat exchangers, and other main equipment.

Related Standards Work

Most nuclear standards are listed in Ref. [6,7]. Two other organizations writing standards of direct interest to shielding specialists are:

1. American Society for Testing and Materials

ASTM, publisher of the world-renowned *Book of ASTM Standards*, is the world's largest source of voluntary consensus standards for materials, products, systems and services. Since 1898, the Society—mainly through the intensive activities of standards committees—has conducted vast numbers of investigations and researches leading to a better knowledge of the properties of materials and the development of more than 4400 widely used standards—specifications and methods of testing for materials.

Beginning with the 1974 edition of the *Annual Book of ASTM Standards*, the Society plans to provide a separate part or volume on ASTM's nuclear related standards. Part 45 of the 1974 *Annual Book of ASTM Standards* [8] contains all ASTM standards dealing with nuclear materials and materials related to nuclear reactors. There are 104 standards in the book of which 159 are new, revised or changed in status since 1973. Sixty-six have also been approved by ANSI and a number of others by other organizations. The standards in Part 45 cover: concrete products for nuclear applications; graphite products for nuclear applications; metal products for nuclear applications (hafnium, nickel and nickel alloys, steel, tantalum, titanium and titanium alloys, zirconium and zirconium alloys); nuclear grade materials; radiation effects in organic materials; radioactivity, inorganic materials in water; analysis, dosimetry and radiation effects in metals; and temperature measurement.

The ASTM Headquarters staff of 150 is located at 1916 Race Street, Philadelphia, Pa. 19103; William T. Cavanaugh, Managing Director.

2. U. S. Nuclear Regulatory Commission (NRC)

The Commission has the responsibility for establishing licensing procedures and regulatoy functions for the control of materials and facilities essential to the nuclear energy industry. The two basic reasons for the regulatory duties of the NRC are to protect the public health and safety, and to promote the common defense and security. Regulations of the NRC are included as parts of Title 10 of the Code of Federal Regulations, and are published in the *Federal Register*. Regulatory Guides are issued to describe and make available to the public methods acceptable to the NRC staff of implementing specific parts of the Commissions's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory Guides are not substitutes for regulations and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit of license by the Commission.

Published guides will be revised periodically, as appropriate, to accommodate comments and to reflect new information or experience.

Copies of published guides may be obtained by request indicating the divisions desired to the U. S. Nuclear Regulatory Commission, Washington, D. C. 20555, Attention: Director of Regulatory Standards.

The guides are issued in the following ten broad divisions:

1. Power Reactors
2. Research and Test Reactors
3. Fuels and Materials Facilities
4. Environmental and Siting
5. Materials and Plant Protection
6. Products
7. Transportation
8. Occupational Health
9. Antitrust Review
10. General

3. U. S. Energy Research and Development Administration (ERDA)

The ERDA Division of Reactor Research and Development (RRD) is responsible for the safe development of reactor technology in the U. S. Toward that end, they are concerned with the development of standards covering design, analytical methods, materials, equipment, systems, fabrication, construction. quality assurance, inspection, testing, operation, and maintenance for government-owned civilian water reactors. Toward this end, standards are being prepared, reviewed, reproduced, distributed and revised in order to incorporate latest developments, information, techniques, and experience. This work is being performed under contract to Oak Ridge National Laboratory (ORNL) with the assistance of other ERDA offices and contractors as a continuing activity in this program. The standards program will serve as a base on which to build current and future reactor programs with greater quality assurance and the attendant improvement in reactor reliability and safety. A thorough investigation of records, experience, knowledge, expertise, and evaluation from all available qualified sources is required for the successful attainment of the goals for the standards program. Initial efforts have been directed toward converting available standards into a form that may be used for engineering current (RRD) experimental activities and demonstration reactors and provide usable technical guides for others. ORNL is responsible for overall management of the RDT Standards Program under direction from RRD. Standards are being prepared by ongoing development projects and by ORNL in its specific areas of expertise for which each writer is qualified. Such standards, designated as RDT standards, are also listed in Ref. [6].

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