American Nuclear Society

REAFFIRMED

September 27, 2016

ANSI/ANS-6.4.2-2006; R2016

specification for radiation shielding materials

an American National Standard

This standard has been reviewed and reaffirmed with the recognition that it may reference other standards and documents that may have been superseded or withdrawn. The requirements of this document will be met by using the version of the standards and documents referenced herein. It is the responsibility of the user to review each of the references and to determine whether the use of the original references or more recent versions is appropriate for the facility. Variations from the standards and documents referenced in this standard should be evaluated and documented.
This standard does not necessarily reflect recent industry initiatives for risk informed decision-making or a graded approach to quality assurance. Users should consider the use of these industry initiatives in the application of this standard.

published by the

American Nuclear Society

555 North Kensington Avenue

La Grange Park, Illinois 60526 USA

American National Standard Specification for Radiation Shielding Materials

Secretariat
American Nuclear Society

Prepared by the
American Nuclear Society
Standards Committee
Working Group ANS-6.4.2

Published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA

Approved September 28, 2006
by the
American National Standards Institute, Inc.

American National Standard

Designation of this document as an American National Standard attests that the principles of openness and due process have been followed in the approval procedure and that a consensus of those directly and materially affected by the standard has been achieved.

This standard was developed under procedures of the Standards Committee of the American Nuclear Society; these procedures are accredited by the American National Standards Institute, Inc., as meeting the criteria for American National Standards. The consensus committee that approved the standard was balanced to ensure that competent, concerned, and varied interests have had an opportunity to participate.

An American National Standard is intended to aid industry, consumers, governmental agencies, and general interest groups. Its use is entirely voluntary. The existence of an American National Standard, in and of itself, does not preclude anyone from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard.

By publication of this standard, the American Nuclear Society does not insure anyone utilizing the standard against liability allegedly arising from or after its use. The content of this standard reflects acceptable practice at the time of its approval and publication. Changes, if any, occurring through developments in the state of the art, may be considered at the time that the standard is subjected to periodic review. It may be reaffirmed, revised, or withdrawn at any time in accordance with established procedures. Users of this standard are cautioned to determine the validity of copies in their possession and to establish that they are of the latest issue.

The American Nuclear Society accepts no responsibility for interpretations of this standard made by any individual or by any ad hoc group of individuals. Requests for interpretation should be sent to the Standards Department at Society Headquarters. Action will be taken to provide appropriate response in accordance with established procedures that ensure consensus on the interpretation.

Comments on this standard are encouraged and should be sent to Society Headquarters.

Published by

American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA

Printed in the United States of America

Foreword

(This Foreword is not a part of American National Standard "Specification for Radiation Shielding Materials," ANSI/ANS-6.4.2-2006.)

The need for this standard was identified in mid-1977 by Working Group ANS-6.4. At that time, it was recognized that an increasing number of different material/design shielding concepts were being introduced into nuclear power plants to solve neutron and gamma-ray streaming problems. For protection against neutron streaming, materials varying from water-filled rubber bags, rubber balls, special concretes, treated plastics, and silicone gels were proposed, while lead-filled silicone rubber and gels were proposed for gamma-ray streaming. With such a variety of materials, some only a year or two after initial commercial introduction, a clear need was discerned to standardize the specification of these materials to assist the material manufacturer in the type of information he or she needs to provide to the user.

The focus of the working group's initial work was to orient the standard toward the reporting requirements used by material suppliers rather than toward the preparation of specifications by designers and end users. This focus has been maintained through the development of this standard as that representing the true needs of nuclear power plants in this area. The standard was reaffirmed in 1997 and again in 2004, at which time a working group was appointed and charged with revision of the standard.

Working Group 6.4.2 of the American Nuclear Society Standards Committee had the following membership at the time of this revision:

R. E. Faw (Chair), *Individual*

C. C. Graham, *AmerenUE Callaway Plant*
S. J. Haynes, *Sandia National Laboratories*
T. M. Lloyd, *EnergySolutions*
J. D. Olson, *Black & Veatch Corporation*
J. K. Shultis, *Kansas State University*
R. W. Roussin, *Individual*
J. K. Warkentin, *Individual*
N. B. Willoughby, *Individual*

Subcommittee ANS-6, Radiation Protection and Shielding, had the following membership at the time of its approval of this standard:

W. C. Hopkins (Chair), *Individual*

F. A. Alpan, *Westinghouse Electric Company*
J. Tanner, *Pacific Northwest National Laboratory*
R. E. Faw, *Individual*
J. C. Wagner, *Oak Ridge National Laboratory*
R. M. Westfall, *Oak Ridge National Laboratory*
T. M. Raby, *National Institute of Standards and Technology*
N. Hertel, *Georgia Institute of Technology*

Consensus Committee N-17, Research Reactors, Reactor Physics, Radiation Shielding, and Computational Methods, had the following membership at the time it reviewed and approved this standard:

T. M. Raby (Chair), *National Institute of Standards and Technology*
A. Weitzberg (Vice Chair), *Individual*

W. H. Bell, *American Institute of Chemical Engineers* (Alt. R. D. Zimmerman, *American Institute of Chemical Engineers*)
R. E. Carter, *Individual*
D. Cokinos, *Brookhaven National Laboratory*
B. Dodd, *Health Physics Society*
B. K. Grimes, *Individual*
N. Hertel, *Georgia Institute of Technology*

W. A. Holt, *Individual*
W. C. Hopkins, *Individual*
M. A. Hutmaker, *U.S. Department of Energy*
L. I. Kopp, *Individual*
P. M. Madden, *U.S. Nuclear Regulatory Commission* (Alt. A. Adams, *U.S. Nuclear Regulatory Commission*)
J. F. Miller, *James F. Miller Consulting Services*
J. E. Olhoeft, *Individual*
W. J. Richards, *National Institute of Standards and Technology*
T. R. Schmidt, *Sandia National Laboratories*
A. O. Smetana, *Savannah River National Laboratory*
R. Tsukumura, *Aerotest Operations*
S. H. Weiss, *National Institute of Standards and Technology* (Alt. Thomas J. Myers, *National Institute of Standards and Technology*)
W. L. Whittemore, *General Atomics*

Contents

Specification for Radiation Shielding Materials

1 Scope

This standard sets forth physical and nuclear properties that shall be reported by the supplier as appropriate for a particular application in order to form the basis for the selection of radiation shielding materials.

2 Conformance

The word "shall" is used to denote a requirement; the word "should" is used to denote a recommendation; and the word "may" is used to denote permission, neither a requirement nor a recommendation. To conform with this standard, materials that are to be considered for use as a radiation shield shall be evaluated against the physical and nuclear properties that the standard sets forth. Accuracy of the determined values shall be provided. Unless otherwise specified, it will be assumed that all values are at a pressure of 1 atm. Units used in specifying properties shall be in the SI system as specified in this standard but may be expressed in other convenient units as well.

3 Terms and definitions

The following terms and definitions are provided to assure uniform understanding of the selected terms as are used in this standard. A large number of additional terms that are used are defined in the following documents: "Standard Terminology Relating to Methods of Mechanical Testing," ASTM E6-06 [1];[1)] "Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases," ASTM E12-70 (R1991, withdrawn 1996) [2]; "Standard Terminology of Fire Standards," ASTM E176-05a [3]; "Standard Terminology Relating to Rubber," ASTM D1566-06 [4]; "Cement and Concrete Terminology," ACI-116R-00 (R2005) [5]; and *Glossary of Terms in Nuclear Science and Technology* (1986) [6].

Arrhenius model: A model commonly used in accelerated aging tests that relates the rate of reaction of a material to temperature by a simple exponential function, $r = A\exp(-\Phi/kT)$, where r is the reaction rate, A is a material constant (frequency factor), Φ is the activation energy of the material (eV), k is Boltzmann's constant (0.8617×10^{-4} eV/K), and T is the absolute temperature (K).

bremsstrahlung: Gamma radiation emitted by an electron when it is deflected by the Coulomb field of an atomic nucleus of charge Z; the fraction of energy radiated as photons by an electron of initial energy E (MeV) is approximated numerically by $ZE/1000$.

equivalent test: A test method utilized in place of a standard or reference test that achieves the same end result.

induced radioactivity: Radioactivity due to the interaction of an external neutron radiation field with the nuclides of a material.

operating range: The range of values over which a parameter, indicative of environmental conditions, is stated to vary during the expected life of a material as it performs its intended function.

photoneutron: Neutron released from an atomic nucleus in a photonuclear reaction with a gamma ray of sufficiently high energy. The threshold energy required of the gamma ray is $\sim$2 MeV for beryllium and deuterium but $>$8 MeV for other elements.

specific gravity: For the purposes of this standard, specific gravity is considered numerically equal to density expressed in units g/cm^3.

trace element: An element found in small quantities (usually $<$1%) within a material.

trace radioactivity: Radioactivity due to trace amounts of naturally occurring radioisotopes contained within a material.

[1)] Numbers in brackets refer to corresponding numbers in Sec. 8, "References."