American Nuclear Society

calculation and measurement of direct and scattered gamma radiation from LWR nuclear power plants

an American National Standard

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American National Standard for Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plants

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American Nuclear Society

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American National Standard

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Foreword

(This Foreword is not a part of American National Standard for Calculation and Measurement of Direct and Gamma Radiation from LWR Nuclear Power Plants, ANSI/ANS-6.6.1-1987.)

In mid 1973, a need for a standard on this subject was identified by D. K. Trubey, chairman of ANS-6. The proposed standard had been listed among those having a high priority by the Atomic Energy Commission Directorate of Regulatory Standards. The project was assigned by the NTAB Executive Committee in September 1973. Working Group ANS-6.6 was formed and E. A. Warman was appointed chairman in September 1973. The first meeting of the working group was held in November 1973. Twelve subsequent meetings were held from February 1974 through June 1978.

The first working draft was completed in June 1975. A revised working draft was distributed for initial review by ANS-6 chairmen in June 1976. The completed Draft 1 was submitted to ANS-6 for ballot in September 1977. This draft was unanimously approved in subsequent balloting by ANS-6 subcommittee chairmen, with the sole negative ballot being changed to affirmative after resolution of comments. A reorganized working group, ANS-6.6.1, was established in 1984 to reconsider the status of the standard. In December 1985, that working group recommended reaffirmation of the standard with minor editorial changes.

In preparing this standard, the working group decided to provide a series of reference calculations with which a radiation analyst should compare results obtained by the method he elected to use in a given application. Comparison with the results of these reference calculations is intended to provide some assurance that the methods being considered by the user of this standard produce results which are in reasonable agreement with those of other methods. These reference calculations are intentionally simplistic to make this comparison effort easier to accomplish.

This standard addresses contained sources of direct and scattered radiation and specifically excludes effluent releases and accident sources. Measurements at some operating plants, which have no local shielding to reduce reactor cavity/nozzle inspection port streaming, have indicated that localized streaming can be measurable outside the containment. Such localized streaming effects are not addressed in this standard.

Particular emphasis is placed on the direct and scattered radiation from ^{16}N sources in Boiling Water Reactors (BWRs). This emphasis reflects the fact that analysis and measurement of radiation associated with ^{16}N sources at BWRs was identified as a major area of interest in establishing priority for development of this standard. The three appendices to the standard are included as examples of the type of measurements and analyses which have been performed in connection with the ^{16}N sources at BWRs. In Appendices 1 and 2, the assumption is made that the observed dose rates are entirely due to ^{16}N activity. The net effect of this assumption is to increase the amount of conservatism in the quantification of the source terms, in that other radiations are included in the measurements from which the ^{16}N source terms are developed.

Working Group ANS-6.6.1 of the ANS Standards Committee had the following membership:

R. E. Faw, Chairman, *Kansas State University*
J. A. Broadway, *U.S. Environmental Protection Agency*
J. Celnik, *Stone & Webster Engineering Corporation*
F. J. Congel, *U.S. Nuclear Regulatory Commission*
K. O'Brien, *U.S. Department of Energy*
J. V. Pace III, *Martin-Marietta Energy Systems, Inc.*
J. K. Shultis, *Kansas State University*
Shiaw-der Su, *GA Technologies, Inc.*
M. B. Wells, *Radiation Research Associates*
N. B. Willoughby, *Consultant*

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

D. K. Trubey, Chairman, *Oak Ridge National Laboratory*
E. T. Boulette, *Maine Yankee Atomic Power Company*
J. C. Celnik, *Stone & Webster Engineering Company*
D. R. Harris, *Rensselaer Polytechnic Institute*
W. C. Hopkins, *Bechtel Corporation*
E. Normand, *Boeing Aerospace Company*
P. J. Persiani, *Argonne National Laboratory*
D. J. Schuh II, *GEB Controls Group, Inc.*

Consensus Committee N17, Research Reactors, Reactor Physics, and Radiation Shielding, had the following membership at the time it reviewed and approved this standard:

R. S. Carter, Chairman
T. M. Raby, Secretary

J. D. Buchanan . . . . . Health Physics Society
A. D. Callihan (Subcommittee ANS-1) . . . . . Individual
R. E. Carter . . . . . U.S. Nuclear Regulatory Commission
C. Thomas (Alt.)
R. S. Carter . . . . . American Nuclear Society
A. De La Paz (Subcommittee ANS-14) . . . . . Department of U.S. Army
D. Duffey . . . . . American Institute of Chemical Engineers
H. Goldstein . . . . . American Physical Society
P. B. Hemming . . . . . U.S. Department of Energy
J. W. Lewellen (Alt.)
W. A. Holt . . . . . American Public Health Association
L. I. Kopp (Subcommittee ANS-10) . . . . . U.S. Nuclear Regulatory Commission
J. E. Olhoeft . . . . . Individual
T. M. Raby . . . . . National Bureau of Standards
W. J. Richards (Subcommittee ANS-15) . . . . . Argonne National Laboratory
M. M. Ter Pogossian . . . . . American College of Radiology
D. K. Trubey (Subcommittee ANS-6) . . . . . Oak Ridge National Laboratory
A. Weitzberg (Subcommittee ANS-19) . . . . . NUS Corporation
W. L. Whittemore . . . . . Individual

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1. Scope

This standard defines calculational requirements and discusses measurement techniques for estimates of dose rates near light water reactor (LWR) nuclear power plants due to direct and scattered gamma-rays from contained sources on-site. On-site locations outside plant buildings and locations in the offsite unrestricted area are considered. All sources that contribute significantly to dose rates are identified and methods for calculating the source strength of each are discussed. Particular emphasis is placed on ^{16}N sources as they are significant sources of direct and scattered radiation for boiling water reactors (BWRs). The standard specifically excludes radiation from gaseous and liquid effluents. The standard describes the considerations necessary to compute dose rates, including component self-shielding, shielding afforded by walls and structures, and scattered radiation. The requirements for measurements and data interpretation of measurements are given. The standard includes normal operation and shutdown conditions but does not address accident or normal operational transient conditions.

2. Applicable Documents

The following documents supplement or support this standard:

Glossary of Terms in Nuclear Science and Technology [1].[1]

American National Standard Guidelines for the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants, ANSI/ANS-6.4-1985 [2].

American National Standard Radioactive Source Term for Normal Operation of Light Water Reactors, ANSI/ANS-18.1-1984 [3].

[1]Numbers in brackets refer to corresponding numbers in Section 8, References.

3. Terms and Definitions

The following terms and definitions are provided to help to assure uniform understanding of selected terms as they are used in this standard.

A number of terms are used in this standard as defined in textbooks on the subject of radiation shielding and radiation detection. They are not used in any special sense in this standard.

capacity factor. The capacity factor is defined as the energy actually supplied by a plant in a given time interval, divided by the product of the design power and the time interval. The capacity factor may be used in assessing the annual absorbed dose, provided the principal sources are directly related to capacity.

direct gamma rays. The term direct gamma rays is used to denote those gamma rays which do not undergo scattering interactions in transit from the source volume to the receptor location. It differs from “uncollided gamma rays” in that scattering internal to distributed sources (such as a pipe containing radioactive fluid) may be included in the direct category.

dose rate and absorbed dose. The term dose is used herein to refer to either exposure (roentgens), absorbed dose (rad), dose equivalent (rem), or dose equivalent index (rem). These latter terms are specifically defined in Report No. 19 of the International Commission on Radiation Units and Measurements (ICRU) [4]. For gamma rays, to the degree of approximation acceptable, for practical purposes, and for the purposes of this standard, the absorbed dose, dose equivalent, and dose equivalent index may be considered numerically equivalent.

essentially unshielded. As used in this standard, essentially unshielded relative to air scat-