



# 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  
Calculation and Measurement of Direct and Scattered  
Gamma Radiation from LWR Nuclear Power Plants**

Secretariat  
**American Nuclear Society**

Prepared by the  
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## Foreword

(This foreword is not a part of American National Standard, "Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plants," ANSI/ANS-6.6.1-2015.)

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.

When preparing the initial version of this standard, the 1973 working group provided a series of reference calculations with which a radiation analyst should compare results obtained by the method he/she 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 this standard's user produce results that are in reasonable agreement with those of other methods. These reference calculations are intentionally simplistic to make this comparison effort easier to accomplish.

The first working draft was completed in June 1975. A revised working draft was distributed for initial review by ANS-6 chairs in June 1976. The completed first draft (Draft 1) was submitted to ANS-6 for ballot in September 1977. This draft was unanimously approved in subsequent balloting by ANS-6 subcommittee chairs, with the sole negative ballot being changed to affirmative after resolution of comments. A reorganized working group, ANS-6.6.1, was established in 2012 to reconsider the status of the standard. In June 2013, that working group recommended revisions of the standard to (a) correct editorial errors, (b) update the list of referenced documents, (c) update the definitions and units of the dose terms, (d) update Figs. 6.3 through 6.8 to include dose rate results for the reference calculations computed based on a modern Monte Carlo (MCNP5) computer program, and (e) incorporate three new tables (Tables 6.3, 6.4, and 6.5) providing the MCNP5-computed dose rate results and their relative statistical uncertainty.

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  $^{16}\text{N}$  sources in boiling water reactors (BWRs). This emphasis reflects the fact that analysis and  $^{16}\text{N}$  measurement of radiation associated with 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 that have been performed in connection with the  $^{16}\text{N}$  sources at BWRs. In Appendices A and B, the assumption is made that the observed dose rates are entirely the result of  $^{16}\text{N}$  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  $^{16}\text{N}$  source terms are developed.

This standard might reference documents and other standards that have been superseded or withdrawn at the time the standard is applied. A statement has been included in Sec. 8, References," that provides guidance on the use of references.

This standard does not incorporate the concepts of generating risk-informed insights, performance-based requirements, or a graded approach to quality assurance. The user is advised that one or more of these techniques could enhance the application of this standard.

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# Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plants

## 1 Scope

This standard defines calculational requirements and discusses measurement techniques for estimates of dose rates near light water reactor (LWR) nuclear power plants because of direct and scattered gamma rays from contained sources on-site. On-site locations outside plant buildings and locations in the off-site 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  $^{16}\text{N}$  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. The standard also applies to the gamma dose resulting from dry fuel storage facilities.

## 2 Applicable documents

The following documents supplement or support this standard:

*Glossary of Terms in Nuclear Science and Technology* [1].<sup>1)</sup>

ANSI/ANS-6.4-2006, "Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants" [2].

ANSI/ANS-18.1-1999 (withdrawn), "Radioactive Source Term for Normal Operation of Light Water Reactors" [3].

## 3 Terms and definitions

### 3.1 Acronyms

**BWR:** boiling water reactor

**LWR:** light water reactor

**PWR:** pressurized water reactor

**RPV:** reactor pressure vessel

**TLD:** thermoluminescence dosimeter

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<sup>1)</sup>Numbers in brackets refer to corresponding numbers in Sec. 8, "References."