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Radiation Safety for the Design and Operation of Particle Accelerators

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Preface

The previous ANSI N43.1 standard was published for use in December 1969 and covered mainly technical aspects with a stipulation that the standard applied principally to accelerators with energies less than 100 MeV. In 1974, a review of the standard was conducted that resulted in changes (principally dosimetric quantities) and a revised standard that was approved in July 1978. Currently, accelerators exist in a variety of types, sizes, power capabilities, operational modes, and applications. Therefore, accelerators can vary widely in their radiation hazard producing capacity and diversity, and the hazard analysis and control are more complex and challenging. The regulatory environment is also more demanding.

This new N43.1 standard is developed to address the hazards and controls for accelerators in the current technical, operational, and regulatory environment. The goal is to provide a consistent and sound radiation protection framework for accelerator community.

The new N43.1 standard has the following major new elements and/or changes:

1. It covers most fixed, non-medical accelerators, encompassing most particle types and energies.
2. It covers all phases of the accelerator facility (the life-cycle approach).
3. It addresses both technical and management aspects of the radiation safety program.
4. It sets requirements and recommends good practices for the protection of workers, the public, and the environment.
5. It takes a graded approach for the hazard control that is commensurate with the risk levels.
6. It addresses the subjects of engineered and/or interlocked safety systems for prompt radiation and accelerator operations in more detail.

Radiation Safety for the Design and Operation of Particle Accelerators

1.0 Purpose, Scope, and Introduction

1.1 Purpose

This standard sets forth accelerator facility ionizing radiation safety requirements for workers, public, and the environment produced during and from accelerator operations. This standard also recommends good practices that provide a level of radiation protection consistent with those established across the accelerator community.

1.2 Scope

This standard applies to all phases of the accelerator facility's life cycle, including design, installation, commissioning, operation, maintenance, upgrade, and decommissioning. This standard specifies requirements and recommendations for radiation safety program management and technical aspects.

This standard is suitable for all accelerator facilities using electron, positron, proton, or ion particles capable of producing ionizing radiation hazards. However, accelerators used within a formalized medical setting directly for diagnosis and/or therapy, such as medical accelerators used for radiotherapy and radio-diagnosis in hospitals, are not covered by this standard.

Accelerator facilities covered by this standard include, but are not limited to, the following accelerator systems:

- Small table-top accelerators
- Radiography machines > 1 MeV (inspection systems for security, contraband, etc.)
- Industrial accelerators (ion implanters, electron beam welders, medical sterilization accelerators, etc.)
- Accelerators such as cyclotrons producing radioisotopes for medical or non-medical uses
- Facilities manufacturing and testing medical or industrial accelerators
- Multi-use facilities that use accelerators for both medical and non-medical purposes (sub-facilities used only for medical purposes are excluded)
- Van de Graaff and other DC-type accelerators
- Pulse beam machines providing high peak currents at low duty factors
- Large, high-dose-rate R&D machines
- Synchrotron light and free electron laser (FEL) facilities
- Heavy ion accelerators

1.3 Introduction

Accelerators of varying types and sizes have different power capabilities, operational modes, and/or applications and can vary widely in their potential to pose a hazard. Therefore, this standard takes a graded approach and sets forth requirements and recommended practices based on the accelerator facility's complexity and hazard levels.

For example, an accelerator may be low-power, small, and self-shielded and have incorporated engineered controls limiting access to radiation levels of concern. These accelerators may be obtained as a pre-manufactured unit with safety operating procedures provided by the manufacturer or may be assembled from component parts in a small room. Due to their inherently safe nature (limited maximum radiation output and/or shielding containment), these accelerators may have simple radiation safety programs that require minimal radiation safety support and limited user training or operational requirements.

The other end of the spectrum includes complex accelerator facilities covering up to several square kilometers delivering kilowatt to megawatt peak or average beam power and involving many distinct beam enclosures. These large accelerator facilities typically require extensive radiation safety programs as well as significant support by radiation safety professionals and well-trained accelerator operation staff (Operations). Within a complex, high-hazard accelerator facility, there may be sub-facilities or secondary beamlines with low radiation hazard and uncomplicated safety requirements. However, the principles of radiation safety should be consistently applied across the entire facility.

This standard uses the word “shall” to identify a required practice or the minimum acceptable level of performance. The word “should” is used to identify good practices (preferred practices) recommended by this standard. The word “may” is used to identify permitted practice (neither a requirement nor a recommendation). “Shall” is used in the non-normative appendices not to indicate mandatory practice but to indicate an elevated level of importance.

It should be noted that throughout the text the word “requirement” is intended to convey a practice that is necessary to meet the intent of this standard, not to convey any regulatory authority.

The requirements and recommendations in this standard are not intended to preclude alternative means of achieving the same radiation protection objectives. However, the responsibility of establishing alternative means sufficiency is borne by the facility.

Section 1.0 defines the purpose, scope and introduction. Section 2.0 provides common acronyms and defines common terms. Section 3.0 specifies the radiation safety programs for the accelerator facilities and sets forth the basis of the radiation safety program presented throughout the standard. Each main topic in Section 3.0 is presented in detail later in the document.

Section 4.0 provides details on radiation safety system (RSS) requirements and recommendations. The RSS includes the access control system (ACS) and radiation control system (RCS). Section 5.0 details the ACS, and Section 6.0 details the RCS.

Section 7.0 covers accelerator operations. The operational radiation safety (also called operational health physics) program is described in Section 8.0. Finally, Section 9.0 covers personnel training.

Appendices A–D provide detailed guidance and resources to assist accelerator facilities in addressing four key issues covered by this standard: 1) development of the safety assessment document, 2) the interlocked-type ACS, 3) decommissioning program, and 4) measurements of radiation and radioactivity. Note that these four appendices are *informative* only and are, therefore, not part of this standard’s requirements and recommendations.

It is recognized that many parts of this standard address large and complex accelerator facilities with significant hazards. As discussed earlier, there are many commercially available, industrial, and/or production-type accelerators whose radiation hazards and radiation safety program for the facilities are much less complicated. In general, this type of facility is inherently safe and low-risk (due to the machine’s physical capabilities and/or engineered safety controls) and is operated by a limited number of staff. Therefore, it is desirable to give specific requirements and recommendations for this type of facility. Appendix E provides a summary of the minimum requirements and recommendations for these facilities, which allows the facilities to develop and conduct radiation safety programs in conformance with the standard. Appendix E follows the N43.1 standard layout and is *normative,* and therefore part of the standard requirements and recommendations.

Note that radiation safety requirements for single-purpose accelerators may be addressed by other ANSI standards that have been or are currently being developed. In that case, the general requirements for such types of accelerators may be covered by this standard, particularly Appendix E (if applicable), whereas detailed requirements are covered by the specific ANSI standard (if available).

At the end of this standard, some useful reports and documents are referenced and given as resources.

Note: Several accelerator design and operating characteristics, as well as associated prompt radiation hazards and engineered safety control/mitigation measures, are fundamentally different from nuclear facilities with nuclear weapons, nuclear reactors, or nuclear criticality potential. Therefore, the nuclear facility