ANSI N43.1 Standard

Radiation Safety for the Design and Operation of Particle Accelerators

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DOE-ASW in ANL, Sept. 20-22, 2011

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Contents

1. **Why the new ANSI N43.1 Standard?**
2. **N43.1 Standard: Chapters/Sections**
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“Old” ANSI N43.1 (1979-1989)

Chapter 1: Scope

Chapter 2: Definitions

Chapter 3: Radiation Protection Design Criteria

Chapter 4: Operational Health Physics

Chapter 5: Radiation Measurements

Chapter 6: Dose Assessment

“Old” ANSI N43.1

1. **Applied to accelerators < 100 MeV**
2. **Covered only technical aspects**
3. **Did not apply to facilities or machines with high or complicated hazards**
4. **Need to be updated and improved, due to insufficient requirements and guidance to address the hazards associated with the increasing types, modes, and applications of accelerators in current technical, operational and regulatory environment.**

U.S. Regulations and Guides

1. **NRC and State**
   1. **10 CFR Part 20**
   2. **Conference of Radiation Control Program Directors (CRCPD) SSR Vol. 1, Part I (1991) "Radiation Safety Requirements for Particle Accelerators"**
2. **DOE**
   - **10 CFR 835 and G 441.1 "RPP"**
   - **O 420.2C (2010) and G 420.2-1 (2005) "Safety of Accelerator Facilities"**
   - **G 441.5-5 (1999) "Radiation Generating Devices"**

Scope of New N43.1

1. **Applies to most fixed, non-medical accelerators in the community covering industry, universities, R&D environment, etc.**
   - **Good-faith effort to harmonize with federal and state regulations and guides**
2. **Covers all phases of the accelerator facility**
   - **Life-cycle approach covering design, installation, commissioning, operation, upgrade and decommissioning**

Purpose of New N43.1

1. **Protect workers, public and environment**
2. **Sets <u>requirements</u> that must be met to address the hazard of ionizing radiation produced during, and from, accelerator operations.**
3. **Recommends <u>good practices</u> that are consistent with the level of protection offered across accelerator community.**

Approach of New N43.1

1. **Set requirements and recommendations for both <u>management</u> and <u>technical</u> aspects of the radiation safety program**
2. **A graded approach in setting requirements and recommendations according to the complexity and level of the hazards**
3. **Balances general requirements for flexibility and specific guidance for uniformity**

New N43.1 Chapters

1. Purpose and Scope
2. Definitions
3. Radiation Safety Program
4. Radiation Safety System (RSS)
5. Access Control System (ACS)
6. Radiation Control System (RCS)
7. Accelerator Operations
8. Operational Radiation Safety
9. Training

What, Why, How, Who, When

New N43.1 Appendix

A. Safety Assessment Document (SAD)
B. Interlocked-type Access Control Systems (ACS)
C. Decommissioning Program
D. Measurements of Radiation and Radioactivity
E. Safety Standards for Commercially Available and/or Production-Type Accelerators (normative)

Chapter 3 - Radiation Safety Program

- **Sets forth the basis of the radiation safety program presented throughout the Standard.**
- **Highlights key elements of radiation safety program.**
- **Each element in Chapter 3 is presented in more details in Chapters 4-9.**

Chapter 3 - Radiation Safety Program

3.1 General

- Integrated Safety Management Approach
- Graded approach and ALARA
- Vendor-provided standardized safety program

3.2 Organization and Administration

- Roles, responsibilities, authorities for all parties
- Facility Management and Operations
- Radiation Safety Professionals (ABHP)
- RSO and/or RSC

Chapter 3 - Radiation Safety Program

3.3 Hazard Identification and Safety Assessment

- Current SAD as a guide for design and operations
- Appendix A to aid the SAD development

3.4 Design and Implementation of Safety Controls and Monitoring (Chapters 4, 5 and 6)

- Workers, public and environment
- Normal Operation and Abnormal Operation
- Radiation Safety System (RSS) = Access Control System (ACS) + Radiation Control System (RCS)
- Operation Envelope (Operations & Safety)
- Safety Envelope (MCBP, management or regulator)

Chapter 3 - Radiation Safety Program

3.5 Accelerator Operations (chapter 7)

3.6 Operational Radiation Safety (chapter 8)

- General (e.g., formal and procedural)
- 10CFR835 and 10CFR20 health physics programs
- Radiological environmental protection
- Cleanup and Decommissioning

3.7 Training and Qualification (chapter 9)

Chapter 3 - Radiation Safety Program

3.8 Program Review and Performance Evaluation

- **A systematic process to identify deficiencies and recommendations & to develop, implement and track corrective actions**
- **Performance indicators (leading & lagging)**
- **Performance comparable with peer facilities**
- **Self assessment & peer review (internal & external)**
- **Readiness reviews for design, operation and major changes**
- **Periodic and complete (≤ 3 y)**

Chapter 3 - Radiation Safety Program

3.9 Quality Assurance (QA), Quality Control (QC)

- **Clear roles, responsibilities and authorities**
- **Trained and competent individuals**
- **Documented programs and procedures**
- **Configuration control (CC) of safety systems**
- **Readiness review**
- **Self-assessment and peer review**

QA and QC should be incorporated into the development and implementation of each element of the radiation safety program.

Chapter 3 - Radiation Safety Program

3.10 Document and Record Management

- A document and record management system
- Guide the design and operations and record activities
- Make program auditable
- Examples of vital records:
  - SAD, Safety Envelope, Operation Envelope
  - Facility operation procedures and records
  - RSS tests and bypasses
  - Manuals, Technical Basis Documents, SOPs
  - Measurements, surveys, calibration
  - Training
  - Program audit and review

Chapter 4 - Radiation Safety System

4.1 General

- **RSS (ACS + RCS) for prompt radiation hazard**
- **Access Control System (ACS): keeps people away from radiation (rope, fence with locked gate, interlocked entry control)**
- **Radiation Control System (RCS): keeps radiation away from people (shielding, fence, beam interlock systems, and radiation interlock systems)**
- **Graded approach (from administrative controls to engineered, interlocked systems)**

Chapter 4 - Radiation Safety System

4.2 Features of Radiation Safety System

4.3 Requirements and Guidance

- Reliable
- Fail-safe
- Tamper resistance
- Quality assurance
- Configuration control
- Certification and checks

4.4 Radiation Not Related To Beam

4.5 Induced Radioactivity (workers and environment)

Chapter 5 - Access Control System

5.1 General

5.2 Graded Approach (> 0.05 mSv/h)

5.3 System Features

- **Warnings and signs**
- **Enclosures (ropes and/or barriers)**
- **Personnel entry doors/gates**
- **Exclusion Area (> 10 mSv/h)**

5.4 Beam Inhibiting Devices (shutter, power sources, etc.)

Section 5.2 - Graded Approach

Dose Rate (mSv h^{-1}) [1]	Dose Category	Start-up Warning	Enclosure	Personnel Entryway Door/Gate	Interlock Redundancy	Area Secure System
0.05 - 1	Minimum	None	Rope	No Restriction	None	Not Required
1 - 10	Low	Visible & Audible	Barrier	Locked or Interlocked	Recommended	
10 - 100	Moderate	Visible & Audible Emergency-off recommended	Barrier	Locked Interlock Recommended	Recommended	Required (Exclusion Area)
> 100	High	Visible & Audible Emergency-off	Barrier	Locked & Interlocked	Required	

1) 1-h exposure is assumed.
2) Interlock redundancy is required for High dose category.
3) Areas ≤ 0.05 mSv/h are subject to administrative access controls in Chapter 8.

Chapter 5 - Access Control System

5.5 ACS Interlocks

- Redundancy via independent chains
- Reliability, Maintainability, Testability, Simplicity
- Use of Computer-Based Logic Systems

5.6 Review for Interlocked-type ACS

- Appendix B for interlocked-type ACS

5.7 Certification and Checks

- Annual certification and frequent checks
- Written procedures, authorized personnel, proper documentation

Chapter 6 - Radiation Control System

6.1 General

- **Passive Elements (preferred): Shielding and Fence**
- **Active Elements: Beam Interlocks and Radiation Interlocks**
- **Active Elements have same requirements as interlocked-type ACS (redundancy, fail-safe, and testability, etc) .**

Chapter 6 - Radiation Control System

6.2 Performance Requirements

6.2.1 Normal Operation (within Operation Envelope)

- RCS ensures dose rates as Table 5.1
- Shielding design:
  - 20% of annual dose limit for Radiation Worker
  - ≤ 1 mSv/y for Non-Radiation Worker
  - Direct/skyshine public dose should ≤ 0.1 mSv/y
  - ALARA principle

6.2.2 Abnormal Operation

- RCS ensures 0.01-1 Sv/h & dose per event ≤ 10 mSv
- Maximum Credible Beam Loss (MCBL) analysis
- Layers of controls or protection

Chapter 6 - Radiation Control System

6.3 Passive Systems: Shielding & Fences

- Conservative design (Normal & Abnormal)
- Designed or reviewed by Safety Professional
- Verification surveys

6.4 Active Systems

- Limiters for beam (energy, current, beam losses)
- Radiation detectors (warning, trip, fail-safe)
- Periodically calibrated and active status verified during operation

6.5 Administrative Controls

- To supplement the Passive/Active Systems

Chapter 7 - Accelerator Operations

7.1 General

7.2 Readiness Review

7.3 Operating Practices

7.4 Testing, Routine Maintenance, and Unscheduled Repairs

7.5 Interlock Bypasses and Deviations from Procedures

7.6 Emergency Response

Chapter 8 - Operational Radiation Safety

8.1 General

8.2 Area Classification, Worker Classification, and Access Control

8.3 Personnel Dosimetry (External and Internal)

8.4 Area Monitoring (Active and Passive)

8.5 Radiation Surveys (Prompt and Induced)

8.6 Radiological Work Control

8.7 Control of Induced Radioactivity

8.8 Instrumentation

8.9 Management of Radioactive Material, Sources and Waste

8.10 Radiological Environmental Protection

8.11 Facility Cleanup and Decommissioning

Chapter 9 - Training

9.1 General

- Training, Retraining and Qualification

9.2 Procedures and Records

9.3 Training Requirements

9.4 Performance-based Radiation Safety Training Program (ANSI/HPS13.36-2001)

9.5 Training Topics

- Basic, Accelerator-Specific, Facility-Specific)

9.6 Instructor Qualifications

Summary

- **Applicable to most fixed, non-medical accelerators**
- **Set requirements and recommendations based on a graded approach**
- **Life-cycle concept for the protection of workers, public and environment**
- **Technical and management aspects of radiation safety program**
  - **SAD, Operation Envelope, and Safety Envelope**
  - **RSS (ACS+RCS) for prompt radiation**
  - **Accelerator operations**
  - **Operational radiation safety programs**