U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Technical Support & Emergency Management
Office of Technical Programs and Coordination Activities

Special Purpose Particle Accelerators

Safety and Health Information Bulletin

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Purpose

The purpose of this Safety and Health Information Bulletin is to:

- Review the types and uses of particle accelerators;
- Provide information to employers and employees to assist in recognizing the safety and health hazards, both radiation and non-radiation, associated with the operation of special purpose particle accelerator facilities;
- Provide information to employers and employees about basic and specific safety and health considerations and to help ensure they are adequately protected from hazards when operating and working near special purpose particle accelerators;
- Identify specific Occupational Safety and Health Administration (OSHA) and Nuclear Regulatory Commission (NRC) regulatory requirements that address operating and working at special purpose accelerator facilities; and
- Recognize that working at special purpose accelerator facilities entails the utilization of high voltage electrical systems which can lead to electric shock and arc-flash/blast events and fires caused by overheating.

This Safety and Health Information Bulletin (SHIB) is not a standard or regulation, and it creates no new legal obligations. It contains recommendations as well as descriptions of mandatory safety and health standards. The recommendations are advisory in nature, informational in content, and are intended to assist employers in providing a safe and healthful workplace. The Occupational Safety and Health Act requires employers to comply with safety and health standards and regulations promulgated by OSHA or by a state with an OSHA-approved state Plan. In addition, the Act's General Duty Clause, Section 5(a)(1), requires employers to provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm.

Introduction

A particle accelerator (or "accelerator") is a device (linear or circular) that uses electrostatic or electromagnetic fields to increase the speed (energy) of electrically charged particles (molecular, atomic, or subatomic) or electrons and to direct the charged particles to collide with each other or a target. The collision or interaction of the charged particles releases subatomic particles or produces various types of ionizing and nonionizing radiation. Examples of nonionizing radiation produced by accelerators include visible light such as the light produced by a cathode ray tube (CRT) in a television, ultraviolet light, infrared light, radio waves, and electric and magnetic fields. A type of ionizing radiation produced by accelerators includes x-rays that can be used in numerous ways. For example, when charged particles are captured on a specific target, medical-related isotopes are produced. When electrons are accelerated onto a metallic (typically tungsten) target, x-rays are produced. Both medical isotopes and x-rays are used to treat cancer and other tumors.

The information presented in this bulletin does not cover all types of particle accelerators. Instead, the content focuses on special purpose accelerators such as the research accelerators generally found at universities and Department of Energy (DOE) sites.

Types of accelerators

Accelerators come in a wide range of sizes from small and simple to very large and complex. They also vary extensively in energy levels, from low-energy tabletop medical accelerators to high-energy accelerators whose dimensions are measured in miles. There are several types of accelerators in use today including: deuterium-tritium generators, Cockcroft-Walton accelerators, Van de Graaff accelerators, linear accelerators, and circular accelerators. Circular accelerators include cyclotrons, synchrotrons and betatrons.

Uses of accelerators

Accelerators were once used almost exclusively for physics research. They are now commonly used for:

- **Television** or other visual instruments using a CRT;
- **Medical therapy.** Accelerator-produced x-rays and particle beams of electrons, protons, neutrons, or heavy ions can be directed at tumors not reachable by other treatment techniques;
- **Research and materials analysis.** X-rays or accelerated particles can be directed at a target to analyze its structure by measuring the resulting scattering of particles;
- **Non-invasive security assessment.** Accelerators produce x-rays that can quickly identify the contents of containers located in trucks, shipping containers, or luggage to detect hidden explosives, chemicals, or contraband;
- **Radionuclide production.** High-energy protons or charged particles can be directed at targets to create radionuclides (radioactive atoms) for medical, research, and industrial uses; and
- **High-energy and nuclear physics studies.** Particles produced from accelerator targets can be used to study the basic structure of matter and the origin of the universe.

There are approximately 17,500 special purpose particle accelerators in use throughout the world, with about 4,000 such devices operating in the United States. They range from small and simple accelerators to very large and complex ones. Table 1, below, shows the approximate number of special purpose accelerators used in different technical applications.[1]

TABLE 1
Approximate Number of Special Purpose Accelerators Worldwide

CATEGORY OF ACCELERATOR	NUMBER IN USE
High energy acclerators (E>1 GeV)	~120
Synchrotron radiation sources	>100
Medical radioisotope production	~200
Radiotherapy accelrators	>7,500
Research accelerators including biomedical research	~1,000
Accelerators for industrial processing and research	~1,500
Ion implanters, surface modification	>7,000
TOTAL	**>17,500**

Accelerator hazards

Accelerator operations present a range of potential workplace safety and health hazards in addition to those posed by ionizing radiation. For example, electrical hazards are common because high-voltage and supporting cable tray systems are used in operating accelerators. Large accelerators frequently operate in tunnels which have restricted access and egress. The use of compressed gasses and cryogenics (very low temperatures) in the operation and maintenance of

[1] From W. Maciszewski and W. Scharf, Particle Accelerators for Radiotherapy, Int. J. of Radiation Oncology (2004), available at http://villaolmo.mib.infn.it/ICATPP8th_2003/Medical%20Applications/Maciszewski.doc

accelerators increases the likelihood of oxygen-deficient atmospheres, especially in confined spaces.

Lasers, used to align the accelerator's beam, pose nonionizing radiation hazards to the eyes and skin. Ionizing radiation hazards are associated with the active particle beam and materials in the beam's path.

Basic safety and health considerations for operating and working at accelerator facilities

The following are basic procedures for helping to ensure the safety of employees operating or working near accelerators:

- Specifically define work processes for accelerator activities.
- Identify and analyze hazards of accelerator and associated operations.
- Implement controls to eliminate or reduce hazards.
- Perform work in compliance with the prescribed controls.
- Provide opportunities for employees to give feedback to management regarding improvements to accelerator operations and controls.
- Train employees based upon the particular hazards identified and use competent instructors to provide training.

Specific safety and health considerations for operating and working at accelerator facilities

Although the list below is not comprehensive, it provides examples of important considerations to help ensure the safe operation of accelerators and accelerator facilities:

- **Electrical hazards.** High-voltage electrical systems are required to power most accelerator operations. OSHA General Industry and Construction standards, specify electrical safety requirements. These requirements range from guarding energized live parts to following safety practices, including the use of personal protective equipment (PPE) when working on or near energized equipment. The National Electric Code® and the National Fire Protection Association (NFPA) 70E ("Standard for Electrical Safety in the Workplace") also include electrical safety practices.

    - 29 CFR 1910 Subpart S — Electrical — Establishes electrical safety requirements necessary for the practical safeguarding of employees in the workplace.

    - 29 CFR 1910.269 — Electric power generation, transmission and distribution – Establishes requirements for the safe operation and maintenance of electric power generation, control, transformation, transmission and distribution lines and equipment.

- **Control of hazardous energy (lockout/tagout).** Accelerators depend on high-voltage systems and associated electrical equipment. Appropriate controls are required for servicing and maintenance of those machines and equipment where energization, start-up, or release of any stored energy may have the potential to injure an employee (29 CFR 1910.147).

- **Egress and fire protection.** Workplaces that operate large accelerators with high-voltage electrical systems and extensive enclosures should have a comprehensive fire protection and life safety program. Appropriate precautions include conducting a fire and egress hazard analysis and complying with OSHA's General Industry standards in subparts E (Means of Egress, 29 CFR 1910.33-39) and subpart L (Fire Protection, 29 CFR 1910.155-165). See also, the NFPA voluntary national consensus standards, including the Life Safety Code (NFPA 101).

- **Potential oxygen-deficient atmospheres and confined spaces.** For some large accelerators, leaks of liquefied gases used in operations can displace oxygen and pose life-threatening hazards in confined spaces. Liquefied (super cold) gases also present significant cryogenic hazards.

Appropriate precautions include conducting detailed hazard analyses, use of appropriate personal protective equipment, (29 CFR 1910.132), strict compliance with safety and health requirements and, if necessary, implementing a permit-required confined space entry program as outlined in 29 CFR 1910.146.

- **Lasers.** Lasers produce a highly directional monochromatic beam of light used to ensure that the accelerator's beam is properly aligned with the target. Appropriate controls, such as interlocks and warnings as well as PPE, are needed to protect the eyes and skin from exposure. (see the American National Standards Institute (ANSI) voluntary national consensus standard **Z136.1 (2007) Safe Use of Lasers**)

- **Ionizing radiation hazards.** Accelerators generate ionizing radiation when the primary beam is activated. In addition, residual radioactive material may be produced by interactions between the particle beam and materials in the path of the beam, such as targets and associated enclosures. Radiation such as x-rays generally ceases once the beam is deactivated, minimizing the potential for exposure. On the other hand, radiation generated from isotopes (radiation sources, with half-lives varying from very short to extremely long duration) may not always dissipate quickly and may pose more extended exposure hazards.

  OSHA adopted its Ionizing Radiation standard in 1971, incorporating the radioactive materials exposure limits issued in 1969 by the Atomic Energy Commission, the predecessor to the Nuclear Regulatory Commission (NRC). NRC has revised its exposure limits several times since 1969 (910 CFR 20.113 through 20.2008).

  To promote a coordinated and effective federal program for the protection of employees exposed to ionizing radiation, the Federal Radiation Protection Guidance (FRPG) was issued in 1960 and updated in 1987. The 1987 Federal Guidance document, developed collectively by 10 federal agencies including NRC and OSHA, generally incorporated recommendations on the limits for occupational exposure and the approach to radiation protection published by the International Commission on Radiation Protection (ICRP) in 1977. The ICRP updated its recommendations in 1990.

  In addition, applicable national consensus standards (e.g., National Council on Radiation Protection and Measurements No. 144; Radiation Protection for Particle Accelerator Facilities) identify effective ionizing radiation controls including use of interlocks, shielding, administrative controls, warning systems, and appropriate PPE.

- **Nonionizing radiation hazards.** Operation of particle accelerators, by their nature, can generate very high electric and magnetic fields as well as very high levels of radiofrequency radiation. Guidelines and standards by standard-setting scientific organizations such as the International Commission on Nonionizing Radiation Protection, and the American National Standards Institute (ANSI) should be reviewed and followed to protect employees. In addition to potential biological effects and health risks, nonionizing electric and magnetic fields can pose safety concerns for persons with metallic medical implants and devices such as pacemakers.

Accelerator Occupational Safety and Health Jurisdiction

As explained below, OSHA has the authority to regulate the occupational safety and health hazards associated with (1) the operation of particle accelerators, and (2) incidental radioactive material produced by particle accelerators operated to produce only particle beams and not radioactive materials, to the extent these hazards are not regulated by other Federal agencies.

OSHA regulates employee exposure to ionizing radiation under authority granted by the Occupational Safety and Health Act of 1970 (OSH Act) (29 U.S.C. 651 et seq.). This includes, for example, occupational safety and health hazards associated with the operation of X-ray equipment, electron microscopes, and accelerators.

Several other Federal agencies, including NRC and DOE, also have responsibility to regulate employee exposure to ionizing radiation in certain circumstances. OSHA's Ionizing Radiation standard (29 CFR 1910.1096) covers occupational exposure to ionizing radiation sources not regulated by other Federal agencies. States with OSHA-approved occupational safety and health programs exercise parallel authority within their states. State programs must enforce standards that are at least as effective as Federal OSHA standards.

NRC has statutory authority for licensing and regulating nuclear facilities and materials as mandated by the Atomic Energy Act of 1954 (AEA), as amended, (42 U.S.C. 2011 *et seq*.) and other applicable statutes. This authority covers radiation hazards in NRC-licensed facilities as well as conditions in those facilities that affect the safety of radioactive materials that may present an increased radiation hazard to employees. Specifically, NRC has the authority to regulate the following nuclear materials: source, byproduct and certain special nuclear materials. The AEA defined "by-product material" to mean (1) material made radioactive incident to or yielded in the process of producing or utilizing special nuclear material, and (2) wastes or tailings produced during extraction (or concentration) of uranium or thorium from any ore that is being "processed primarily for its source material content" (42 U.S.C. 2014(e)).

The Energy Policy Act of 2005 (EP Act) expanded the definition of "byproduct material" that NRC is authorized to regulate to include, among other materials, any material that has been made radioactive by use of a particle accelerator (i.e., "accelerator-produced materials") (42 U.S.C. 2011 et seq.). On October 1, 2007, NRC issued regulations implementing the EPAct (72 FR 55864).

The NRC regulations divide particle accelerators into three groups:

- Accelerators that are always operated to intentionally produce radioactive materials in quantities that are useful for their radioactive properties for a commercial, medical, or research activity;
- Accelerators that are operated to produce only particle beams and not radioactive materials (e.g., linear accelerators used for medical treatment, electron microscopes, ion implanters); and
- Accelerators that are used to produce both radioactive materials and particle beams for other uses.

The NRC regulations specify that the Agency will not regulate the "incidental radioactive material" produced by accelerators that are operated to produce only particle beams and not radioactive materials for use for a commercial, medical or research activity. In addition, the regulations clarify that the EP Act does not give NRC authority to regulate the possession or operation of particle accelerators. Accordingly, OSHA continues to retain authority to regulate the occupational safety and health hazards associated with the operation of particle accelerators and incidental radioactive material produced by particle accelerators that produce only particle beams and not radioactive materials.

Additional information

- Nuclear Regulatory Commission, Requirements for Expanded Definition of Byproduct Material; 10 CFR Parts 20, 30, 31, 32, 33, 35, 50, 61, 62, 72, 110, 150, 170 and 171 available at http://www.nrc.gov/about-nrc/regulatory.html#issuing

- Conference of Radiation Control Program Directors (CRCPD), Suggested State Radiation Control Regulations, Vol. I, Part 1, Radiation Safety Requirements for Particle Accelerators (January 1991).

- Accelerator Facility Safety Implementation Guide for DOE O 420.2B, Safety of

Accelerator Facilities, July 1, 2005, U.S. Department of Energy, available at http://www.directives.doe.gov.

- Accelerator Safety, Self-Study, Los Alamos National Laboratory, LA-UR-99-5089, Course #12325, April 1999, available at https://www.sns.gov/projectinfo/operations/training/lectures/Good%20information/Acceleratorsafety.pdf.

- Radiation Protection for Particle Accelerator Facilities, National Council on Radiation Protection and Measurements, NCRP Report No. 144 (Bethesda, MD, 2003), available at http://www.ncrponline.org.

- OSHA Safety and Health Topics: Ionizing Radiation, available at http://www.osha.gov/SLTC/radiationionizing/index.html.

- OSHA Safety and Health Topics: Electrical, available at http://www.osha.gov/SLTC/electrical/index.html.

- OSHA Safety and Health Topics: Control of Hazardous Energy (Lockout/Tagout), available at http://www.osha.gov/SLTC/controlhazardousenergy/index.html.

- OSHA Safety and Health Topics: Confined Spaces, available at http://www.osha.gov/SLTC/confinedspaces/index.html.

- OSHA Safety and Health Topics: Laser Hazards, available at http://www.osha.gov/SLTC/laserhazards/index.html.

- Safe Use of Lasers, American National Standards Institute, ANSI Z136.1 (Washington, DC), available at http://www.ansi.org.

- Information on OSHA-approved State plans is available at: http://osha.gov/dcsp/osp/index.html

- Laser Institute of America is available at: http://www.laserinstitute.org/

- Occupational Safety and Health Administration OSHA is available at: http://www.osha.gov/

- National Fire protection Association (NFPA) is available at: http://www.nfpa.org/itemDetail.asp?categoryID=164&itemID=18021&cookie%5Ftest=1

- American National Standards Institute (ANSI) is available at: http://webstore.ansi.org/default.aspx

- International Commission on Non-Ionizing Radiation Protection (ICNIRP) is available at: http://www.icnirp.de/