Designation: C1533 – 15

Standard Guide for General Design Considerations for Hot Cell Equipment[1]

This standard is issued under the fixed designation C1533; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *Intent:*

1.1.1 The intent of this guide is to provide general design and operating considerations for the safe and dependable operation of remotely operated hot cell equipment. Hot cell equipment is hardware used to handle, process, or analyze nuclear or radioactive material in a shielded room. The equipment is placed behind radiation shield walls and cannot be directly accessed by the operators or by maintenance personnel because of the radiation exposure hazards. Therefore, the equipment is operated remotely, either with or without the aid of viewing.

1.1.2 This guide may apply to equipment in other radioactive remotely operated facilities such as suited entry repair areas, canyons or caves, but does not apply to equipment used in commercial power reactors.

1.1.3 This guide does not apply to equipment used in gloveboxes.

1.2 *Applicability:*

1.2.1 This guide is intended for persons who are tasked with the planning, design, procurement, fabrication, installation, or testing of equipment used in remote hot cell environments.

1.2.2 The equipment will generally be used over a long-term life cycle (for example, in excess of two years), but equipment intended for use over a shorter life cycle is not excluded.

1.2.3 The system of units employed in this standard is the metric unit, also known as SI Units, which are commonly used for International Systems, and defined by IEEE/ASTM SI 10: American National Standard for Use of the International System of Units (SI): The Modern Metric System.

1.3 *Caveats:*

1.3.1 This guide does not address considerations relating to the design, construction, operation, or safety of hot cells, caves, canyons, or other similar remote facilities. This guide deals only with equipment intended for use in hot cells.

1.3.2 Specific design and operating considerations are found in other ASTM documents.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

A276 Specification for Stainless Steel Bars and Shapes

A320/A320M Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

A354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A479/A479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A489 Specification for Carbon Steel Lifting Eyes

A490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength

C859 Terminology Relating to Nuclear Materials

C1217 Guide for Design of Equipment for Processing Nuclear and Radioactive Materials

C1572 Guide for Dry Lead Glass and Oil-Filled Lead Glass Radiation Shielding Window Components for Remotely Operated Facilities

C1615 Guide for Mechanical Drive Systems for Remote Operation in Hot Cell Facilities

C1661 Guide for Viewing Systems for Remotely Operated Facilities

C1725 Guide for Hot Cell Specialized Support Equipment and Tools

D676 Method of Test for Indentation of Rubber by Means of a Durometer; Replaced by D 2240 (Withdrawn 1964)[3]

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[1] This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.14 on Remote Systems.

Current edition approved Jan. 1, 2015. Published February 2015. Originally approved in 2002. Last previous edition approved in 2008 as C1533 – 08. DOI: 10.1520/C1533-15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

D5144 Guide for Use of Protective Coating Standards in Nuclear Power Plants
F593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *Other Standards:*
10CFR830.120 Nuclear Safety Management Quality Assurance Requirements[4]
ANSI/ANS-8.1 Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors[5]
ANSI/ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications[6]
ANSI/ISO/ASQ 9001 Quality Management Systems[5]
ASME Y14.5 Dimensioning and Tolerancing[6]
ICRU Report 10b Physical Aspects of Irradiation[7]
NCRP Report No. 82 SI Units in radiation Protection and Measurements[8]

3. Terminology

3.1 The terminology employed in this guide conforms to industry practice insofar as practicable.

3.2 For definitions of terms not described in this guide, refer to Terminology C859.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *canyon*—a long narrow, remotely operated and maintained radiological area within a facility where nuclear material is processed or stored.

3.3.2 *cave*—typically a small-scale hot cell facility, but is sometimes used synonymously with hot cell.

3.3.3 *dose equivalent*—the measure of radiation dose from all types of radiation expressed on a common scale. The specialized unit for dose equivalent is the rem. The SI unit for dose equivalent is the sievert (Sv), which is equal to 100 rem. Human exposure is often expressed in terms of microsieverts (μSv), 1×10^{-6} sieverts, or in terms of millirem (mrem),1×10^{-3}.

3.3.4 *electro-mechanical manipulator (E/M)*—usually mounted on a crane bridge, wall, pedestal, or ceiling and is used to handle heavy equipment in a hot cell. Each joint of the E/M is operated by an electric motor or electric actuator. The E/M is operated remotely using controls from the uncontaminated side of the hot cell. Most E/Ms have lifting capacities of 100 lbs or more.

3.3.5 *gamma radiation*—high energy, short wavelength electromagnetic radiation which normally accompanies the other forms of particle emissions during radioactive decay. Gamma radiation has no electrical charge.

3.3.6 *high density concrete*—a concrete having a density of greater than 2400 kg/m^3 (150 lb/ft^3).

3.3.7 *hot cell*—an isolated shielded room that provides a controlled environment for containing highly radioactive and contaminated material and equipment. The radiation levels within a hot cell are typically 1 Gy/h (100 rads per hour) or higher in air.

3.3.8 *master-slave manipulator (MSM)*—a device used to handle items, tools, or radioactive material in a hot cell. The in-cell or slave portion of the manipulator replicates the actions of an operator outside of the hot cell by means of a through-wall mechanical connection between the two, usually with metal tapes or cables. MSMs have lifting capacities of 9 to 23 kg (20 to 50 lb).

3.3.9 *mock-up*—a facility used to represent the physical environment of a radiological facility in a non-radiological setting. Mock-ups are full scale facilities used to assure proper clearances, accessibility, visibility, or operability of items to be subsequently installed in a radiological environment.

3.3.10 *radiation absorbed dose (rad)*—radiation absorbed dose is the quotient of the mean energy imparted by ionizing radiation to matter of mass. The SI unit for absorbed dose is the gray (NCRP Report No. 82).

3.3.11 *radiation streaming*—unshielded beams of radiation.

3.3.12 *roentgen equivalent man (rem)*—a measure of the damaging effects of ionizing radiation to man. See *dose equivalent* (NCRP Report No. 82, ICRU Report 10b).

4. Significance and Use

4.1 The purpose of this guide is to provide general guidelines for the design and operation of hot cell equipment to ensure longevity and reliability throughout the period of service.

4.2 It is intended that this guide record the general conditions and practices that experience has shown is necessary to minimize equipment failures and maximize the effectiveness and utility of hot cell equipment. It is also intended to alert designers to those features that are highly desirable for the selection of equipment that has proven reliable in high radiation environments.

4.3 This guide is intended as a supplement to other standards, and to federal and state regulations, codes, and criteria applicable to the design of equipment intended for hot cell use.

4.4 This guide is intended to be generic and to apply to a wide range of types and configurations of hot cell equipment.

5. Quality Assurance Requirements

5.1 The manufacturer and Owner-Operator of hot cell equipment should have a quality assurance program. QA programs may be required to comply with 10CFR830.120, ANSI/ASME NQA-1, or ANSI/ISO/ASQ 9001.

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[4] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[7] Available from International Commission on Radiation Units and Measurements, Inc., 7910 Woodmont Ave., Suite 400, Bethesda, MD 20814-3095, http://www.icru.org.

[8] Available from National Council of Radiation Protection and Measurements, 7910 Woodmont Ave., Suite 400, Bethesda, MD 20814-3095, http://www.ncrponline.org.

5.2 The Owner-Operator should require appropriate quality assurance of purchased hot cell equipment to assure proper remote installation, operation and reliability of the components when they are installed in the hot cell.

5.3 Hot cell equipment should be designed according to quality assurance requirements and undergo quality control inspections as outlined by the authority having jurisdiction.

6. Nuclear Safety

6.1 The handling and processing of special nuclear materials requires the avoidance of criticality incidents. Equipment intended for use in handling materials having a special nuclear material content should undergo a criticality assessment analysis in accordance with the requirements of ANSI/ANS-8.1 and other such standards and regulations as may be applicable.

7. Design Considerations

7.1 Hot cell equipment should be designed and fabricated to remain dimensionally stable throughout its life cycle.

7.2 Fabrication materials should be resistant to radiation damage, or materials subject to such damage should be shielded or placed and attached so as to be readily replaceable.

7.3 Special consideration should be given to designing hot cell equipment that may be exposed to or may create high temperatures, high rate of temperature changes, caustic conditions, or pressure changes. Abrupt changes in the hot cell temperature or pressure may cause the hot cell windows to crack, lose clarity, and potentially lose containment and cause liquid spillage. Refer to Guide C1572 for information regarding hot cell windows. The effect of handling and operating high temperature hot cell equipment utilizing master-slave manipulators or other in-cell handling equipment should be considered to preclude damage to those items.

7.4 Preventive maintenance based on previous experience in similar environments and similar duty should be performed as required to prevent unscheduled repair of failed components.

7.5 Hot cell equipment may be required to be leak-tight when handling liquids. Leak tightness prevents radioactive liquid from entering the interior of hot cell equipment where it can cause corrosion, shorting of electrical components, higher chronic radiation to components and it complicates decontamination.

7.6 Hot cell equipment should generally be designed to function indefinitely, or within a pre-planned specified life cycle within the highly radioactive environment. However, in many cases this may not be possible since radiation degrades some materials over time. Alpha, beta, gamma, and neutron radiation can severely damage most organic materials, for example, oils, plastics, and elastomers. Materials that come into direct contact with alpha- and beta-emitting materials can experience severe radiation damage due to the large amount of energy transferred when stopping the alpha and beta particles. Commercially available equipment containing organic materials may require disassembly and the internal components replaced with more radiation resistant materials. If suitable alternate materials cannot be used, special shielding may have to be integrated into the design to protect the degradable components. In the case of some electronic equipment, it may be possible to separate and move the more radiation sensitive components outside of the hot cell and operate the equipment in the hot cell remotely. Where possible and appropriate, equipment should be designed to withstand an accumulative radiation dose of approximately 1×10^8 rads (H_2O)[^{60}Co].

7.7 Since hot cells have a limited amount of space, the equipment designs should be standardized where possible to reduce the number of one-of-a-kind parts. Standardization of hot cell equipment will reduce design time, fabrication costs, operator training time, maintenance costs, and the number of special tools required to perform a certain operation. Standardization in design, drawing control and excellent quality control assure that components are interchangeable. Specially designed equipment should be standardized for use with equipment in similar applications or systems to reduce spare parts inventories and to maintain familiarity for the operators. Commercially available components should be used, and modified if necessary, wherever possible in preference to specially designed equipment.

7.8 All hot cell equipment should be designed in modules for ease of replacement, maintainability, interchangeability, standardization, and ease of disposal. The modules should be designed to be remotely removable and installed using the in-cell handling equipment, that is, master-slave manipulators, cranes, etc. Consideration should also be given to the transfer path to get equipment into the hot cell and size equipment modules accordingly. Components with a higher probability of failure should be made modular for ease of replacement. Remotely operated electrical connectors must be compatible with the hot cell materials handling equipment. Drawings of hot cell equipment should reflect the as-built configuration for all replaceable components to provide reliable documentation control, and conform to ASME Y14.5 Dimensioning and Tolerancing. Interfacing components should be toleranced to fit the in-field conditions. Replaceable components should be labeled with a standard identification and the component weight. Examples of modular designs might include subassemblies of removable motors, resolvers, valves, limit switches, and electrical cables.

7.9 The hot cell atmosphere can have an adverse affect on hot cell equipment. Hot cells can have air or inert gas atmospheres and are usually kept at a negative differential pressure of 2.5 cm to 5 cm (1.0 to 2.0 in.) of water gauge with respect to the surrounding operating areas. Hot cells with inert atmospheres or very low moisture content can make it difficult to operate some types of equipment. Some brush type motors, for example, will stall or simply fail to operate. One solution has been to replace the motor brushes with high altitude type brushes made of silver-graphite or use brushless motors. A good understanding of the effects of the hot cell atmosphere on equipment is essential when purchasing or designing new hot cell equipment.

7.10 It is generally advisable to perform qualification testing on new hot cell equipment in a mockup facility prior to putting the equipment into service. The mockup generally uses the