Designation: C1615/C1615M – 17 (Reapproved 2022)

Standard Guide for Mechanical Drive Systems for Remote Operation in Hot Cell Facilities[1]

This standard is issued under the fixed designation C1615/C1615M; 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 standard is to provide general guidelines for the design, selection, quality assurance, installation, operation, and maintenance of mechanical drive systems used in remote hot cell environments. The term mechanical drive systems used herein, encompasses all individual components used for imparting motion to equipment systems, subsystems, assemblies, and other components. It also includes complete positioning systems and individual units that provide motive power and any position indicators necessary to monitor the motion.

1.2 *Applicability:*

1.2.1 This standard is intended to be applicable to equipment used under one or more of the following conditions:

1.2.1.1 The materials handled or processed constitute a significant radiation hazard to man or to the environment.

1.2.1.2 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.

1.2.1.3 The equipment can neither be accessed directly for purposes of operation or maintenance, nor can the equipment be viewed directly, for example, without radiation shielding windows, periscopes, or a video monitoring system (Guides C1572 and C1661).

1.2.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *User Caveats:*

1.3.1 This standard is not a substitute for applied engineering skills, proven practices and experience. Its purpose is to provide guidance.

1.3.1.1 The guidance set forth in this standard relating to design of equipment is intended only to alert designers and engineers to those features, conditions, and procedures that have been found necessary or highly desirable to the design, selection, operation and maintenance of mechanical drive systems for the subject service conditions.

1.3.1.2 The guidance set forth results from discoveries of conditions, practices, features, or lack of features that were found to be sources of operational or maintenance problems, or causes of failure.

1.3.2 This standard does not supersede federal or state regulations, or both, and codes applicable to equipment under any conditions.

1.3.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *Industry and National Consensus Standards*—Nationally recognized industry and consensus standards which may be applicable in whole or in part to the design, selection, quality insurance, installation, operation, and maintenance of equipment are referenced throughout this standard and include the following:

2.2 *ASTM Standards:*[2]

ASTM/IEEE SI-10 Standard for Use of the International System of Units

C859 Terminology Relating to Nuclear Materials

C1533 Guide for General Design Considerations for Hot Cell Equipment

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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.

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[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.

C1554 Guide for Materials Handling Equipment for Hot Cells
C1572 Guide for Dry Lead Glass and Oil-Filled Lead Glass Radiation Shielding Window Components for Remotely Operated Facilities
C1661 Guide for Viewing Systems for Remotely Operated Facilities

2.3 *Other Standards:*
NEMA MG1 Motors and Generators[3]
AGMA 390.0 American Gear Manufacturers Association, Gear Handbook[4]
ANS Design Guides for Radioactive Material Handling Facilities and Equipment[5]
ASME B17.1 Keys and Keyseats[6]
NLGI American Standard Classification of Lubricating Grease[7]
ASME NOG-1 American Society of Mechanical Engineers Committee on Cranes for Nuclear Facilities – Rules for Construction of Overhead and Gantry Cranes[6]
ANSI/ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications[8]
ANSI/ISO/ASQ Q9001 Quality Management Standard Requirements[8]
NCRP Report No. 82 SI Units in Radiation Protection and Measurements[9]
ICRU Report 10b Physical Aspects of Irradiation[10]
CERN 70-5 Effects of Radiation on Materials and Components[11]

2.4 *Federal Standards and Regulations:*[12]
10CFR 830.120, Subpart A Nuclear Safety Management Quality Assurance Requirements
10CFR 50 Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
40CFR 260-279 Solid Waste Regulations – Resource Conservation and Recovery Act (RCRA)

3. Terminology

3.1 *General Considerations:*

3.1.1 The terminology employed in this standard conforms with industry practice insofar as practicable.

3.1.2 For definitions of general terms used to describe nuclear materials, hot cells, and hot cell equipment, refer to Terminology C859.

3.2 *Definitions:*

3.2.1 *encoders, n*—for the purpose of this standard, are measuring devices that detect changes in rotary or linear motion, direction of movement, and relative position by producing electrical signals using sensors and an optical disk.

3.2.2 *inert gas, n*—a type of commercial grade moisture free gas, usually argon or nitrogen that is present in the hot cell.

3.2.3 *linear variable differential transformer (LVDT), n*—a transducer for linear displacement measurement that converts mechanical motion into an electrical signal that can be metered, recorded, or transmitted.

3.2.4 *mechanical drive systems, n*—refers to but is not limited to motors, gears, resolvers, encoders, bearings, couplings, bushings, lubricants, solenoids, shafts, pneumatic cylinders, and lead screws.

3.2.5 *resolvers, n*—for the purpose of this standard, are rotational position measuring devices that are essentially rotary transformers with secondary windings on the rotor and stator at right angles to the other windings.

4. Significance and Use

4.1 Mechanical drive systems operability and long-term integrity are concerns that should be addressed primarily during the design phase; however, problems identified during fabrication and testing should be resolved and the changes in the design documented. Equipment operability and integrity can be compromised during handling and installation sequences. For this reason, the subject equipment should be handled and installed under closely controlled and supervised conditions.

4.2 This standard 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 this use.

4.3 This standard is intended to be generic and to apply to a wide range of types and configurations of mechanical drive systems.

5. Quality Assurance and Quality Requirements

5.1 The owner-operator should administer a quality assurance program approved by the agency of jurisdiction. QA programs may be required to comply with 10CFR 50, Appendix B, 10CFR 830.120, Subpart A, ASME NQA-1, or ISO Q9001.

5.2 The owner-operator should require appropriate quality assurance of purchased mechanical drive systems and components to assure proper fit up, operation and reliability of the equipment in the hot cell.

6. General Requirements

6.1 For safe and efficient operation, a minimum number of mechanical drive system components should be placed in a hot cell. Unnecessary equipment in a cell adds to the cost of

[3] Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1752, Rosslyn, VA 22209, http://www.nema.org.
[4] Available from American Gear Manufacturers Association (AGMA), 500 Montgomery St., Suite 350, Alexandria, VA 22314-1581, http://www.agma.org.
[5] Available from ANS, 555 North Kensington Avenue, LaGrange Park, Ilinois 60526.
[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 NLGI, 4635 Wyondotte Street, Kansas City, MO 64112.
[8] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[9] Available from National Council of Radiation Protection and Measurements, 7910 Woodmont Avenue, Suite 400, Bethesda, MD 20814-3095.
[10] Available from International Commission on Radiation Units and Measurements, Inc., 7910 Woodmont Avenue, Suite 400, Bethesda, MD 20814-3095.
[11] Available from CERN European Organization for Nuclear Research, CH-1211, Geneva 23, Switzerland.
[12] 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.

operating and maintaining the cell and adds to the eventual decontamination and disposal costs of hot cell equipment. A thorough review of the mechanical drive systems necessary to perform the hot cell operations should be performed prior to introducing the equipment into the hot cell.

6.2 All hot cell equipment should be handled with extreme care during transfers and installation sequences to ensure against collision damage.

6.3 Installation should be planned and sequenced so that other equipment is not handled above and around previously installed components to the extent practicable.

6.4 Principles of good modular design and standardization should be considered for maintainability of equipment during its design life. Determination should be made early in the design at which level of subassembly the equipment will be disassembled and replaced if necessary. The optimal level is strongly influenced by the estimated maintenance time and associated cell down time costs, radiation exposure to personnel, and disposal costs for the failed subassembly. Design with standardized fasteners and other components to limit the inventory of tools needed for maintenance. Use prudent judgement in the selection of fastening materials to avoid galling problems, especially when using stainless steel fasteners.

6.5 Equipment intended for use in hot cells should be tested and qualified in a mock-up facility prior to installation in the hot cell. **C1533**

6.6 Where possible, electrical and instrumentation controls, readouts, and alarms for mechanical drive systems should be located outside of the hot cell.

6.7 Consideration should be given to the materials of construction for hot cell equipment and their ultimate disposal per RCRA jurisdiction. **40CFR260-279**

7. Materials of Construction

7.1 Plastics, elastomers, resins, bonding agents, solid state devices, wire insulation, thermal insulation materials, paints, coatings, and other materials are subject to radiation damage and possible failure. Not all such materials and components can be excluded from service in the subject environment. Their use should be carefully considered for their particular application and material qualification testing under expected conditions prior to use should also be considered.

7.2 Alpha and beta irradiation can severely and rapidly damage sensitive components when they are exposed to the radiation source. Special consideration should be given to material selection in applications where the equipment is exposed to alpha or beta radiation.

7.3 The method of replacement, the ease of replacement, and/or the substitution of more radiation resistant materials should be considered for components having materials subject to radiation damage.

7.4 Polytetrafluoroethylene (PTFE) should be avoided since it degrades rapidly in radiation environments.

7.5 Polyetheretherketone is a recommended plastic material for seals, valve seats, and other applications because of its resistance to beta and gamma radiation.

8. Equipment Selection

8.1 *General:*

8.1.1 Mechanical drive system components should be selected based on their operability and reliability in a high radiation or high contamination environment, or be modified in a way that will extend the equipment service life or ease of use. The installation position, the orientation, and the attachment methods should be such as to simplify removal and replacement of mechanical equipment susceptible to periodic maintenance or unpredictable failure.

8.2 *Motors:*

8.2.1 *General:*

8.2.1.1 A variety of motors may be used in a high radiation hot cell environment. More than one type of motor may work for the same application. Motor selection depends on many factors, such as the required speed, torque or horsepower, physical frame size, voltage requirements, enclosure type, mounting requirements, bearing type, service factor, and duty cycle. The longevity of a motor in a hot cell environment depends on several variables such as the hot cell atmosphere, the amount of moisture and corrosive fumes in the atmosphere, the quality of the motor, the materials of construction, and the radiation exposure to the motor.

8.2.1.2 Motors smaller than 7500 watts [10 hp] are usually pre-lubricated at the factory and will operate for long periods of time under normal service conditions without requiring periodic lubrication. The bearings of larger motors however, may require periodic lubrication using high-quality grease with a consistency suitable for the motor's insulation class. Motors with sealed-for-life lubricated bearings are preferred over motors that require periodic lubrication. Refer to the section on lubrication for lubricants recommended for hot cell applications, 8.5 and Fig. 1.

8.2.1.3 Capacitor start, single-phase, alternating current (AC) motors have proven to be reliable in hot cells and are typically less expensive than direct current (DC) motors of equivalent horsepower. Generally, AC motors are also smaller than DC motors for the same horsepower. This can be an advantage in some uses where a larger motor may adversely affect the design. Three-phase induction AC motors are the preferred choice because of their robustness and starting simplicity. In lower radiation areas, that is, less than 250 mGy/hr [25 rad/hr], an off-the-shelf single phase AC motor usually works well and will typically last for several years.

8.2.1.4 Lower voltage motors are generally preferable to high voltage motors when used in an argon gas environment hot cell. For example, a 240-volt AC three-phase motor is preferred over a 480-volt AC motor because of the potential for arcing at higher voltages particularly inside electrical feed-throughs. However, 208/440-volt AC three-phase motors will often be used in low horsepower applications in place of 110-volt AC single phase motors in order to minimize the required wire size and connector ampacity. Refer to the ANS