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

[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

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[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 feedthroughs. 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

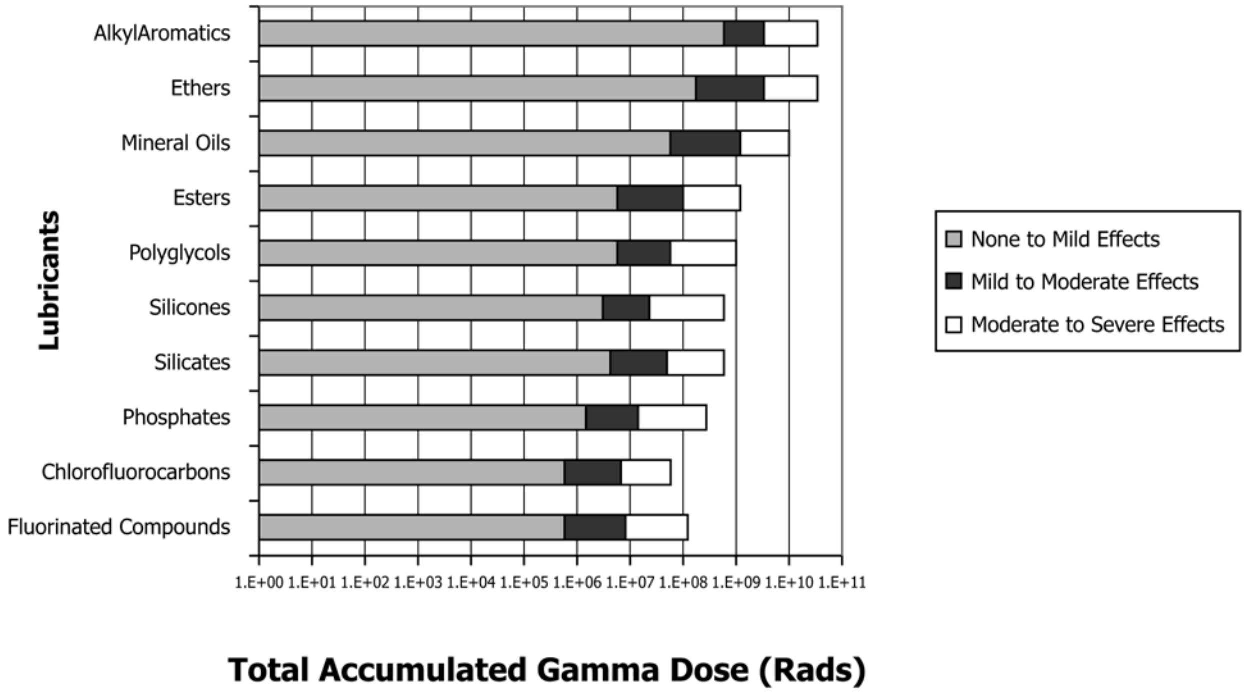

FIG. 1 Radiation Resistance of Lubricants (CERN 70-5)

Design Guide #2 for extensive information regarding hot cell penetration and feed-through design, installation, and testing. **ANS Design Guides**

8.2.1.5 Typically, motors with high temperature insulation, type H for example, are better suited to withstand radiation damage than motors with lower temperature rated insulation.

8.2.1.6 Most types of motors may need to be de-rated when used in hot cells with a higher ambient temperature and/or a thermally insulating gas such as argon.

8.2.1.7 Motors used in a hot cell should, where feasible, be similar in make and size in order to reduce the number of spare motors and to standardize on the size and type of electrical connectors and method of control.

8.2.2 *AC and DC Motors:*

8.2.2.1 Both AC and DC motors have been used successfully in air and argon gas atmosphere hot cells. In cases of high purity atmosphere hot cells, motors with brushes may not be acceptable because of the impurities generated from brush wear. Some brushless DC motors contain sensitive electronics that may be susceptible to radiation damage and should be evaluated for their use in high radiation hot cells. Table 1 shows various types of motors and their recommended applications in hot cells.

8.2.3 *Servomotors:*

8.2.3.1 Servomotors are used in situations requiring high accuracy in positioning and speed. Servomotors can be AC, DC brush-type, or brushless DC. Closed-loop servo control systems use feedback devices to provide information to a digital controller, which in turn produces the command signal which drives the motor. Wire-wound resolvers are the preferred method for position and velocity feedback in a hot cell environment for servomotors due to their inherent physical simplicity and the fact that semi-conductors are not required to be in close proximity to the resolvers.

8.2.3.2 Brushless DC servomotors have been used successfully in hot cells because they have the advantage of not having brushes that may wear out over time, but they may have electronic circuits that are susceptible to radiation damage. If the horsepower requirements go beyond 3750 watts [5 hp] an AC motor should be considered.

8.2.3.3 The motor cable length, design, and connector requirements should be to the vendor's recommendations. Problems of motor operation or positioning and/or feedback errors commonly occur if the wiring is beyond the vendor's recommended length.

8.2.4 *Gearmotors:*

8.2.4.1 A gearmotor is an electric motor combined with a geared speed reducer. The geared speed reducer is made of helical, worm, or spur gears used in single or multiple stages. The geared output shaft may be parallel with the motor, or may be at a right angle to the motor.

8.2.4.2 An important consideration when using gearmotors is the type of lubricant used in the gear housing. It may be advisable to supply a preferred lubricant to the gearmotor vendor at the time of purchase to be used in the gearmotor gear housing. Refer to the section on lubrication for hot cell recommended lubricants in 8.5 and Fig. 1.

8.2.4.3 Some small gearmotors may contain materials that are susceptible to radiation damage and may not be suitable for long term use in a hot cell.

8.2.5 *Brakemotors:*

8.2.5.1 A brakemotor is an electric motor connected to a spring-set brake. In the event of a power failure, the brake stops the motor and holds the load in position. When the motor is

TABLE 1 Motors and Their Recommended Applications for Hot Cells

Type	Horsepower (1 Hp = 750 watts)	Typical Size (dia.) (1 in. = 25.4 mm)	Application	Comments
AC Shaded Pole 115/208-2300-VAC	0 – 1	3" – 6"	Fans and blowers	• Inexpensive • Non reversible • Light duty • Low starting torque • Simple controller • Non-precision positioning • No position or velocity feedback • Applications requiring small motors
AC capacitor start, 115 VAC, single phase	½ – Up	6" – Up	Pumps and blowers	• Inexpensive • General purpose motor • Fixed speed • High current per horsepower • Moderate to high starting torques • Light duty
AC Three-phase 208-230 VAC	½ – Up	6" – Up	pumps, blowers, fans, compressors, agitators, hoists, general purpose motor	• Inexpensive • Reversible • High starting torque • Requires three-phase source • Generally fixed speed, but variable speed can be achieved by using variable freq.drive (VFD)
DC brush (permanent magnet)	1⁄16 – 1	1" – 8"	Variable speed drives, mixers, conveyors, high torque small gearmotors	• Can be low voltage • Inexpensive motor and controller • Variable speed • No position feedback • Non-precision positioning • Brushes may require replacement with high altitude brushes for longer life
DC Brushless – (permanent magnet⁄servo)	1⁄32 – 5	1" – 8"	High torque small gearmotors, robotics, linear actuators	• Compact • Expensive • Precision positioning • Reversible • Velocity control • Can be low voltage • Long life in high radiation fields if the drive electronics are moved out of cell
DC Shunt-Wound	5 – Up	6" – Up	Larger loads requiring variable speed, direction, and position control	• Variable speed/torque control available • Larger motors operated at low speeds require forced cooling • Limited use
Stepper (Brushless DC)	¼ – ½	3" – 5"	Robotics	• Consumes power to hold position (heat buildup) • Requires feedback for closed-loop position indication • Requires computer/micro processor control system • Can be operated open-loop • Expensive motor controls
Universal AC or DC	Fractional	3" – 6"	Power tools and vacuum cleaners	• High torque available in a small motor • Inexpensive • Low efficiency • Brushes may require replacement if motor is used in low moisture or inert gas environment • Normally powered by 120 VAC

operated, electric current is applied to the brake, releasing the set. Brakemotors are commonly used on hoists or other lifting devices. The electronics for brakemotors should be removed from the brakemotors before installation and placed in a non-radiation area. In the event that a brake does not release, careful consideration must be given to the proper method for supporting the load while the brake is repaired or replaced.

8.2.6 *Stepper Motor:*

8.2.6.1 A stepper motor operates by rotating a shaft in incremental steps. Electrical pulses are supplied to the motor using a translator drive or indexer. The motor converts the digital signals into fixed mechanical increments of motion. This allows the stepping motor to accurately position a load without using a feedback system, such as a resolver or compatible encoder. Feedback systems may be incorporated into the stepping motor system to provide a comparative function or to provide a true closed-loop system, although as a rule, stepper motors are run open-loop. A position sensor may be required to determine a "home" position if control power is interrupted. Stepper motors become thermally hot regardless of whether they are turning or not. Also, when power is lost, the motor can no longer support a load. When installing the stepper motor in a hot cell, it may be necessary to separate the electronic drives from the motor and move them out of the cell or to a lower radiation area. Note that motor performance may be affected when separating the electronics and the motor. Consideration should be given to reduce the generation or reception of electrical noise on the cables between the drive and the motor.

8.2.7 *Induction Motors:*

8.2.7.1 Induction motors come in either three phase or single phase. At lower horsepower ratings, the single-phase motor is more commonly used by equipment vendors. The single-phase induction motor requires an internal wiring method to develop starting torque such as a starting winding and capacitor. The start winding and capacitor also determine the starting direction of the motor. Three phase induction motors (squirrel cage) are simple, dependable and work well in hot cells. In an induction motor, the AC voltage is supplied directly to the stationary stator winding and this generates a rotating magnetic field in the stator winding. The rotating magnetic field of the stator induces a current in the rotor of the motor. The current flowing in the rotor generates a magnetic field that causes the rotor to rotate. Variable frequency drives are commonly used to control motor speed when using a three phase induction motor.

8.2.8 *Linear Motors:*

8.2.8.1 Linear motors are typically used to move objects along a horizontal track. The linear motor and track can be straight or may contain slight curves. In hot cell applications, their primary use would be to move material in carts. Linear motors produce linear motion with only a stationary component, usually the stator, and a moving component, usually a reaction plate or a permanent magnet, located on the cart. The simplicity of a linear motor gives it an advantage over conventional motors and cylinders used to produce a linear motion because the linear motors do not require additional hardware to convert rotary motion to linear motion. Also, linear motors typically can control acceleration, speed and multiple (more than two) positions more precisely than a pneumatic or hydraulic cylinder. There are two types of linear motors; linear induction motors and linear synchronous motors.

8.2.8.2 *Linear Induction Motor: (1)* A linear induction motor is essentially a three-phase, rotary, induction motor with the squirrel cage, or stator, laid flat. When energized, a three-phase, AC, traveling-wave magnetic field is produced in the stator. The reaction plate is the equivalent of the rotor. Currents are induced in the reaction plate by the traveling wave. The reaction between these two fields produces linear thrust. The primary induces a magnetic field in the secondary that is opposite the field produced in the excited primary. This produces the motive force. When stopped, no induced field is produced in the secondary, and therefore no holding force is available without using ancillary braking systems. Also, since it is an inductive process, heat is produced in the secondary that must be dissipated. Duty cycle, secondary surface area, position sensors, and convection cooling requirements must be considered when selecting a linear induction motor.

8.2.8.3 *Linear Synchronous Motor: (1)* A linear synchronous motor is similar to a linear induction motor; however, the reaction plate is replaced by a permanent magnet, so that the magnetic field is permanent, not induced. Typically, there is no significant heating of the magnet of a linear synchronous motor. A linear synchronous motor may hold the load in a fixed position with no significant heating of the magnet, which can be a significant advantage in hot cell applications.

8.2.9 *Motor Enclosure Types:*

8.2.9.1 *Open Drip Proof (ODP)*—These motors have venting in the end frame situated to prevent drops of liquid from falling into the motor within a 15 degree angle from vertical. These motors are designed for use in areas that are reasonably dry, clean, and well ventilated.

8.2.9.2 *Totally Enclosed Non-Ventilated (TENV)*—These motors have no vent openings. They are tightly enclosed to prevent the free exchange of air, but are not airtight. TENV motors rely on convection for cooling. They are suitable for use in areas where the atmosphere is damp or dirty. TENV motors are preferred over ODP motors for hot cell use because of the reduced potential for internal contamination. If used in an atmosphere other than air, the motor should be de-rated. For example, in argon gas atmospheres, the motor should be de-rated by at least 30 % because convection heat removal in argon gas is less than in air.

8.2.9.3 *Totally Enclosed Fan Cooled (TEFC)*—These motors are the same as TENV except that they have an external fan that provides cooling air over the outside of the motor frame.

8.2.9.4 *Explosion Proof*—These motors are specifically designed for use in hazardous (explosive) locations. Explosion proof motors can be TENV or TEFC.

8.2.10 *Motor Mounting:*

8.2.10.1 Commercially available or off-the-shelf motors used in a hot cell should be of a standard NEMA frame size. Standard NEMA motor frames come in a variety of sizes and often have a letter suffix which provides more specific frame information. If necessary, the frame mounting can be modified as required to accommodate different mounting schemes. Note that stepper and servomotors may not be available in NEMA motor frame sizes. **NEMA MG1**

8.2.10.2 The standard motor frames should be mounted to brackets or to remotely removable mountings. These mountings may in turn be held in place using toggle clamps and aligned using dowel pins or tapered guide pins. Other fastening systems include ball-lock pins or captured bolts. Occasionally, it is advantageous to make the motor and its mount sufficiently heavy to keep them in place by gravity and eliminate the need for fasteners.

8.2.11 *Causes of Electric Motor Failure in a Hot Cell:*

8.2.11.1 Motor failure in a hot cell is generally from the motor brushes or the electrical connecting cables. Motor windings are rarely the cause of motor failure in a hot cell.

8.2.11.2 A common reason for motor failure in a hot cell is that over time, the constant exposure to radiation embrittles the wire insulation, and the constant flexing of the wire cables causes the brittle insulation to crack and the wires to short circuit. A silicone rubber coated glass fiber-reinforced sleeving over the wire insulation has sometimes been used to minimize the effects of insulation failure.

8.2.11.3 In argon gas atmosphere hot cells, over-heating is a cause of motor failure because of the poor heat transfer characteristics of argon gas. Additional failures may result from higher electrical conductivity or low breakdown voltage of argon gas. Experience has shown that in an argon atmosphere hot cell, moisture content less than 50 ppm water causes motor brush failure. The lubrication properties of the motor brush depend on the graphite content of the brush and on the layer of copper oxide (commutator surface) that normally forms in the presence of oxygen and moisture. In argon atmosphere hot cells with low moisture, the standard motor brushes have been replaced with high altitude brushes made of silver-loaded self-lubricating carbon to extend the life of the motor.

8.2.12 *Pneumatic Motors:*

8.2.12.1 Pneumatic motors are generally less expensive and smaller than electrical motors, but they are not typically used in hot cells for several reasons. First, the high volume and velocity of the gas required to operate the tool contributes to the spread of radioactive contamination inside the hot cell; second, the introduction of an increased volume of gas into the hot cell may cause problems with the hot cell pressure control system; and third, they generally require frequent lubrication. Pneumatic motors and tools may be useful in applications where the motor may experience frequent stalls. The type of gas used to power the motor/tool must be compatible with the hot cell atmosphere. The type of application and the consequences of using a pneumatic motor/tool in a hot cell should be thoroughly evaluated before placing the motor into service.

8.2.13 *Hydraulic Motors:*

8.2.13.1 Hydraulic motors are not typically used in hot cells because it is generally undesirable to introduce a moderator (hydraulic fluid) into the hot cell and because there is a potential for a hydraulic fluid leak. In cases where hydraulic motors are used in hot cells, the reservoir and pumping system components are located outside the cell and the hydraulic hoses pass through the cell wall boundary through a feed-through. Another potential problem would be the cleanup and disposal of radioactively contaminated hydraulic fluid in the event of a leak inside the hot cell. When hydraulic systems are used, consideration should be given to using fluids that are non-hazardous (RCRA) and do not present flammability or mixed waste disposal problems if they become radioactively contaminated.

8.2.13.2 The hydraulic hose should be made of a material suitable for hot cell environments and be rated for the expected hydraulic pressure.

8.2.14 *Motor Maintenance/Repair/Replacement:*

8.2.14.1 Maintenance, troubleshooting, and repair of motors should be performed by personnel familiar with the equipment.

8.2.14.2 Repair of motors that have been used in a hot cell can be difficult and time consuming. It is generally advisable to discard and replace motors that fail in service. The motors should be equipped with a mounting scheme that allows easy change-out of the failed motor using the remote handling methods. Otherwise, the equipment may have to be transferred to a radioactive repair area where personnel suited in protective clothing enter to repair and/or replace the failed motor. C1554

8.2.14.3 Motors should be periodically checked for loose connections. Also, the heat sink areas should be cleaned regularly and the vent slots should be cleared of dust and debris on motors that require forced cooling.

8.3 *Bearings/Bushings:*

8.3.1 *General:*

8.3.1.1 Bearings and bushings are often designed as part of a larger subassembly that will be replaced if needed due to the problems of replacing individual pieces installed with typical clearances. If desired, commercial split-housing bearings can be mounted with more complex tapered shafts as shown in Figs. 2 and 3 for individual remote disassembly and replacement. Any advantages gained with this approach must offset the increased initial costs. It is recommended that a proper lubricant be selected and that bearings used in-cell be lubricated for the life of the bearing. Only bearings and bushings designed to be operated and replaced in a remote hot cell environment should be considered for use in this type of facility, unless the module containing the bearing is designed to be replaced in its entirety. Bearings should be a self-contained unit to avoid loss of parts during maintenance. Typically, bearings used in hot cells can be classified as *(1)* ball, *(2)* roller, *(3)* needle, *(4)* tapered roller, and *(5)* thrust types. The bearing

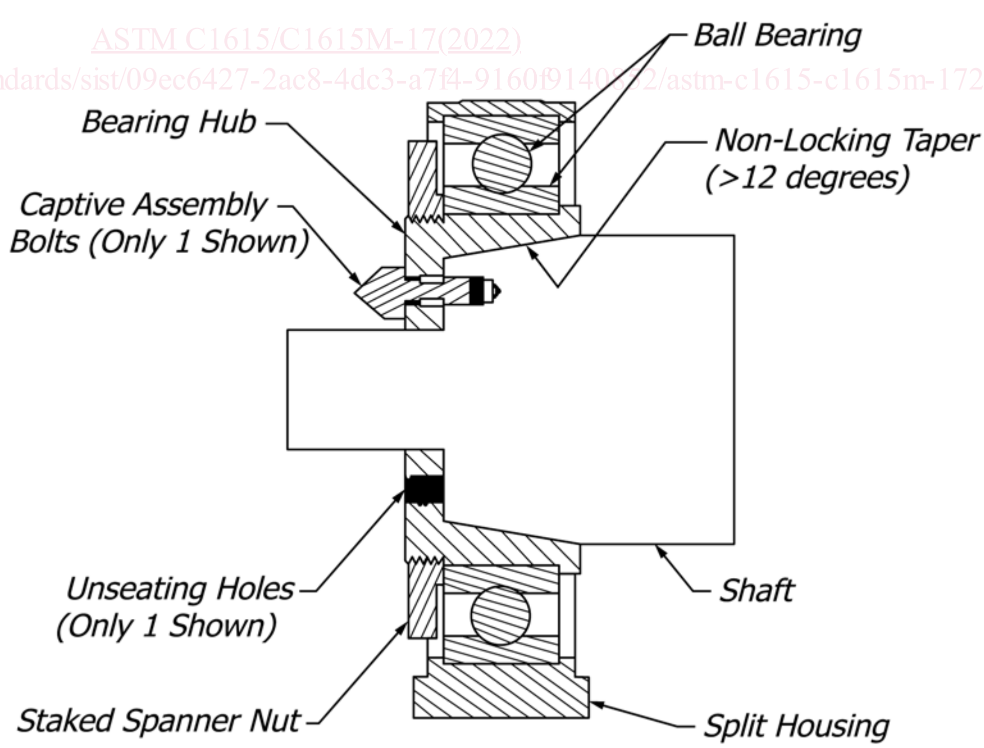

FIG. 2 Example of a Large Shaft Mounting For Remote Bearing Replacement