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Standard Guide for Hot Cell Specialized Support Equipment and Tools[1]

This standard is issued under the fixed designation C1725; 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 This guide presents practices and guidelines for the design and implementation of equipment and tools to assist assembly, disassembly, alignment, fastening, maintenance, or general handling of equipment in a hot cell. Operating in a remote hot cell environment significantly increases the difficulty and time required to perform a task compared to completing a similar task directly by hand. Successful specialized support equipment and tools minimize the required effort, reduce risks, and increase operating efficiencies.

1.2 *Applicability:*

1.2.1 This guide may apply to the design of specialized support equipment and tools anywhere it is remotely operated, maintained, and viewed through shielding windows or by other remote viewing systems.

1.2.2 Consideration should be given to the need for specialized support equipment and tools early in the design process.

1.2.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *Caveats:*

1.3.1 This guide is generic in nature and addresses a wide range of remote working configurations. Other acceptable and proven international configurations exist and provide options for engineer and designer consideration. Specific designs are not a substitute for applied engineering skills, proven practices, or experience gained in any specific situation.

1.3.2 This guide does not supersede federal or state regulations, or both, or 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 *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

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

A453/A453M Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

C859 Terminology Relating to Nuclear Materials

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

C1533 Guide for General Design Considerations for Hot Cell Equipment

C1554 Guide for Materials Handling Equipment for Hot Cells

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

C1661 Guide for Viewing Systems for Remotely Operated Facilities

SI10-02 IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *Federal Regulations:*[3]

10 CFR 830.120 Subpart A, Nuclear Safety Management, Quality Assurance Requirements

[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.

[3] 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.

2.3 *Other Standards:*[4]

ANSI/ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications

ANSI/ISO/ASQ 9001 Quality Management Standard Requirements

3. Terminology

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

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

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *acorn-head (cone-head) fastener*—a bolt or screw with a rounded spherical head tapering into a standard hex head resembling the shape of the bottom portion of an acorn (or cone), the purpose of which is used to guide and align a tool onto the bolt head.

3.3.2 *alignment (guide) pin*—a pin used to align two mating components by mating a pin mounted in one component with a precisely sized and positioned hole in the mating part. Multiple pins are typically required for proper alignment depending on the configuration and orientation of the mating surfaces.

3.3.3 *captive fastener*—a bolt or screw physically retained on a component that remains attached when mating parts are separated. Using captive fasteners eliminates the risk of dropping the fastener and helps to maintain the fastener in a ready to use position. It can also apply to nuts when mating components are too thin for threading.

3.3.4 *grapple*—a removable tool that attached by means of a non-threaded connection to equipment and interfaces with an overhead crane or electro-mechanical manipulator to lift and move the equipment.

3.3.5 *lifting bail*—lifting handle, hook, or cable generally attached over the center of gravity of the equipment to aid remote handling.

3.3.6 *power manipulator*—manipulator controlled by an operator outside of the hot cell with the in-cell slave-arm powered by electric, pneumatic, or hydraulic actuators.

4. Significance and Use

4.1 This guide is relevant to the design of specialized support equipment and tools that are remotely operated, maintained, or viewed through shielding windows, or combinations thereof, or by other remote viewing systems.

4.2 Hot cells contain substances and processes that may be extremely hazardous to personnel or the external environment, or both. Process safety and reliability are improved with successful design, installation, and operation of specialized mechanical and support equipment.

4.3 Use of this guide in the design of specialized mechanical and support equipment can reduce costs, improve productivity, reduce failed hardware replacement time, and provide a standardized design approach.

5. Design Requirements

5.1 The complexity, performance, reliability, and life expectancy of support equipment will be determined by the facility purpose, configuration, and radiation levels. A production facility may require robust designs intended to be extensively used for the life of the facility. In contrast, equipment for a research or analytical facility may be intended only for limited short-term experiments.

5.2 Present and future radiation levels, chemical exposures, and other severe environmental conditions should be well understood for their impact on material performance, life expectancy, and disposal.

5.3 Limitations of the facility handling equipment should be identified and possible constraints imposed on support equipment and tools understood. Applicable inputs include lift capacities, range of motion, force limits, and areas of coverage. A specific example is to use the repeatable minimum incremental movement of the handling equipment to size features for easy alignment with appropriate tool.

5.4 Operator interfaces with handling equipment should also be identified to understand how the operator verifies successful task completion or recognizes when a problem occurs. Refer to Guides C1217, C1533, C1554, C1615, and C1661 for additional descriptions of hot cell equipment design requirements.

6. Quality Assurance, Qualification and Acceptance

6.1 Facility owners and program managers should establish a quality assurance program to assure proper equipment operation and reliability consistent with that required for facility operations as outlined by law or the agency of jurisdiction. Quality assurance programs may be required to comply with 10 CFR830.120, ANSI/ASME NQA-1, or ANSI/ISO/ASQ 9001.

6.2 Quality assurance specifications should be established to ensure all procurement and fabrication meets the design specifications. The level of complexity and risk consequences should be used to determine the level of required certification documentation and the degree of inspection.

6.3 Components should be tested in a simulated operating environment (mockup) before in-cell installation or use to verify remote operability, maintainability, and to reduce the risk of unexpected problems. The level of complexity and risk consequences should be used to determine the degree of simulation required to test designs before remote implementation.

6.4 Equipment to be used in nuclear or other regulatory controlled facilities may be required to meet specific qualification requirements and documentation by the regulatory agency prior to installation or use.

7. Remote Handling Features

7.1 *Manipulator Finger Guides*—Guides for the fingers on the in-cell portion of the manipulators provide positive grips

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

when handling items and prevent unnecessary damage and delays resulting from dropped items. Fig. 1 is an example of finger grips fabricated from sheet metal and attached to a tool. Fig. 2 shows an example of flats machined into a round shaft to match the manipulator fingers.

7.2 *Positive Latch Indicators*—Latch indicators identify when a component is properly positioned or when a grapple is properly engaged. Fig. 3 is an example of a positive latch indicator for a threaded grapple that must engage mating threads in a non-visible location. As the grapple is threaded into position, the push rod contacts the bottom surface of the mating hole and slides a sleeve over a color-coded band. Full engagement is indicated when the color band is no longer visible.

7.3 *Lanyards*—A lanyard may be used to secure loose parts at risk of being dropped. Lanyards may also be attached to connectors or pins to aid in releasing latching mechanisms that are difficult to operate when using manipulators. Lanyards are typically thin wire ropes that are attached to the part and to a more rigid or fixed equipment item. Fig. 4 shows an example of a removable pin being secured using a lanyard.

7.4 *Lifting Features:*

7.4.1 *Hooks*—Crane hooks used in hot cells typically have no motorized rotational capability. To compensate for this limitation, hooks can be modified or an additional special purpose hook can be used below the regular hook. Fig. 5 is an example of a modified hook with an extended nose that guides the hook onto lifting features. Fig. 6 is an example of a detachable treble hook requiring minimal rotation for alignment. The treble hook is also inherently self-standing when removed from the regular crane hook and stored. The crane hooks illustrated do not have load locking mechanisms. Locking mechanisms that lock the load into the hook require special consideration. As a result, hooks without locks are common and often designed with deeper throats to help secure loads during handling. When used, locks should be designed so actuator failures leave the lock in the open position. A lock in the open position should not hinder normal crane hook operation. Manual actuation of a lock limits its use to locations where the locking mechanisms can be reached with a manipulator.

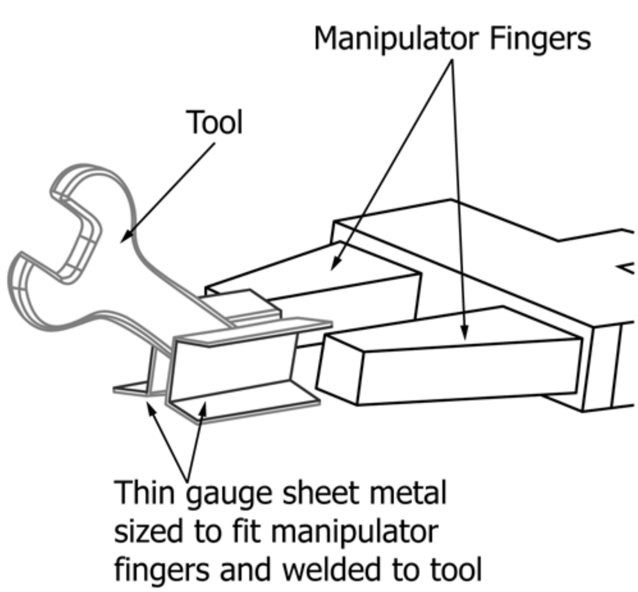

FIG. 1 Sheet Metal Grips

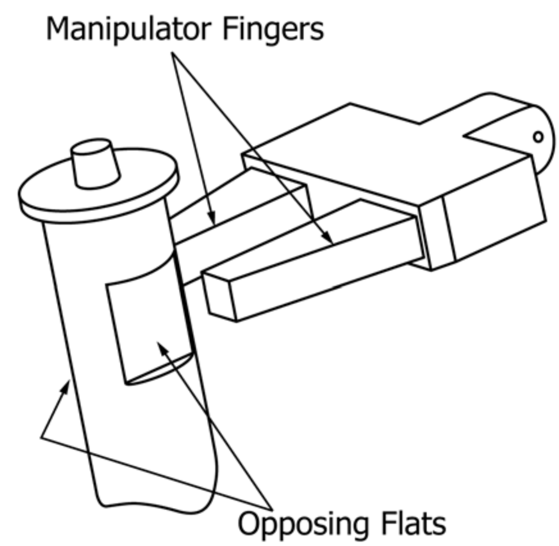

FIG. 2 Machined Flats

7.4.2 *Swivel Hoist Rings*—Swivel hoist rings have been used extensively in hot cells for lifting equipment because of their multidirectional loading capability. They swivel 360° to compensate for pitch, roll and sway when lifting unbalanced loads. Fig. 7 is an illustration of a typical swivel hoist ring using a convenient deep-socket head screw for ease of installation.

7.4.3 *Lifting Bails*—Lifting bails on equipment should be self-standing or have locking positions maintaining clearances for easy engagement of hooks as shown in Fig. 8. Cable bails should be constructed from self-supporting stiff material and attached using a shoulder bolt with large diameter washer to secure the loop at each end. Fig. 9 shows details for typical cable bail attachment. Bails should be located over the center of gravity to avoid uncontrollable motions when the lifted component becomes unrestrained. Potential shifting of the center of gravity needs to be considered when multiple handling configurations exist, such as handling a container either empty or loaded.

7.4.4 *Grapples*—A grapple is a lifting device that is typically separate from the equipment to be lifted, and may be designed to lift several different equipment items. Using grapples is a way to standardize lifting schemes for multiple pieces of equipment and it may simplify lifting designs and improve ease of handling. Grapples generally have positive locking mechanisms. The locking mechanisms should be operable by manipulators and include latched and unlatched indication. Fig. 10 is an example of a ball-detent quick-lifting grapple designed to handle flat cover plates and container lids. To use, the grapple is inserted a mating hole and locked by rotating a handle pushing locking balls outward into a larger diameter recess. The mating hole in the load must be precisely machined with proper clearance for expansion of the locking

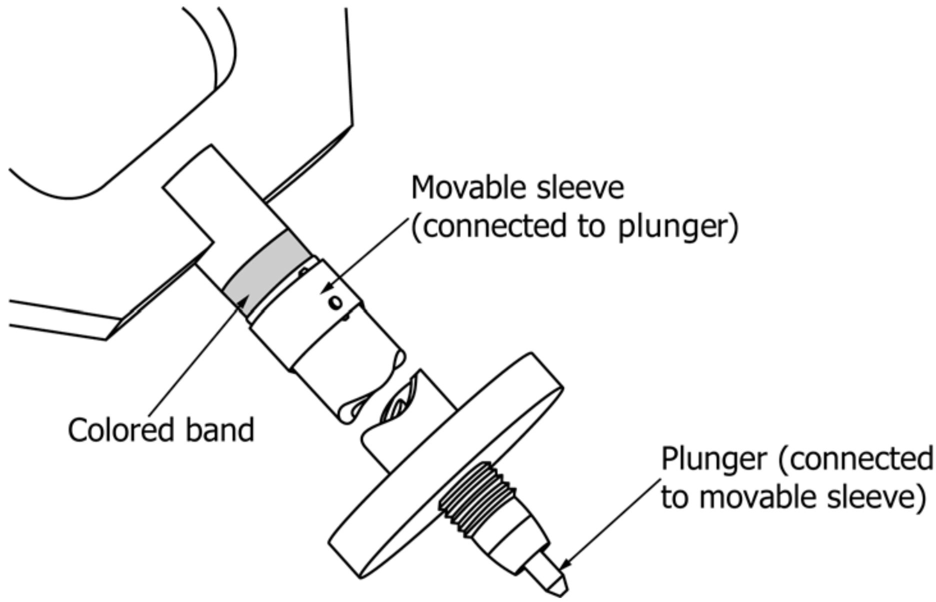

FIG. 3 Positive Latch Indicator

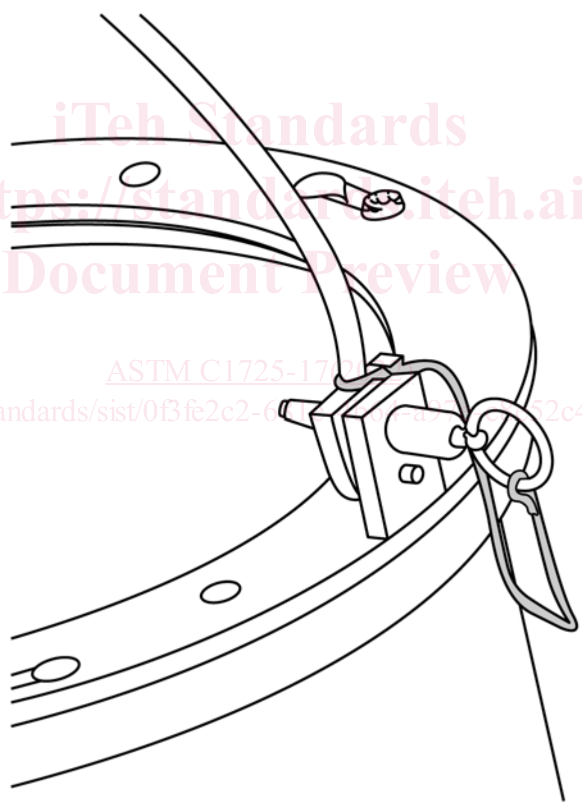

FIG. 4 Lanyard Securing Removable Pin

balls and also provide a shoulder to restrain the balls when the grapple lifts the load. The lifting capacity is limited by the material characteristics of the locking balls and hole shoulder. As shown, the hole in the load may be a single diameter when the mating plate is thin or a stepped hole when thicker. Fig. 11 illustrates a grapple designed to handle round bails and is equipped with a sliding sleeve to lock the bail in the grip.

7.5 *Positioning and Clamping Features:*

7.5.1 *Toggle Clamps*—Toggle clamps come in a variety of sizes and configurations and function as a quick action clamping device. Toggle clamps are typically used in light-duty clamping applications for parts that are frequently installed and removed. They are useful in hot cell environments because they are easily actuated using master-slave manipulators. An advantage of most toggle clamp designs are that when the handle is opened, the clamping arm completely clears the work

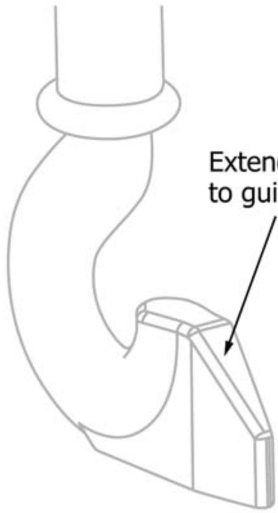

FIG. 5 Extended Nose

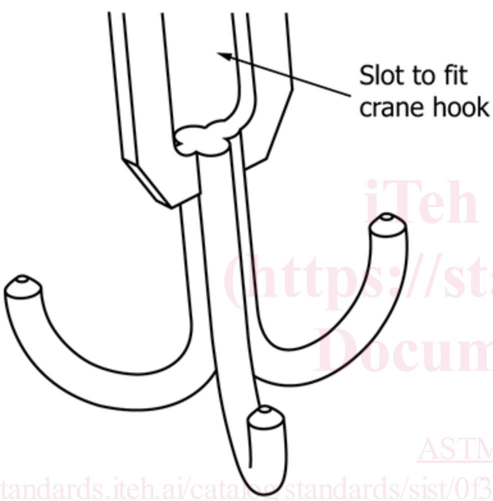

FIG. 6 Detachable Treble Hook

area, providing clearance for loading and unloading parts. Most toggle clamps feature locking handles to provide a continuous holding force using an over-center cam action that also provides protection against unintentional release. See Fig. 12.

7.5.2 *Double-acting Ball Lock (Quick Release) Pins*—Single-acting ball lock pins require two manipulators to operate and are not suitable for remote operations. Double-acting pins provide positive locking for many types of remote applications. An internal spring holds the spindle in a center position locking the balls. Pushing the spindle retracts the balls allowing insertion of the pin and pulling the spindle also retracts the balls allowing removal of the pin. This motion can be accomplished with a single manipulator for both insertion and removal of the pin. These pins are typically available in heat treated steel to withstand high shear loads or stainless steel to resist corrosion. The mating-hole clearance for the pin must be precisely machined per manufacturer's instructions for reliable operation. Different handle styles are available. The ring handle style shown in Fig. 13 allows insertion of a slave finger into the ring for a positive grip and is recommended for most applications. The ring is often brazed to the spindle to fix it in the most accessible position. A captive configuration is shown in Fig. 13. For non-captive designs, a lanyard is recommended for securing the pin to equipment as shown in Fig. 4. Lanyard use eliminates the potential for dropping loose pins while handling.

7.5.3 *Spring Plungers*—Retractable spring plungers are useful as positioners, locating pins, and indexing devices in remote equipment applications. The locking T- and L- handle plungers have a rest position where the plunger can stay in the retracted position as shown in Fig. 14. The T- and L- handles are easily withdrawn and re-engaged using master-slave manipulators.

7.6 *Alignment Features*—Mating components often need guides to assure successful remote assembly and to prevent damage or incorrect assembly orientation.

7.6.1 *Guide Pins*—Guide pins provide precise alignments for applications such as when mating electrical connectors. Dual diameter (two stage) or long taper pins provide initial gross alignment followed by fine alignment and are recommended when multiple pins are used with a single connection. The small pin diameter provides an initial gross alignment to the mating hole that transitions to the final precise alignment as the large pin diameter engages. Multiple pins of unequal length allow for an easier one-hole-at-a-time engagement. The use of a single pin controls positional alignment with rotation remaining free. Engaging a second pin controls angular orientation and may be a pin mating to a slot with relaxed tolerances in the slotted direction as shown in Fig. 15. Fig. 16 shows an alternative configuration using a diamond shaped pin mating with a round hole to control angular orientation. It also illustrates the use of different diameter pins to eliminate multiple mating possibilities with symmetrical layouts. Asymmetrical guide pin layouts are also used to prevent incorrect assembly orientation as shown in Fig. 17.

7.6.2 *Guide Brackets (Guide Plates)*—Flat plates are often bevel cut or bent to provide alignment when tolerances are less critical. Fig. 18 is an illustrative example showing alignment guide plates.

7.6.3 *Key Slots*—These features allow components to be correctly aligned and easily assembled in remote applications. The key slot is cut in a flat plate of one part and typically mates with a shoulder bolt or pin with a flange on the mating part. The circular portion of the key slot provides some coarse alignment with more precise alignment occurring as the mating part slides to the end of the slot. Vertical slots as shown in Fig. 19 often use gravity to hold the mating parts in the assembled position. The slots shown in Fig. 20 use a counter bore and locking cap screw to provide a positive locking position.

7.6.4 *Guide Combinations*—Combinations of guides and securing features keep designs simple, robust, and reliable while meeting process requirements. Gravity, for example, is often used to help position and secure components. For each redundant guide that can be eliminated, the design solution is simplified and the assembly time is reduced. Fig. 21 shows a horizontal drive motor positioned and secured in such a manner. It is possible to complete the assembly with only a single power manipulator or crane. Fig. 22 shows details of the drive coupling. An external tooth spline gear is fixed to each shaft. The internal tooth spline coupling is held in position on

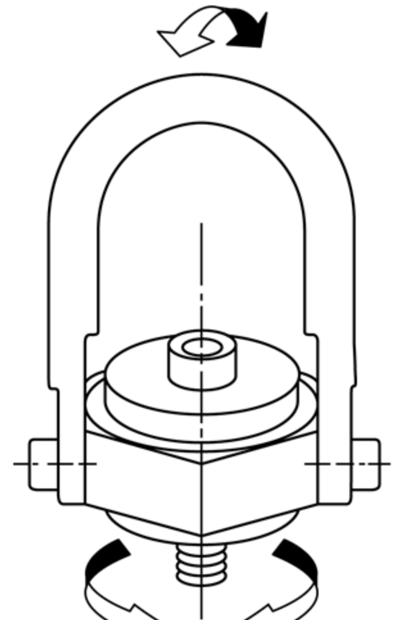

FIG. 7 Swivel Hoist Ring

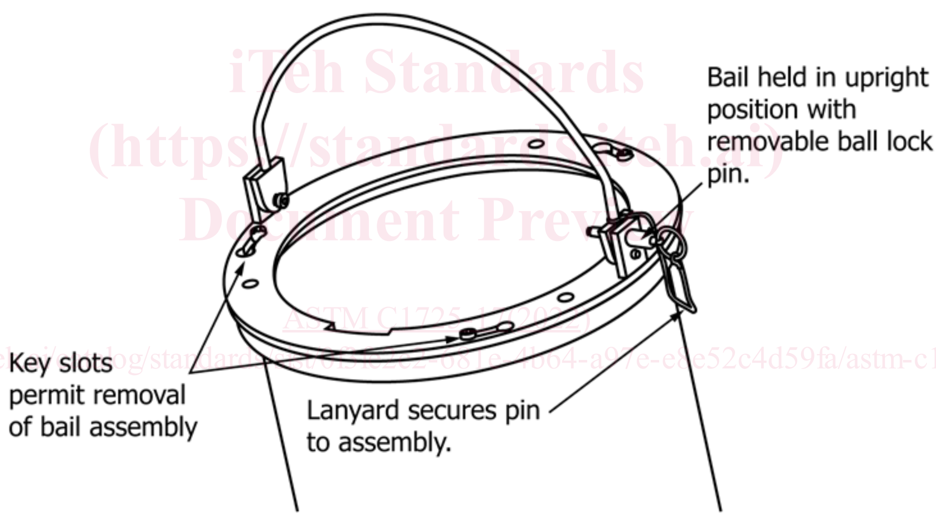

FIG. 8 Lifting Bail with Locking Position

one of the external spline gears with two internal snap rings allowing some movement between the two gears. Chamfers on the mating faces of the splines guide the splines into position as they meet. Making multiple connections with a single multi-connector plate can simplify the process of making multiple connections and reduce the needed space. Fig. 23 shows the two halves of a multi-connector plate system. Making multiple connections simultaneously requires the use of multiple guide pins, captive closure bolts, and controlled application of closure forces. Cranes or power manipulators are typically used to initially position plates until the connectors begin to engage. Captive screws are then engaged for the final closure and securing. In the example shown, a single fastener is used which requires analysis and balancing of closure forces about the fastener to prevent binding.

7.7 *Threaded Connections*—Remote-assembled threaded connections can be difficult to design and it is recommended alternatives be considered whenever feasible. The needed rotary motion is difficult for manual manipulators to execute and the consequence of cross-threading or galling is catastrophic. When threaded fasteners are selected, consider standardizing with a single or a limited number of fastener types and sizes to minimize the variety and number of tools needed.

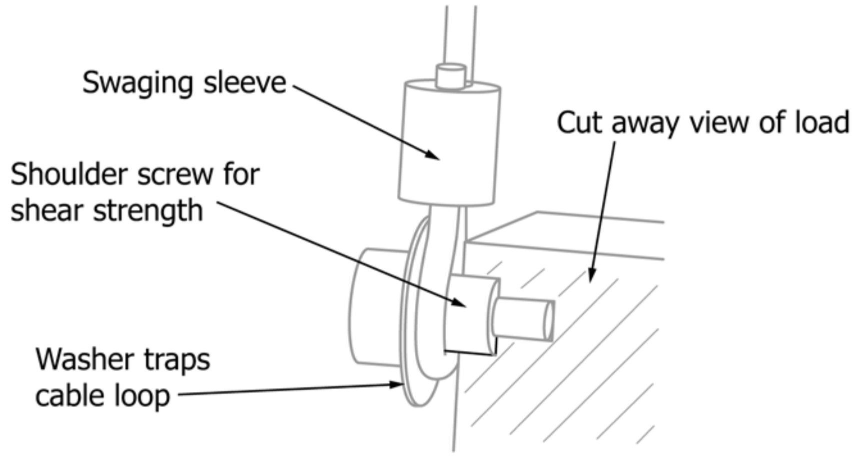

FIG. 9 Cable Bail Attachment Detail

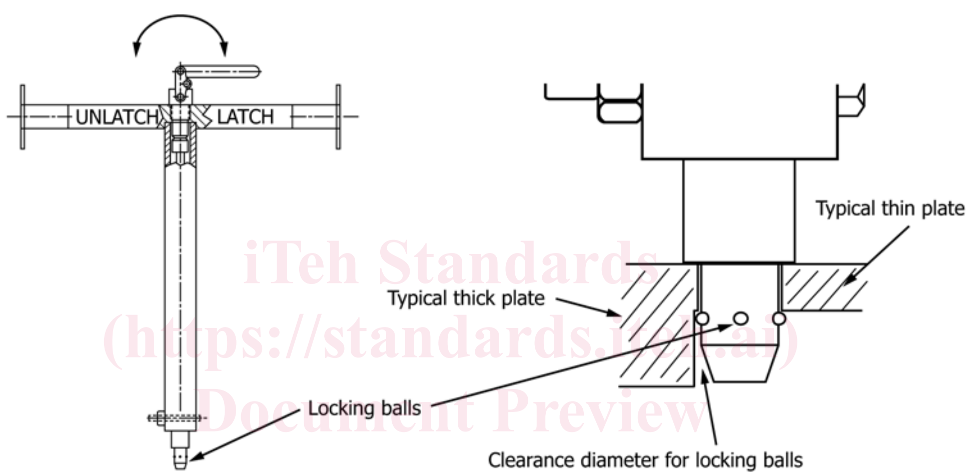

FIG. 10 Ball-detent Quick-lifting Handle with Detail of Locking Balls and Clearances

Avoid fastener sizes smaller than 0.25 in. (M6), slotted head screws, Phillips head screws, or shallow depth socket-head cap-screws.

7.7.1 *Captive Systems*—Use captive systems to prevent dropped and lost parts. Avoid loose washers and nuts. Spring loaded screws provide a positive indication when threads are disengaged. Fig. 24 and Fig. 25 below illustrate some possible configurations.

7.7.2 *Fastener Head Styles*—Consider using tall hex-head or deep socket-head bolts and screws that self-support sockets and hex wrenches. Cone or acorn shaped hex-head fasteners, as shown in Fig. 24 may be necessary to guide socket wrenches onto the fasteners. Welding key stock to the fastener head forms a T-handle, as also shown in Fig. 24 enabling manipulators to rotate the fastener without the need for additional tools. The manipulator can often turn the T-handle with a circular whole-arm motion pushing on one end of the handle. This motion is easier than rotating the manipulator wrist.

7.7.3 *Cross-Threading Resistance*—Removing external threads for a length of ½ the thread diameter of a screw provides an assembly lead-in and reduces the risk of cross-threading. Fig. 24 and Fig. 25 illustrate the use of a thread lead-in. Coarse threaded fasteners are preferred as they are less prone to damage and cross threading.

7.7.4 *Thread Types*—ACME (or similar) threads reduce torque requirements and increase galling resistance. Conventional and ACME threads are shown in Fig. 26. The ACME thread is a mechanically robust thread used extensively in power transmission. The thread design applies a higher and more consistent loading with the same input torque when compared to a conventional thread, but has less self-locking capacity which increases the potential for loosening due to vibration. Consider ACME threads when frequent assembly or high torque is required, or when conventional thread performance is unsatisfactory.

7.7.5 *Corrosion, Wear, and Galling Resistance:*

7.7.5.1 Select material combinations for compatibility with mechanical requirements and environmental conditions to avoid excessive wear, galling, and galvanic or chemical corrosion. This ensures components can be remotely assembled and disassembled for maintenance and repair throughout their life expectancy. The use of conventional lubrication may be limited or not permitted if it is considered a neutron moderating material or if it could contaminate sensitive in-cell processes.