ESTA

BSR E1.4-3 - 201x
Entertainment Technology—Manually Operated Hoist Rigging Systems

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The ESTA Technical Standards Program

The ESTA Technical Standards Program was created to serve the ESTA membership and the entertainment industry in technical standards related matters. The goal of the Program is to take a leading role regarding technology within the entertainment industry by creating recommended practices and standards, monitoring standards issues around the world on behalf of our members, and improving communications and safety within the industry. ESTA works closely with the technical standards efforts of other organizations within our industry, including USITT, ESTA, and VPLT, as well as representing the interests of ESTA members to ANSI, UL, and the NFPA. The Technical Standards Program is accredited by the American National Standards Institute.

The Technical Standards Council (TSC) was established by to oversee and coordinate the Technical Standards Program. Made up of individuals experienced in standards-making work from throughout our industry, the Committee approves all projects undertaken and assigns them to the appropriate working group. The Technical Standards Committee employs a Technical Standards Manager to coordinate the work of the Committee and its working groups as well as maintain a "Standards Watch" on behalf of members. Working groups include: Control Protocols, Electrical Power, Event Safety Floors, Fog and Smoke, Followspot Position, Photometrics, Rigging, and Stage Lifts.

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The Rigging Working Group, which authored this [DRAFT] Standard, consists of a cross section of entertainment industry professionals representing a diversity of interests related to rigging and stage machinery for theatrical events. ESTA is committed to developing consensus-based standards and recommended practices in an open setting. Future Rigging Working Group projects will include updating this publication as changes in technology and experience warrant, as well as developing new standards and recommended practices for the benefit of the entertainment industry.

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Foreword

Prior to final approval of ANSI E1.4-2009, no American National Standard had addressed safety of counterweight rigging systems for the entertainment industry. The first documented recognition that safety standards were needed occurred in the early 1960's, when the United States Institute for Theatre Technology (USITT) established its Codes Commission to monitor and report on development of national codes that might be applicable to the entertainment industry. This commission eventually expanded its scope to include the Health & Safety subcommittee. By 1965 USITT had acknowledged that industry standards were necessary to ensure safety in the industry. The first formal, documented effort to accomplish this goal spawned from a Theatre Architecture Commission panel discussion at the 1980 USITT Conference in Kansas City, Missouri. In order to improve the level of safety and to establish a minimum standard for the manufacture of rigging equipment for use in the entertainment industry, the United States Institute for Theatre Technology, Inc. (USITT) established its Rigging and Stage Machinery Standards Committee, with the mission of creating a comprehensive set of standards for this purpose. To further this goal, sub-committees were established to write standards in several areas that combine to achieve a set of standards to fully describe the mechanical equipment used in theatres. This document is an evolution of work first started by separate sub-committees for Manual Counterweight Flying Systems and for Rope and Sandbag Flying Systems. The resulting efforts were combined to form the basis of this document.

It was originally intended that this document be accepted as a standard of USITT and that it ultimately become an American National Standard. In order for the latter to happen, the USITT draft document was turned over to ESTA's Technical Standards Program (now the ESTA Technical Standards Program). It has been further developed by the Rigging Working Group within that program. Members of the Rigging Working Group include appropriately qualified people who represent the broader industry of people who specify, manufacture, sell, and use this equipment, so that all interests are recognized and the standards represent a great depth of knowledge and experience in regards to the equipment.

In 2014, the RWG approved expansion of E1.4's scope, into a suite of related standards, which are currently in development. This draft represents the 3rd installment to a planned suite of 4.

This document establishes minimum standards for equipment. However, the proper installation and operation of this equipment are equally important. Equipment shall be installed, operated and maintained under the supervision of a competent person. Further, the selection of the proper equipment for any application shall be entrusted only to experienced personnel with the proper knowledge and training to recognize and understand all of the hazards and functional requirements involved in the particular installation.

This standard represents equipment manufactured under the constraints of current technology. It is not intended to restrict further developments or enhancements. Revisions of this standard will be considered by the committee in the light of further advances in technology, changes in entertainment requirements, and operating practices. Future revisions will not imply that previous editions of the standard were inadequate. Nor is it the intention of this standard to suggest that equipment manufactured before the creation of this standard is inherently inadequate.

Reference standards organizations

The following standards organizations have developed specific standards documents that may pertain to certain normative requirements of this standard. It is not intended to identify all such organizations, or their respective standards, nor is it intended to imply that compliance with any such standard constitutes an exemption from any legal, jurisdictional, or OSHA-related safety requirements that may exist.

AISI - American Iron and Steel Institute, Inc.
ANSI - American National Standards Institute
ASME - American Society of Mechanical Engineers
ASTM - American Society for Testing and Materials
AWS - American Welding Society
ESTA - Entertainment Services and Technology Association
IFI - Industrial Fasteners Institute
ISO - International Organization for Standardization

NACM - National Association of Chain Manufacturers
SAE - Society of Automotive Engineers

1 Scope

1.1 General
This standard applies to permanently installed, manually operated hoists used as part of rigging systems for raising, lowering, and suspension of scenery, properties, lighting, and similar loads. This standard establishes requirements for the design, manufacture, installation, inspection, and maintenance of manually operated hoist systems for lifting and suspension of loads for performance, presentation, and theatrical production.

1.2 Building Structures

This standard applies to the mechanical hoist and rigging hardware only, not to the structure from which it is supported. While not part of this standard, the ability of the building structure to support the intended loads shall be considered in the design and application of rigging systems.

1.3 Annex note references
This document uses annex notes to provide additional reference information about certain specific section requirements, concepts, or intent. Subject matter with a corresponding annex note reference is identified by the asterisk (*) symbol and the text “See Annex note;” the associated reference text is found in the Annex A section, identified with the referring text section number, e.g. an Annex Note to section 3.2 will be identified in the annex section as A.3.2.

1.4 Exclusions

1.4.1 Performer flying
This standard does not apply to performer flying, or to raising or lowering people.

1.4.2 Powered rigging
This standard does not apply to any equipment used in permanently powered rigging systems.

1.4.3 Other rigging
This standard does not apply to E1 Entertainment Technology equipment covered under the scope of other existing standards.

1.5 Intent
The purpose of this standard is to establish minimum performance requirements for manually operated hoists used in rigging systems. This standard establishes safeguards to public health, safety and general welfare with the intent to minimize hazards associated with Manually Operated Rigging Systems.

1.6 Alternative designs
This standard is not intended to prevent or limit alternative designs, materials, or technology. Alternative designs, materials or technology shall comply with the intent of this standard, and with the requirements of any other standard deemed applicable by a qualified person.

2 References

All equipment shall be manufactured and installed to comply with this standard and any applicable codes or jurisdictional regulations where the requirements of such codes or regulations are more stringent.

The following documents are referenced. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document, including any amendments, shall apply.

ANSI E1.2-2012 Design, Manufacture and Use of Aluminum Trusses and Towers

ANSI E1.4-1-2016 Manual Counterweight Rigging Systems

ANSI E1.6-1-2019 Entertainment Technology--Powered Hoist Systems

ANSI Z535.1-2017, Safety Colors

ANSI Z535.2-2011 (R2017), Environmental and Facility Safety Signs

ANSI Z535.3-2011 (R2017), Criteria for Safety Symbols

ANSI Z535.4-2011 (R2017), Product Safety Signs and Labels

ANSI Z535.6-2011 (R2017), Product Safety Information in Product Manuals, Instructions and Other Collateral Materials

3 Definitions

3.1 Batten: A pipe, tube, or other singular structural shape that is secured to the lift lines for the purpose of connecting loads to the system.

3.2 Block: An assembly of one or more sheaves in a housing designed to support one or more lines to allow a change of direction.

3.3 Characteristic load: The maximum force applied to a component of a hoist system resulting from normal intended operating conditions while the system is at rest or in motion. This includes the apportioned fractions of the working load limit (WLL), self-weight including that due to load carrying devices and lifting media, and the forces due to inertia in normal use. *(See Annex note.)

3.4 Clew: A device with multiple holes used to connect several lift lines into a common line.

3.5 Competent person: A person who is capable of identifying existing and predictable hazards in the workplace, and who is authorized to take prompt corrective measures to eliminate them.

3.6 Design factor: (a) A ratio of the ~~design~~ working load limit to the yield strength of a material or component; (b) A ratio of the ~~design~~ working load limit to the ultimate strength of a material or component where the material does not plastically deform prior to failure. *(See Annex note.)

~~**3.6 Design load:** See **3.35 working load limit**.~~

3.7 Drive augmentation: Use of a non-integrated powered device as the prime mover to operate a hoist. (e.g., drill drive).

3.8 Guide system: Components and assemblies used to guide a clew, including components attached to the clew specifically for such purpose, and including clew travel- limiting components such as a stop.

3.9 Hand winch: See **3.18 Manually operated hoist.**

3.10 Haul line(s): The primary tension load path element connecting the hoist to the other rigging components.

3.11 Hoist system: See **3.15 Line set.**

3.12 Installer: The person or organization that is responsible for the installation of the rigging equipment.

3.13 Lift line: Any lifting media reeved through head blocks and loft blocks, and attached to a load. Lift lines operate singly, as spot lines, or in "sets" of several lift lines working together to support a load or a batten.

3.14 Lifting medium: the load-carrying element that is driven by the hoist to move the load (e.g. wire rope, roller chain).

3.15 Limits of use: the parameters under which the system is designed to operate (e.g. working load limit, speed of movement, duty cycle, environmental conditions, user skill level, availability of maintenance).

3.16 Line set: A system of one or more lift lines, operated together to raise, lower, or suspend a load; all of the mechanical, component subsystems required for supporting, positioning, and operating those lift lines as a system.

3.17 Load carrying device: the component(s) of the hoist system that connect a suspended load to the lifting media (e.g. batten, truss, and hook).

3.18 Load securing device: a mechanical device that prevents unintentional movement in the hoist system.

3.19 Manually operated hoist: A hoist primarily intended and designed to be hand-operated.

3.20 Peak load: The maximum force applied to a component of a hoist system, while the system is at rest or in motion, resulting from abnormal conditions or irregular operation. *(See Annex note.)

3.21 Pile-on drum: drum in which the individual lifting media are confined in separate winding chambers so that the lifting media winds in concentric layers.

3.22 Pitch diameter: The diameter of a sheave or drum measured to the centerline of the rope for which it is designed.

3.23 Power transmission system: the components within the hoist that create, transfer, support, or dissipate mechanical force and motion (e.g. gears, shafts, clutches, couplings, bearings, brakes).

3.24 Qualified person: A person who by possession of a recognized degree or certificate of professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

3.25 Reeve: To pass lifting media over the sheaves in a block or a system of blocks.

3.26 Reverse bend: A condition where a line is reeved so that it bends in opposing directions, over two or more sheaves.

3.27 Rigging: General term for arrangements of hardware and systems for the raising, lowering, and suspension of scenery, properties, lighting, and similar loads used in performance venues.

3.28 Risk: combination of the probability of occurrence of harm and the severity of that harm.

3.29 Risk assessment (RA): the process of identifying, evaluating, and quantifying the potentially hazardous conditions, severity, and probability of occurrence of harm.

3.30 Risk reduction (RR): mitigation of risk created by hazardous conditions.

3.31 Shall: A term used in this standard to indicate that an action is mandatory.

3.32 Should: A term used in this standard to indicate that an action is recommended under most conditions, but is not mandatory

3.33 Static load: The maximum force applied to a component of a hoist system resulting from normal intended operating conditions while the system is at rest. This includes the apportioned fractions of the working load limit (WLL) and self-weight, including that due to load carrying devices and lifting media. *(See Annex note.)

3.34 Tension load path: The path of tension-only load that follows the axis of the lifting media, including all connections and terminations along this path.

3.35 Ultimate load carrying capacity: The maximum load an assembly may support without failure. ~~or permanent deformation, as determined by nationally recognized construction standards appropriate for the given material.~~ . This value may be calculated as the nominal strength using nationally recognized construction standards appropriate for the given material or by laboratory tests

3.36 Wire guide: Tensioned wire ropes used to guide the path of counterweight arbors or clews.

3.37 Working load limit: ~~The maximum rated capacity of a component or system during normal operating conditions, as determined by the component manufacturer, or as determined by a qualified person for a specific application.~~ The maximum static load the user may apply.

4 Risk assessment and risk reduction

4.1 Risk assessment and risk reduction (RA/RR) for a hoist or hoist system shall be performed throughout design, fabrication, installation, and testing. Risk assessment and risk reduction shall be performed when hoists or hoist systems are modified.

4.2 Risk assessment and risk reduction shall be performed by a group of two or more competent persons. When a group of two or more competent persons are not available, completion of the risk assessment and risk reduction by one qualified person shall be permitted.

4.3 The group or person performing the risk assessment and risk reduction shall determine the acceptable level of residual risk.

4.4 The group or person conducting a risk assessment and risk reduction shall:

4.4.1 Identify and document the limits of use;

4.4.2 Identify and document the tasks anticipated throughout the life of the system;

4.4.3 Identify and document the hazards associated with each task;

4.4.4 Estimate the severity of harm associated with exposure to the hazard;

4.4.5 Estimate the probability of occurrence of harm from the hazard;

4.4.6 Identify the risk by considering the severity and probability of harm;

4.4.7 Evaluate the risk associated with each hazard to determine if the risk is acceptable;

4.4.8 Take measures to reduce unacceptable risks;

4.4.9 Determine whether new or additional hazards have been introduced, or if the level of existing risks have been changed;

4.4.10 Repeat this process until an acceptable level of residual risk is achieved; and

4.4.11 Document the risk assessment and risk reduction including the mitigating actions taken for each hazard and the resulting reduction in risk.

5 General design requirements

5.1 Hoist systems shall be designed by qualified persons.

5.2 Hoist systems shall incorporate all aspects of mechanical requirements herein unless otherwise determined by the risk assessment and risk reduction.

5.3 Hoist systems shall be designed for use in the anticipated environmental and operating conditions. These conditions shall be included in the limits of use.

5.4 All components of the system shall be used in accordance with manufacturers' recommendations.

5.5 The distribution of loads in a multiple line hoist system, or between hoists in a multiple hoist system, shall be assessed.

5.6 Variations caused by the uneven application of load, deflections of lifted objects, deflection of supporting structure and/or hoist system supports shall be assessed.

5.7 Hoist systems shall be free from vibration that threatens the integrity or functionality of the hoist under normal operating conditions.

5.8 Hoist systems shall be protected against uncontrolled speed and unintentional movements.

5.9 Hoist systems shall be designed for anticipated duty cycles and product life.

5.10 Where the supplier of any component or sub-assembly of the hoist system is not responsible for the entire hoist system, the system designer shall specify the safety requirements for the component or subassembly.

5.11 Design of components not specifically referenced within this document shall be reviewed according to applicable standards. In the absence of an applicable standard, the designer shall apply generally accepted engineering principles.

5.12 Design of the hoist shall anticipate a reasonable amount of force a user would be expected to exert upon the ~~control handle(s)~~ hoist input under characteristic loads as well as the maximum force that the user may exert as a peak load.

6 Mechanical design

6.1 General requirements

A qualified person shall determine or approve design factors for all equipment not included in the tension load path. Unless modified by other sections of this document, other codes listed, or governing bodies with jurisdiction over a particular facility, the factors listed in ANSI E1.4-1 - 2016 shall be used as a minimum performance guideline for tension load path equipment, unless a registered design professional determines that lower values are permitted.

6.1.1 Unless specifically addressed herein, all manual rigging equipment shall comply with the relevant requirements of ANSI E1.4-1 - 2016 Manual Counterweight Rigging Systems. Component assemblies shall be designed, engineered, and manufactured to withstand all characteristic ~~design~~ loads without permanent deformation or damage to components and shall meet the requirements of section 6.2.1 Design Factors.

6.1.2 The hoist system shall be capable of moving the lifted load from a static condition and returning it to the static state, maintaining control throughout the operation.

6.1.3 ~~Design loads~~ Characteristic and peak loads shall be considered in determining the loads applied to the building structure. *(See Annex note.)

~~**6.1.4** Housings and mounting components shall use materials having ductile properties that will deform plastically without fracturing. *(See Annex note.)~~

~~**6.1.5** Strength, material, quality and marking requirements for externally-threaded fasteners shall not be less than SAE J429 Grade 5 or ISO R898 Class 8.8 rating. Bolts in tension shall have nuts of equivalent rating. Fasteners shall be self-locking, or secured by alternate means to prevent loosening. Fasteners shall be installed in accordance with manufacturer's instructions. Attachments made through slotted, elongated, or over-sized holes (more than 1/16" over the fastener diameter), shall use flat washers. *(See Annex note.)~~

6.1.4 All components shall resist unintentional loosening.

6.1.5 Welding shall be in accordance with current American Welding Society standards.

6.2 Power transmission components

6.2.1 Design factors

For power transmission components that have a manufacturer's recommended load rating, the characteristic ~~design~~ load shall not exceed the load rating at a minimum Service Factor of 1.0. Power transmission components without manufacturer's load ratings shall be designed so that stresses ~~due to the design loads~~ do not exceed the following:

6.2.1.1 ~~Shear stresses - 33% of the yield strength; and~~ Yield strength of the material shall be a minimum of 3X the shear stresses due to the characteristic load.

6.2.1.2 ~~Bearing (contact) stresses - 63% of the yield strength~~ Yield strength of the material shall be a minimum of 1.58X the bearing (contact) stresses due to the characteristic load.

6.2.1.3 Ultimate load carrying capacity shall be minimum of 4X the static loading of any component.

6.2.1.4 For power transmission components for which the manufacturer has recommended load ratings, the load shall not be released upon application of the peak load. Power transmission components without a manufacturer's peak load rating shall be selected such that the peak load is less than the yield strength of the component.

6.2.2 Load-securing devices

6.2.2.1 Hoists shall include at least two independently functioning load-securing devices.

6.2.2.2 At least one of the load-securing devices shall have constant engagement or automatically engage when input force is removed.

6.2.2.3 Each load-securing device shall be capable of holding 125% of the static ~~design~~ load.

6.2.2.4 A low back-driving efficiency gear reducer may be used in place of a load-securing device only when risk assessment and risk reduction mitigates hazards associated with descent of the load as a result of release or failure of the other load-securing device.

6.2.2.5 It shall be possible to test the effectiveness of each load-securing device separately. Single use devices shall be acceptable if they have proven reliability based upon independently verified manufacturer testing.

6.2.4 ~~Wire rope~~ Winding drums* (See Annex note.)

6.2.4.1 Winding drums shall take up the media in a defined and repeatable manner.~~Wire rope drums shall be designed to take up wire rope in a defined and repeatable manner.~~

6.2.4.2 Winding drums shall be designed to take up the lifting media in a way as to not cause damage or undue wear to the lifting media.~~Grooves on wire rope drums shall be sized as recommended by the wire rope manufacturer.~~

6.2.4.3 Pitch diameter of a winding drum shall not cause damage or undue wear to the lifting media. Drum pitch diameters should shall be sized as recommended by the wire rope manufacturer. Smaller pitch diameters shall be acceptable with risk assessment including any reductions in capacity, travel speed, travel distance, duty cycle and/ or lifecycle of wire rope or other components.

6.2.4.4 Drum material and construction shall resist tread pressures imposed by the lifting media. Drums shall resist tread pressures imposed by the wire rope.

6.2.4.5 Drums may be grooved or non grooved. Drums shall be designed and installed to ensure even lay, tight wrapping and stacking of the wire rope.

6.2.4.4.1 The maximum allowable fleet angle for a grooved drum shall be two (2) degrees from perpendicular. * (See Annex note.)

6.2.4.4.2 The maximum allowable fleet angle for a smooth drum shall be one and one half (1-1/2) degrees from perpendicular to the drum.

6.2.4.4.3 Grooves on rope drums shall be sized as recommended to support the media and to prevent crushing.

6.2.4.5 When pile-on drums are used, each wire rope shall have its own winding chamber to ensure the rope is layered in such a manner that the rope centerlines are aligned. Reduced capacity of wire rope due to pile on condition shall be considered in design. * (See Annex note.)

6.2.4.6 8 The attachment of the lifting media to the drum shall have a strength equal to or greater than 1.33X the peak load. This shall be accomplished by end termination alone, or by including the friction from the minimum turns of lifting media on the drum. The attachment of the wire rope to the drum shall remain secure for a load at least 80% of the wire rope's minimum breaking strength. This shall be accomplished by end termination alone, or by including the friction from the minimum turns of wire rope on the drum.

6.2.4.8 9 When a clamping method is used to attach lifting media to the drum, it shall be ensured that a single failure of the attachment method (e.g. screw) does not lead to the failure of the connection. When clamps are used to attach the wire rope to the drum, it shall be ensured that a single failure of the attachment method (e.g. screw) does not lead to the failure of the connection. * (See Annex note.)

6.3 Hoist frames and static load bearing components

6.3.1 Hoist frames and static load bearing components shall be designed such that the design load does not exceed 50% of the yield strength of the material or 33% of the ultimate load carrying capacity. designed with a yield strength at least 2X the characteristic load. The ultimate load carrying capacity of the device shall be at least 3X the characteristic load

6.3.2 Hoist frames and static load bearing components shall be designed with an ultimate load carrying capacity at least 2X the peak load.

6.3.3 Deflection of load bearing components shall not be detrimental to hoist operation.

7 Ancillary and tension load path components.

7.1 Clew and guide systems

7.1.1 Clews shall be used where multiple lift lines are connected to fewer haul lines.

7.1.2 Clews shall be guided or restrained to prevent fouling and twisting of the lines during operation. Clew guides may be wire, or rigid members. Other clew guiding methods shall be permitted.* (See Annex note.)

7.1.2.1 Clew systems shall be designed to withstand anticipated loads.

7.1.2.2 Clew systems may be oriented in any direction. ~~Non-vertical clew guide systems shall be supported as determined by a qualified person.~~

7.1.2.3 Clew systems shall permit full intended travel of the batten or load.

7.1.2.4 Guide attachments shall be located to permit clew travel without excessive deflection of the clew or its guides. A load-rated tension adjustment device shall be incorporated into the assembly, and shall be fixed in position after final adjustments are made.

7.1.2.4.1 Wire guide attachment points shall be designed to accept the loads imposed by both tension in the guide wires and any loads due to sway of the clew during operation. A registered design professional shall evaluate anticipated guide wire loads to the existing structure.

7.1.2.4.2 The minimum spacing between adjacent clews shall be such that clew system components cannot come into contact with each other under normal operating conditions.

7.2 Lifting media

7.2.1 General

7.2.1.1 Minimum tensile strength of lifting media shall ~~meet or exceed eight (8) times the design load.~~ be no less than the following:

5X the characteristic load.
5X the static load if hand operated.
8X the static load if using drive augmentation.
1.33X the peak load.

7.2.1.2 The minimum tensile strength shall include termination efficiency and other applicable strength reduction factors.

7.2.1.3 In multiple line hoist systems, lifting media shall have a method of length adjustment.

7.2.1.4 Lifting media shall not contact any part of the building structure, adjacent systems, or other equipment not intended for contact.

7.2.1.5 In cases where inspection is not possible, risk analysis and risk reduction shall address means to mitigate this additional risk.

7.2.2 Lifting media terminations

7.2.2.1 Termination hardware shall be load rated and shall have a minimum tensile strength not less than 80% of the minimum tensile strength of the lifting media.

7.2.2.2 Shackles, wire rope clips, eyebolts, eye nuts, and turnbuckles shall be of forged steel or equivalent construction. Malleable wire rope clips shall not be permitted.

7.2.2.3 Turnbuckles shall be secured after adjustment to prevent turnbuckle body rotation.

7.2.2.4 Screw pin shackles and turnbuckles with screw pin jaws shall be secured to prevent pin rotation.

7.2.2.5 Thimbles shall be sized in accordance with the wire rope diameter.

7.2.3 Wire rope

7.2.3.1 The grade and construction of wire rope shall be appropriate for the intended use.

7.2.3.2 Anticipated duty cycle and detrimental conditions such as reverse bending shall be factored into the selection of wire rope.

7.2.4 Other lifting media

Other lifting media shall be permitted provided the manufacturer approves it for this use.

7.3 Blocks

Blocks shall conform to the requirements of ANSI E1.4-1 - 2016

7.4 Load carrying devices

7.4.1 Load carrying devices shall be selected so that the ~~design load does not exceed 75% of the available strength permitted by published design standards applicable to the material.~~ yield strength of the device is at least 2X times the characteristic load. Load carrying devices shall be selected so that the ultimate load carrying capacity of the device is at least 1.5X the characteristic load or the peak load.

7.4.2 ~~Battens or their equivalents shall be designed so that the calculated deflection in the span between two suspension points due to the design load uniformly distributed along the entire length of the batten is not greater than the length of the span divided by 180.~~ The maximum deflection of battens or their equivalents under the characteristic load shall not exceed 1/180 of the span distance between adjacent lift lines. Where there is not a specific load distribution pattern, the load shall be assumed to be uniformly distributed along the length of the batten.

7.4.3 Aluminum trussing shall meet the requirements of ANSI E1.2-2012, and deflection shall be calculated based on the characteristic load designated in the system designer's limits of use. Forces generated by the calculated deflection shall not exceed the maximum allowable component forces.

7.5 Drive Augmentation * (See Annex note.)

7.5.1 Drive augmentation of a hoist shall be temporary. Drive augmentation left in the load path shall be considered permanent and subsequently subject to ANSI E1.6.1-2019.

7.5.2 Drive augmentation must be supported and resist counter torque solely by the operator. Augmentation using a torque arm or other means to mitigate the torque supported by the operator shall be subject to ANSI E1.6.1-2019.

7.5.3 Operation of device shall require constant pressure on the switch. Trigger locks and other means of continuous operation shall not be used.

7.5.4 The use of percussive devices, (e.g., hammer drills, impacts) shall be prohibited.

7.5.4 Drive augmentation shall be used only with hoists explicitly designed, labeled and documented for use with augmentation.

7.5.4.1 Drive augmentation shall comply with hoist manufacturers' recommendations including, but not limited to allowable speed, maximum input torque and duty cycle.

7.5.5 Drive augmentation shall include a device to limit torque and/or duration transmitted to the hoists in accordance with the hoist manufacturers published rating. (e.g. drive clutch, thermal overload).

8 Basic functional, safety, and operational requirements

8.1 System manuals. All rigging installations shall include an operations and maintenance manual ("systems manual") for the system, describing its limits of use. All unique elements of the particular system shall be identified and documented. The systems manual shall include final print drawings, applicable maintenance requirements, servicing guidelines, and a listing of component working load limits. Manuals shall include inspection requirements.* (See Annex note.)

8.1.1 System manuals shall include a supplemental maintenance log providing a place to record inspections, modifications and repairs to the system, and identifying the person(s) performing such actions.

8.1.2 System manuals shall be made available upon request. The operations portion of the system manual shall be readily accessible to all users of the system.

8.1.3 The operation of the system shall be clearly described and include comprehensive operator instructions.

8.2 Maintenance. The maintenance section shall include recommendations for inspection, testing, and maintenance of the system.

8.2.1 Systems shall be maintained under the supervision of a qualified person.

8.2.2 Manually operated hoist systems shall be maintained in accordance with the System Manual.

8.2.3 Replacement components and hardware shall be of equivalent grade or rating as the originals.

8.2.4 Modifications or alterations shall be performed under supervision of a qualified person according to the provisions of this standard.

9 Labeling, marking, and signage

9.1 Labeling and signage shall comply with the requirements of the following standards, where such requirements can be implemented with rigging components, assemblies, and systems:

9.1.1 ANSI Z535.1-2017, Safety Color Code

9.1.2 ANSI Z535.2-2011 (R2017), Environmental and Facility Safety Sign

9.1.3 ANSI Z535.3-2011 (R2017), Criteria for Safety Symbols

9.1.4 ANSI Z535.4-2011 (R2017), Product Safety Signs and Labels

9.2 The hoist shall have a label affixed indicating the manufacturer's working load limit.

9.3 Hoist systems shall be marked with their working load limit.

9.4 Signage or label(s) shall indicate both WLL point load and WLL uniformly distributed load (UDL) of the load-carrying device for each hoist system.

9.5 The lifting media size and type shall be clearly indicated either by a label affixed to the hoist or a sign or label directing the maintenance personnel to the system manual.

9.6 The manufacturer's name or grade reference mark shall be permanently displayed on hardware. Or, where permanent labeling or marking of individual components is impractical; the load, manufacturer, or grade reference information shall be indicated in the system manual.

9.7 Signage shall be placed in clearly visible, accessible location(s).

9.8 Signage shall state that operation of the hoist system shall be restricted to authorized persons.

9.9 Signage shall list the contact information for the supplier of the system.

9.10 System shall include “spiking” or marking of travel extents for easy identification by the operator.

10 Installation

10.1 Systems shall be installed under the supervision of a qualified person. All components shall be installed in accordance with the manufacturer's recommendations.

~~**10.1** Manually operated hoists and other load bearing components shall be securely attached to the supporting structure. The mounting shall be designed to prevent unanticipated movement and prohibit loosening of the component or mounting hardware over time by either load or vibration.~~

~~**10.2** Welding shall be permitted with the approval of a registered design professional. This attachment method shall only be performed in a manner that permits removal of the hoist or component when maintenance or replacement becomes necessary.~~

~~**10.3** Drilling of structural framing, for attachment of hoists and other components with bolts, shall be permitted with the approval of a registered design professional.~~

~~**10.4** When attaching hoists to materials requiring anchors, the anchors shall be selected and installed according to both the anchor manufacturer's recommendations and local code requirements.~~

~~**10.5** Attachments to the supporting structure shall provide a minimum design factor of 5. The design factor shall be based on the static load and the ultimate strength permitted by 3 against the material yield strength, if applicable, and a minimum design factor of 5 against ultimate strength, based on published design standards applicable to the material.~~

10.2 Manually operated hoists shall be installed to allow operation of the hoist from a stable and safe location.

11 Inspection and testing

11.1 General requirements

11.1.1 Design and operating criteria of the rigging system shall be established or confirmed prior to inspection or testing.

11.1.2 Inspection and testing shall verify that all system components and connections are present in the system, and that they comply with the design and operating criteria.

11.1.3 Tests shall be non-destructive.

11.1.4 The system designer's recommendations for inspection and maintenance shall be followed unless they are less stringent than the requirements herein.

11.1.5 Inspection and testing shall be performed by a qualified person.

11.1.6 Systems shall be inspected annually, or on a more frequent schedule, as determined by a qualified person.

11.1.7 Systems shall be tested after installation, mishap, repair, or modification.

11.1.8 Deficiencies discovered during inspection or testing shall be repaired under the supervision of a qualified person prior to returning the system to operation.

11.1.9 Test failure shall result in corrections and retesting until the system passes the test.

11.2 Inspection procedures

11.2.1 Components of the hoist system shall be visually inspected for wear and damage.

11.2.2 Each hoist or hoist system shall be operated through its full range of travel and speeds. Unusual noises, motions, or other issues shall be reported and resolved.

11.2.3 All relevant inspection requirements shall comply with ANSI E1.47 - 2017.

11.3 Testing procedures

11.3.1 The hoist system shall be inspected.

11.3.2 Each hoist or hoist system shall undergo a static load test at a minimum 1X ~~at125%~~ the WLL.

11.3.3 Any additional tests required by the designer or manufacturer shall be conducted.

11.4 Frequency of inspections

Installed systems shall be inspected annually or more frequently, as determined by a qualified person.

11.5 Documentation

11.5.1 Inspection reports and test reports shall include the name of the inspector, the location of the equipment, and the date of the inspection. Reports shall be signed by the inspector.

11.5.2 Test reports shall include documentation of the test procedures and the results of the tests.

11.5.3 Inspection reports and test reports shall be placed in a system log.

Annex A

This annex contains informative notes that are not part of the normative requirements of the standard.

A3.3

A3.6

A3.20

A3.33

A.6.1.3

Design calculations performed according to this standard are based on three basic loading conditions: static, characteristic and peak. The static load is that which occurs in a component while the system is in normal use but at rest. The characteristic load includes the static load but also any other forces that might occur during use such as inertial forces due to acceleration and those due to a moving or variable load on the batten. Finally, the peak load is the maximum load that can be reasonably anticipated to occur as a result of normal or abnormal conditions or irregular operation. All of these loads are apportioned to each component based on the hoist system geometry and the maximum loads defined in the limits of use.

It is not possible to foresee every type of peak load or situation in which a piece of equipment might be misused. It is incumbent on the designed to anticipate those situations which are either likely to occur or could be of such great consequence that the user must be protected. The peak load should include conditions where excessive force may be applied to the hoist such as where the lift line load is caught on adjacent obstructions or otherwise overloaded. Peak loads for hoists used with drive augmentation shall also consider potential overloads resulting from the stalling of the drive.

Design factors applied to the static and characteristic loads are intended to be large enough to result in equipment that performs well throughout the product life just as long as it is operated within the limits of use. Design factors applied to the peak load are smaller by comparison and reflect the philosophy that although the machine is not intended to move those larger, atypical loads on a routine basis, it is intended that such an overload does not result in a failure that would allow the load to fall.

A.6.1.4

Since the general definition of ductile refers to a material's ability to be drawn out into a wire, the standard elaborates further by requiring plastic deformation. Another way to relate this concept is by comparison of the material's yield point to its ultimate tensile strength. Materials having non-ductile properties, and that do not deform plastically without fracturing have either a yield point very close to its ultimate tensile strength, or have no yield point value because the yield point is, essentially, equal to its ultimate tensile strength. Acceptable materials will give a clear indication of failure, by first deforming within its plastic range, before ultimate failure actually occurs.

A.6.1.5

Torque values for threaded connections vary based upon the materials, type of connection, and the predominant forces to which the connection is subjected (e.g. tensile, shear, etc.). Often, a connection will not require a specified torque value, while in some cases a minimum torque value is critical in order to achieve and maintain the full connection strength. Each type of connection and application should be evaluated by a registered design professional in order to determine a) if a minimum torque value is applicable, b) if applicable the actual torque value or range, and c) the correct method for obtaining the specified torque, where required. The use of flat washers is also relevant to minimum torque values. Where no minimum torque values are specified, the use of flat washers is probably not important. Conversely, any time minimum torque values must be achieved, or in applications where slotted or elongated holes are part of the connection, consideration should be given to the use of hardened flat washers as part of the appropriate connection method.

A.6.2.1.3

A distinction is made between components that are rated based on endurance and specified using service factors, e.g. gear reducers and couplings, and those for which strength is the basis of design such as keys and shafts.

A.6.2.4
It is anticipated that the ratio of the drum diameter to that of the wire rope (D/d) will have an effect on the static breaking strength of the rope. The D/d ratio is more likely to have a significant effect on the rate at which the rope fatigues during use and the rate at which the drum or sheave material is eroded by the action of the rope bearing on the groove. Smaller diameter drums tend to increase the stresses in the rope and the "tread pressure" of the rope bearing on the groove. This tends to shorten the life of those components.

References such as the Wire Rope User's Manual[1] may serve as a guide to dimensions such as the radius and depth of the groove that supports the rope. Although valuable as a guide, recommendations within that text are based on specific types of rope constructions or drum materials, and many of the materials in common use within the entertainment industry are not addressed. While making recommendations for D/d ratios that result in the maximum service life for certain types of wire rope, the Wire Rope User's Manual acknowledges that those same recommendations are not adhered to in other industrial hoisting standards. Factors such as frequency of use, service life requirements, and the requirements for mechanical efficiency can vary greatly even between different types of machines in the same venue. These factors should be considered when D/d ratios are specified.

The introduction of new types of wire ropes and materials for drums is not uncommon, and it is not the intention of this document to limit their use by imposing restrictions made necessary by those materials most common at the time of writing. In all cases the application of a new material must be consistent with the recommendations of its manufacturer. The manufacturer is often the best source for recommendations concerning design.

~~A.6.2.4.5~~
~~Careful consideration should be given to drum diameter, drum width and overall lifting media capacity to ensure minimizing of wear on the media due to scrubbing, small winding diameters, etc.~~

A6.2.4.4.1
In all sheave instances, defining fleet angle as a measurement against a line drawn perpendicular to the rotational axis is valid and accurate as shown in Figure 1a below. For helically grooved drums it is more accurate to measure fleet angle relative to the helix angle of the groove. This is indicated with a center line of a groove in Figure 1b below. In traditional drum applications and in situations with great distances between drum and sheave the difference is negligible. In some instances, typically with smaller diameter drums, calculation of the maximum fleet angle may be modified to take the helix angle into account. The actual fleet angle may be calculated by adding or subtracting the helix angle from the initially calculated fleet angle. For additional information see ISO 4308-1 2003 Cranes and Lifting Appliances and/or the US Navy Wire Rope Handbook Vol 1.

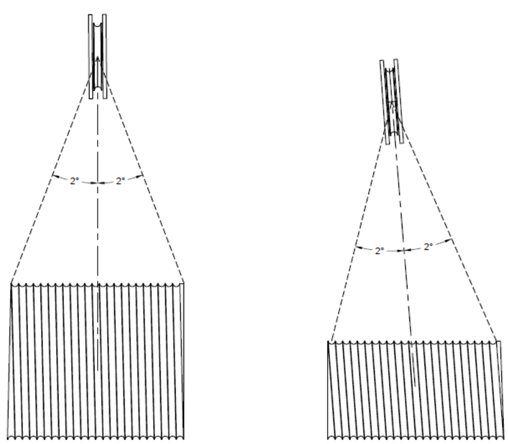

Figure 1a Figure 1b

Figure 1

1 *Wire Rope User's Manual*. Alexandria, VA: Wire Rope Technical Board

A.6.2.4.5 7

Pile-on drums should be used with caution. As the lifting media winds on to the drum the pitch diameter is increased with each layer, resulting in increased media speed and reduced load capability. The pitch diameter is affected by factors such as the clearance between the lifting media and the drum side plates, and by the crushing, stretching, or distortion of the lifting media. Synchronizing multiple lift lines may be especially difficult.

A6.2.4.8

This system of cable attachment refers to cables that are attached to the surface of the drum without the wire rope penetrating the drum shell or rim.

A.7.1.2

Dual haul line systems with no additional guide system may be used as a method to restrain rotation of the clew with no additional guide system.

A.7.5

The use of a drill drive to augment operation of a manually-operated hoist is a common practice. Use of devices such as drill drives to temporarily augment manual operation is covered within Section 7.5, although drill drives and other means of augmentation themselves are not covered by this standard. Care must be taken as this provides a means to motorize a hoist, but it does not necessarily, and in most cases does not meet the requirements of E1.6.1-2019 for motorized hoists. Drill drives should only be used on hoist that have been designed for and identified by the manufacture for use with a drill. Furthermore, drill performance requirements provided by the hoist manufacturer must be followed. While introduced in Section 7.5, a complete list of all potential risks, designs, situations and characteristics is beyond the scope of this standard and should be evaluated per application by a qualified person.

A.8.1

Users of the system should read and thoroughly understand the information contained in the systems manual. Knowledge of the system-specific load capacities, operating instructions, and maintenance schedules are important to establishing safe operating practices.