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ANSI E1.6-1 – 2012
Entertainment Technology – Powered Hoist Systems

Rig/2006-2011r5

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The PLASA Technical Standards Program

The PLASA Technical Standards Program was created to serve the PLASA 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. PLASA works closely with the technical standards efforts of other organizations within our industry, including USITT and VPLT, as well as representing the interests of PLASA members to ANSI, UL, and the NFPA. The Technical Standards Program is accredited by the American National Standards Institute.

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The Rigging Working Group, which authored this Standard, consists of a cross section of entertainment industry professionals representing a diversity of interests. PLASA is committed to developing consensus-based standards and recommended practices in an open setting.

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Interest category codes:

CP = custom-market producer	DE = designer
DR = dealer rental company	G = general interest
MP = mass-market producer	U = user

Table of contents

1 Scope

This standard establishes requirements for the design, manufacture, installation, inspection, and maintenance of powered hoist systems for lifting and suspension of loads for performance, presentation, and theatrical production.

This standard does not apply to the structure to which the hoist is attached, attachment of loads to the load carrying device, systems for flying people, welded link chain hoists, and manually powered hoists.

The provisions of this standard are not intended to prohibit any design, materials, or methods of fabrication, provided that any such alternative is at least the equivalent of that described in this standard in quality, strength, and effectiveness. (See Annex note.)

2 References

All equipment shall be manufactured 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.

Aluminum Design Manual, 2010 edition[1]

American Welding Society standards[2]

ANSI/AISC 360-05 Specification for Structural Steel Buildings

ANSI B11.TR3 2000 Risk Assessment and Risk Reduction

ANSI/ASME B29.4 2002 Roller Load Chains for Overhead Hoists

ANSI E1.2 2006 Design, Manufacture and Use of Aluminum Trusses and Towers

ANSI Z535 2006
1 - Safety Color Code
2 - Environmental and Facility Safety Signs
3 - Criteria for Safety Symbols
4 - Product Safety Signs and Labels
6 - Product Safety Information re Product Manuals, Instruction and Other Collateral Materials

NFPA 70: National Electric Code, 2008 edition[3]

NFPA 79: Electrical Standard for Industrial Machinery, 2007 edition[4]

3 Definitions

3.1 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.)

[1] The Aluminum Association 1525 Wilson Boulevard, Suite 600 Arlington, VA 22209, www.aluminum.org
[2] American Welding Society 550 N.W. LeJeune Road Miami, FL 33126, www.aws.org
[3] National Fire Protection Society 1 Batterymarch Park Quincy, MA 02169-7471, www.nfpa.org
[4] National Fire Protection Society 1 Batterymarch Park Quincy, MA 02169-7471, www.nfpa.org

3.2 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.

3.3 control station: a part of the control system that governs motion control of one or multiple hoists. The control station includes at least one motion control device (such as a "go" button, a "joystick", an "up / down" button pair, or any other device) that, when actuated, initiates motion of a hoist.

3.4 enabling device: a manually operated control device used in conjunction with a control station, which when continuously actuated, will allow a machine to function. (See Annex note.)

3.5 fault: the state of an item characterized by inability to perform a required function.

3.6 hoist: a machine used to raise or lower a suspended load.

3.7 hoist system: an arrangement of one or more hoists and associated lifting media, reeving, sheaves, and controls used for raising or lowering a suspended load.

3.8 interlock device: a switch, sensor, or interconnected logic system that permits or prevents motion.

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

3.10 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).

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

3.12 load securing device: a mechanical device that prevents unintentional movement in the hoist system.

3.13 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 (e.g. effects of uncontrolled stops, stalling of the prime mover, extreme environmental conditions). (See Annex note.)

3.14 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.

3.15 positive break operation: the achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (i.e. not dependent upon springs).

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

3.17 prime mover: a device that originates mechanical force and motion within a hoist power transmission system (e.g. electric motor, hydraulic actuator). (See Annex note.)

3.18 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.

3.19 reasonably foreseeable misuse: use in a way that is predictable, but not intended (e.g. deliberate misuse of the machine to save time or materials, inadequate operator training).

3.20 risk: combination of the probability of occurrence of harm and the severity of that harm.

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

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

3.23 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.

3.24 stop categories

category 0 stop: an uncontrolled stop caused by the immediate removal of power to the machine actuators.
category 1 stop: a controlled stop with power to the machine actuators available to achieve the stop, then removed when the stop is achieved.
category 2 stop: a controlled stop with power left available to the machine actuators.

3.25 system designer: the person or persons who specify the limits of use of the system and may also select and integrate the components of the system.

3.26 ultimate load carrying capacity: the maximum load a component may support without fracture, buckling or crushing as determined by nationally recognized construction standards appropriate for the given material.

3.27 working load limit (WLL): the maximum 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. (See Annex note.)

4.2 Risk assessment and risk reduction preferably shall be performed by a group of two or more competent persons. When the risk assessment and risk reduction is completed by a single individual, that individual shall be a qualified person.

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. For each identified hazard: (See Annex B.)

4.4.3.1 Estimate the severity of harm associated with exposure to the hazard.

4.4.3.2 Estimate the probability of occurrence of harm from the hazard.

4.4.3.3 Identify the risk by considering the severity and probability of harm.

4.4.3.4 Evaluate the risk associated with each hazard to determine if the risk is acceptable.

4.4.3.5 Take measures to reduce unacceptable risks.

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

4.4.3.7 Repeat this process until an acceptable level of residual risk is achieved.

4.5 Documentation of the risk assessment and risk reduction shall include the mitigating actions taken for each hazard and the resulting reduction in risk.

(See Annex B.)
(See Annex C.)
(See Annex D.)

5 General design requirements

5.1 Hoist systems shall be designed by qualified persons.

5.2 Hoist systems shall incorporate all aspects of mechanical and control requirements herein (Section 6 – Mechanical design and Section 7 – Electrical equipment and control systems), 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. The system designer shall define the limits of use.

5.4 All components shall be used in accordance with the manufacturer's recommendations.

5.5 The maximum number of hoists or hoist systems capable of simultaneous operation shall be determined and shall be included in the limits of use. (See Annex note.)

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

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

5.8 Calculation of the peak load shall assess the maximum torque output from the prime mover in a stalling condition.

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

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

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

5.12 Where the supplier of any component or subassembly 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.

5.13 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.

6 Mechanical design

6.1 General requirements

6.1.1 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.

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

6.1.3 Category 0 stops shall not cause permanent deformation or failure of any component or portion of the system.

6.1.4 All components shall be designed to resist unintentional loosening.

6.2 Power transmission components

6.2.1 Design factors
(See Annex note.)

6.2.1.1 For power transmission components that have a manufacturer's recommended load rating, the characteristic 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 characteristic load do not exceed the following:

6.2.1.1.1 shear stresses - 33% of the yield strength

6.2.1.1.2 bearing (contact) stresses - 63% of the yield strength

6.2.1.2 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 designed such that the peak load does not exceed the yield strength of the component.

6.2.2 Motors

6.2.2.1 Hoist system motors shall have a minimum starting torque of 150% of the static load.

6.2.2.2 Hoist systems shall be designed to prevent loss of directional control while reversing the motor.

6.2.3 Load securing devices

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

6.2.3.2 At least one of the load securing devices shall automatically engage when operational controls are released or drive power is removed. Neither load securing device shall require external power to engage.

6.2.3.3 Each load securing device shall be capable of stopping and holding 110% of the static load unless otherwise permitted by section 6.2.3.4.

6.2.3.4 A low back-driving efficiency gear reducer, or a device that slows a load without stopping it, 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.

6.2.3.5 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 Drive sprockets

6.2.4.1 This section applies to sprockets that transmit power to the lifting media.

6.2.4.2 Roller chain sprockets in the power transmission system shall have a minimum of 12 teeth, and a minimum of 120 degrees of the chain shall be form-locked around the sprocket.

6.2.4.3 A mechanism shall be included to prevent the chain from disengaging the sprocket teeth.

6.2.5 Wire rope drums
(See Annex note.)

6.2.5.1 Wire rope drums shall be designed to take up wire rope in a defined and repeatable manner.

6.2.5.2 Grooves on wire rope drums shall be sized as recommended by the wire rope manufacturer.

6.2.5.3 Drum pitch diameters shall be sized as recommended by the wire rope manufacturer.

6.2.5.4 Drums shall resist tread pressures imposed by the wire rope.

6.2.5.5 Drums that take up wire rope in a single layer shall have helical grooves.

6.2.5.6 The maximum allowable fleet angle from a grooved drum shall be two (2) degrees from perpendicular to the drum.

6.2.5.7 When pile-on drums are used, each wire rope shall have its own winding chamber that ensures the rope is layered in such a manner that the rope centerlines are aligned. (See Annex note.)

6.2.5.8 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.

6.2.5.9 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.

6.2.6 Power screw drives

6.2.6.1 This section applies to power screw drives that directly support the lifted load.

6.2.6.2 The power screw shall have a greater wear resistance than the load-supporting nut.

6.2.6.3 Each power screw nut shall be provided with a means of wear indication.

6.2.6.4 The power screw nut shall have a minimum residual strength of 1.6 times the characteristic load or 1.2 times the peak load, whichever is greater.

6.2.7 Hydraulic systems

6.2.7.1 This section applies to elements of a hydraulic circuit that directly support a lifted load.

6.2.7.2 The pressure resulting from 2 times the characteristic load shall not exceed the manufacturer's recommended maximum operating pressure.

6.2.7.3 The pressure resulting from 1.2 times the peak load shall not exceed the manufacturer's recommended maximum operating pressure.

6.2.7.4 Hydraulic actuators shall be provided with local, manual valves with which each actuator can be locally disabled.

6.2.7.5 The operating pressure shall be limited by means of a pressure limiting device. It shall be possible to measure the system pressure.

6.2.7.6 If the pressure is generated by means of a gaseous cushion that has a direct influence on the hydraulic fluid, all drive systems shall automatically switch off once the fluid reserve goes below the minimum level.

6.2.7.7 Accumulators shall depressurize automatically at hoist system shutdown.

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 characteristic load does not exceed 50% of the yield strength of the material nor 33% of the ultimate load carrying capacity.

6.3.2 Hoist frames and static load bearing components shall be designed such that the peak load does not exceed 50% of the ultimate load carrying capacity.

6.3.3 All welds shall comply with current American Welding Society standards.

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

6.4 Lifting media

6.4.1 General

6.4.1.1 Minimum tensile strength of lifting media shall exceed the following:
five (5) times the characteristic load.
eight (8) times the static load.
1.33 times the peak load.

6.4.1.2 For multiline hoists, the peak load for lifting media may be assumed to not exceed 6 times the characteristic load. (See Annex note.)

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

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

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

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

6.4.2 Lifting media terminations

6.4.2.1 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.

6.4.2.2 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.

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

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

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

6.4.3 Wire rope

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

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

6.4.4 Roller Chain

6.4.4.1 Roller chain used as lifting media shall comply with ASME B29.24 or otherwise be approved by the manufacturer specifically for use in overhead lifting applications.

6.4.4.2 Where roller chains are used in combination with wire rope, provisions shall be made to prevent torsion induced by the wire rope twisting the roller chain beyond the roller chain manufacturer's recommended limits.

6.4.4.3 Roller chain connections shall distribute the load evenly to the link plates on both sides of the chain. A connection that pivots freely about an axis perpendicular to that of the chain pins shall be permitted.

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

6.5 Blocks

6.5.1 The working load limit for the block shall meet the following criteria:

6.5.1.1 For failure modes that result in yield of ductile materials, the application of the characteristic load shall not result in stresses greater than 25% of the yield strength of the material.

6.5.1.2 For failure modes that result in collapse or fracture, application of the characteristic load shall not result in stresses greater than 16% of the yield strength of the material.

6.5.1.3 For bearing contact stress failure modes, application of the characteristic load shall not result in stresses greater than the yield strength of the material.

6.5.1.4 For rolling element bearings, application of the characteristic load shall result in a calculated L10 life of at least 2000 hours at maximum system design speed.

6.5.2 Blocks shall be selected so that the characteristic load does not exceed its working load limit.

6.5.3 Blocks shall be selected so that the peak load does not exceed 90% of the block's ultimate load carrying capacity.

6.5.4 For single line blocks within multiline systems, the peak load for blocks may be assumed to not exceed 6 times the characteristic load. (See Annex note.)

6.5.5 Blocks and other reeving components shall be mounted in a manner that permits inspection, maintenance, and replacement.

6.5.6 Shafts shall be installed so that no thread contacts the bearing or sheave housing. Shafts shall be locked against rotation within the block housing, unless specifically designed to rotate. Shafts shall not move axially.

6.5.7 The maximum allowable fleet angle for lifting media through a block shall follow the recommendations of the lifting media manufacturer.

6.5.8 Lifting media shall be prevented from unintentionally disengaging from sheaves or sprockets.

6.5.9 Sheave diameter, sheave material, lifting media, and anticipated duty cycle shall be factored into the selection of the block.

6.6 Load carrying devices

6.6.1 Load carrying devices shall be selected so that the characteristic load does not exceed 75% of the static capacity permitted by published design standards applicable to the material for static loads.

6.6.2 Battens or their equivalents shall be designed so that the calculated deflection in the span between two suspension points due to the characteristic load uniformly distributed along the entire length of the batten is not greater than the length of the span divided by 180.

6.6.3 Aluminum trussing shall meet the requirements of ANSI E1.2-2006, 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.

6.7 Guarding

6.7.1 Exposed moving parts within 2.13 m (7 ft) of a walking/working surface or that otherwise constitute a hazard shall be guarded.

6.7.2 Equipment located in technical spaces shall be guarded in accordance with this section, except that the lifting media, sheaves, drums used for lifting media, sprockets, and shaft assemblies turning at the same speed as the drums need not be guarded when the following requirements are met:

6.7.2.1 Access to the technical space is limited to authorized persons only.

6.7.2.2 Clearances shall be provided around machines such that people need not contact unguarded components to access any part of the technical space. Contact with lifting media shall be permitted.

6.7.3 When guards are located underfoot, or in such a manner that they could serve as a step, they shall be capable of supporting, without permanent distortion, the weight of a 140 kg (310 lb) person.

6.7.4 Guards shall be secured.

6.7.5 Guards shall not create a hazard in themselves.

6.7.6 Guards shall be removable for service.

7 Electrical equipment and control systems

7.1 General

7.1.1 Hoist systems shall incorporate all aspects of control requirements herein, unless otherwise determined by the risk assessment and risk reduction.

7.1.2 Electrical equipment and control systems shall conform to NFPA 79 Electrical Standard for Industrial Machinery, 2007.

7.1.3 The following sections address additional requirements or exceptions to the referenced standards. In the case of conflicts between the referenced standards and this document, this document shall take precedence.

7.1.4 The electrical equipment covered by this standard commences at the point of connection of the power supply to the hoist system.

7.2 Control functions

7.2.1 All movements shall be initiated and ended by means of a control device, with the direction of movement indicated. When it is possible to initiate contrary movements of multiple machines concurrently, this function shall be indicated.

7.2.2 Control devices shall be protected against unintentional and unauthorized actuation.

7.2.3 The hoist system shall require a hold-to-run device that, when activated, allows hoist operation and, when deactivated, stops movement of the hoist or hoist system.

7.2.3 Visual monitoring

7.2.3.1 Control devices shall be located where movement of the load may be visually monitored via direct line-of-sight.

7.2.3.2. When direct line-of-sight visual monitoring of the load is not possible, an aid, such as closed circuit television, an enabling device, or other monitoring means, shall be used.

7.2.4 The control system shall not permit simultaneous movement of more than the allowable number of hoists.

7.2.5 Where a system has multiple control stations, hardware or software interlocks shall prevent the simultaneous control of a hoist or group of hoists by more than one control station.

7.2.6 Cableless control systems (also known as wireless control systems) shall meet the same design and safety requirements as wired systems.

7.3 Safety functions and devices

7.3.1 Safety functions for hoists or hoist systems shall incorporate the following:

7.3.1.1 Emergency stop system

7.3.1.2 Ultimate (overtravel) limit switches

7.3.1.3 End of travel (initial, normal) limit switches

7.3.2 The risk assessment and risk reduction may indicate that the hoist system shall incorporate additional sensors and interlock devices. (See Annex note.)

7.3.3 Faults shall not lead to hazardous operating conditions. (See Annex note.)

7.3.3.1 Faults shall not hinder stopping.

7.3.3.2 Faults shall be indicated.

7.3.3.3 Removal of a fault shall not automatically restart the hoist.

7.3.4 Functions integrated into a programmable electronic control system (PES) may also serve as safety functions. The implementation in the PES shall meet the same design, safety, and reliability requirements as a respective electronic or electromechanical solution.

7.3.5 Failure of a programmable electronic system shall not disable safety functions. When safety functions implemented in programmable electronics fail, the hoist system shall automatically stop and be disabled.

7.3.6 In the event of a control signal loss, the hoist that lost the signal shall stop. The category of stop shall be determined by the risk assessment and risk reduction. Unintended startup shall not occur when the control signal is reacquired.

7.3.7 If required by the risk assessment and risk reduction, redundancy for electrical devices (e.g. contactors, relays, valves) in safety circuits shall be provided. Such devices shall be monitored separately.

7.4 Performance of safety devices

7.4.1 General

7.4.1.1 When a safety device is activated, the hoist or hoist system shall stop and indicate a fault. The category of stop and allowable successive action shall be appropriate for the safety device or function activated, as determined by the system designer.

7.4.1.2 When multiple hoists are grouped together to lift a common load or are grouped together for interrelated motion, a position feedback device and monitoring method shall be provided to ensure group movement. A stop of one hoist shall stop the entire group of hoists. This requirement shall not apply to groups of hoists that move simultaneously in an unrelated manner.

7.4.1.3 The activation of a safety device shall be indicated as long as the activation is in effect.

7.4.1.4 When a single hoist has a fault not affecting the remaining hoists, it shall be permitted to disable the faulted hoist.

7.4.1.5 It shall be possible to test the effectiveness of each safety device and function individually, where it is nondestructive and safe to do.

7.4.2 Emergency stop system (E-stop)

(See Annex note.)

7.4.2.1 Hoist systems shall have an emergency stop function that stops the hoist system by implementing either a category 0 or a category 1 stop. The choice of category shall be on the basis of the risk assessment and risk reduction and the functional needs of the hoist system.

7.4.2.2 Activation of an emergency stop device shall create a fault condition.

7.4.2.3 Motion following an emergency stop shall be permitted only after the fault condition has been corrected.

7.4.2.4 Removing or resetting of the emergency stop fault condition shall not restart the hoist system, but only permit restarting.

7.4.2.5 Emergency stop pushbuttons shall be self-latching.

7.4.2.6 Emergency stop pushbuttons shall have a positive break operation.

7.4.2.7 Where there is more than one operator control station for the same hoist or hoist system, each station shall be equipped with an emergency stop.

7.4.2.8 All control stations shall be equipped with a common emergency stop system. Activation of any of the emergency stops shall stop all hoists in the system. (See Annex note.)

7.4.3 Limit switches

7.4.3.1 All limit switches or position sensors shall be installed so that overtravel by the hoist shall not damage the limit switch or sensor.

7.4.3.2 There shall be a minimum of two sets of limit switches in any direction of motion: normal (end of travel, initial) and ultimate (overtravel) limit switches.

7.4.3.3 The normal (end of travel, initial) limit switch shall prevent further movement in the direction of travel. A position sensor may be used as a normal limit switch. When the normal limit is activated, movement in the opposite direction shall be allowed.

7.4.3.4 The ultimate (overtravel) limit switch shall be a snap-acting or positive break mechanical limit switch that immediately initiates a category 0 or category 1 stop utilizing a means separate from the main drive device. The stop category shall be determined by the risk assessment and risk reduction and by the functional needs of the hoist system. (See Annex note.)

7.4.3.5 Design of the hoist system shall allow enough distance for deceleration from full speed after activation of any limit switch, so that damage to the machine or additional fault conditions shall not occur.

7.4.3.6 Where the hoist can be reconfigured after the initial installation, it shall be possible to reset normal (end of travel, initial) and ultimate (overtravel) limit switches. The resetting of normal (end of travel, initial) and ultimate (overtravel) limit switches shall be performed by a competent person.

7.4.3.7 Means shall be provided for temporarily overriding the normal (end of travel, initial) limit switches to test the ultimate (overtravel) limit switches.

7.4.3.8 Means shall be provided for temporarily overriding ultimate (overtravel) limit switches.

7.4.4 Additional sensors

7.4.4.1 When the hoist is equipped with load cell overload sensor(s), sensor activation shall disable hoist movement when the load exceeds the value determined by the risk assessment and risk reduction. The system shall allow corrective movement based on the risk assessment and risk reduction process.

7.4.4.2 When the hoist is equipped with underload or slack line sensors, sensor activation shall stop the hoist in the direction of travel, but movement shall be allowed in the opposite direction.

7.4.4.3 When the hoist is equipped with a speed sensor, the sensor shall identify unintended speed deviations, and initiate a stop. The category of stop and allowable successive action shall be appropriate for the safety device or function activated as determined by the hoist system designer.

7.5 Interlock devices

7.5.1 Interlock devices shall be permitted for use as safety functions.

7.5.2 When used for safety functions, activation of an interlock device shall prevent movement or initiate a stop.

7.5.3 Interlock device fault conditions shall be indicated while the fault condition exists.

8 Manuals

(See Annex note.)

8.1 General

8.1.1 The supplier shall furnish a system manual or manuals, covering operations and maintenance of the system. (See Annex note.)

8.1.2 The system manual shall be composed of an operation section and a maintenance section. The system manual may be bound in multiple volumes.

8.1.3 Record drawings of the hoist system shall be included.

8.1.4 The system manual shall state the limits of use and include requirements that operation of the hoist system shall be restricted to competent persons who are trained in the system operation and who are familiar with the manual.

8.2 Operation

The system shall be clearly described in this section and shall include, at minimum:

8.2.1 A description of each safety function.

8.2.2 Descriptions of fault indications, including system responses and corrective procedures.

8.2.3 Comprehensive operator instructions.

8.3 Maintenance

The maintenance section shall include recommendations for inspection, testing, and maintenance of the system. A log for documenting inspections and work performed on the system shall be included.

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 Z535.1-2006, Safety Color Code

9.1.2 ANSI Z535.2-2006, Environmental and Facility Safety Sign

9.1.3 ANSI Z535.3-2006, Criteria for Safety Symbols

9.1.4 ANSI Z535.4-2007, Product Safety Signs and Labels

9.2 The hoist shall have a label affixed indicating the manufacturer's rated capacity of the hoist.

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 Electrical equipment and control systems shall be marked and labeled in compliance with the requirements of NFPA 79.

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

9.9 Signage shall state the operational limits.

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

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

10 Installation

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

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 manufacturer's recommendations for inspection and maintenance shall be followed unless the manufacturer's recommendations 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.

11.3 Testing procedures

11.3.1 The hoist system shall be inspected.

11.3.2 Operation of the control system including all limit switches, safety devices and interlock devices shall be confirmed. Mechanical over-speed braking devices may be excluded from this requirement when the hoist manufacturer supplies written verification of a successful test of representative samples.

11.3.3 Each hoist or hoist system shall undergo a static load test at 100% of the WLL.

11.3.4 Each hoist or hoist system shall undergo a dynamic load test at 100% of the WLL and maximum rated speed.

11.3.5 The emergency stop function shall be tested at 100% of the WLL and maximum rated speed. This test shall be conducted in both the ascending and descending directions. Components shall be observed for indications of malfunction. (See Annex note.)

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

11.4 Documentation

11.4.1 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.

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

11.4.3 Inspection reports and test reports shall be placed in a system log. (See Annex note.)

12 Maintenance

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

12.2 Systems shall be maintained following the manufacturer's instructions.

12.3 All maintenance performed shall be recorded in a system log.

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

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

ANNEX A, Supplemental information

This annex is not part of the requirements of this standard and is included for informational purposes only. It contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1

This standard acknowledges current industry practice and risk assessment and risk reduction for decision making. The standard is influenced by the European standard CWA15902-1 2008 Lifting and Load-bearing Equipment for Stages and other Production Areas within the Entertainment Industry[5], as well as ANSI Standards E1.4-2009 Entertainment Technology – Manual Counterweight Rigging Systems and B30.16-2007 Overhead Hoists (Underhung).

A.3.1
A.3.13
A.6.1.2

The characteristic load is the maximum load that occurs in a component of the hoist system during normal operation. It includes the working load limit, weight of load carrying devices such as battens and liftlines, and inertial forces due to acceleration. These loads are apportioned to each component based on the hoist system geometry and the maximum loads defined in the limits of use. The peak load is the maximum load in a component that results from abnormal conditions or irregular operation. Two of the most common sources of peak loads are uncontrolled stops, such as in the event of a power failure, or a stalled motor.

[5] Cen Workshop Agreement (CWA), Cen – European Committee for Standardization, www.cen.eu

The following examples illustrate the types of loads. Figure 1 shows a simple two line hoist system with a uniform working load limit of 4500 N (1012 Lb). The weight of the batten (load carrying device) is 200 N (45 Lb). The batten has a maximum speed of 0.25 m/s (50 fpm) and the acceleration and deceleration time is controlled to 0.5 seconds.

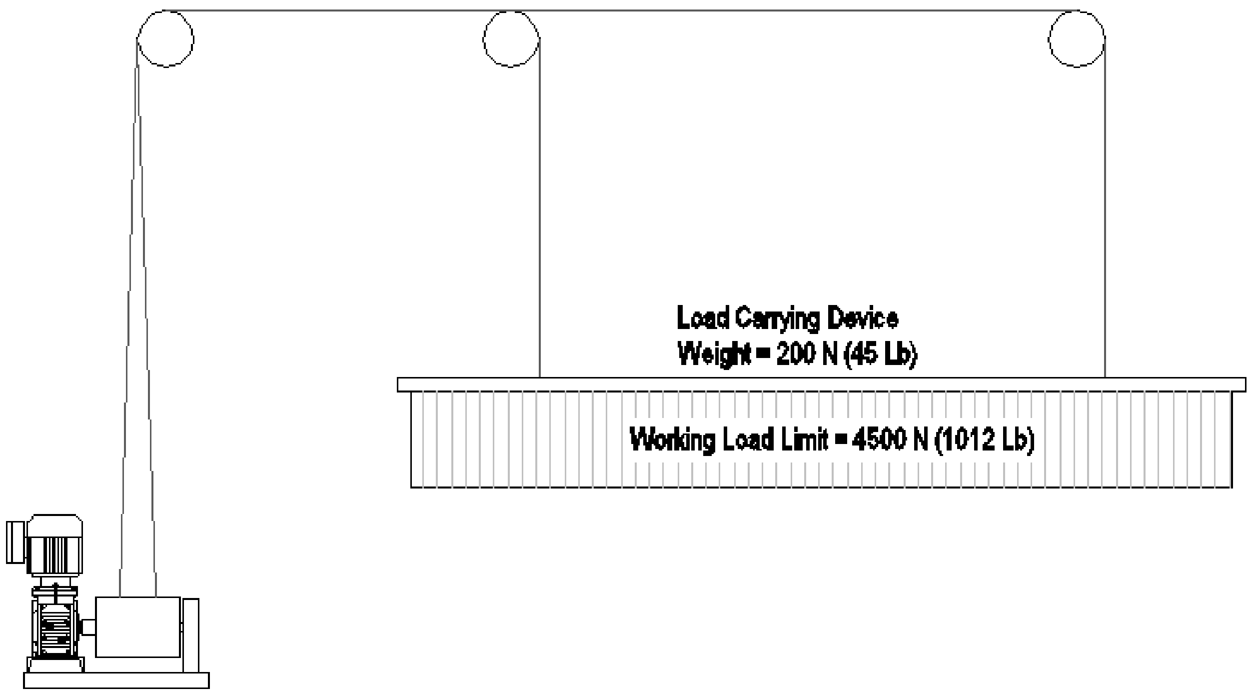

Figure 1

Calculations for this example determined that the inertial load during normal operation is 0.05g.
The characteristic load at the hoist and head block is

1.05 X (4500 N + 200 N) = 4935 N

1.05 X (1012 Lbs + 45 Lbs) = 1110 Lbs

Since each loft block supports half of the total load, the characteristic load of each loft block is

4935 N/2 = 2467.5 N

1110 Lbs /2 = 555 Lbs

These characteristic loads are shown in figure 2.

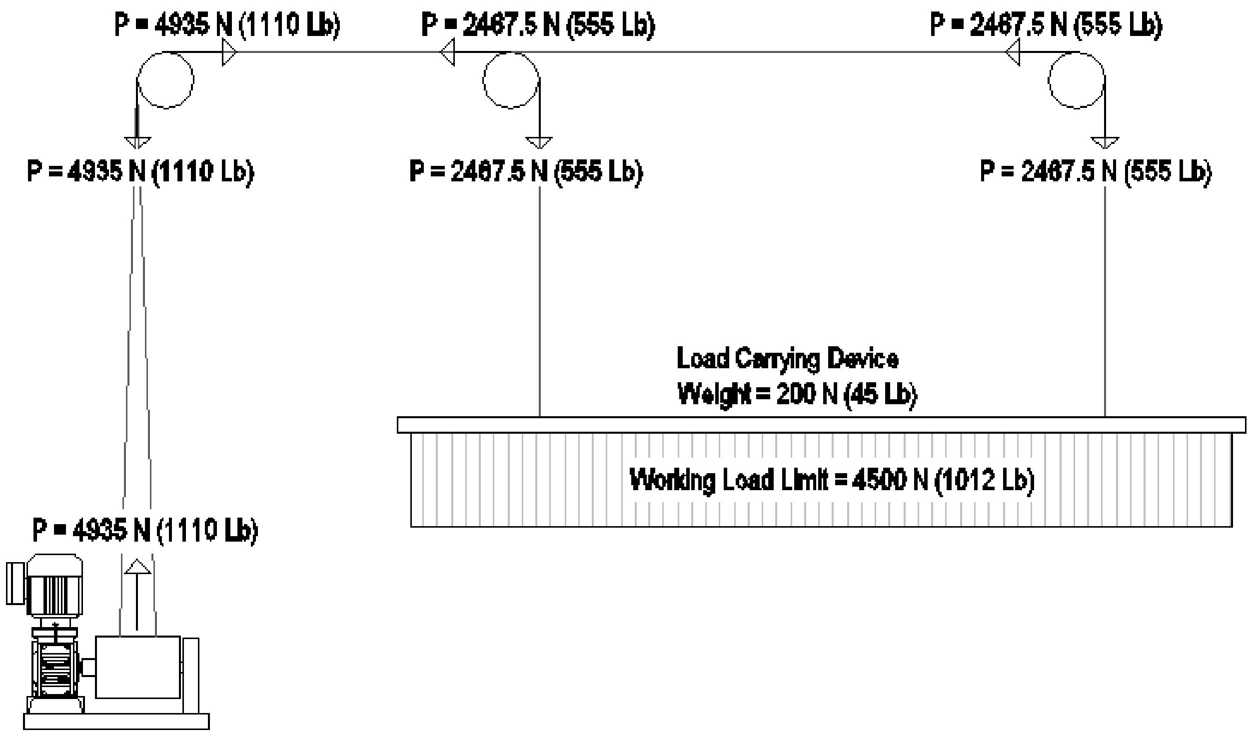

Figure 2

Calculations have determined that the inertial load due to an uncontrolled stop is 0.75g. The resulting peak load at the hoist and head block from an uncontrolled stop is

1.75 X (4500 N + 200 N) = 8225 N
1.75 X (1012 Lbs + 45 Lbs) = 1849 Lbs

However, if the batten were snagged on an object or the hoist motor otherwise stalled, the breakdown or stalling torque is approximately 300% of the full load torque. The peak load for a stalled hoist is

3.00 X (4500 N + 200 N) = 14100 N
3.00 X (1012 Lbs + 45 Lbs) = 3170 Lbs

Since the stalling load is higher, this is the governing peak load. Figures 3 and 4 show two possibilities for how peak loads can change in both magnitude and location, depending upon the conditions governing peak load evaluation. (Working load limit is not shown in figures 3 and 4 since the peak load is determined by the motor.)

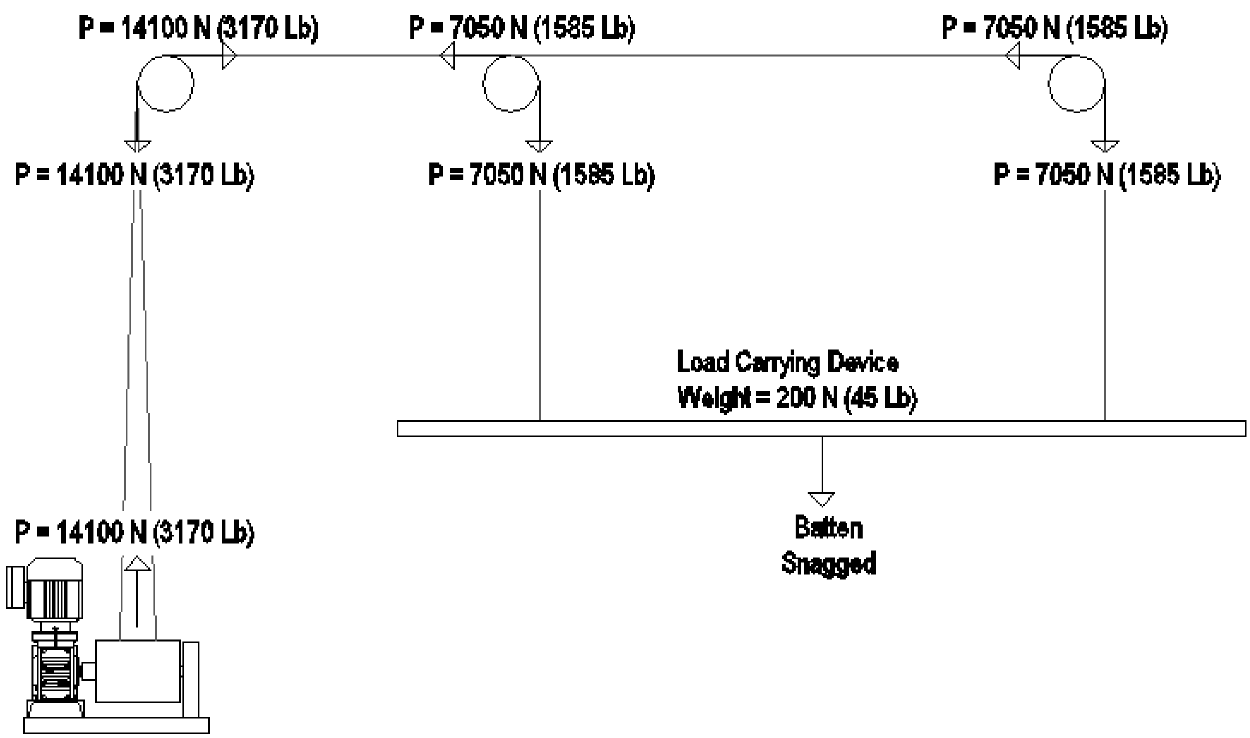

Figure 3

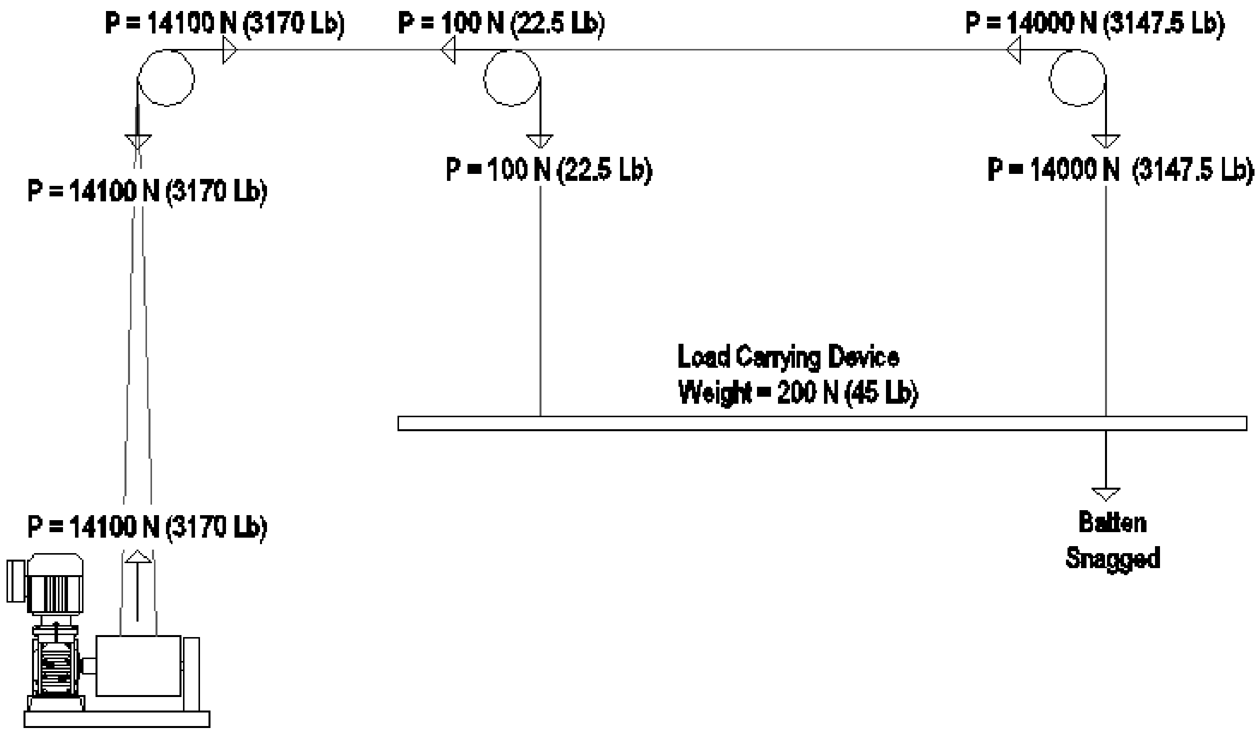

Figure 4

A.3.4
An enabling device is a secondary switch that must be manually actuated in addition to the primary control switch to operate the hoist. De-actuation of the enabling device will stop the hoist. An enabling device is often employed with a secondary operator, and may be used in situations where the primary operator does not have direct line of sight to the entirety of the object being hoisted, or when the operation requires that an operator be in a particular location. In some cases, the person operating the enabling device could be a performer.

Typical examples of an enabling device include a pendant with a hold to run button or pressure mats. It should not be confused with a limit switch, but may be considered a type of manually-activated interlock.

A.3.17
In practice, the prime mover is often a motor that converts electricity directly into rotating mechanical power that acts on the winding device via the power transmission. In other cases, an electric motor may be used to create an intermediate form of power, e.g. hydraulic, that is transmitted to a motor or cylinder within the hoist power transmission system. In such an arrangement, the hydraulic motor or cylinder is the prime mover for the purposes of this document because it converts the fluid power into mechanical motion that moves the hoist machinery. The stalling force of the actuator needs to be considered in deriving the peak load, and that may or may not be limited by the stalling force of the motor that drives the hydraulic pump.

A.4.1
Note that there is no requirement that only one entity is responsible for the entire RA/RR. The entity performing the RA/RR should take into consideration how the RA/RR of others may impact the analysis. RA/RR is an ongoing process. There are key points within the design, fabrication, installation, and testing phases when the RA/RR must be performed in relation to the specific phase.

For example, the initial specifier will perform a RA/RR to define the limits of use of the hoist system and its capabilities. The hoist designer will perform a RA/RR for elements within the framework of the specification, such as inclusion of chain guards or secondary load securing devices. An installer will perform a RA/RR to safely put the system in place.

A.5.5

It may be necessary to limit the maximum number of hoists in simultaneous operation for a number of reasons. These could include:

- The ability of the operator(s) to observe all hoists with adequate attention.
- The application of a category 0 stop during a power failure. This could result in loads that exceed the building's structural limitations.
- The available power supply.
- Control system or software limitations.

A.6.2.1

Uniform load and eight hours per day of use are equivalent to a Service Factor of 1.0. The service factor may need to be increased to account for duty cycle and environmental conditions.
The 33% of yield is approximately equal to the current ASME B30 series requirements for a 5:1 design factor on the static load assuming an additional 75% for dynamic loading.

Peak loads are limited to the manufacturer's peak load rating or the yield strength of the component to prevent excessive deformation or failure.

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.6.2.5

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*[6] 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 proportions 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.6.2.5.7

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

[6] *Wire Rope User's Manual.* Alexandria, VA: Wire Rope Technical Board

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.

A.6.4.1.2
A.6.5.4
In multiple line hoist systems, the actual peak load on a single line may be equal to the stalling strength of the hoist. Current practice assumes that this may result in isolated failure of lifting media or rigging components. Limiting the peak load to 6 times the characteristic load provides reasonable design strength.

A.7.3.2
Additional sensors and interlock devices may include, for example:

- Overload sensors
- Underload or slack-line condition sensors
- Overspeed device(s) or sensors
- Phase rotation and phase loss sensors

A.7.3.3
Fault conditions which may lead to hazardous operation conditions include, for example:

- the prescribed speed is exceeded
- lifting media are overloaded or slack
- the wear limit of the power screw is reached
- the permissible group synchronization tolerance is exceeded
- the prescribed trajectories are not maintained
- too many hoists move at one time

A.7.4.2
For additional information on selection of emergency stop buttons, reference applicable industrial control standards such as NFPA 79 and IEC 60947-5-1.

A.7.4.2.8 Additional stop switches are permitted. Stop switches for stopping of hoist systems that do not stop all hoists shall follow a separate color and labeling scheme than the color and labeling scheme used for emergency stop, even if the stop switch executes a category 0 stop.

A.7.4.3.4
Typically, the main drive device for an electrically powered hoist uses either a set of reversing contactors or a variable frequency drive to control the motion of the hoist. The normal (end of travel, initial) limit switch is usually tied into the control of this device.

A failure of this device (such as a welded contactor or a mis-configured drive) could lead to a motor that can no longer be stopped via user controls or normal (end of travel, initial) limit switches.

When this occurs, a separate contactor in the feed of the reversing contactors or the drive, which is turned off by the overtravel limit switches to stop this hoist, can be used.

When using a variable frequency drive equipped with a certified Safe Torque Off (STO) input, it is possible to use this input in place of the separate circuit interrupting device, e.g. a contactor a shunt trip breaker.[7]

When using “solid state reversing contactors”, with a certified “Safe Off“ input, it is possible to use this input in place of the separate contactor.

[7] IEC 61800-5-2: 2007 Adjustable Speed Power Drive Systems – Part 5-2: Safety Requirements – Functional International Electrotechnical Commission, IEC Central Office 3 rue de Varambé, P.O. Box 131, 1211 Geneva 20, Switzerland www.iec.ch/

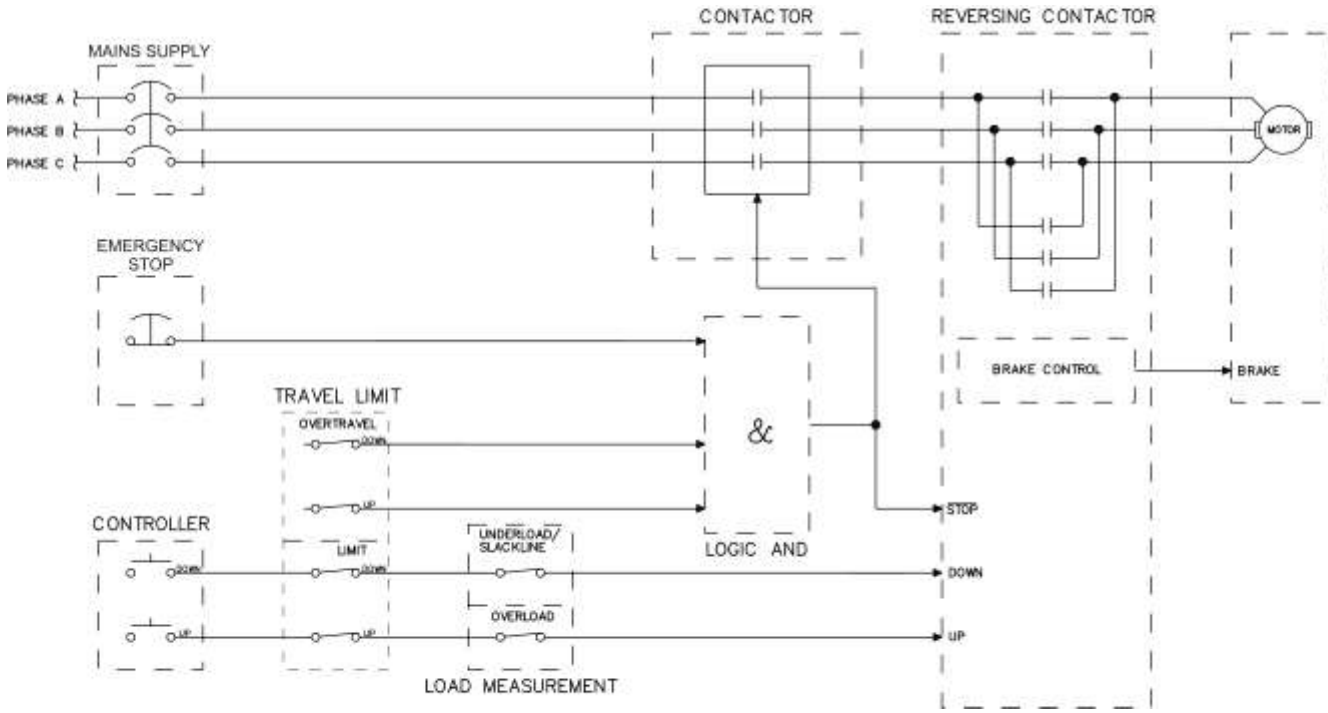

Figure 5, Block diagram, fixed speed controls

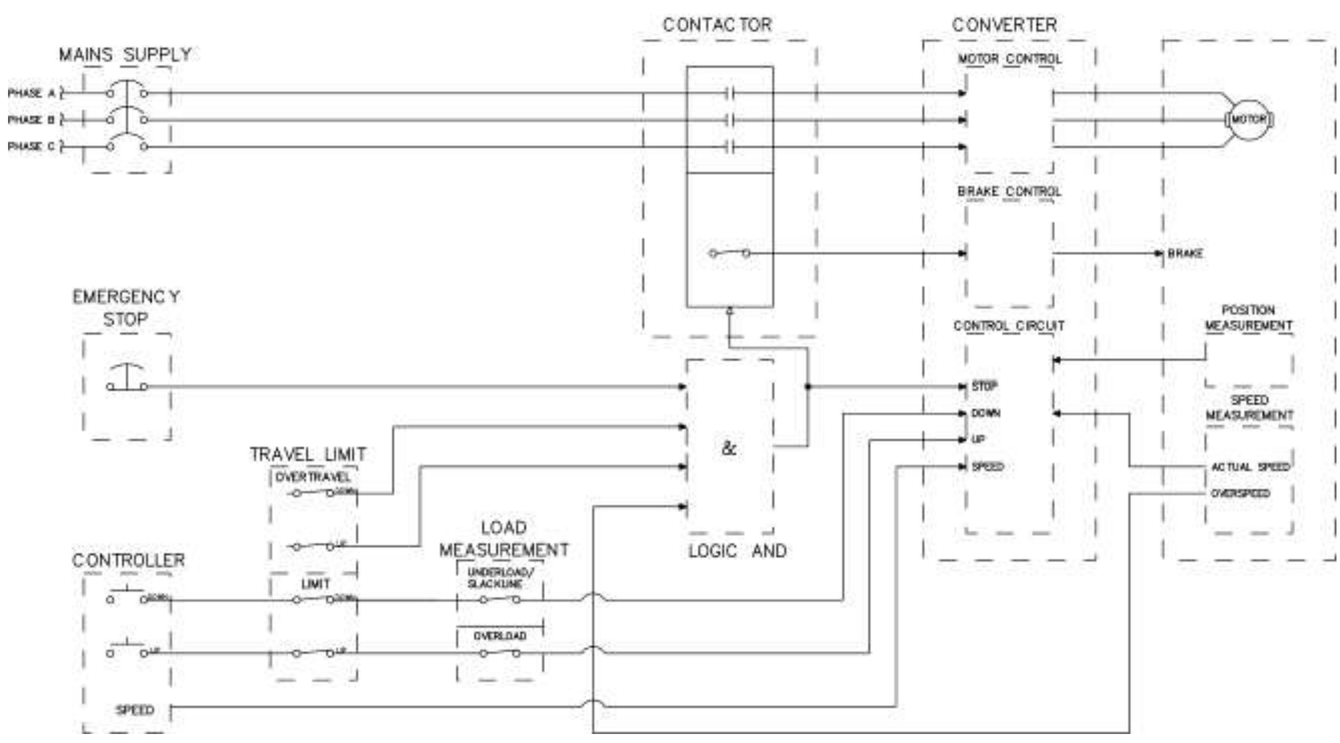

Figure 6, Block diagram, variable speed controls

A.8

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.

A.8.1
Manuals should comply with the requirements of ANSI Z535.6-2006, Product Safety Information in Product Manuals, Instructions, and other Collateral Materials.

A.11.3.5
In addition, the building structure, though outside the scope of this document, shall be observed for indications of malfunction.

A.11.4.3
The log should be made available to inspectors and technicians.

ANNEX B, Examples of hazards and hazardous situations

This annex is not part of the requirements of this standard, and is included for informational purposes only.

1.0	**Mechanical hazards:**
	a) Size and shape of hoist system
	b) Relative location
	c) Mass and velocity of elements in controlled and uncontrolled motion
	d) Inadequacy of mechanical static structural components
	e) Inadequacy of mechanical components to resist repetitive elastic stresses
	Component checklist for failure mode analysis:
	a) Motor capacity
	b) Primary braking capacity
	c) Secondary braking capacity
	d) Suitability of lifting medium
	e) Attachment of lifting medium
	f) D/d value of sheaves and drums (if used)
	g) Shaft size and design including hollow components and keyways
	h) Secondary drive mechanisms (chains, belts, etc.)
1.1	Crushing hazard
1.2	Shearing hazard
1.3	Cutting and severing hazard
1.4	Entanglement hazard
1.5	Drawing in or trapping hazard
1.6	Impact hazard
1.7	Stabbing or puncture hazard
1.8	Friction or abrasion hazard
1.9	High pressure fluid injection or ejection
1.10	Exposure to hazardous materials used in the manufacture or operation of the hoisting machine
2.0	**Electrical hazards:**
2.1	Contact of persons with live parts (direct contact)
2.2	Contact of persons with parts that have become live under faulty conditions
2.3	Approach to live parts under high voltage
2.4	Electrostatic phenomena
2.5	Low frequency, radio frequency, microwave interference
2.6	Failure of power supply
2.7	Failure of control circuit
3.0	**Environmental hazards:**
3.1	Burns and other injuries due to contact with objects that achieve high operating temperatures
3.2	Damage to hoist or hoist system or personnel due to hot or cold working environment
3.3	Additional loads due to wind
3.4	Damage to hoist or hoist system due to excessive moisture
3.5	Inadequate access for maintenance
3.6	Inadequate local lighting for maintenance and operation
3.7	Fire or explosion hazards
4.0	**Noise hazards:**
4.1	Hearing loss (deafness) and other physiological disorders (e.g. loss of balance or awareness)
4.2	Interference with speech communication, acoustic signals, etc.
5.0	**Vibration hazards:**
5.1	Personnel exposure to machine vibrations
5.2	Damage to hoist or hoist system due to environmental or self imposed vibrations
6.0	**Control system hazards:**

6.1	Human error, human behavior
6.2	Inadequate design or location of local controls
6.3	Inadequate design location of programmable controls
6.4	Improper use of E-stop
6.5	Inadequate limit over-ride procedures
6.6	Software errors
6.7	Operational ergonomic concerns
6.8	Mental overload (e.g. due to number of channels controlled at one time)
6.9	Mental underload stress (e.g. due to repetitive tasks)
6.10	Control system position feedback errors
6.11	Simultaneous motion of multiple hoists
7.0	**Unexpected startup, unexpected overrun/overspeed due to:**
7.1	Failure/disorder of the control system
7.2	Restoration of energy supply after an interruption
7.3	External influences on electrical equipment
7.4	Software errors on startup/restart
7.5	Operator error
8.0	**Emergency hazards:**
8.1	Mechanical failure during operation
8.2	Failure of emergency stop devices, interlocks
8.3	Impossibility of stopping the hoist or hoist system
8.4	Combination of hazards

ANNEX C, Risk assessment and risk reduction example

The following example is based on the risk assessment and risk reduction process (see figure 6 and table 1) and guidelines established in ANSI B11.TR3-2000.

The example below includes only an abbreviated list of the limits of use, the tasks, and the associated hazards.

The estimated severity of harm and probability of occurrence of harm was quantified using table 1 in the example.

Although not shown explicitly, the following factors were considered when estimating the probability of the occurrence of harm:

- Exposure to the hazard
- Personnel who perform the tasks
- Machine / task history
- Workplace environment
- Human factors
- Reliability of safety functions
- Possibility to defeat or circumvent protective measures
- Ability to maintain protective measures

The method used to identify the risk value (R) associated with a hazard is to multiply its probability (P) by its severity (S). (R = P * S). The criteria for acceptable risk is shown in table 1.

		Probability				
		Unlikely	Unlikely but Possible	Likely	Highly Possible	Certain
Severity	**Trivial injury**	**1**	**2**	**3**	**4**	**5**
	Minor injury	**2**	**4**	**6**	**8**	**10**
	3 day injury / loss of work	**3**	**6**	**9**	**12**	**15**
	Major injury	**4**	**8**	**12**	**16**	**20**
	Death	**5**	**10**	**15**	**20**	**25**
1-4: Acceptable risk; 5-8: Acceptable only if risk is as low as is reasonably practicable; 9-25: Unacceptable risk						

Table 1 Hazard risk rating table

It is possible that a hazard (e.g. falling objects) can have a multitude of causes (e.g. lift line or brake failure), and each cause needs to be evaluated separately.

Although not necessarily shown in the example below, the supporting design data used for producing the initial probability, severity, and mitigation values for more complex design changes (e.g. drawings and calculations) should be recorded with the documentation of the risk assessment and risk reduction.

Risk assessment and risk reduction is an iterative process that is repeated until the risk is at an acceptable level. An abbreviated schematic of the process is shown in figure 6.

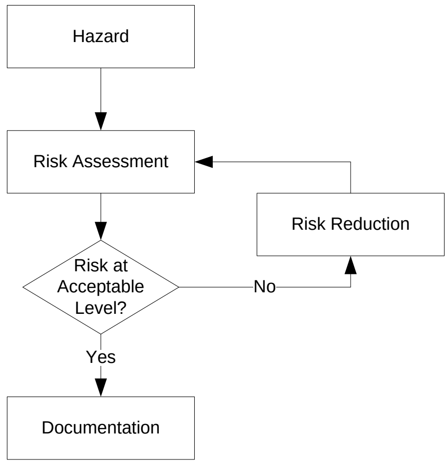

Figure 6: Risk assessment and risk reduction flow chart

Example risk assessment and risk reduction
Sections in "*italics"* are not actual parts of the example.

The following risk assessment and risk reduction was conducted using the procedure established in ANSI B11.TR3-2000.

This is an examination of what has the potential to cause harm to people as considered during the design and manufacture of a typical hoist. Support documentation, drawings and calculations would be supplied in a separate document.

This assessment is designed to assess the risk of injury to the following people:
1. Hoist system installation personnel
2. Maintenance personnel
3. Hoist operators
4. Stage performers and technical personnel
5. Visitors

It identifies the severity of potential hazards and probability of occurrence as per table 1 and documents steps taken to minimize the risk.

Limits of Use
This is a partial list of typical limits of use for this example.

Hoist capacity (working load limit) ....340 kg (750 pounds)
Maximum speed ....Maximum 0.914 m/s (180 feet per minute)
Duty cycle...Maximum 2 complete cycles under full load followed by 15 minutes of rest
Mounting...Adequately mounted to the grid that is suited to support the hoist
User..Operated by qualified users only
Operating environment...Indoor use only
Temperature: 4°C - 49°C (40°F-120°F)
Humidity: 20% – 85% non-condensing
Power supply ....480V, 3 Phase, 20A

Some anticipated tasks throughout the life of the product
More additional tasks exist than are shown in this example.

- Installation
  - Unpacking
  - Hoisting
  - Attaching to the building
  - Connecting power and control

- Usage (including reasonably foreseeable misuse)
  - Performing movements in normal operating conditions
  - Attaching loads to the load carrying device
  - Move and suspend the attached load
  - Overloading hoist (foreseeable misuse)

- Test and Maintenance
  - Troubleshooting
  - Annual Inspection
    - Gaining access to the machine or other parts of the system
    - Test brakes

- Test limit switches
- Test E-stop system
- Inspect wire rope
- Inspect loft blocks

- Replace wire rope

List of hazards
Refer to table 1 for (S) and (P) values.

Phase of life: Usage
Task: Move and suspend the attached load.

Hazard / cause	Hazard Severity (S)	Probability (P)	Risk Rating (S * P)	Mitigation technique	Hazard Severity (S2)	Probability (P2)	Residual Risk (S2 * P2)
Crushing hazard, load falls after catching on HVAC duct close to pipe end	5 Falling objects can kill people	3 As currently designed, pipe ends within 6 inches of ductwork	15	Shorten pipe to maintain clearance.	5	1	5
Crushing hazard, operator cannot see load in motion	4 A fast moving pipe can severely injure a person	4 Upstage sets can not be seen from the control location	16	Supply an enable switch in a location from which the upstage sets can be seen	4	1	4
Crushing hazard, unauthorized user lowers pipe on person	4 A fast moving pipe can severely injure a person	3 Controls system in public space	12	Supply control system with keyswitch	4	1	4
Many additional hazards may exist that are not shown in this example.							

Phase of life: Maintenance
Task: Troubleshooting

Hazard / cause	Hazard Severity (S)	Probability (P)	Risk Rating (S * P)	Mitigation technique	Hazard Severity (S2)	Probability (P2)	Residual Risk (S2 * P2)
Electrocution due to touching live parts	5 Electrocution can kill a person	1 All electrical components touch safe in a fully enclosed cabinet in locked room	5	Not required	5	1	5

Many additional hazards may exist that are not shown in this example.

Conclusion

Significant hazards have been identified and satisfactory mitigation techniques have been introduced so that the risk is reduced to an acceptable level. Please refer to engineering drawings and documentation for additional details.

ANNEX D, Risk assessment publications

The following publications do not address the field of entertainment machinery and controls specifically, but they can add insight into the field of risk assessment and can serve as guidance to teams and individuals in creating risk assessment and risk reduction procedures. ANSI B11.TR3-2000 is of interest to the entertainment industry due to its accommodation and recommendation for input from the end user.

Standards publications

ANSI B11.TR3-2000 Risk Assessment and Risk Reduction - A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools.

ANSI/RIA R15.06-1999 American National Standard for Industrial Robots and Robot Systems - Safety Requirements (revision of ANSI/RIA R15.06-1992)

ANSI/ISO 12100-1:2007 Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology

ANSI/ISO 12100-2:2007 Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles

ISO[8] 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction

ISO[9] 14121-1:2007 Safety of machinery - Risk assessment - Part 1: Principles

ISO[10] 14121-2:2007 Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods

ISO[11] 13849-1:2006 Safety of machinery – Safety related parts of control systems – Part 1: General principles for design

ISO[12] 13849-2:2006 Safety of machinery – Safety related parts of control systems – Part 2: Validation

IEC[13] 61508-1 through 7 Functional safety of electrical/electronic/programmable electronic safety-related systems

Reference publications

Main, Bruce W.
Risk Assessment: Basics and Benchmarks
Publisher: Design Safety Engineering Inc. (2004) Oxford, UK
Hardcover: 485 pages
Language: English
ASIN: B0025YG7U6

Smith, David and Simpson, Kenneth G.L.

8 International Organization for Standardization www.iso.org
9 International Organization for Standardization www.iso.org
10 International Organization for Standardization www.iso.org
11 International Organization for Standardization www.iso.org
12 International Organization for Standardization www.iso.org
13 International Electrotechnical Commission, IEC Central Office 3 rue de Varambé, P.O. Box 131, 1211 Geneva 20, Switzerland www.iec.ch/

Functional Safety" - A Straightforward Guide to Applying IEC 61508 and Related Standards
Publisher: Butterworth-Heinemann; 2 edition (August 10, 2004) Ann Arbor, MI
Hardcover: 280 pages
Language: English
ISBN-10: 0750662697
ISBN-13: 978-0750662697

Abkowitz, Mark D.
Operational Risk Management
Publisher: Wiley (April 4, 2008) Hoboken, NY
Hardcover: 278 pages
Language: English
ISBN-10: 0470256982
ISBN-13: 978-0470256985