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Entertainment Technology - Powered Rigging Systems

Approved by the ANSI Board of Standards Review on [insert date here]

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Voting members:

Observer (non-voting) members:

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 is to be used in conjunction with Stage Machinery Control Systems, ANSI E1.64.

This standard does not apply to the structure to which the hoist is attached or attachment of loads to the load carrying device.

This standard does not apply to systems for flying performers per ANSI E1.43. Note that hoists built to this standard may be used for flying performers when all of the requirements of E1.43 are also met.

Excluded are Electric Chain Hoists per ANSI E1.6-2, E1.6-3, E1.6-4 and E1.6-5.

Excluded are manually powered hoists per ANSI E1.4-3, including auxiliary drill operation. (See Annex note.)

Excluded are Powered Curtain Machines per ANSI E1.71. Note that utility battens which support curtains are not a curtain machine.

Excluded are low-mass stage effects with a self-contained load and lifting system. (See Annex note.)

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, 2020 edition[1]

American Welding Society standards[2]

ANSI/AISC 360-16 Specification for Structural Steel Buildings

ANSI B11.TR3 2000 (R2015) Risk Assessment and Risk Reduction

ANSI E1.2 2021 Design, Manufacture and Use of Aluminum Trusses and Towers

ANSI E1.22 Entertainment Technology - Fire Safety Curtain Systems

ANSI E1.64 Stage Machinery Control Systems in the Entertainment Industry

ANSI Z535
1 - Safety Color Code - 2022
2 - Environmental and Facility Safety Signs - 2023
3 - Criteria for Safety Symbols - 2025
4 - Product Safety Signs and Labels - 2023
6 - Product Safety Information re Product Manuals, Instruction and Other Collateral Materials-2011 (R2017)

[1] The Aluminum Association 1525 Wilson Boulevard, Suite 600 Arlington, VA 22209, www.aluminum.org
[2] American Welding Society 8669 NW 36th Street #130, Miami, FL 33166, www.aws.org

ASME B30-30-2023 Ropes[4]

NFPA 70: National Electric Code, 2023 edition[3]

NFPA 79: Electrical Standard for Industrial Machinery, 2024 edition[3]

NFPA 80: Standard for Fire Doors and Other Opening Protectives, 2025 edition[3]

3 Definitions

3.1 bend cycle. Bend cycle is the change from the straight state of the rope into the bent state and back again into the straight state.

- Whenever a rope is wound onto a drum it carries out half a bending cycle and is a complete cycle when it's unwound off the drum. *When a section of rope travels winds onto a drum (raising) it completes one half bend cycle and when the same section of rope winds off the drum (lowering) it completes the full bend cycle.*

- Whenever a rope runs over a sheave the respective rope zone carries out a complete bending cycle. *When a section of rope travels over a pulley in one direction (raising) it completes one bend cycle and when the same section of rope travels over the pulley in the opposite direction (lowering) it completes a second bend cycle.*

3.2 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.)

3.3 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.

3.4 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.

3.5 curtain. A flexible finished scenic, decorative, architectural, or utility element used to provide cover or separation between areas. A curtain may be transparent, translucent, or opaque. Curtains may be fabricated from one or more materials combined into a singular finished flexible element. For the purposes of these definitions, retractable projection screens can be considered curtains. (See Annex note.)

3.6 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.)

3.7 fault. The state of an item characterized by inability to perform a required function.

3.8 failure. Termination of the ability of an item to perform a required function. After a failure, the item has a "fault". A "failure" is an event, as distinguished from "fault," which is a state.

3.9 hoist. A machine used to raise or lower a suspended load.

3.10 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.

3.11 interlock device. A switch, sensor, or interconnected logic system that permits or prevents motion.

3 National Fire Protection Society 1 Batterymarch Park Quincy, MA 02169-7471, www.nfpa.org
4 The American Society of Mechanical Engneers Two Park Avenue New York, NY 10016, www.asme.org

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

3.13 limit, normal (hard). A limit switch or sensor that prevents further movement in the direction of travel, i.e., end of travel, initial.

3.14 limit, software (soft). A programmed reference position that prevents further movement in the direction of travel.

3.15 limit, ultimate. A limit switch that senses over-travel in the event of failure of the normal position limit, i.e., over-travel.

3.16 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).

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

3.18 load securing device. A mechanical device that prevents unintentional movement in the hoist system.

3.19 may. Indicates a feature, accessory, or methodology is permissible.

3.20 must. Indicates a mandatory requirement.

3.21 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.)

3.22 programmable electronic system (PES). A system for control, protection, or monitoring based on one or more programmable electronic devices, including all elements such as power supplies, sensors and other input devices, data highways, other communication paths, operators, and other output devices.

3.23 pile-on drum. Drum in which the individual lifting media winds in concentric layers, and are constrained to rest on the prior layer.

3.24 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).

3.25 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).

3.26 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.)

3.27 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.

3.28 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).

3.29 risk. Combination of the probability of occurrence of harm and the severity of that harm.

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

3.31 risk reduction (RR). Mitigation of risk created by hazardous conditions.

3.32 shall. Indicates a mandatory requirement.

3.33 should. Indicates a recommendation that is not a mandatory requirement.

3.34 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.

3.35 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 remove power when the stop is achieved.

category 2 stop. A controlled stop with power left available to the machine actuators.

3.36 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.

3.37 ultimate load carrying capacity. The maximum load a component may support without fracture, buckling or crushing This value may be calculated as the nominal strength using nationally recognized construction standards appropriate for the given material or by laboratory tests.

3.38 winding drum: A device used to connect the lifting media to the power transmission of a hoist; converts rotary motion of the gear shaft to linear motion of the lifting media.

3.39 working load limit (WLL). The maximum static load the user may apply.

4 Risk Assessment

4.1 General

A risk assessment shall be performed to determine what hazards are present and their severity. The risk assessment shall prioritize which risks are most in need of mitigation or elimination. The risk assessment should be performed for all possible stage conditions, including the unoccupied facility, load-in, load-out, and performance. The risk assessment may be one large document or multiple documents covering the different uses or operating modes of the machine.

It is preferable that risk assessment be performed by a group of two or more competent persons. When the risk assessment is completed by a single individual, that individual shall be a qualified person.

4.2 Identify the Affected Parties

The risk assessment shall identify all at-risk persons and the risk. Reasonable risk mitigation depends on who is at risk.

4.3 Identify the Hazards

Hazards should be identified on multiple levels.

Risk assessment and hazard determination are ongoing activities as conditions change. Hazards that were once unlikely may become probable as equipment or performers age or the equipment or scenery changes. Risk reduction solutions that were once impractical may become reasonable.
In its simplest form, a hazard assessment answers the question “What if...?”

- there isn’t a barricade or lanyard preventing access during non-working hours?
- the actors are late to their positions at the top of the act and rush onstage?
- the carpenters need to do last-minute touch-ups on the set using a personnel lift just before curtain?
- the electricians have to do a last minute refocus or relamp?
- the janitor has to access the supplies closet on stage left to service the toilets on stage right, and does this late at night after the show?

		Severity				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Probability	Very Unlikely (1)	1	2	3	4	5
	Unlikely (2)	2	4	6	8	10
	Possible (3)	3	6	9	12	15
	Probable (4)	4	8	12	16	20
	Very Likely (5)	5	10	15	20	25

Sample Risk Assessment Table

Low risk 1 – 3Moderate risk 4 – 8
High risk 9 – 14
Extreme risk 15 – 25

The above "Sample Risk Assessment Table" is one of many possible risk assessment tables. Different tables will have different number ranges and different criteria for separating different risk levels, but all serve the function of helping a person doing a risk assessment rank the risk levels of various hazards. The details of the table used matter little; what matters is that hazards are identified and ranked, so that risks can be addressed in reasonable priority. The risk ranking helps in developing an agenda for what needs to be mitigated.

As can often be the case at the inception of a new machine or machine use, there is little reliable accident data available to you. However, it is important to put forth a concerted effort to conduct risk assessments where needed. Leveraging past experience or simply approaching the process on an intuitive basis to assess how likely a slip, trip or fall is to occur or the damage that might result from an accident is often enough to allow an understanding of what must be done. Certainly, making no attempt to assess risk or to control it because too much is unknown would be to neglect a basic duty of care for workers and other people.

Additional sources of information can assist in identifying where a risk assessment is most needed or needs to be repeated. Sources such as internal incident and accident reports, OSHA 300 log data and insurance claim/loss information can all be sources that can be used to identify injury trends. This data may identify trends from both a frequency and severity of injury perspective.

- for the facility/venue/worksite
- for each department (Wardrobe, Props, Scenic Construction, Scenic Art, Stage, Front of House, etc.)
- for each production and the activities involved
- for the entire life cycle of the machine

There are many ways to identify hazards:

- walk around the worksite and look at how work is done
- ask crew members, technicians and performers at the venue what they consider unsafe
- think about what could possibly go wrong, being sure not to overlook things that people may have “worked around” for years

- review incidents that have occurred at the venue
- talk to others in the industry to find out what hazards they have identified or what sort of incidents they have had

In its simplest form, a hazard identification answers the question “What if...?”.

4.4 Assess and Rank the Risk
The risk assessment shall determine the severity and likelihood of a possible injury caused by the hazard. Risk is the product of the severity of a hazard and the probability of it happening.

4.5 Risk Mitigation

4.5.1 Take measures to reduce unacceptable risks.

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

4.5.3 Repeat the risk assessment and mitigation process until an acceptable level of risk is achieved.

4.6 Record the Risk Assessment & Mitigation
The risk assessment should be recorded in a format that is convenient and durable and that can be shared with the affected parties, those people who are at risk or those needing to carry out the risk remediation. Stating the risk assessment in writing is an obvious and usually convenient format, but it might not be appropriate if some of the people needing access to the risk assessment cannot read. Audio or video recordings might be better media in some instances.

(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 Hoist systems shall be designed to allow for inspection, maintenance, and replacement.

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

5.6 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.)

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

5.8 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.

5.9 Calculation of the peak load shall assess the maximum torque output from the prime mover in a stalling condition and the effects of uncontrolled stops. Uncontrolled stop calculations shall account for potential variations in braking torque.

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

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

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

5.13 Hoist system components shall resist both unintentional sliding and detachment from the supporting structure.

5.1.14 Fasteners shall be self-locking, or secured by alternate means to prevent loosening. Fasteners shall be installed in accordance with manufacturer's instructions.

5.15 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 sub-assembly.

5.16 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 (See Annex note.)

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. Fire safety curtain hoist systems operating during emergency descent in compliance with applicable standards are deemed to comply.
(See Annex note.)

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.

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

6.1.6 Weld designs and bolted connections shall have a Design Factor that is 20% above the Design Factor of the assembly (See Annex note.)

6.1.7 Design engineer shall determine fastener capacities by following a nationally recognized code. The calculated tensile strength shall then be reduced to a factor of 0.8.

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 mechanical load rating at a minimum Service Factor of 1.0. Power transmission components without manufacturer's load ratings shall be designed so that stresses do not exceed the following:

6.2.1.1.1 Power transmission components shall be designed and selected with minimum Design Factor Against Yield of 3X the shear stresses due to the characteristic load. (See Annex note.)

6.2.1.1.2 Power transmission components shall be designed and selected with a minimum Design Factor against Yield of 1.58X the bearing (contact) stresses due to the characteristic load.

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 selected such that the peak load is less than the yield strength of the component.

6.2.1.3 The thermally limited load rating of power transmission components shall be suitable for the limits of use of the hoist system. (See Annex note.)

6.2.2 Motors

6.2.2.1 Hoist system motors shall be sized appropriately for hoist capacity, design criteria and duty cycle.

6.2.2.2 Fixed speed hoist system motors shall have a minimum starting torque of 1.5X of the static load. Variable speed hoist system motors shall have a minimum starting torque of 1.1X of the characteristic load.

6.2.2.3 Hoist systems shall be designed to prevent loss of directional control while reversing the motor. (See Annex note.)

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.

6.2.3.3 Neither load securing device shall require external power to engage.

6.2.3.4 Each load securing device shall be capable of stopping and holding 1.1X the static load unless otherwise permitted by section 6.2.3.5.

6.2.3.5 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. Fire safety curtain hoists are deemed to comply.

6.2.3.6 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 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 Chain shall wrap the sprocket for sufficient distance to provide adequate tooth strength and avoid the chain rollers from disengaging the sprocket teeth.

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

6.2.4.4 Sprockets shall be selected to mitigate the effects of chordal action.

6.2.5 Winding drums (See Annex Note.)

6.2.5.1 Winding drums shall take up the media in a defined and repeatable manner.

6.2.5.2 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.

6.2.5.3 Pitch diameter of a winding drum shall not cause damage or undue wear to the lifting media.

6.2.5.4 Drum material and construction shall resist tread pressures imposed by the lifting media.

6.2.5.4.1 The maximum allowable fleet angle from a grooved drum shall be two (2) degrees relative to the helix of the groove. (See Annex Note.)

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

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

6.2.5.5 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.)

6.2.5.6 The attachment of the lifting media to the drum shall be designed and selected with a minimum Design Factor of 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.

6.2.5.7 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. (See Annex note.)

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 Power nut screws shall be designed and selected with a minimum Design Factor of 1.6X the characteristic load and1.2X the peak load.

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 2X the characteristic load shall not exceed the manufacturer’s recommended maximum operating pressure.

6.2.7.3 The pressure resulting from 1.2X 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. Disabling an actuator shall not interfere or impede safety devices.

6.2.7.5 The operating pressure shall be limited by means of a pressure limiting device.

6.2.7.6 It shall be possible to measure the system pressure.

6.2.7.7 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.

6.2.7.8 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 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.

6.4 Lifting media

6.4.1 General

6.4.1.1 Lifting media shall be designed and selected with a minimum Design Factor as follows:

8X static load.
5X characteristic load
1.33X peak load.

6.4.1.1.1 Reduction in Design Factors

In situations where the characteristic loads and peak loads are confirmed by documented empirical testing data conducted under the supervision of a qualified person or by engineering calculations prepared by a qualified person it may be possible to reduce the Design Factors.

Provided the lifting media will be inspected daily or will be subjected to less than 1000 bend cycles between inspections, and the inspection shall be done at all bending points along the lifting path, it may be possible to use the following design factors:

6.5X static load.
4X characteristic load
1.33X peak load.

6.4.1.2 For multiline hoists, the peak load for lifting media shall not exceed 6X the characteristic load. (See Annex note.)

6.4.1.3 The minimum tensile strength shall include termination efficiency and other applicable strength reduction factors. End termination of the lifting media shall have a minimum tensile strength not less than 80% of the strength of the lifting media. (See Annex note.)

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 strength equal to or greater than 1.33X the peak load.

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 disconnection.

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 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.

6.4.4.2 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

6.4.5.1 Other lifting media shall be permitted provided the lifting media manufacturer approves it for this use. (See Annex note.)

6.4.5.2 Terminations shall be made by a competent person.

6.4.5.3 The individual terminating synthetic rope shall require third party or rope manufacturer's certification.

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 yield strength of the material shall be at least 4X the characteristic load stresses.

6.5.1.2 For failure modes that result in collapse or fracture, block components shall be designed and selected with a minimum Design Factor Against Yield of characteristic load.

6.5.1.3 For bearing contact stress failure modes, block components shall be designed and selected with a minimum Design Factor Against Yield of 1X characteristic load.

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 as listed by the supplier.

6.5.3 Blocks shall be designed and selected with a minimum Design Factor of 1.33X the peak load.

6.5.4 For single line blocks within multiline systems, the peak load for blocks shall not exceed 6X 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 not cause damage to the sheave or the lifting media.

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 designed and selected with a minimum Design Factor of 2X the characteristic load.

6.6.2 Load carrying devices shall be designed and selected with a minimum Design Factor of peak load.

6.6.3 Battens or their equivalents shall be designed so that the maximum deflection for a uniformly distributed or concentrated point 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 entire length of the batten.

6.6.4 Aluminum trussing shall meet the requirements of ANSI E1.2 - 2021, 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.

6.6.5 Visibility markings
A minimum of 100 mm (4 inches) at each end of the batten or truss shall be durably marked with an approved OSHA safety color, except in architecturally sensitive areas.

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 An Emergency Stop station shall be located at the entrance to the technical space at each level.

6.7.2.3 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.

6.7.6 Guards shall be removable for service.

7 Electrical equipment and control systems

7.1 General

Electrical equipment and control systems for the machinery covered by this standard shall comply with the requirements of ANSI Entertainment Technology E1.64 – Stage Machinery Control Systems in the Entertainment Industry, unless otherwise determined by risk assessment or instructed by a local AHJ or the manufacturer’s chosen Nationally Recognized Testing Laboratory (NRTL).

7.2 Specific requirements and exceptions for electrical equipment on powered hoists

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.

7.2.1 Constraining travel

Design of the hoist control system shall allow enough distance for deceleration of the hoisted load from full speed to a full stop when a position sensor is struck or triggered. Deceleration of the machinery under load shall be calculated and accommodated to prevent hazards from damage to machinery, hoisted load(s), or structure(s).

7.2.2 Constraining sensor terminologies
Constraining sensors should be named and labeled as follows:

TERM	ABBREVIATION
Ultimate Plus	U+
Initial Plus	I+
Soft Plus	S+
Soft Minus	S-
Initial Minus	I-
Ultimate Minus	U-

7.2.3 Applying direction terminologies to stage directions

Constraining sensors should relate to the following direction of motion and stage positions/directions:

TERM	Position	Vertical Motion	Motor Rotation
Ultimate (+)	Increase from origin	Out	CW
Initial (+)	Increase from origin	Out	CW
Soft (+)	Increase from origin	Out	CW
Soft (-)	Decrease from origin	In	CCW
Initial (-)	Decrease from origin	In	CCW
Ultimate (-)	Decrease from origin	In	CCW

7.2.4 Planning the use of position constraining sensors

The planning of constraining sensor use has been included in the normative language of this standard due to its impact on safe operation of the hoisting system and movement of the hoisted load.

Rigging system designers shall determine the stopping distances required by the application by considering, at minimum, the following:

- Inertia when fully loaded at maximum and minimum speed in the OUT direction

- Inertia when unloaded at maximum and minimum speed in the OUT direction
- Inertia when fully loaded at maximum and minimum speed in the IN direction
- Inertia when unloaded at maximum and minimum speed in the IN direction
- The inherent spring capacitance of the lifting media

Reference for the configuration and setting of position constraints

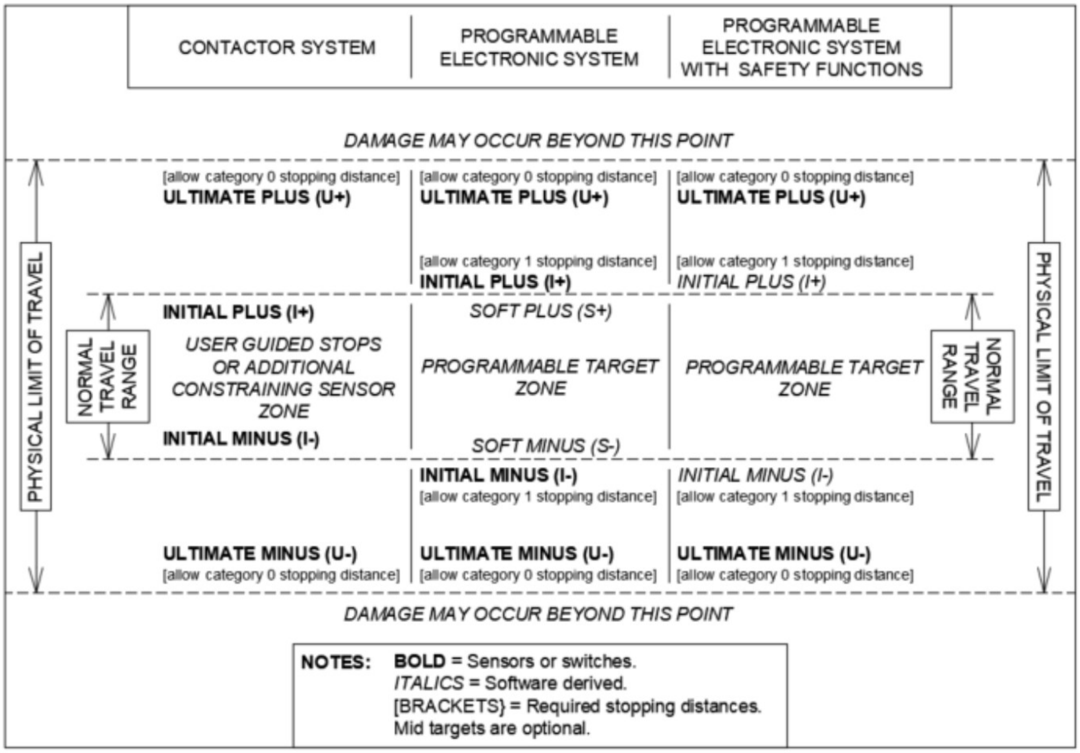


Figure 1

7.2.5 Selection and use of constraining sensors

In addition to Section 12 of ANSI E1.64, sensors used for constraining motion on hoisting equipment must be selected to work with the operation of the hoist. The mechanical, physical, or electronic action of the sensor must deliver the constraining signal to the control system with repeatable position accuracy.

7.2.5.1 Constraining sensors must be installed per the manufacturer's recommendations and securely fastened to the mechanics of the hoist system.

7.2.5.1.1 Sensors for initial and ultimate end of travel may function in any of the following methods:

- Directly driven by the mechanics of the hoist machine
- Actuated by the movement of a counterweight arbor directly coupled to the load
- Actuated by the movement of the load relative to the building structure.

7.2.5.1.2 A system may use a combination of the above

7.2.5.1.3 Sensors shall be located where they can be inspected.

7.2.5.1.4 Sensors and their fasteners that cannot be inspected shall require a mechanically triggered interlock switch contact that opens the sensor circuit if the sensor becomes mechanically separated from the hoist system.

7.2.5.2 Hoists that utilize moving drum or pulley carriages for elimination of fleet angle on lifting media may require an additional set of constraining sensors to prevent damage to the carriage as determined by the hoist designer.

7.2.6 Sensing devices – types

7.2.6.1 Mechanically activated switches
Mechanically activated switches shall have contacts that are snap-acting or positive break.

7.2.6.1.1 Installation of mechanically activated switches shall be completed to meet with the manufacturer's recommended overtravel of the actuator/operator (i.e. lever arm, roller, or push button).

7.2.6.1.2 The actuator/operator must remain in the contacted position when the switch application is to cause the control system to stop the hoist. Other applications may or may not require the actuator/operator to remain in the contacted position pending evaluation and may require performance of a risk assessment.

7.2.6.1.3 The control signal output from mechanically activated switches shall be wired to the normally closed contact block so that when the switch actuator/operator is struck or a cable is damaged the control signal circuit opens.

Exception: A switch may use normally open contact blocks that are normally held closed and open when the switch is triggered.

7.2.6.2 Electronic, Optical, and Photo actuated sensors
Electronic, optical, and photo actuated sensors shall be chosen to operate repeatably, reliably, and accurately in the physical environment of the application. Designers shall ensure that manufacturer recommendations for temperature, vibration, and magnetic field limitations are observed.

7.2.6.3 Positioning tolerance
All sensors shall be selected, positioned, and installed to provide repeatable signaling of position to the control system. Tolerance values for misalignment and repeatability shall be determined by risk assessment of the control reaction to the position of the object being monitored.

7.2.7 Constraining sensor use and control reactions
Control reactions may differ between the specific requirements of the constraining sensor application.

7.2.7.1 Constraining sensor stop categories

7.2.7.1.1 The required stop category of the position constraining sensor shall be determined by risk assessment.

7.2.7.1.2 The basis of determining the required stop category for the risk assessment shall be drawn from one of the following standards:

- IEC 60204-1, Safety of machinery — Electrical equipment of machines — Part 1: General requirements
- NFPA 79, Electrical Standard for Industrial Machinery
- ISO 13850, Safety of machinery — Emergency stop function — Principles for design
- IEC 60204-1, NFPA79, and CSA C22.2 No.301 all describe the different types of stopping – commonly referred to as Category 0, Category 1, and Category 2, not to be confused with control architecture categories of ISO 13849. (See Annex Note)

(Note: The chart below is provided as a reference of the descriptive actions required by the standards named above. It has been included in the normative language of this standard to provide details of stop categories.)

Category	IEC 60204-1	NFPA79	CSA C22.2 No. 301

0	stopping by immediate removal of power to the machine actuators	an uncontrolled stop by immediately removing power to the machine actuators	stopping by immediate removal of power to the machine actuators (i.e., an uncontrolled stop)
1	a controlled stop with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved	a controlled stop with power to the machine actuators available to achieve the stop then remove power when the stop is achieved	a controlled stop with power available to the machine, actuators to achieve the stop and then removal of power when the stop is achieved
2	a controlled stop with power left available to the machine actuators	a controlled stop with power left available to the machine actuators	a controlled stop with power left available to the machine actuators

7.2.7.2 Ultimate Limit
Ultimate limits are required on all hoists and in both directions of travel.

7.2.7.2.1 Ultimate limits shall interrupt a safety that is independent of the normal stopping circuit, e.g. line contactor or STO (safe torque off). (See annex note.)

7.2.7.2.2 The control system shall respond to the opening of the ultimate limit control signal by immediately initiating a stop and reporting a fault.

7.2.7.2.3 Restarting the hoist after activation of this sensor shall require the user to operate a safety override device.

7.2.7.2.4 The design and application of safety override devices shall be inherently temporary, requiring removal or deactivation to restore normal operation once the override action is complete.

7.2.7.2.5 While the safety override device is activated, the machinery shall only be allowed to move in the direction opposite to the direction it was moving when the sensor was struck.

7.2.7.3 Initial Limit
Initial limits are required on all hoists and in both directions of travel.

7.2.7.3.1 The control system shall respond to the opening of the initial limit control signal by immediately initiating a stop and reporting the limit strike to the user.

7.2.7.3.1.1 The stop category for initial limit signal loss shall be determined by review of the application and may also require a risk assessment.

7.2.7.3.2 While the initial limit is activated, the machinery shall only be allowed to move in the direction opposite to the direction it was moving when the sensor was struck.

7.2.7.3.3 A means for temporarily overriding initial limit switch(es) to test ultimate limit switch(es) shall be provided. The design and application of the override devices shall be inherently temporary requiring removal or deactivation to restore normal operation once the override action is complete. (See Annex note.)

7.2.7.4 Soft limits
Soft limits are a function of a PES (programmable electronic system) and are used to complete a programmed motion or to prevent hoisted loads from physically contacting other objects. Soft limits may be triggered by any type of position sensor; safety rated is not required.

7.2.7.5 Co-located limit sensors
The physical travel of some hoisted objects may be limited by permanent or temporary obstructions and require co-located limit sensors. When this scenario arises a risk assessment shall determine the arrangement of position constraining sensors and the required response of the control system.

7.2.7.6 Encoder
Encoding systems may be employed to provide position sensing within the operating range of the hoist system controlled by a PES. Encoding systems may be employed to provide the function of the initial limit pending the results of a risk assessment. Encoding systems shall never be employed to act as ultimate limit sensor.

7.2.7.6.1 Multiple encoders may be used to monitor drum rotation separate from motor rotation or rotation of chain or belt coupled devices (such as rotary limits or carriages). This feature may be used to cause a reaction of the hoist control system as determined by a risk assessment.

7.2.8 Additional sensors
Additional sensors may be required based on a risk assessment.

7.2.9 Interlock devices (See Annex note.)

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

7.2.9.2 When used for safety functions, activation of an interlock device shall prevent movement or initiate a stop. The necessity for the control system to utilize safety rated inputs shall be determined by risk assessment.

7.2.9.3 The control system shall provide indication of the status of interlock devices to the hoist control operator.

7.2.9.4 A means for temporarily overriding interlocks to test the application or overcome a fault shall be provided. The design and application of the override devices shall be inherently temporary requiring removal or deactivation to restore normal operation once the override action is complete.

7.2.10 Multi-hoist systems
The design of multi-hoisting systems shall include the following:

7.2.10.1 When multiple hoists are grouped together to lift a common load or are grouped together for interrelated motion, a monitoring method shall be provided to ensure group movement.

7.2.10.1.1 Where the hoists are not mechanically coupled the machinery designer shall use RA/RR to determine the controls strategy to monitor their movement.

7.2.10.1.2 Overload detection and/or load cells on each machine may monitor the reported loading independently and as a group. The control system shall evaluate either the min/max loads of each hoist or the maximum allowable load differential between the hoists.

7.2.10.1.3 Comparison of encoder values in a master/follower configuration shall evaluate maximum allowable position differential between the hoists compared to the programmed offset. The use of absolute encoders is recommended for this method.

7.2.10.1.4 Tilt switches or inclinometers may be used to detect or measure the load and be programmed to allow for a maximum forward and reverse angle as the hoists move the load.

7.2.10.1.5 The control system of a multi-hoist system shall cause a fault and bring all machinery to a safe stop in the event of a mismatched load between the hoists (based on scaling and tolerance) or group overload.

7.2.10.2 Disconnecting or turning off one machine in the hoist group shall cause the control system to place all hoists in the group in a faulted state and prevent motion of any hoist that is part of the multi-hoist system.

7.2.10.3 The faulting of one machine in the hoist group shall cause the control system to place all hoists in the group in a faulted state and prevent motion of any hoist that is part of the multi-hoist system.

7.2.10.4 An unintended stop of one machine in the hoist group shall cause the control system to place all hoists in the group in a faulted state to prevent motion of any hoist that is part of the multi-hoist system.

7.2.11 Cable and wire selection

Wire and cables shall be selected and sized for the current and voltage being carried. The insulation surrounding individual conductors within a multi-core cable shall be rated for the highest voltage carried by the cable.

7.2.11.1 Insulation ratings
The overall sheath of multi-core cables and conductors shall meet with the requirements of NFPA 70 in respecting the voltage carried by the conductors.

7.2.11.2 Cable and wire protection
Wire and cable run along the framework of the machine shall be protected from damage.

7.2.11.2.1 Securing wire, cables, and containment

7.2.11.2.1.1 Wire, cables, cable energy chain, and conduits shall be securely fastened to the machine frame using mechanical fasteners.

7.2.11.2.1.2 Cable ties wrapped around a machine framework or mechanical cable tie mounts are acceptable if installed according to the manufacturer's recommendations. The use of adhesive backed cable tie mounts without mechanical fasteners is not permitted on the exterior of the hoist.

7.2.11.2.1.3 Rigid or flexible conduits shall be connected to electrical enclosures with manufacturer's recommended box connectors.

7.2.11.3 Use of flexible cable
Wires and cables that are intended to move or flex during normal operation of the machine shall be selected considering the frequency of flex and bend radius. Where the wire or cable requires mechanical protection, the flexible cable shall be installed within a mechanical wire protection system such as cable energy chain.

7.2.12 Machine mounted electrical enclosures
Electrical enclosures mounted to the machinery shall be accessible and serviceable – see installation section.

7.2.12.1 Internal components of electrical enclosures shall be made accessible by a secure device such as a key or tool. Fasteners used to keep access panels closed or prevent unauthorized access shall be fitted to allow service personal to remove and restore them. The use of special tools is permissible.

7.2.12.2 Control level voltages shall be separated from motor power voltages by a barrier of appropriate dielectric strength.

7.2.12.3 Terminals and terminal blocks
Terminal blocks shall be sized for the application taking into consideration voltage, current, and wire gauge of the conductors being terminated in accordance with the manufacturer's instructions.

7.2.12.3.1 The manufacturer's instructions for the size and number of permissible conductors terminated under a single terminal shall be strictly adhered to.

7.2.12.3.2 The use of ferrules for the termination of stranded conductors to any type of terminal clamping method shall be guided by the instructions of the manufacturer of the termination device.

7.2.13 Machine disconnecting means
There shall be a lockable rated means of disconnect located near the machinery. Distance from the machine to the disconnect shall not exceed the limits as designated by OSHA or the local AHJ.

7.2.13.1 The disconnecting means shall simultaneously disconnect the power to the brake circuit(s).

7.2.13.2 The disconnecting means may also disconnect the control voltages or signals.

7.3 Phase loss and rotation protection
Where a phase loss or an incorrect phase sequence of the supply voltage causes a hazardous condition or damage to the machine, protection shall be provided. (See Annex note.)

7.4 Fire safety hoist controls

7.4.1 Fire safety hoist controls shall be a separate system from all other hoist equipment in the venue.

7.4.2 Fire safety hoist controls are intended for routine operation in non-emergency situations.

7.4.3. A control station is not required for the emergency descent operation of fire safety curtain hoists. If emergency descent of a fire safety curtain is enacted, all fire safety hoist action controls shall be rendered inoperative until the curtain release mechanism is reset. (See Annex note)

7.4.4 The following controls requirements are mandated by NFPA 80 and as such incorporated herein:

- Winch operation of the fire safety curtain assembly for nonemergency operation shall be accomplished by the use of a minimum of one control station.
- Controls shall be unobstructed at all times.
- The operator shall have a clear view of operation of the fire safety curtain assembly.
- Function labels shall be permanent and located on the buttons or on the control station adjacent to the buttons.
- A latching emergency stop button shall be located at every control station for stopping emergency operation.
- The emergency stopping operation shall not prevent emergency closing of the fire safety curtain.
- A sign shall be mounted adjacent to each fire safety curtain control station stating the following:
    - NONEMERGENCY FIRE SAFETY CURTAIN OPERATION ONLY
- Nonemergency operation of the fire safety curtain assembly shall be accomplished by one person.
- For nonemergency operation, controls shall require constant pressure to close the fire safety curtain, unless otherwise permitted by 21.7.2.3.
- 21.7.2.3 Constant pressure on the controls shall not be required where the fire safety curtain is provided with a continuous sensing device attached to the bottom of the curtain to stop or reverse the curtain upon contact with an obstruction.
- The fire safety curtain shall be capable of automatic closing without the use of normal building-applied power. (see annex)

7.5 Motion or Descent alarms

When a hoist may start automatically without an operator, motion or descent alarms should be incorporated. The requirement for descent alarms shall be determined by risk assessment. The risk assessment shall, at minimum, take into consideration:

- Exposure of people to crushing or striking hazard
- Frequency of use of the passage or opening being protected by the fire safety curtain or door
- Movement of acoustical ceilings or other elements to allow sprinklers to function properly
- Speed of descent
- Mass of the descending structure or object and its associated counterweight (if utilized in the design)

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 may be composed of multiple volumes and be either in hard copy or electronic format.

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

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 Z535.1-2022, Safety Color Code

9.1.2 ANSI Z535.2-2023, Environmental and Facility Safety Sign

9.1.3 ANSI Z535.3-2025, Criteria for Safety Symbols

9.1.4 ANSI Z535.4-2023, Product Safety Signs and Labels

9.1.5 Standards developed by ESTA specifically for Entertainment Technology.

9.2 Signage general requirements

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

9.2.2 Signage shall state the operational limits.

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

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

9.3 Label

The hoist shall have a label affixed indicating the manufacturer’s name, unique identification, date of manufacture, and rated capacity of the hoist.

9.4 Working Load Limit (WLL)

Hoist systems shall be marked with their working load limit (WLL). (See Annex note.)

9.5 Point loads and Uniformly Distributed Loads

9.6 Lifting Media
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.

9.7 Hardware
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.

9.8 Electrical Equipment and Control Systems
Electrical equipment and control systems shall be marked and labeled in compliance with the requirements of NFPA 79. See ANSI E1.64 for operator controls exemptions.

9.9 Fire Safety Curtains
Signage at each fire safety curtain control station shall include the statement NON-EMERGENCY FIRE SAFETY CURTAIN OPERATION ONLY. (See Annex note.)

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 The system designer or manufacturer shall establish recommended criteria for inspection and testing. These criteria shall be included in the systems operation manuals. In absence of established criteria, testing and inspection shall follow the procedures included herein.

11.1.2 Inspection and testing following installation 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 Systems shall be tested after installation, mishap, repair, or modification.

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

11.1.5 Deficiencies discovered during inspection or testing shall be repaired under the supervision of a qualified person.

11.2 Inspection procedures (See Annex note.)

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

11.2.2 Minimum criteria for inspection

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

11.2.2.2 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 for resolution.

11.2.2.3 Functionality of the control system shall be verified.

11.2.2.4 Functionality of all user access points and Emergency Stop operators shall be verified.

11.2.2.5 The presence of all mandatory signage and labeling as required in Section 9 shall be verified.

11.3 Testing procedures

11.3.1 Tests shall be non-destructive.

11.3.2 Operation of the control system including all limit switches, safety devices and interlock devices shall be confirmed.

11.3.3 Each hoist or hoist system shall undergo a static load test at a minimum of 1X the WLL.

11.3.4 Each hoist or hoist system shall undergo a dynamic load test at a minimum 1X the WLL and at minimum and maximum rated speed and acceleration.

11.3.5 The emergency stop function shall be tested at one 1X 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 Each load securing device shall be tested independently. 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.

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

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

11.4 Documentation

11.4.1 Inspection reports and test reports shall include the name of the qualified person who performed the inspection or tests, the location of the equipment, and the date of the tests or inspection. Reports shall be signed by the qualified person who performed the inspection or tests.

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

12.2 Manufacturer’s Instructions
Systems shall be maintained following the manufacturer’s instructions. (See Annex Note.)

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

12.4 Replacement Components
Replacement components and hardware shall be of equivalent or higher grade or rating than the originals.

12.5 Modifications and Alterations
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.

Note: An annex note may refer to multiple clauses in the normative document.

A.1

The addition of an auxiliary power source, e.g. drill operation, to a manual hoist does not in itself convert the machine into a powered hoist as defined by this document. Look to standards for manually powered hoists and manufacturers instruction manuals for their recommended usage.

A *hoist* is a machine for lifting and lowering. A *winch* is a machine for pulling. A h*oist* lifts a load and has a locking brake that can support a suspended load. This simple distinction is why a capstan winch is not covered by this standard.

Capstans are useful tools for overhauling an out of balance counterweight arbor to a position for adjusting weights during loading and unloading operations. The nature of the machine requires a skillful and dexterous operator to both operate the winch controls and maintain tension on the rope that is pulling the load. The human element cannot be overstated. The operator must maintain the winch engaged under the reaction bar or the load will be lost. The operator must correctly select the rotation of the capstan in relation to the direction the rope is wound onto the drum. The operator has some control of speed by the amount of slip; and is completely responsible for suspending the load when the capstan drum rotation is stopped. The ability to belay the rope to a cleat does not constitute suspending the load from a powered hoist point of view.

There are many hoists that may serve the same function for overhauling counterweight arbors that are covered by this standard. Some features that identify them are lifting media that is securely attached to the drum, load securing devices that set when the load is stopped, and limits of travel, i.e. limit switches.

Standards are in development to address the definition of low-mass stage effects.

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[4], as well as ANSI Standards E1.4-2022 Entertainment Technology – Manual Counterweight Rigging Systems and B30.16-2007 Overhead Hoists (Underhung).

A.3.2
A.3.21
A.6.1.2

The dynamic forces in motorized stage equipment vary over a much greater range than those for manual rigging. For machinery of this type calculations based on the static load alone have been found to result in unacceptable variation of the strength of components when compared to the actual applied forces.

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 designer to anticipate those situations which are either likely to occur or could be of such a great consequence that the user must be protected. One common source of peak loads is an uncontrolled stop such as that experienced in the event of a power failure and the resulting sudden application of the brakes. Another common peak load would occur when the full strength of a stalled motor comes to bear on a load in

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

excess to the hoist capacity such as a condition where the lifted load is caught on adjacent obstructions or is pulled into a loft block (two block) or during an attempt to lift a load that is just too heavy.

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.

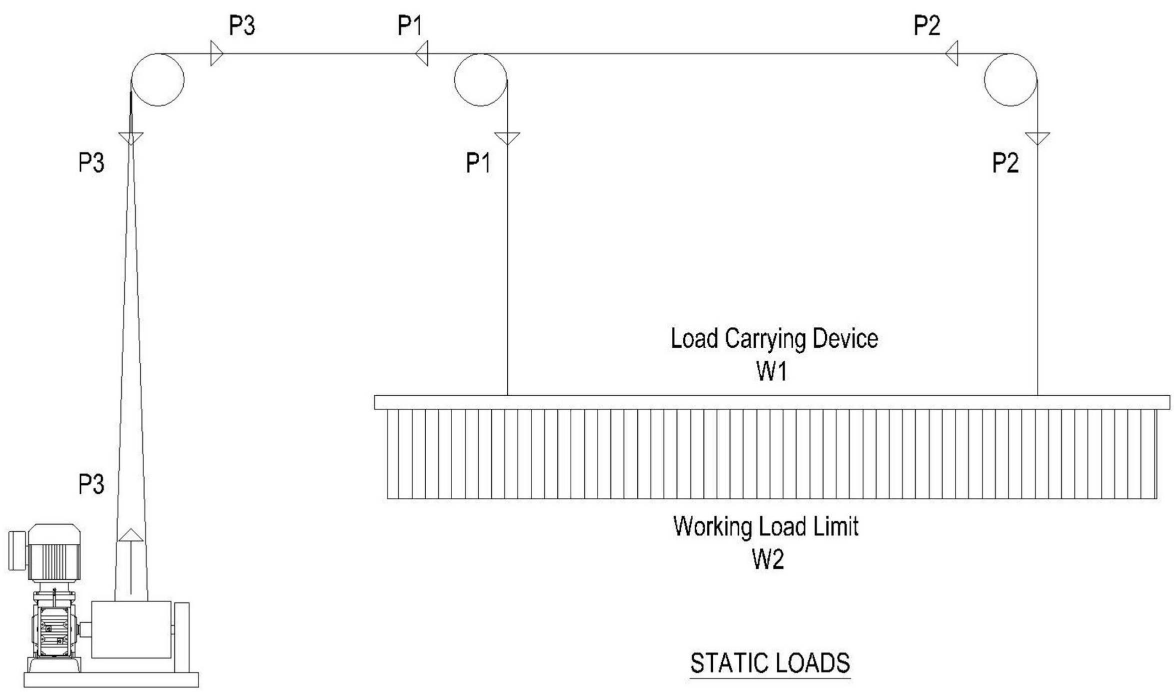
The following examples illustrate the types of loads.

The figure shows a simple two-line hoist system with a uniform load.

P1 + P2 = P3

The static load at the hoist and head block = (W1 + W2)

The static load at each loft block = (W1+W2) / 2



Static Loads					
Units	P1	P2	P3	W1	W2
Imperial	530 lbs	530 lbs	1,060 lbs	45 lbs	1,015 lbs
Si	2,350 N	2,350 N	4,700 N	200 N	4,500 N

Figure 2

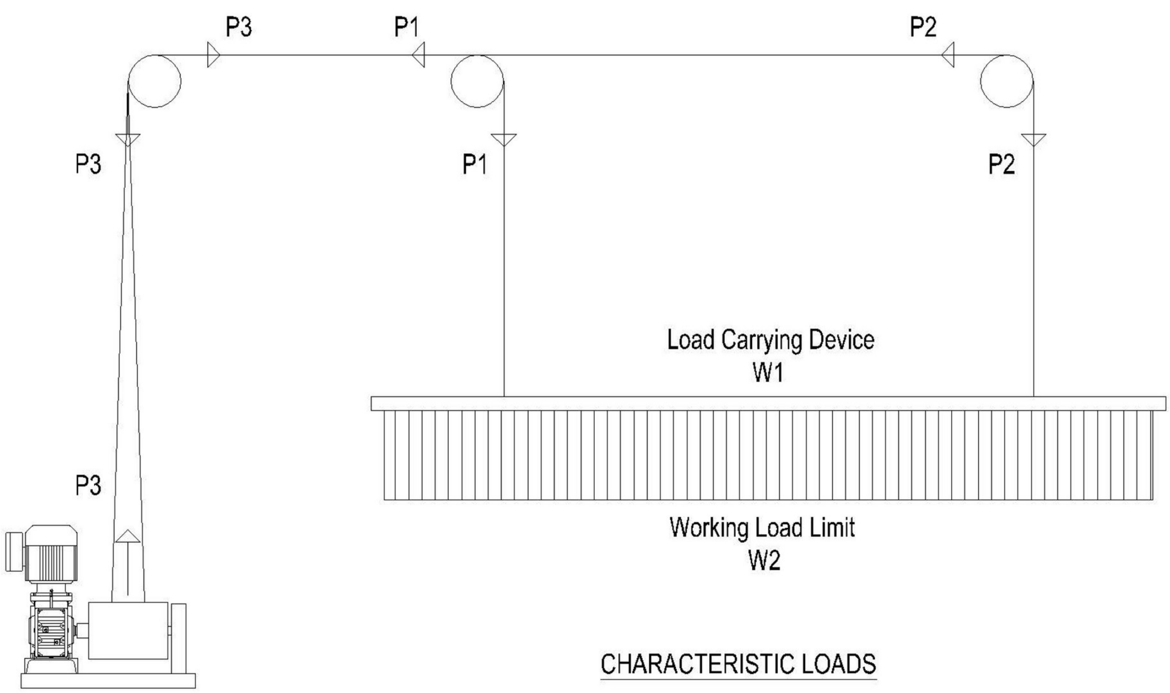
The figure shows a simple two-line hoist system with a uniform load.

The hoist has a maximum speed of 0.25 m/s (50 FPM) and the acceleration and deceleration time is controlled to 0.5 seconds.

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 (W1 + W2)

The characteristic load at each loft block is: 1.05 x (W1 + W2) /2



Characteristic Loads					
Units	P1	P2	P3	W1	W2
Imperial	556.5 lbs	556.5 lbs	1,113 lbs	47.3 lbs	1,065.7 lbs
Si	2,467.5 N	2,467.5 N	4,935 N	210 N	4,725 N

Figure 3

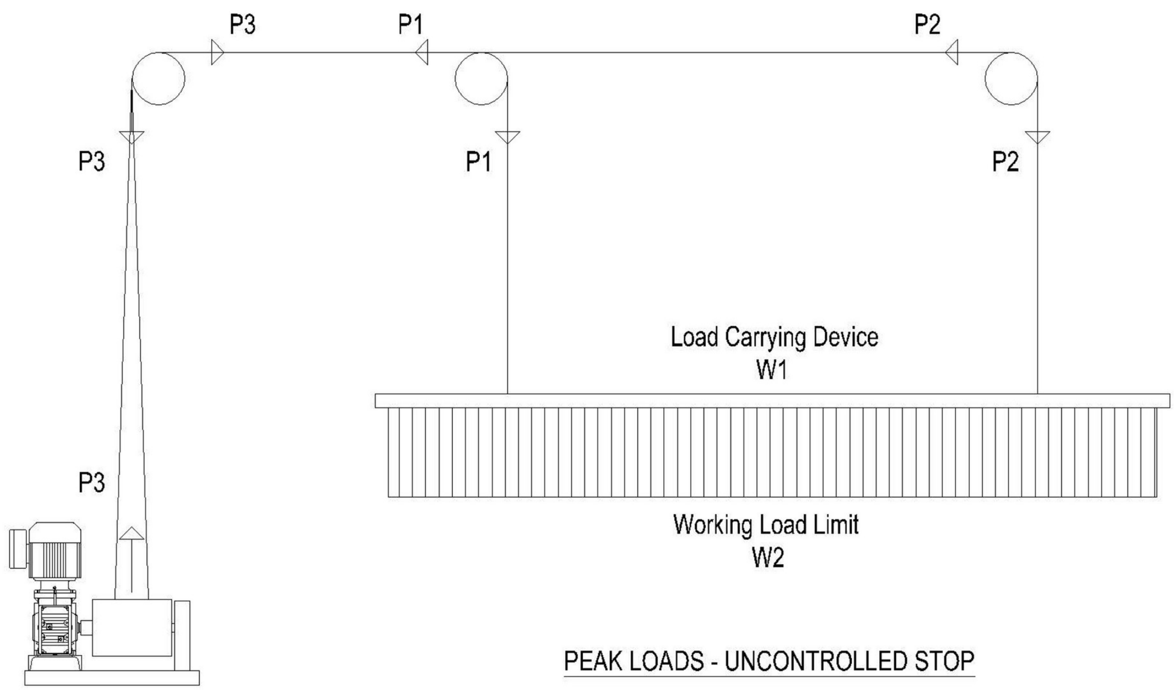
The figure shows a simple two-line hoist system with a uniform load.

The hoist has a maximum speed of 0.25 m/s (50 FPM) and the acceleration and deceleration time is controlled to 0.5 seconds.

Calculations for this example determined that the inertial load due to an uncontrolled stop is 0.75g. The resulting peak loads from an uncontrolled stop are:

The peak load at the hoist and head block is: 1.75 x (W1 + W2)

The peak load at each loft block is: 1.75 x (W1 + W2) /2



Peak Loads Due to Uncontrolled Stop					
Units	P1	P2	P3	W1	W2
Imperial	927.5 lbs	927.5 lbs	1,855 lbs	78.7 lbs	1776.3 lbs
Si	4,112.5 N	4,112.5 N	8,225 N	350 N	7875 N

Figure 4

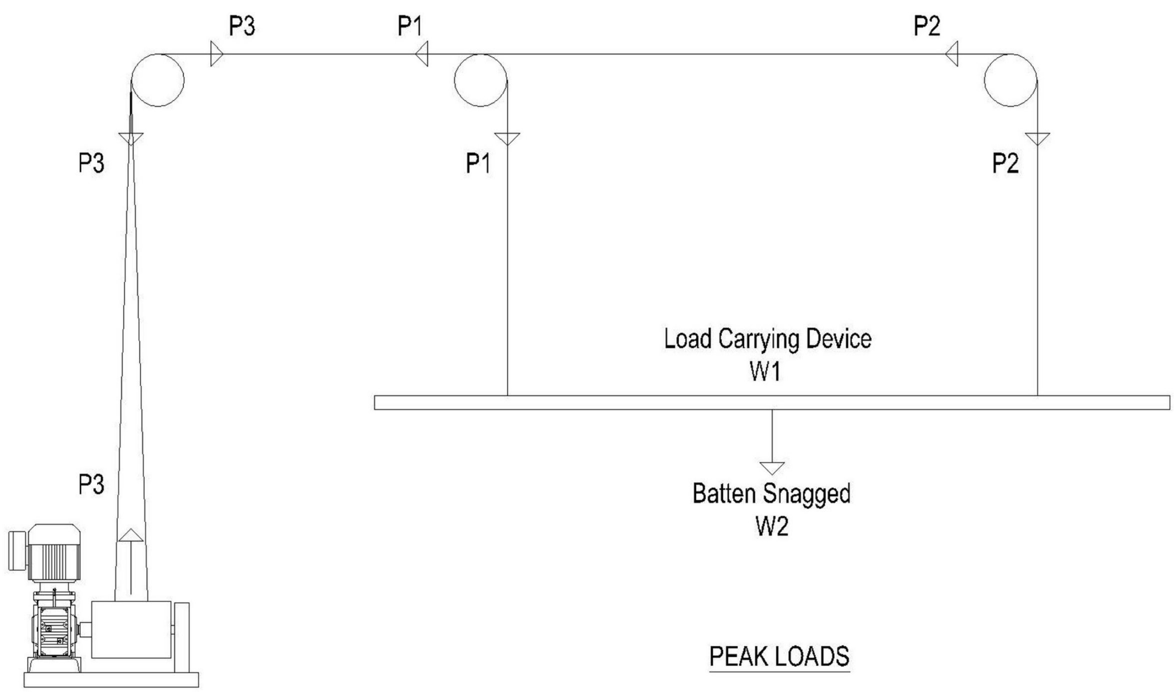
If the batten were snagged on an object or the hoist otherwise stalled, the breakdown or stalling torque of the hoist is approximately 3X the full load torque. The peak loads for a stalled hoist are:

The peak load for a stalled hoist at the hoist and head block is: 3 x (W1 + W2)

The peak load for a stalled hoist at each loft block is: 3 x (W1 + W2) /2

Since the stalling load is higher than the uncontrolled stop peak load, this is the governing peak load.

There are two possibilities for how peak loads can change in both magnitude and location, depending on conditions governing the peak load evaluation. (The working load limit is not shown since the peak load is determined by the motor). Example #1:



Peak Loads Due to Batten Snagged at Center			
Units	P1	P2	P3
Imperial	1,590 lbs	1,590 lbs	3,180 lbs
Si	7,050 N	7,050 N	14,100 N

Figure 5

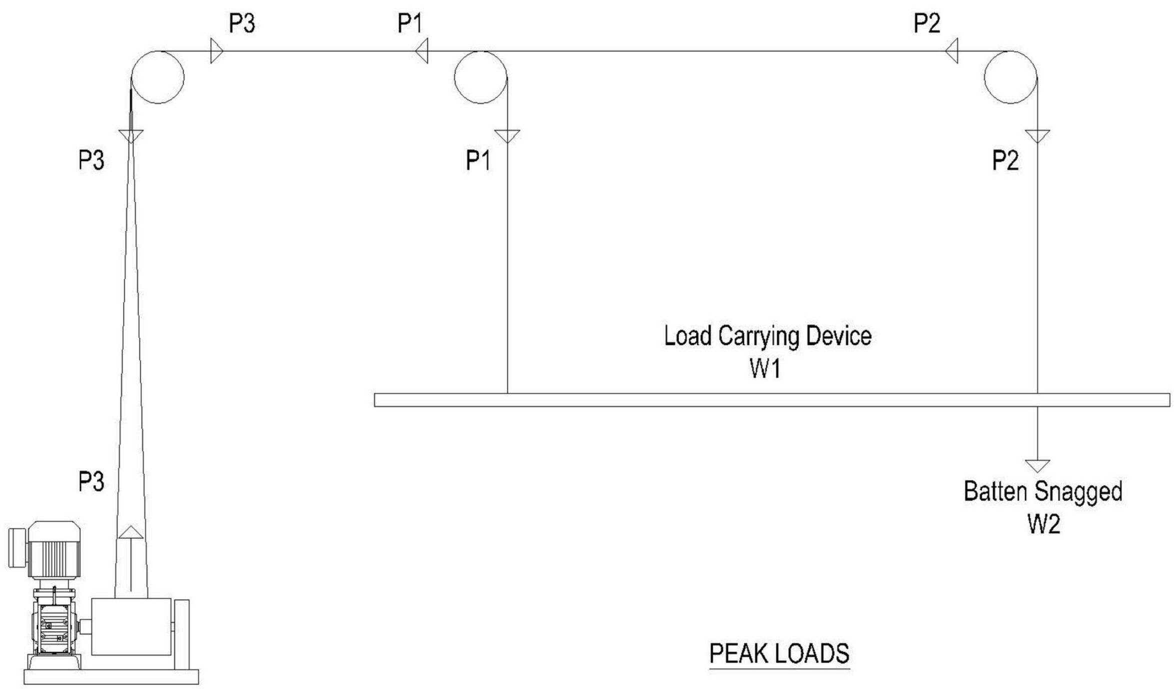
If the batten were snagged on an object or the hoist otherwise stalled, the breakdown or stalling torque of the hoist is approximately 3X the full load torque. The peak loads for a stalled hoist are:

The peak load for a stalled hoist at the hoist and head block is: 3 x (W1 + W2)

The peak loads for a stalled hoist at each loft block are variable.

Since the stalling load is higher, this is the governing peak load.

There are two possibilities for how peak loads can change in both magnitude and location, depending on conditions governing the peak load evaluation. (The working load limit is not shown since the peak load is determined by the motor). Example #2:



Peak Loads Due to Batten Snagged at One End			
Units	P1	P2	P3
Imperial	22.5 lbs	3,157.5 lbs	3,180 lbs
Si	100 N	14,000 N	14,100 N

Figure 6

A.3.5
Curtains can be comprised of many materials and may include columns of chain, beads, rope or other flexible medium (e.g., bead or chain mesh curtains). Curtains may have a rigid leading edge but are not entirely framed or rigid.

Framed panels and hard scenery are not allowed under this standard. Just because it is covered in fabric does not make it a curtain.

A.3.6
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 it may be considered a type of manually-activated interlock.

A.3.21 (See A.3.2)

A.3.26
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.5.6
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.6.1
Design factors used in this standard are based on strength. Deflection, fatigue and other serviceability concerns also need to be considered when selecting hoist system components. The thermal limits of power transmission components need to be evaluated per intended limits of use.

A.6.1.1 By design the emergency descent of fire safety curtains is driven by gravity rather than by the hoist. Emergency descent is initiated by a separate set of operators that, once activated, will cause the curtain to close completely at a specific speed regardless of the fault status of the hoist. The emergency descent functions of a fire safety curtain hoist are distinct from and additional to the non-emergency functions. The requirements for non-emergency functions of the fire safety curtain hoist are identical to other machines within the scope of this standard.

A.6.1.2 (See A.3.2)

A.6.1.6 Derived from the ASME Crane Code

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. 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.

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.6.2.1.1.1
The 3X shear stress factor 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.6.2.1.3
A distinction is made between mechanical strength and thermal capacity of power transmission components. When thermally limited components are selected it is important to verify that the mechanical design factors within this standard are maintained.

A.6.2.2.3
Hoists powered by most single-phase motors require the brakemotor to come to a complete stop prior to reversing the direction. This stop allows the centrifugal direction starting switch to come to rest and the motor to be electrically reversed. An example of the potential hazard occurs when a hoist is running in the up direction. If the down pushbutton is simultaneously pressed and then the up pushbutton is released, the hoist will not change direction of travel. The hoist will bypass the initial limit switches and only be stopped by the ultimate limits. Preventive remedies include mechanically interlocking switches, and interposing timer relays.

Hoists powered by three phase motors may exhibit a loss of direction control when a phase has been lost in the power circuit. Initially the hoist may run down in a "single phasing mode", where gravity has started the rotation. Attempts to reverse the direction of operation from down to up will not be successful and motion will only continue in the down direction. The inclusion of phase loss monitors in the control system are a common preventive remedy.

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*[5] 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.6.2.5.4.1

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

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 7a 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 7b 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 16625:2013 Cranes and hoists — Selection of wire ropes, drums and sheaves and/or the US Navy Wire Rope Handbook Vol 1.

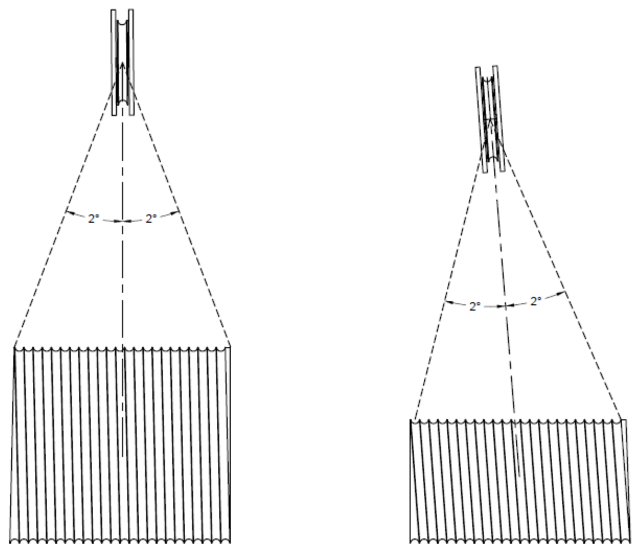


FIGURE 7a FIGURE 7b

Figure 7

A.6.2.5.5
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.

A.6.2.5.7
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.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 6X the characteristic load provides reasonable design strength.

A.6.4.1.3
Lifting media should be selected, consistent with the application, for cut and abrasion resistance; heat weakening and flammability resistance; strength reduction from bending ratios and fatigue, and in consideration of environmental factors (cold, heat, atmospheric) for strength, flexibility, and durability.

A.6.4.5.1
The approval is required from either the hoist manufacturer, the lifting media manufacturer or both, depending on the lifting media. In the cases where the lifting media has no specific manufacturer or is not specifically manufactured for use as a lifting media, it is the responsibility of the hoist system manufacturer to incorporate it in the design and approve it for use in the hoist system as a lifting media. In the cases where lifting media is being

replaced in a hoist system by something other than the original lifting media, the original hoist system manufacturer or a qualified person needs to approve its use.

A.6.5.4 (See A.6.4.1.2)

A.7.1.5

A typical motor disconnect interrupts the three phase T-leads to the motor. In the case of a constant speed hoist, using a motor-powered brake, this is acceptable. Thermostat leads and/or control leads to the brake rectifier do not require interruption. In the case of a variable speed hoist, the power leads to the brake are energized separately from the motor T-leads. This requires a disconnect with a minimum of 5 poles. The hazard is two-fold. With the disconnect off, the possibility exists for electrocution while servicing the motor and brake. Secondly, an operator could command the hoist to travel; the brake would release dropping the load. In the case where the hoist has secondary electric brakes, the power leads to those devices must also be disconnected.

A.7.2.7.1.2

CSA C22.2, which draws heavily on IEC 60204-1 and NFPA 79 may also be referenced but is not a normative requirement of this standard.

A.7.2.7.2.1

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, should be used.

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.

Block diagram, fixed speed controls

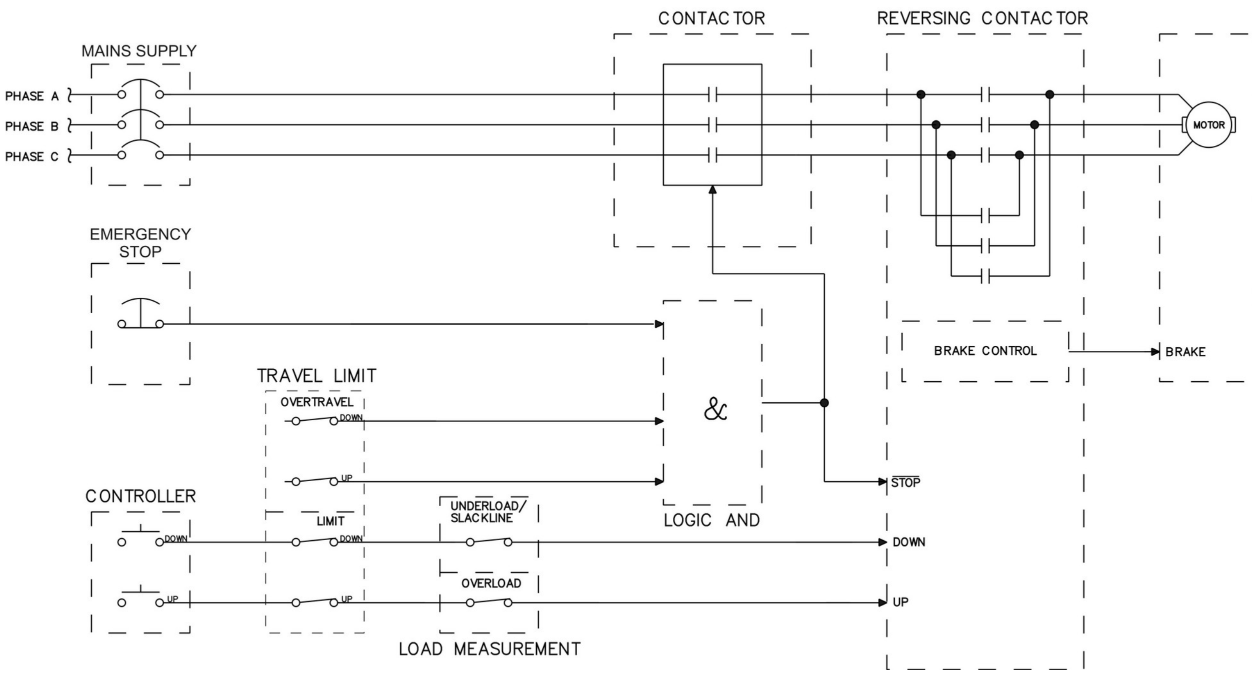


Figure 8.

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.

Block diagram, variable speed controls

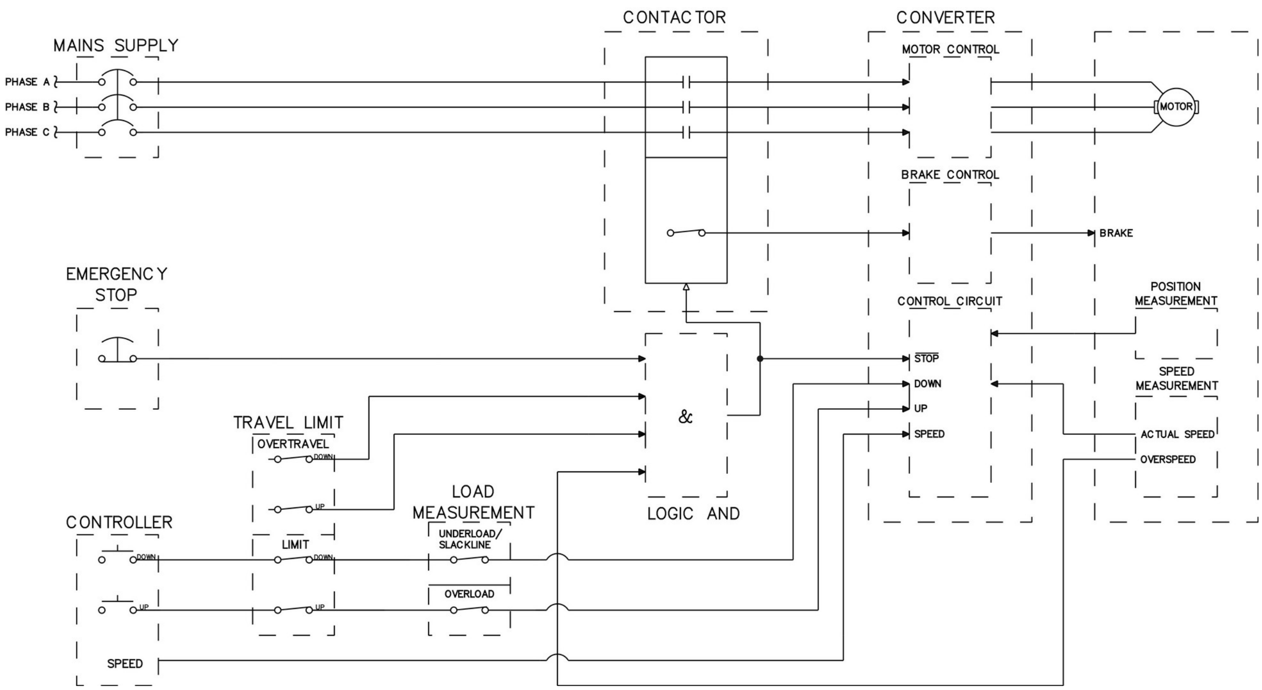


Figure 9.

A.7.2.9

Interlock devices may be part of the hoist system or they may be signals from other electro-mechanical systems. Some examples are as follows:

- A door limit switch that indicates a bomb-bay door is open so that a speaker cluster may be lowered.
- A tilt sensor that indicates the position of a ceiling shell so that it may be raised into a storage position.
- A tilt sensor on a ceiling shell that prevents adjacent battens from being lowered onto a deployed shell.
- A stage wagon position sensor that limits or prevents the travel of battens when scenery is in position.
- A ramp or gate sensor at the egress to a light bridge.
- A limit switch on a roll style movie screen that is also flown on a motorized truss.

Interlocks may be software rules which are written on a show by show basis into the controller.

A.7.3

This is a requirement of NFPA 79 Chapter 7.7. Some practical scenarios are:

Phase loss is common after electrical storms. If the electrical supply loses a phase, the hoist when commanded to operate cannot generate torque, and in many cases the brake will be released. If the commanded direction of travel is down, it is possible the hoist will run down. If the commanded direction of travel is up, the hoist may travel down.

Phase reversal is common when physical plant transformers are replaced or electrical maintenance or upgrades within the panelboard occur. If the electrical supply has a phase reversal, the hoist when commanded to go up will go down and vice versa. The initial limits will have no affect and the only constraints to travel will be the ultimate limits.

A.7.4.3
A fire safety curtain hoist should be equipped with a sensor to disable the prime mover once emergency closing is initiated.

When released, a fire safety curtain hoist may back-drive against a hydraulic governor. Frequently the rotor is spinning at up to twice the motor operational RPM. Should an operator attempt to stop a falling fire curtain by depressing the Up-command pushbutton, a hazard may be created.

A.7.4.4
Annex Note for NFPA 80 A.21.8.7 reads: The use of normal building-applied power to either activate or lower the fire safety curtain in an emergency would not be possible if there is a power outage. Any power needed to activate or lower the fire safety curtain must either have a monitored battery backup or be connected to the building's emergency power system.

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.8.1.1
Manuals should comply with the requirements of ANSI Z535.6-2011 (R2017), Product Safety Information in Product Manuals, Instructions, and other Collateral Materials.

A.9.4 In cases where the hoist system's working load limit differs from the hoist manufacturer's rated capacity for operational or safety reasons, the system should be labeled accordingly.

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

A.9.9 This is a requirement of NFPA 80.

A.11.2
This text is a comprehensive guideline for many systems. The procedures must be customized to match features and equipment of the systems to be inspected.

SAMPLE MOTORIZED RIGGING SYSTEM INSPECTION PROCEDURES

- Verify that operations manuals are available and accessible to system users.
- Verify that operational and warning signage is in place.
- Inspect components for damaged, loose or missing hardware.
- Inspect samples of lifting media termination hardware, no less than 20% per set, for the correct type and installation.
- Inspect the lifting media at all terminations for excessive wear and damage.
- Verify that shackles, turnbuckles, and other rigging hardware are of the appropriate material, grade, and are secured to resist loosening.
- Observe and document any loose sheaves.
- Verify that sheave material does not show signs of excessive wear, cracks or chips.
- Verify that all equipment operates smoothly throughout the available range of travel and without unusual friction, noise, or motions.
- Verify that fleet angles are suitable and lifting media does not contact any obstructions.

- Verify that the working load limits of the systems are known and visible to the operators.
- Verify that guards, if required, are existing and in good condition.
- Verify that the direction of movement is correctly labeled on the controls.
- Test the emergency stop(s). Verify that the emergency stop(s) disconnect power to the motor and not to the control circuit.
- Visually inspect the condition of controller cables, strain reliefs and junction boxes adjacent to rigging equipment.
- Verify that all indicator lamps are functional.
- Verify that all fuses and disconnects are the correct size and type for the applications and for the machines.
- Verify that indicators show the correct position of the load.
- Verify that the brake(s) stop the machinery when the operator control device is released. Full load testing is not required.
- Verify that the upper and lower normal travel limit sensors are functional and set to avoid collision with surrounding objects.
- Verify that moving elements are lubricated to comply with the manufacturers limits of use or as determined by a qualified person. Covers and guards, designed to be removed, should be removed to inspect components within. The condition and suitability of lubricants should be determined, based on the manufacturer’s recommendations.
- Visually observe welds for the presence of cracks and porosity.
- At the completion of the inspection reset any inspection reminder indicators according to the manufacturer’s recommendations.
- Verify that documentation exists for identification of trained users and training dates.
- Verify that a maintenance log is in use and up to date.

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

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

A.12.2
Some maintenance activities may require temporarily disabling or bypassing mechanical or electrical devices required by this standard. Methods that mitigate the additional risks should be determined by the manufacturer or a qualified person.

ANNEX B, Examples of hazards and hazardous situations

This annex is not part of the requirements of this standard. It 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 10.

Figure 10: 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	5 Electrocution	1 All electrical	5	Not required	5	1	5

touching live parts	can kill a person	components touch safe in a fully enclosed cabinet in locked room					
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[6] 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction

ISO[7] 14121-1:2007 Safety of machinery - Risk assessment - Part 1: Principles

ISO[8] 14121-2:2007 Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods

ISO[9] 13849-1:2006 Safety of machinery – Safety related parts of control systems – Part 1: General principles for design

ISO[10] 13849-2:2006 Safety of machinery – Safety related parts of control systems – Part 2: Validation

IEC[11] 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.
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

[6] International Organization for Standardization www.iso.org
[7] International Organization for Standardization www.iso.org
[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 Electrotechnical Commission, IEC Central Office 3 rue de Varambé, P.O. Box 131, 1211 Geneva 20, Switzerland www.iec.ch/

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