DRAFT

BSR E1.4-3

Entertainment Technology—Manually Operated Hoists

Approved by the ANSI Board of Standards Review as an American National Standard on DD MMMM YYYY

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Notice and Disclaimer

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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

Foreword

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

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

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

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

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

Reference standards organizations

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

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

1 Scope

1.1 General

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

1.2 Building Structures

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

1.3 Annex note references

This document uses annex notes to provide additional reference information about certain specific section requirements, concepts, or intent. Subject matter with a corresponding annex note reference is identified by the asterisk (*) symbol and the text "See Annex "x";" where "x" identifies the specific annex. e.g. Section 3.6 includes a reference, "*(See Annex A note). The associated reference text is found in the Annex A section where it is identified as A.3.6.

1.4 Exclusions

1.4.1 Performer flying

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

1.4.2 Powered rigging

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

1.4.3 Other rigging

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

1.5 Intent

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

1.6 Alternative designs

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

2 References

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

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

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

ANSI E1.4-1-2022 Manual Counterweight Rigging Systems

ANSI E1.47-2020 Entertainment Technology - Recommended Guidelines for Entertainment Rigging System Inspections

ANSI E1.6-1-2021 Entertainment Technology--Powered Hoist Systems
ANSI Z535.1-2022, Safety Colors
ANSI Z535.2-2023 , Environmental and Facility Safety Signs
ANSI Z535.3-2022 , Criteria for Safety Symbols
ANSI Z535.4-2023 , Product Safety Signs and Labels

ANSI Z535.6-2023 , Product Safety Information in Product Manuals, Instructions and Other Collateral Materials

3 Definitions

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

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

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

3.4 Clew: A device with multiple holes used to connect several lift lines into a haul line(s).

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

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

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

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

3.9 Hand winch: See **3.19 Manually operated hoist.**

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

3.11 Hoist system: See **3.16 Line set.**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.35 Ultimate load carrying capacity: The maximum load an assembly may support without failure.

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

3.37 Working load limit: 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.

- 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.

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 – 3
Moderate 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.

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 requirements herein unless otherwise determined by the risk assessment and risk reduction.

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

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

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

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

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

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

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

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

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

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

6 Mechanical design

6.1 General requirements

6.1.1 A qualified person shall determine or approve design factors for all equipment not included in the tension load path. Unless modified by other sections of this document, other codes listed, or governing bodies with jurisdiction over a particular facility, the factors listed in ANSI E1.4-1 - 2021 shall be used as a minimum performance guideline for tension load path equipment, unless a registered design professional determines that lower values are permitted.

6.1.2 Unless specifically addressed herein, all manual rigging equipment shall comply with the relevant requirements of ANSI E1.4-1 - 2021 Manual Counterweight Rigging Systems. Component assemblies shall be designed, engineered, and manufactured to withstand all characteristic loads without permanent deformation or damage to components and shall meet the requirements of section 6.2.1 Design Factors.

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

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

6.1.5 All components shall resist unintentional loosening.

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

6.2 Power transmission components

6.2.1 Design factors
For power transmission components that have a manufacturer’s recommended load rating, the characteristic load shall not exceed the load rating at a minimum Service Factor of 1.0. Power transmission components without manufacturer’s load ratings shall be designed so that stresses do not exceed the following:

6.2.1.1 Yield strength of the material shall be a minimum of 3X the shear stresses due to the characteristic load.

6.2.1.2 Yield strength of the material shall be a minimum of 1.58X the bearing (contact) stresses due to the characteristic load.

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

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

6.2.2 Load-securing devices

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

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

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

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

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

6.2.3 Winding drums* (See Annex A note.)

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

6.2.4.2 Winding drums shall be designed to take up the lifting media in a way as to not cause damage or undue wear to the lifting media.

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

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

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

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

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

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

6.2.3.6 The attachment of the lifting media to the drum shall have a strength equal to or greater than 1.33X the peak load. This shall be accomplished by end termination alone, or by including the friction from the minimum turns of lifting media on the drum.

6.2.3.8 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 A note.)

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.

7 Ancillary and tension load path components.

7.1 Clew and guide systems

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

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

7.1.2.1 Clew systems shall be designed to withstand anticipated loads.

7.1.2.2 Clew systems may be oriented in any direction.

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

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

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

7.1.2.4.2 The minimum spacing between adjacent clews shall be such that clew system components cannot physically touch each other under normal operating conditions.

7.2 Lifting media

7.2.1 General

7.2.1.1 Minimum tensile strength of lifting media shall be no less than the following:
5X the characteristic load.
5X the static load if hand operated.
8X the static load if using drive augmentation.
1.33X the peak load.

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

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

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

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

7.2.2 Lifting media terminations

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

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

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

7.2.2.4 Screw pin shackles shall be secured to prevent pin rotation.

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

7.2.3 Wire rope

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

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

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

7.3 Blocks
Blocks shall conform to the requirements of ANSI E1.4-1 – 2022

7.4 Load carrying devices

7.4.1 Load carrying devices shall be selected so that the yield strength of the device is at least 2X times the characteristic load. Load carrying devices shall be selected so that the ultimate load carrying capacity of the device is at least 1.5X the characteristic load or the peak load.

7.4.2 The maximum deflection of battens or their equivalents under the characteristic load shall not exceed 1/180 of the span distance between adjacent lift lines. Where there is not a specific load distribution pattern, the load shall be assumed to be uniformly distributed along the length of the batten

7.4.3 Aluminum trussing shall meet the requirements of ANSI E1.2- 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.

7.5 Drive Augmentation * (See Annex A note.)

7.5.1 Drive augmentation of a hoist shall be temporary. Drive augmentation left in the load path shall be considered permanent and subsequently subject to ANSI E1.6.1- 2021.

7.5.2 Drive augmentation must be supported and resist counter torque solely by the operator. Augmentation using a torque arm or other means to mitigate the torque supported by the operator shall be subject to ANSI E1.6.1-2021.

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

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

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

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

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

8 Basic functional, safety, and operational requirements

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

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

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

8.1.3 System manuals shall comply with the requirements of the following standards, where such requirements can be implemented with rigging components, assemblies, and systems:

8.1.3.1 ANSI Z535.6-2023, Product Safety Information in Product Manuals, Instructions and Other Collateral Materials

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

8.2 Maintenance.

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

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

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

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

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

9 Labeling, marking, and signage

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

9.1.1 ANSI Z535.1- 2022, Safety Color Code

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

9.1.3 ANSI Z535.3- 2022, Criteria for Safety Symbols

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

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

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

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

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

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

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

9.8 Signage shall state that operation of the hoist system shall be restricted to authorized person(s).

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

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

10 Installation

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

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

11 Inspection and testing

11.1 General requirements

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

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

11.1.3 Tests shall be non-destructive.

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

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

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

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

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

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

11.2 Inspection procedures

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

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

11.2.3 All relevant inspection requirements shall comply with ANSI E1.47 – 2020

11.3 Testing procedures

11.3.1 The hoist system shall be inspected.

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

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

11.4 Frequency of inspections

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

11.5 Documentation

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

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

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

Annex A, Supplemental information

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

A3.3
A3.6
A3.20
A3.33
A.6.1.3 Design calculations performed according to this standard are based on three basic loading conditions: static, characteristic and peak. The static load is that which occurs in a component while the system is in normal use but at rest. The characteristic load includes the static load but also any other forces that might occur during use such as inertial forces due to acceleration and those due to a moving or variable load on the batten. Finally, the peak load is the maximum load that can be reasonably anticipated to occur as a result of normal or abnormal conditions or irregular operation. All of these loads are apportioned to each component based on the hoist system geometry and the maximum loads defined in the limits of use.

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

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

A.6.1.4 Since the general definition of ductile refers to a material's ability to be drawn out into a wire, the standard elaborates further by requiring plastic deformation. Another way to relate this concept is by comparison of the material's yield point to its ultimate tensile strength. Materials having non-ductile properties, and that do not deform plastically without fracturing have either a yield point very close to its ultimate tensile strength, or have no yield point value because the yield point is, essentially, equal to its ultimate tensile strength. Acceptable materials will give a clear indication of failure, by first deforming within its plastic range, before ultimate failure actually occurs.

A.6.1.5 Torque values for threaded connections vary based upon the materials, type of connection, and the predominant forces to which the connection is subjected (e.g. tensile, shear, etc.). Often, a connection will not require a specified torque value, while in some cases a minimum torque value is critical in order to achieve and maintain the full connection strength. Each type of connection and application should be evaluated by a registered design professional in order to determine a) if a minimum torque value is applicable, b) if applicable the actual torque value or range, and c) the correct method for obtaining the specified torque, where required. The use of flat washers is also relevant to minimum torque values. Where no minimum torque values are specified, the use of flat washers is probably not important. Conversely, any time minimum torque values must be achieved, or in applications where slotted or elongated holes are part of the connection, consideration should be given to the use of hardened flat washers as part of the appropriate connection method.

A.6.2.1.3 A distinction is made between components that are rated based on endurance and specified using service factors, e.g. gear reducers and couplings, and those for which strength is the basis of design such as keys and shafts.

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

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

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

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

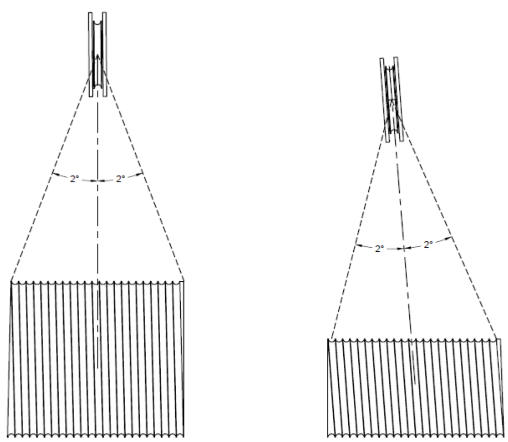

Figure 1a Figure 1b

Figure 1

A.6.2.4.5 7 Pile-on drums should be used with caution. As the lifting media winds on to the drum the pitch diameter is increased with each layer, resulting in increased media speed and reduced load capability. The pitch diameter is affected by factors such as the clearance between the lifting media and the drum side plates, and by the crushing, stretching, or distortion of the lifting media. Synchronizing multiple lift lines may be especially difficult.

A6.2.4.8 This system of cable attachment refers to cables that are attached to the surface of the drum without the wire rope penetrating the drum shell or rim.

A.7.1.2 Dual haul line systems with no additional guide system may be used as a method to restrain rotation of the clew with no additional guide system.

A.7.5 The use of a drill drive to augment operation of a manually operated hoist is a common practice. Use of devices such as drill drives to temporarily augment manual operation is covered within Section 7.5, although drill drives and other means of augmentation themselves are not covered by this standard. Care must be taken as this

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

provides a means to motorize a hoist, but it does not necessarily, and in most cases does not meet the requirements of E1.6.1- 2021 for motorized hoists. Drill drives should only be used on hoist that have been designed for and identified by the manufacture for use with a drill. Furthermore, drill performance requirements provided by the hoist manufacturer must be followed. While introduced in Section 7.5, a complete list of all potential risks, designs, situations and characteristics is beyond the scope of this standard and should be evaluated per application by a qualified person.

A.8.1 Users of the system should read and thoroughly understand the information contained in the system(s) manual. Knowledge of the system-specific load capacities, operating instructions, and maintenance schedules are important to establishing safe operating practices.

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. Defined examples may or may not be directly applicable to this standard.

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

This annex is not part of the requirements of this standard. It is included for informational purposes only. Defined examples may or may not be directly applicable to this standard.

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.

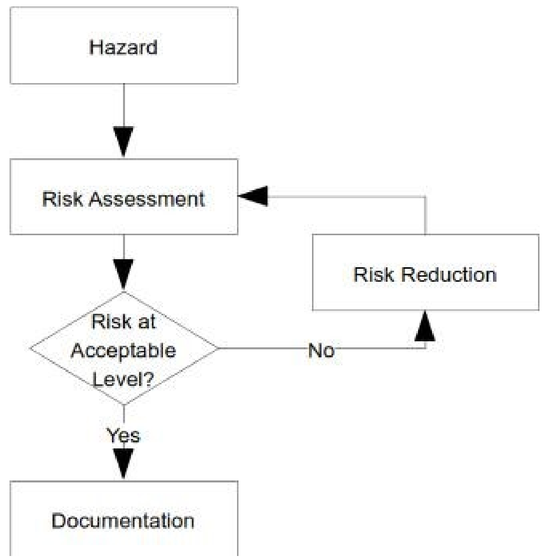

Figure 10: Risk assessment and risk reduction flow chart

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 touching live parts	5 Electrocution can kill a person	1 All electrical components touch safe in a fully enclosed cabinet in locked room	5	Not required	5	1	5
Many additional hazards may exist that are not shown in this example.							

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

Annex D, Risk assessment publications

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

Standards publications

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

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

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

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

ISO[2] 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction

ISO[3] 14121-1:2007 Safety of machinery - Risk assessment - Part 1: Principles

ISO[4] 14121-2:2007 Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods

ISO[5] 13849-1:2006 Safety of machinery – Safety related parts of control systems – Part 1: General principles for design

ISO[6] 13849-2:2006 Safety of machinery – Safety related parts of control systems – Part 2: Validation

IEC[7] 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

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2 International Organization for Standardization www.iso.org

3 International Organization for Standardization www.iso.org

4 International Organization for Standardization www.iso.org

5 International Organization for Standardization www.iso.org

6 International Organization for Standardization www.iso.org

7 International Electrotechnical Commission, IEC Central Office 3 rue de Varambé, P.O. Box 131, 1211 Geneva 20, Switzerland www.iec.ch/

Language: English
ISBN-10: 0750662697
ISBN-13: 978-0750662697

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