E1.72 – 202x
Powered Floor Machinery

Approved by the ANSI Board of Standards Review on_____

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Entertainment Services and Technology Association (ESTA)
271 Cadman Plaza PO Box 23200
New York, NY 11202-3200
USA
Phone: +1-212-244-1505
Email: standards@esta.org

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Contact Information

Technical Standards Manager
Karl G. Ruling
ESTA
271 Cadman Plaza PO Box 23200
New York, NY 11202-3200
USA
+1-212-244-1505
karl.ruling@esta.org

Assistant Technical Standards Manager
Richard J. Nix
ESTA
271 Cadman Plaza PO Box 23200
New York, NY 11202-3200
USA
+1-212-244-1505
richard.nix@esta.org

Technical Standards Council Chairpersons

Mike Garl
Mike Garl Consulting LLC
+1-865-389-4371
mike@mikegarlconsulting.com

Mike Wood
Mike Wood Consulting LLC
+1-512-288-4916
mike@mikewoodconsulting.com

Stage Machinery Working Group Co-chairpersons

Dan Culhane
Wenger Corp.
dan.culhane@gmail.com

Joe Jeremy
Niscon, Inc.
jjeremy@nisconinc.com

Acknowledgments
The Stage Lifts Working Group members when this document was approved by the working group are shown below.

Voting members:
[Insert list here]

Observer (non-voting) members:
[Insert list here]

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 Administration

1.1 Scope. This standard establishes requirements for the design, manufacture, installation, inspection, operation and maintenance of powered Stage Floor Machinery for performance, presentation, and theatrical production. The following covers the machinery, mechanisms, machine safety devices, and control interface requirements for equipment and systems, installed permanently or temporarily.

This standard does not apply to the structure to which the machine is attached nor the finished floor including its subflooring construction. Machines that produce substantially vertical movement, such as lifts, are also excluded from this standard.

1.2 Purpose. The purpose of this standard is to establish the minimum requirements for safety.

1.3 Alternative designs. The provisions of this standard are not intended to restrict or prevent the use of alternative designs not specifically described herein, provided that such designs meet or exceed the intent of this standard's requirements.

2 Referenced publications

2.1 General
The documents or portions thereof listed here are referenced within this standard and shall be considered part of the requirements of this document. Where the requirements of a referenced standard differ from the requirements of this standard, the more stringent requirement shall govern.

2.2 Publications
A Practical Guide to Health and Safety in the Entertainment Industry, Marco van Beek (2000)
ANSI E1.47, Entertainment Technology – Recommended Guidelines for Entertainment Rigging System Inspections.
ANSI/NFPA 70:2020 National Fire Protection Association - *National Electric Code*
ANSI/NFPA 79:2021 National Fire Protection Agency - *Electrical Standard for Industrial Machinery*
ISO 12100 Safety of machinery — *General Principles for Design — Risk Assessment and Risk Reduction*
Safe Stages Best Practices, Theatre Alberta (2007)

3 Definitions

3.1 Characteristic Load. The maximum force applied to a component of a machine resulting from normal intended operating conditions while the system is at rest or in motion.

3.2 Competent Person. A person who has received training on the operation and hazards involved, is capable of identifying existing and predictable hazards in the workplace, and who is authorized to take prompt corrective measures to eliminate them.

3.3 Control Station. A part of the control system that governs motion control of one or multiple machines. 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 machine.

3.4 Drive System. Part of a load bearing machine that executes movement and holding of the load and which converts energy into movement

3.5 Emergency Stop. Function which is intended to avert arising or reduce existing hazards to persons, damage to machinery or to work in progress, and be initiated by a single human action

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.

3.7 Failure. Termination of the ability of an item to perform a required function

3.8 Fault. State of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

3.9 Ingoing Nip Point. Ingoing nip points (or pinch points) are a special danger arising from rotating or reciprocating parts. They occur whenever machine parts move toward each other or when one part moves past a stationary object.

3.10 Interlock Device. A switch, sensor, or interconnected logic system that permits or prevents motion.

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

3.12 Limit, Initial (soft) A programmed reference position that prevents further movement in the direction of travel.

3.13 Limit, Ultimate. A limit switch that senses over-travel in the event of failure of the normal position limit, i.e., over-travel.

3.14 Load Securing Device. Mechanical device that can bring a load to a stop and prevents unintentional movement. EXAMPLE A brake, self-braking worm gear, shut-off valve.

3.15 Moving Load. The maximum load intended for the user to add to the stage machinery to be moved at the rated speed.

3.16 Peak Load. The maximum force applied to a component of a machine 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).

3.17 Positive Break Operation. The achievement of electrical contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (i.e. not dependent upon springs).

3.18 Power Transmission System. The components within the machine that create, transfer, support, or dissipate mechanical force and motion (e.g. motors, gears, shafts, clutches, couplings, bearings).

3.19 Prime Mover. A device that originates mechanical force and motion within machine power transmission system (e.g. electric motor, hydraulic actuator).

3.20 Qualified Person. One who, by possession of a recognized degree, certificate, or 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 the work.

3.21 Rated Speed. Maximum speed at which the machine is designed to operate

3.22 Risk. Combination of the probability of occurrence of harm and the severity of that harm

3.23 Stage Floor. Stage surface Integral to building architecture. This can include a show-specific layer of sheet goods whose compressive strength does not affect the structural integrity of the architectural floor.

3.24 Static load. The maximum force applied to a component of a 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.

3.25 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.

3.26 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.

3.27 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.

Information on risk assessment can be found in many places. One source is the ASSP Risk Assessment Committee on the Committee's website http://www.oshrisk.org. More information also is available in Safe Stages Best Practices, Theatre Alberta (2007); A Practical Guide to Health and Safety in the Entertainment Industry, Marco van Beek (2000); ISO 12100 Safety of machinery — General principles for design — Risk assessment and risk reduction and other publications.

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. Once the likelihood and severity of an injury are identified the appropriate steps should be taken to abate the hazard.

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				
Probability		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
	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 process until an acceptable level of residual 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.

5 Design Requirements

5.1 General

5.1.1 Stage machinery systems shall be designed by a qualified person.

5.1.2 Stage machinery shall be capable of moving from a static condition and returning to a static state, maintaining control throughout the operation.

5.1.3 Stage machinery shall be protected against uncontrolled speed and unintentional movements.

5.1.4 Stage machinery shall be designed for anticipated duty cycles, operating environment, and product life.

5.1.5 Stage machinery shall be designed in accordance with recognized design standards and component part manufacturer recommendations.

5.1.6 Stage machinery shall allow for inspection, maintenance, and replacement.

5.2 Structural Requirements

5.2.1 Stage machinery shall support all anticipated loads. Loads shall include the following:

- Self-weight of the machinery
- Loads from scenery and other equipment
- Loads from performers and other persons
- Dynamic loads resulting from starting and stopping, including emergency stops.
- Centrifugal forces resulting from rotary motion

5.2.2 Allowable loads shall be defined and documented in a means accessible to the machinery operators and others that may apply load to the machine.

5.2.2.1 The capacity of a machine to support loads may be more than its capacity to move them. In this case, both the static and moving loads shall be defined and documented.

5.2.3 Weights of moving loads shall be increased to account for impact.

5.2.4 Machine Floor Surfaces

5.2.4.1 Floor surfaces integral to the machine and that may be stepped on shall be designed to support a minimum static live load of 40 psf (195.3 kg/m^2) or a 300 lb (136 kg) concentrated load.

5.2.4.2 If loads exceeding the floor's capacity can be applied, the floor surface shall be safeguarded to prevent overloading (e.g. barriers, covers, fencing).

5.2.4.2.1 Any floor opening that is 2" (5 cm) or greater in its least dimension shall be safeguarded or covered.

5.2.4.2.2 Safeguards or covers may be removed during performances if permissible by the risk assessment.

5.3 Motion Requirements

5.3.1 Motion criteria including the characteristic load, speeds, acceleration, and duty cycle shall be defined and documented

5.3.2 The characteristic load shall include forces necessary to overcome friction, the effects of gravity, inertia and start or stop motion.

5.3.3 Travel distances shall be limited if necessary to avoid creating a hazard to personnel or equipment. The stage machinery's limits of travel shall accommodate deceleration and stopping distances.

5.3.4 Motion Restraint: Stage machinery components shall be restrained against movement when not in motion. Examples of motion restraint devices include brakes, pins, and mechanisms that lower moving components off casters.

5.4 Machinery Requirements

5.4.1 General

5.4.1.1 All components shall resist unintentional loosening.

5.4.1.2 All welds shall comply with current applicable American Welding Society standards.

5.4.1.3 Stage machinery shall be secured to provide stable operation and resist peak load.

5.4.1.4 Stage machinery shall be free from vibrations that threaten the integrity or functionality of the machinery.

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

5.4.2 Moving Components

5.4.2.1 Clearances shall be maintained so as to not impede motion.

5.4.2.2 Items resting on any platform surface shall be adequately secured so as to prevent unintended movement.

5.4.2.3 Shear and crushing hazards created by the machine shall be mitigated. Scenic elements attached to the platform may present a hazard as they move past other scenery or facility elements.

5.4.3 Supporting Elements

5.4.3.1 Casters, bearings and other supporting elements shall have a means to ensure accurate alignment.

5.4.3.2 Supporting elements shall withstand peak load.

5.4.4 Power Transmission Components

5.4.4.1 Motors and power transmission components shall be sized appropriately for the characteristic load.

5.4.4.2 Power transmission components shall withstand stresses from peak loads: including stalling of the prime mover and inertial forces from uncontrolled stops.

5.4.4.3 Shafts and Couplings

5.4.4.3.1 Shafting shall be secured in position against excessive endwise movement.

5.4.4.3.2 Keys shall be captured or otherwise secured to prevent walking out of the keyway.

5.4.4.3.3 Belts and Chains

5.4.4.3.3.1 Drive systems that contain belts, chains, or other flexible transmission devices shall have provisions for adjustment.

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

5.4.4.3.4 Friction Drives

5.4.4.3.4.1 Drive friction shall be self adjusting as required for normal operation. The designer should consider the minimum and maximum friction required.

5.4.4.3.4.2 When a friction mechanism such as a rubber wheel or wire rope is employed to drive the platform, the drive may slip. When accurate positioning is required the sensor system should be linked to the movement of the platform and not to the friction drive.

5.5 Guarding

5.5.1 One or more methods of machine guarding should be provided to protect personnel in the machine area from hazards such as those created by ingoing nip points, rotating parts, sliding parts, etc.

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

5.5.2.1 Projecting shaft ends shall present a smooth edge and shall not project more than one-half the diameter of the shaft unless guarded by nonrotating caps or safety sleeves.

5.5.2.2 Suspended counterbalanced tensioners and all parts thereof shall be of substantial construction and securely fastened; the bearings shall be securely capped. Means must be provided to prevent tensioner from failing in case the drive media breaks. Where suspended counterweights are used and not guarded by location, they shall be so encased as to prevent accident

5.5.2.3 The driving point of all friction drives shall be guarded if accessible by personnel, all arm or spoke friction drives and all web friction drives with holes in the web shall be entirely enclosed, and all projecting belts on friction drives where exposed to contact shall be guarded.

5.5.2.4 Equipment located in technical spaces shall be guarded in accordance with this section, except when the following requirements are met:

- Access to the technical space is limited to authorized persons only.
- Clearances shall be provided around machines such that people need not contact unguarded components to access any part of the technical space.

5.5.3 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 310 pound (140 kg) person.

5.5.4 Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible.

5.5.5 Guards shall be of a strength to prevent failed power transmission media from causing a dangerous situation. Where a guard is exposed to contact with moving equipment additional strength may be necessary.

5.5.6 Guards shall not create a hazard in themselves.

5.5.7 Guards shall be removable for service.

5.5.8 Guard Materials: Standard conditions shall be secured by the use of the following materials: Expanded metal, metal sheet, perforated metal, wire mesh, wood or similar durable material.

5.5.9 All materials should be free from burrs and sharp edges.

5.5.10 The surface of the guard with which a belt or wire may come in contact, shall be smooth and free from all projections, except where construction demands it; protruding shallow roundhead rivets may be used.

5.6 Controls and Electrical Components

5.6.1 General

5.6.1.1 Stage machinery systems shall incorporate all aspects of control requirements herein, unless otherwise determined by the risk assessment.

5.6.1.2 Electrical equipment and control systems shall conform to NFPA 79 Electrical Standard for Industrial Machinery, 2021. Exception, the indicator color assignment on control panels and in HMI screens shall be exempt from those in chapter 10.

5.6.1.3 The electrical equipment covered by this standard commences at the point of connection of the power supply to the machinery.

5.6.1.4 Interconnection wiring: Cables and wiring between control equipment shall be installed as required the applicable electrical code.

5.6.1.5 Machinery disconnect: A means shall be provided to disconnect the machinery from the power source. The disconnect method shall not create a hazard.

5.6.1.5.1 All line voltage motor leads and brake leads shall be disconnected.

5.6.1.5.2 A multi-pole cord and plug may be used.

5.6.1.5.3 The disconnecting means must be lockable in the off position.

5.6.1.6 Limited Access: Control equipment shall be guarded against unauthorized access.

5.6.1.6.1 The control system shall be secured against unauthorized use.

5.6.1.6.2 The control system shall have the ability to limit access to critical settings by use of a password, key or other secure means.

5.6.1.7 Electrical components, including motors, motor controllers, and position sensors shall be accessible for maintenance and troubleshooting.

5.6.1.8 The failure or miscommunication of the control system shall not interfere with the proper operation of the safety systems.

5.6.2 Control stations

5.6.2.1 Control access: Control devices shall be protected against unintentional and unauthorized actuation.

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

5.6.2.2.1 When line-of-sight operation is not possible from a control station, a means of visual monitoring shall be provided during machine movement. The method of monitoring shall be determined by the risk assessment.

5.6.2.2.2 Closed circuit monitoring (CCTV) may be used.

5.6.2.2.3 Portable control stations shall be permitted.

5.6.2.3 Control operators, including pushbuttons, toggles, selectors, and joysticks shall be labeled with their function.

5.6.2.4 All control stations shall incorporate an E-stop button.

5.6.2.5 Multiple controls interlock: Where a system has multiple control stations, hardware or software interlocks shall prevent the simultaneous control of a machine or group of machines by more than one control station.

5.6.2.6 Wireless control: Wireless control stations shall be permitted but shall meet the same design and safety requirements as wired systems.

5.6.3 Enable devices

Where remote visual monitoring is not practical or sufficient, an enable device containing a momentary contact shall be provided as determined by the risk assessment. The machine shall only move while every applicable enable device is activated. Enabling device operators shall have no other task assigned at the time of monitoring.

5.6.4 Control system parameters

5.6.4.1 Ready indication: When the system is accessed, and reset, active control stations shall indicate that the system is in a ready state.

5.6.4.2 Control stations: Operator control stations shall contain control means and status indication as required for the operation of the system.

5.6.4.2.1 Activation of any emergency stop shall stop all machines in the system.

5.6.4.2.2 All movements shall be initiated and ended by means of a control device. Direction of movement shall be indicated.

5.6.4.2.3 All movement shall require activation of a hold-to-run device that, when activated, allows machine operation and, when deactivated, stops movement of the machine.

5.6.4.3 The control system shall not permit any operation that exceeds the design parameters of an individual machine in the system.

5.6.4.4 Resetting

5.6.4.4.1 Resetting the control system shall only be possible after all system faults are cleared.

5.6.4.4.2 Removing or resetting of the emergency stop fault condition shall not restart the system. Further activity is not possible until the fault is cleared and the control system reset.

5.6.4.5 Joystick control: Joystick control shall only provide motion after a hold-to-run device is activated. If the joystick is moved from its neutral position prior to activating the enabling device, no movement shall initiate until the joystick enable device is activated.

5.6.4.6 Faults

5.6.4.6.1 Faults shall not lead to hazardous operating conditions.

5.6.4.6.2 Faults shall not hinder stopping.

5.6.4.6.3 Faults shall be indicated as determined by the risk assessment.

5.6.4.6.4 Removal of a fault shall not automatically restart the machine.

5.6.4.6.5 When a single machine has a fault not affecting the remaining machines, it shall be permitted to disable only the faulted machine.

5.6.4.6.6 A method of temporarily overriding fault conditions should be provided to clear a fault. The temporary override shall only permit limited machine movement as determined by risk assessment.

5.6.4.7 Programmable Electronic System (PES)

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

5.6.4.7.2 Failure of a PES shall not disable safety functions. When safety functions implemented in a PES fail, the machine shall automatically stop and be disabled.

5.6.4.8 Unintended start: The start and restart of machine motion shall require deliberate action by the operator.

5.6.4.9 Loss of signal: Loss of signal from position sensors shall stop the machine.

5.6.4.10 In the event of a control signal loss, the affected machinery shall safely stop.

5.6.4.11 In the event of a control signal loss between a control station and the motor controller or a safety device, the system shall activate the E-stop.

5.6.5 Constraining travel

Design of the machinery shall allow enough distance for deceleration from full speed after activation of any position sensors so that damage to the machine or additional hazards shall not be created.

5.6.5.1 Sensor definitions: Position or travel sensors are known by many names while serving common functions. Refer to Figure 1 while referencing the definitions for Ultimate Limit, Initial Limit, and Positioning or Target Limit.

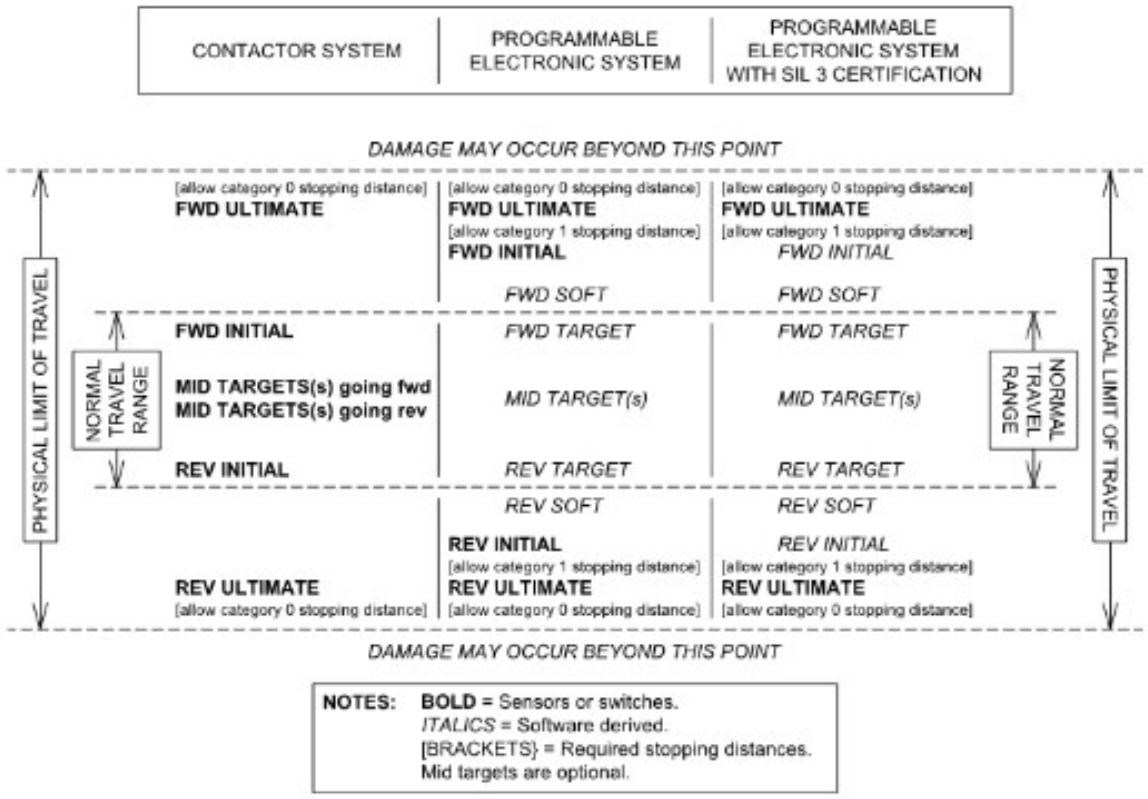

Figure 1.

5.6.5.2 Where the machine can be reconfigured after the initial installation, it shall be possible to reset normal and ultimate limits. The resetting of normal and ultimate limits shall be performed by a competent person.

5.6.5.3 Limit switches and sensors that require removal of covers for adjustments shall be touch safe or a Low Voltage, Limited Energy (LVLE) circuit.

5.6.5.4 Position Sensors

5.6.5.4.1 Ultimate Limits

5.6.5.4.1.1 Ultimate limits are required in both directions of travel in all systems where an overtravel hazard exists.

5.6.5.4.1.2 The ultimate (overtravel) limit shall be a snap-acting or positive break mechanical limit switch.

5.6.5.4.1.3 Initiation of the ultimate limit switch shall immediately initiate a category 0 stop utilizing a means separate from the motor controller (reversing contactor or drive).

- Using a separate contactor between the line and the motor controller complies with this requirement.
- Using Safe Torque Off (STO) input or certified “Safe Off“ input complies with this requirement.

5.6.5.4.1.4 After striking an ultimate limit, further operation of the machine in either direction shall be restricted. Restarting the machine after activation of this sensor shall require operation of a safety override device. While the safety override device is activated, the machine shall only be allowed to move in the opposite direction and away from the sensor.

5.6.5.4.2 Initial Limits

5.6.5.4.2.1 Initial limits are required in both directions of travel in all systems where an travel hazard exists.

5.6.5.4.2.2 Activation of an initial limit shall bring the machine to a stop before it activates the ultimate limit. When the initial limit is activated, movement in the opposite direction shall be allowed.

5.6.5.4.2.3 Activation of an initial limit sensor shall be indicated at the control station.

5.6.5.4.2.4 Means should be provided for temporarily overriding the initial limit sensors to test the ultimate limit switches.

5.6.5.4.3 Positioning or Target Sensor: When operated at any speed and any load, activation of this sensor shall bring the machine to a stop at the predetermined position. Further operation shall not be restricted in either direction.

5.6.5.4.4 Encoder: Encoding systems may be employed to provide position sensing for all positions within the operating range of the machine system. Encoding systems may be employed to provide the function of the Initial Limit, providing the control system and the encoder are certified to meet the requirements of SIL3 safety. Encoding systems shall never be employed to act as ultimate limit sensor.

5.6.5.5 Sensing devices – types: The type of sensing device applied to the individual machine installation shall be chosen with respects to function, reliability and operation as required by the control system and by risk assessment. All sensors shall be installed per the manufacturer's recommendations.

5.6.5.5.1 Mechanical switches: All mechanical switches shall be snap-acting or positive break type.

5.6.5.5.2 Electronic sensors: Electronic sensors shall be installed per the manufacturer's recommendations and limitations. Choose with regard for temperature, vibration, and magnetic fields.

5.6.5.5.3 Optical or Photo actuated sensor: Optical sensors must be capable of operating in all potential artificial atmospheres used within the venue.

5.6.5.5.4 Positioning tolerance: All sensors shall be selected, positioned and installed to provide repeatable signaling to stop the machine at the intended position.

5.6.5.5.5 Machinery with a positively engaged prime mover will not slip; Without any potential slip, the position sensors can be affixed directly to the prime mover or the platform.

5.6.5.5.6 Mechanically struck sensors: Mechanically struck limit switches or position sensors shall be installed so that the sensor is not damaged by overtravel or released back to its deactivated state during the deceleration period.

5.6.6 Safety Systems

5.6.6.1 E-stops

5.6.6.1.1 Control systems shall have an E-stop function that stops the machine system by implementing either a category 0 or a category 1 stop. The choice of category shall be based on the risk assessment and the functional needs of the machine system.

5.6.6.1.2 Activation of any E-stop device shall create a fault condition.

5.6.6.1.3 E-stop switches shall be located at each operator control station and at other locations as determined by risk assessment.

5.6.6.1.4 Switch contacts and switch operators (Buttons)

5.6.6.1.4.1 Contacts for E-stop functions shall be normally closed and shall have a positive break operation.

5.6.6.1.4.2 Operators for activating E-stop functions shall be raised switches in accordance with NFPA 79 Electrical Standards for Industrial Machinery.

5.6.6.1.4.3 E-stop operators shall latch in the depressed position and require a special operation to release.

5.6.6.1.4.4 E-stop operators shall not be of a flat form factor (flush) nor graphic representations based on software applications.

5.6.6.1.4.5 Alternate types of E-stop operators, such as pull-cord-operated switches or push-bar-operated switches may be used as determined by the risk assessment.

5.6.6.2 Machine stops: Machine stops shall perform the function of an E-stop only for the machine to which the button is associated.

5.6.6.2.1 Machine stop operators should be colored yellow. The button or the adjacent background must read Machine Stop.

5.6.6.2.2 Machine stop operators shall latch in the depressed position and require a special operation to release.

5.6.6.3 Additional sensors: Additional sensors may be required based upon the risk assessment. Examples include:

- Overload, underload sensors or load cells.
- Slack-line sensors
- Cross groove sensors
- Overspeed sensors
- Brake or clutch release position sensor
- Shear or crushing sensors

5.6.6.4 Interlock devices

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

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

5.6.6.4.3 Interlock devices shall indicate their status at the control station.

5.6.6.5 Maintenance and Inspection: Sensors and interlock devices must be commissioned, maintained, and routinely tested for confirmed operation.

5.6.7 Motor control panels

5.6.7.1 E-stop contactor: A motor control center shall include a separate contactor or other safety rated means of removing motor power in an E-stop condition. The E-stop contactor or other means shall be in series with or integral to the directional contactors or the motor drive.

5.6.7.2 Phase loss and rotation protection: A phase loss or an incorrect phase sequence of the supply voltage that may create a hazardous condition or damage to the machine shall cause a fault condition.

5.6.7.3 Motor Controllers

5.6.7.3.1 Thermal overload: Motor controllers shall incorporate thermal overload protection.

5.6.7.3.2 Overcurrent protection: Motor controllers shall incorporate overcurrent protection.

5.6.7.3.3 Ambient Conditions: All electrical equipment shall have appropriate protections to operate correctly in the expected environmental conditions.

5.6.7.3.4 Enclosures: Electrical enclosures shall be selected based on the environmental conditions.

5.6.7.3.5 Jogging: Motor contactors shall be rated for any cycle or combination of start, stop, and reverse permitted by the control system.

5.6.7.4 Motor Controller- Fixed Speed: Where the control system includes the ability to reverse the rotation of an electric motor, a method of electrical and mechanical interlocks shall be provided to prevent simultaneous activation in both directions.

5.6.7.5 Motor Controller- Variable Speed: Electronic motor control drives shall be designed for and be compatible with the motor type and load characteristics of the machine.

5.6.6 Multiple machine systems: When multiple machines are grouped together to move a common load or are grouped together for interrelated motion, a monitoring method shall be provided to ensure group movement. An unintended stop of one machine shall stop the entire group of machines. This requirement shall not apply to groups of machines that move simultaneously in an unrelated manner.

6 Operation

6.1 Training

6.1.1 Operator training. Operators shall be trained in accordance with 6.2 and shall read and understand the pertinent sections of the manufacturer supplied documentation where available. Otherwise operators shall be trained by the manufacturer/maker of the machine.

6.1.2 Records. A written record of all operator training including the names of the trainee, the name and affiliation of the trainer, course curriculum and the date of training shall be maintained and shall be made available for inspection on request.

6.1.3 Affected Persons: A performer or other person affected by the operation of a machine shall be trained in hazards associated with its operation.

6.2 Operation

6.2.1 General. The operator shall follow all instructions for operation, including the warning and safety signs, and shall be familiar with all controls, safety devices, warnings, and their locations. The operator shall operate the machine per the manufacturer’s instructions and training.

6.2.2 Pre-operation tasks. The operator shall, before each use, complete the following.

6.2.2.1 Verify that the machine does not present a hazard. Examples of common hazards include:

- fall hazard protection, removable guards, and safety barriers required are missing,
- load exceeds the capacity of the machine,
- objects or personnel are obstructing the machine,
- warning signs or placards are missing or unreadable.

If any hazards are present, the operator shall not operate the machine. If corrective action cannot be taken within the authority of the operator, then the machine shall be taken out of service and referred to a qualified person.

6.2.2.2 Verify that the machine system is not in a fault condition.

6.2.2.3 Verify that the machine system is operable.

6.2.3 In-movement tasks. The operator shall monitor the machine throughout its entire movement using one of the methods in 5.7.2.2. If hazardous conditions develop during operation, the operator shall stop movement until the condition is resolved and, where applicable, perform the duties listed in 6.2.4.

6.2.4 Malfunction. If a fault, malfunction, damage, or other unusual performance of the machine occurs, the operator shall stop the machine and evaluate. If corrective action cannot be taken within the authority of the operator, then the machine shall be taken out of service and referred to a qualified person. Any such event and resulting actions shall be reported in accordance with Chapter 7.

7 Inspection, Maintenance and Repair

7.1 General requirements

7.1.1 The system designer or manufacturer shall establish recommended criteria for maintenance, 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.

7.1.2 Where applicable, inspections should comply with ANSI E1.47, Entertainment Technology – Recommended Guidelines for Entertainment Rigging System Inspections.

7.1.3 Inspection and testing following installation shall verify that all system components and connections are present in the system, operating limits are correctly adjusted, and that they comply with the design and operating criteria.

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

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

7.1.6 Deficiencies discovered during inspection or testing shall be resolved under the supervision of a qualified person. Machines shall be removed from service until deficiencies are resolved.

7.2 Inspection procedures

7.2.1 Systems shall be fully inspected at least annually. A more frequent schedule may be required as determined by a qualified person.

7.2.2 Minimum criteria for inspection

7.2.2.1 Components of the system shall be visually inspected for wear and damage. If any component fails the inspection or testing criteria, or is suspected of being defective, the component shall be removed from service and marked accordingly. Any component damaged beyond repair shall be permanently removed from use or service.

7.2.2.2 Each machine or system shall be operated through its full range of travel and speeds for each axis. Unusual noises, motions, or other issues shall be reported for resolution.

7.2.2.3 Functionality of the control system shall be verified. All Emergency Stop operators shall be verified.

7.2.2.4 Tests shall be non-destructive.

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

7.2.2.6 Each load securing device shall be verified independently.

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

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

7.3 Documentation

7.3.1 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.

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

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

7.4 Maintenance

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

7.4.2 Systems shall be maintained following the manufacturer’s instructions or as directed by a qualified person.

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

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

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