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Entertainment Technology—Performer Flying Systems

DRAFT

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Notice and disclaimer

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ESTA's Technical Standards Program

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

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

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

Investors in Innovation

The Investors in Innovation when this standard was approved on [Insert date here] are listed in the table below.

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Interest category codes

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

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FOREWORD

The first American National Standard specifically addressing performer flying in the entertainment industry was adopted in 2016. This revised and updated document incorporates improvements in technology and practices since the original adoption. It should be noted that other ANSI Standards may be relevant, depending on the application and intended use.

It is the intention of ESTA that this standard be put forward as the basis for a revised American National Standard to the American National Standards Institute.

It has been assumed in the drafting of this standard that the execution of its design provisions is entrusted to appropriately qualified and experienced people, and that the fabrication and use is carried out by qualified and suitably experienced people and organizations.

This standard presents a coordinated set of rules that may serve as a guide to government and other regulatory bodies and municipal authorities responsible for the guarding and inspection of equipment falling within its scope. The suggestions leading to accident prevention are given both as mandatory and advisory provisions; compliance with both types may be required by employers of their employees.

Safety codes and standards are intended to enhance public safety. Revisions result from committee consideration of factors such as technological advances, new data, and changing environmental and industry needs. Revisions do not imply that previous editions were inadequate.

Compliance with this Standard does not of itself confer immunity from legal obligations.

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 note (see annex note), and the associated reference text is found in Appendix A, Commentary, identified with the referring text section number – i.e. an annex note to section 3.2 will be identified in Appendix A, Commentary as A.3.2. The annex notes are informational only, and do not add or subtract from the mandatory requirements of this standard.

1 Scope

This document establishes a minimum level of performance requirements for the design, manufacture, use, and maintenance of statically hung, manually driven, mechanized, and automated performer flying systems used in the production of entertainment events. A performer flying system includes the components, personnel, and procedures used to suspend or transport performers through the air, including the attachment to the facility or other supporting structure down to and including the elements to which the performer is connected. Situations covered by this standard pertain to any and all locations of the flight path, including off-stage, over the stage, and over the audience.

The purpose of this guidance is to establish the minimum acceptable requirements for strength, reliability, and safety of these systems to ensure safety of the performers, other production personnel, and audiences under all circumstances associated with performer flying.

This document covers the principles that are common to all types of performer flying, regardless of the style or type of flying performance. A typical goal of theatrical-style performer flying is to create the illusion of flight. This is most often accomplished by supporting a performer from a harness or ride-on prop to provide a safe means of levitation. A typical goal of aerial acrobatics, circus performance, aerial dance, and some other aerial disciplines is to entertain the audience by displaying feats of human strength, agility, form and/or balance. This is often accomplished by skilled performers, utilizing a wide range of acrobatic props or apparatus, frequently without the use of a harness or other mechanical connection to the rigging system. While these examples of performer flying exemplify the wide range of differing traditions and technologies, the governing principles of performer and non-performer safety (risk assessment and risk reduction, operational preparedness, and many other subject matters) are common to all performer flying situations.

The scope of this document excludes the following:

- Systems for flying the general public or for people engaged in non-performance flying effects.
- Any connection in a performer flying system that ultimately relies on the strength or ability of the flying performer. The rest of the performer flying system is included.
- Bungee cord or other comparable high-stretch lifting medium in the load path.
- Systems for supporting a performer in a non-overhead suspension or non-boom arm manner, such as lifts, elevators, turntables in stages, raked stages, treadmills in stages, or stage wagons.
- Fall protection.

(see annex note)

2 Definitions

Descriptions and definitions relating to participants and personnel involved with performer flying systems are set forth in section 3, Roles and Responsibilities.

2.1 acrobatic prop: (Also known as an “acrobatic apparatus”): A component used as a primary connection between the flying performer and the performer flying system, where the physical activity or interaction of the flying performer with the system is fundamental to the performance (as distinguished from a “ride-on prop”, where the flying performer is fundamentally a passenger.) The connection of the flying performer to the acrobatic prop may be by means of the strength or ability of the flying performer, by mechanical means, or by some combination of the two.

2.2 Allowable Stress Design (ASD): A structural engineering analysis method in which service load stresses in a structure remain below a given stress limit by a specified factor. The stress limits and factors vary depending on what failure mode is being examined, such as tensile rupture or tensile yielding.

2.3 Authority Having Jurisdiction (AHJ): The governmental or regulatory organization, office, or individual responsible for approving equipment, installation, or a procedure. (see annex note)

2.4 axis (pl. axes): A common term used to describe the combined elements that create motion in a single geometric plane. Motion can be linear or rotational and the prime mover can consist of electric, hydraulic, pneumatic, or other sources including human power. Multiple axes can be combined to create motion of an object in more than one plane. (see annex note)

2.5 brake: A load-securing device that is capable of stopping and securing a load.

2.6 breaking strength: The maximum load a component may support without fracture, shear, buckling, or crushing. This value may be calculated as the nominal strength using nationally recognized construction standards appropriate for the given material or by laboratory tests. Related terms include breaking strength, ultimate breaking strength, ultimate load carrying capacity, minimum breaking strength, nominal breaking strength, and tensile strength. (see annex note)

2.7 characteristic load: See 2.21 - Load Categories.

2.8 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.

2.9 D:d ratio: Ratio of the drum or sheave diameter to that of the rope diameter.

2.10 design factor: A ratio of the Ultimate Load Carrying Capacity of a material or component to the design load.

2.11 design factor against yield: A ratio of the minimum yielding value of a material or component to the design load.

2.12 fabricated component: A component that is custom-built for an application in the performer flying system.

2.13 Factory Acceptance Test (FAT): A period of testing during system assembly, often offsite prior to installation, during which the system supplier demonstrates that the performer flying system meets the performance and safety specifications.

2.14 fleet angle: The angle between the centerline of a rope as it enters or exits a sheave or drum groove, and the plane defined by the centerline (pitch) circle of that groove. (see annex note)

2.15 full speed: The maximum designed operating speed of a performer flying system. (see annex note)

2.16 flying harness: A component that is worn by the flying performer to either support the flying performer's body weight, or to secure the flying performer to a ride-on prop such that the harness is fully capable of supporting the flying performer's weight, throughout the flying routine.

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

2.18 lifting medium: The load-carrying element, either static or driven by the means of actuation, to move or suspend the performer and any acrobatic or ride-on props. (see annex note)

2.19 limit categories

2.19.1 limit, normal (hard): A limit switch that prevents further movement in the direction of travel, e.g., end of travel, initial.

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

2.19.3 limit, ultimate: A limit switch that senses over-travel in the event of failure of the normal limit, e.g., over-travel, E-Stop.

2.20 load-bearing hardware: Purchased or fabricated elements, such as fasteners, rigging components, and equipment, which are part of the load path.

2.21 load categories

2.21.1 working load: The static weight applied to the performer flying system resulting from the self-weight of the flying performer, plus load-carrying devices such as lifting medium, flying harnesses, acrobatic props, and ride-on props.

2.21.2 characteristic load: The maximum force applied to a component of a performer flying system resulting from normal intended operating conditions while the system is at rest or in motion. This includes the working load and forces due to inertia and dynamics in normal use. (see annex note)

2.21.3 peak load: The maximum force applied to a component or components of a performer flying system resulting from abnormal conditions or irregular operation (e.g., effects of emergency stops, uncontrolled stops, drive electronics or power failure, stalling of the actuation equipment, or extreme environmental conditions).

2.21.4 performer peak load: The maximum force applied to the performer resulting from abnormal conditions or irregular operation (e.g., effects of emergency stops, uncontrolled stops, drive electronics or power failure, stalling of the actuation equipment, or extreme environmental conditions).

2.22 load path: All contiguous elements that support the flying performer and acrobatic prop or ride-on prop to the supporting structure. Portions of the acrobatic prop or ride-on prop that directly connect the flying performer to the lifting medium shall be considered part of the load path.

2.23 Load Resistance Factor Design (LRFD): A structural engineering analysis method in which factored load stresses in a structure remain below a given stress limit. The load factors and stress limits vary depending on what type of load or combination of loads is being applied and what failure mode is being examined.

2.24 peak load: See 2.21 - Load Categories.

2.25 performer peak load: See 2.21 - Load Categories.

2.26 performer flying system: A system which includes the mechanical components, personnel, and procedures used to suspend or transport performers through the air, including the attachment to the facility or other supporting structure down to and including the elements to which the performer is connected. (See annex note)

2.26.1 manual performer flying system: A performer flying system where the prime mover, if any, for all axes is human power alone. This includes statically (dead) hung performer flying systems that utilize lifting medium which do not raise, lower, or change length such as tissue (silk), trapeze, or rope swing.

2.26.2 mechanized performer flying system: A performer flying system where the prime mover for one or more axes of motion is powered by machinery (electromotive, hydraulic, pneumatic, and the like).

2.26.3 automated performer flying system: A mechanized performer flying system where one or more axes of motion are under command of a programmable electronic system such as a PLC or motion control computer.

2.26.4 established performer flying system: A performer flying system intended for repetitive use in multiple installations that has satisfied specific criteria listed herein, including a documented history of successful repetitive in-service use. An established performer flying system does not require use-by-use validation of the basic performer flying system and allows some reduction of in-use documentation.

2.27 prime mover: The initial natural or mechanical source (such as motor, actuator, human, gravity, or counterweight) that puts a performer flying system, or a flying performer, in motion.

2.28 purchased component: A serially manufactured, commercially available component.

2.29 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 problems relating to the subject matter and work.

2.30 quick-connect hardware: A component used to provide a fast, make-or-break connection in the load path to connect or disconnect the flying performer, acrobatic prop, or ride-on prop to and from the lifting medium.

2.31 rescue: The prompt return of the flying performer to a safe location and disconnecting from the performer flying system in the event of a performer flying system malfunction, performer incapacity, medical emergency, or other emergency situation that requires aborting flight.

2.32 rescue plan: The operational procedures used to perform a rescue.

2.33 rescue system: A system of components and procedures used to perform a rescue.

2.34 ride-on prop: Scenic element supported by the performer flying system that bears the weight of the performer where the flying performer is primarily a “passenger” rather than an active motivator of flight or motion.

2.35 rigid lifting medium: Inflexible structural elements subject to movement, action, or change during the operation of the performer flying system. This may include, but is not limited to, ride-on props, structural shapes, arms, or fabricated components.

2.36 risk: For an identified potentially hazardous condition, the combination of the probability of occurrence of harm and the severity of that harm.

2.36.1 Inherent Risk: the initial level of risk identified during the RA/RR process.

2.36.2 residual risk: the remaining level of risk following the mitigation steps determined during the RA/RR process.

2.37 Risk Assessment (RA): The process of identifying, evaluating, and quantifying potentially hazardous conditions, and assigning levels of risk based on the combination of the probability of occurrence of harm and the severity of that harm.

2.38 Risk Reduction (RR): Mitigation or elimination of risks or hazards determined by the risk assessment.

2.39 Risk Assessment / Risk Reduction (RA/RR): The cyclical process of identifying hazards, evaluating risks, mitigating hazards or risks, quantifying the residual risks, documenting, and repeating as necessary until the risks have been reduced to an acceptable level.

2.40 shall: Indicates that the rule is mandatory and must be followed.

2.41 should: Indicates that the rule is a recommendation, the advisability of which depends on the facts and conditions in each situation.

2.42 Site Acceptance Test (SAT): A final step in the installation during which the system supplier demonstrates to the user by testing that the performer flying system meets the performance and safety specifications. SAT performance criteria shall be agreed upon between the system supplier and the user prior to SAT.

2.43 static load bearing components: Inflexible structural elements lacking in movement, action, or change during the operation of the performer flying system. This may include, but is not limited to, winch frames, equipment support frames, sheave block support frames, carrier support tracks, support brackets, or support trusses.

2.44 stop categories

2.44.1 Category 0 stop: An uncontrolled stop caused by the immediate removal of power from the machine actuators.

2.44.2 Category 1 stop: A controlled stop with power to the machine actuators available to achieve the stop, then when the stop is achieved, power is removed from the machine actuators.

2.44.3 Category 2 stop: A controlled stop with power left available to the machine actuators.

2.45 tensioned cable track: Flexible medium statically suspended and tensioned between two points to form a catenary track.

2.46 working load: See 2.21 - load categories.

2.47 working load limit (WLL): The maximum static weight as defined by the flying system designer that a user is allowed to apply to a lifting medium in the performer flying system.

3 Roles and Responsibilities

The intent of this section is to promote awareness and define the roles and associated responsibilities involved in performer flying effects. These are not necessarily job titles but are roles and responsibilities common to the practice of performer flying. Unless otherwise noted, there shall be a competent person or persons responsible for each of the following roles and responsibilities. A person may take on multiple roles depending on the nature of the flying effect. Terms in parenthesis indicate some of the typical titles often used by various segments of the performer flying industry. (see annex note)

3.1 user (Production / Tour / Company Manager / Production Manager / Technical Director): Person or company that manages and is ultimately responsible for the use of the performer flying system for the intended flying effect. The user manages the people responsible for maintaining and operating the performer flying system.

3.2 flying performer (Artist / Flier): Person who is suspended or transported in the air as part of a performance intended to be in view of the audience.

3.3 creative designer (Acrobatic Performance Designer / Artistic Director / Show Director / Choreographer): Person, or team of persons, who creates the visual concept of the flight, including, but not limited to; flight path, speed, orientation of performer, costumes, props, harness, and connection/disconnection process.

3.4 flying system designer (Acrobatic Equipment Designer / Rigging Designer / Performance Rigging Designer): qualified person responsible for the overall design of the performer flying system. The flying system designer shall assume the following responsibilities.

3.4.1 Analyze the creative design and satisfy, to the greatest extent possible, the intent of the creative designer.
3.4.2 Select and arrange the components, personnel, and procedures that make up a performer flying system.
3.4.3 Validate the safety and integrity of the performer flying system design.
3.4.4 Establish essential protocols and basic parameters for system operations.

3.5 professional engineer: Licensed engineering professional who provides engineering evaluations supporting the performer flying system design. The professional engineer role is not required unless stipulated by the flying performer, user, flying system designer, or Authority Having Jurisdiction.

3.6 system supplier: Person or company who integrates and assembles a performer flying system and supplies that performer flying system to a production for rent or to an end user as a sale.

3.7 system installer (Install Rigger / Production Rigger): qualified person (usually provided by company or user) responsible for the installation of the performer flying system.

3.8 flying team (Acrobatic / Aerial / Performer Rigging Team): Person or persons directly responsible for day-to-day use of the performer flying system. Specific titles, roles, and responsibilities will vary depending on the design of the performer flying system, the size of the production, the style of production, the number of flying performers, the RA/RR process, and other factors.

3.9 flying safety supervisor (Head of Rigging Department / Lead Rigger / Acrobatic Rigger): qualified person responsible for overall safety and operation of the performer flying system. The flying safety supervisor shall either assume the following responsibilities or ensure that the following responsibilities are delegated to a competent person. The person in this role and the responsibilities themselves may be adjusted or delegated during the production process to suit the needs of the production and ensure a continuity of safety for all flying effects. After the installation, commissioning, and training, this person is sometimes not present for rehearsals and performances and may delegate parts of the supervision, inspection, and documentation to the flying supervisor or other person(s).

3.9.1 Establish operational protocols for criteria identified by the risk assessment.
3.9.2 Establish emergency response and rescue plans identified by the risk assessment.
3.9.3 Ensure that equipment required for performer flying-related emergency response is appropriate for the required use, is placed in an appropriate location, and is in good working order.
3.9.4 Ensure that all relevant personnel are trained and prepared for the efficient and effective implementation of the rescue plan.
3.9.5 Confirm suitability of flying performer(s) for intended role.
3.9.6 Confirm suitability of flying operator(s) for intended role.
3.9.7 Ensure that choreography of flying sequences is suitable and within established acceptable risk levels.
3.9.8 Ensure that cuing of flying sequences is suitable and within established acceptable risk levels.
3.9.9 Train the member(s) of the flying team in their respective roles.
3.9.10 Establish required testing of the flying effects equipment.
3.9.11 Establish required inspections of the flying effects equipment.
3.9.12 Establish necessary maintenance of the flying effects equipment.

3.10 flying supervisor (Fly Captain / Lead Rigger / Acrobatic Rigger): Person responsible for operational safety and well-being of the flying performers. They are always present during any flying sessions and may have the oversight of certain inspection, maintenance, and testing duties delegated to them by the flying safety supervisor. The person in this role and the responsibilities themselves may be adjusted or delegated during the production process to suit the needs of the production and ensure a continuity of safety for all flying effects. The person executing this role and the actual roles themselves may be adjusted or delegated during the production process.

3.10.1 Verify that established operational protocols are implemented for all flight sessions.
3.10.2 Verify that emergency response and rescue plans are in place.
3.10.3 Verify that equipment required for performer flying-related emergency response is in place and functional.
3.10.4 Verify that all relevant personnel are prepared for the implementation of the rescue plan.
3.10.5 Confirm suitability and readiness of flying performer(s) for intended flight.
3.10.6 Confirm suitability and readiness of flying operator(s) for intended flight.
3.10.7 Ensure that established flight choreography remains consistent throughout the run of the show.
3.10.8 Ensure that established flying cues remain consistent throughout the run of the show.
3.10.9 Ensure that all members of the flying team are in place for all flight sessions.
3.10.10 Perform required testing of the flying effects equipment.
3.10.11 Perform required inspections of the flying effects equipment.
3.10.12 Perform necessary maintenance of the flying effects equipment.

3.11 flying director (Lead Rigger / Performance Rigger): qualified person authorized by the system supplier to function as flying system designer, system installer, flying safety supervisor, or flying supervisor as required (satisfy the creative design, select and arrange system components, validate safety and integrity, establish essential protocols, install, test, inspect, operate, and train personnel on a performer flying system). When not present for rehearsals or performances, this person continues supervision of the flying supervisor.

3.12 stage manager (Performance Director): Person who manages the overall performance during the show, and who typically coordinates with the flying team in cuing flying performer flight with other show cues. In the absence of a Stage Manager, the flying safety supervisor shall delegate this responsibility.

3.13 flight sequence programmer (Automation Lead / Head of Automation / Automation Technician): qualified person responsible for programming flight cue sequences into a computerized console or PLC of an Automated performer flying system.

3.14 flying operator (Lead Rigger / Performance Rigger / Automation Lead / Head of Automation / Automation Technician): Person responsible for operation of the performer flying system. In a complex flying effect, there may be multiple flying operators with coordinated functions.

3.15 other roles – Observer, Spotter, Technician, Attendant, Assistant, Cast Member, Acrobatic Rigger, Rigger, Assistant Stage Manager: The following responsibilities, as determined by operational protocols, shall, where necessary, be assumed by either the flying safety supervisor or the flying supervisor, or assigned to member(s) of the flying team.

3.15.1 Inspect harnesses, ride-on props, or acrobatic props before each use.
3.15.2 Ensure that all harnesses are properly placed and secured on flying performers.
3.15.3 Observe that conditions are suitable for a flying performer to fly.
3.15.4 Determine that a flying performer is ready for flight.
3.15.5 Hook or unhook the hardware that attaches flying performers to the performer flying system.
3.15.6 Assist flying performers with hand-held props, costume elements, acrobatic props, or ride-on props.
3.15.7 Communicate readiness for flight (clear or not clear) to members of the flying team.
3.15.8 Assist flying performers with launch or landing.
3.15.9 Observe flying performers during flight and take action to protect the flying performers and others.

3.16 emergency response: The roles and responsibilities in this section are required unless it has been determined, through RA/RR, that they are not required. These roles may be performed by people having other duties.

3.16.1 emergency response leader: Person responsible for leading the implementation of the emergency or rescue plan, including directing personnel and rescue operations during an emergency or rescue situation.
3.16.2 first aid attendant (physical therapist / performance medic): Person trained in first aid, in charge of first respondent treatment as may be required.
3.16.3 rescue technician (rescuer / rescue rigger): Person or persons responsible for performing rescue or emergency response operations.

4 Referenced Standards

4.1 Design
The following standards and documents shall be used in the design of the performer flying system and shall be dependent on the intended conditions of use. Where there is a conflict between standards cited below, the provisions of E1.43 shall govern for performer flying applications.

4.1.1 ANSI E1.2-2021 “Entertainment Technology – Design, Manufacture and Use of Aluminum Trusses and Towers”
4.1.2 ANSI E1.4-1-2022 “Entertainment Technology – Manual Counterweight Rigging Systems”
4.1.3 ANSI E1.4-3-2020 “Entertainment Technology – Manually Operated Hoist Rigging Systems”
4.1.4 ANSI E1.6-1-2021 “Entertainment Technology – Powered Hoist Systems”
4.1.5 NFPA 70: National Electrical Code, 2020 edition
4.1.6 NFPA 79: Electrical Standard for Industrial Machinery, 2018 Edition
4.1.7 AWS D1.1-15 Structural Welding Code – Steel
4.1.8 AWS D1.2-14 Structural Welding Code - Aluminum
4.1.9 Wire Rope user’s Manual, 4th Edition – Wire Rope Technical Board

4.2 Application
The following documents are referenced and shall be used as applicable to the performer flying system. For dated references, only the edition cited applies. For undated references, the latest edition of the reference document, including any amendments, shall apply.

4.2.1 ASCE/SEI 7-22, “Minimum Design Loads for Building and Other Structures”
4.2.2 ASCE 19-16 “Structural Applications of Steel Cables for Buildings”
4.2.3 ADM1-20 “Aluminum Design Manual - Specifications for Aluminum Structures”
4.2.4 AISC 360-16 "Specifications for Structural Steel Buildings”
4.2.5 AISC 303-16 "Code of Standard Practice for Steel Buildings and Bridges”
4.2.6 American Institute of Steel Construction, “Manual of Steel Construction,” 15th Edition
4.2.7 ANSI / ASSP Z359.1-2020 “The Fall Protection Code”
4.2.8 ANSI / ASSP Z359.4-2013 (R2022) “Safety Requirements for Assisted-rescue and Self-rescue Systems, Subsystems and Components”
4.2.9 NFPA 1983-2017: Standard on Life Safety Rope and Equipment for Emergency Service

5 Risk Assessment / Risk Reduction (RA/RR)

5.1 General guidelines

5.1.1 RA/RR shall be performed for all aspects and locations of the use of performer flying systems throughout conceptualization, design, fabrication, installation, testing, training, rehearsal, and operations, and shall continue cyclically for the duration of the system’s use to assure that residual risks are limited to acceptable levels.
5.1.2 At a minimum, the RA/RR process shall:
5.1.2.1 Identify and classify the hazards associated with the planned or current use of the performer flying system, including reasonably foreseeable misuse.
5.1.2.2 Evaluate and classify the risks in terms of severity and probability of harm.
5.1.2.3 Identify methods used to eliminate or mitigate the risks (or hazards).
5.1.2.4 Classify residual risks based on criteria used in 5.1.2.1.
5.1.2.5 Establish methods to ensure that residual risks are maintained to acceptable levels.
5.1.2.6 Document the process of identification, evaluation, mitigation, and classification or risks and hazards.
5.1.2.7 Determine methods of response should there be an occurrence of residual risk.

5.2 Personnel
The scope of the RA/RR process shall be determined or approved by a qualified person. RA/RR shall be performed by a group of two or more competent persons or by at least one qualified person. Participation of personnel with health and safety expertise is encouraged. (see annex note)

5.3 Residual risk
The person or persons performing the RA/RR, in consultation with all relevant involved parties, shall determine the acceptable level of residual risk.

5.4 Changes
A review and update of the RA/RR process shall be triggered and implemented whenever a material change in plans, equipment, operations, or other circumstances (for example, changes in the performance itself, show order, personnel, or environmental conditions) could lead to the creation of new hazards or new levels of risk.

5.5 System design
RA/RR shall be performed for new system designs to evaluate infrastructure, such as strength, appropriateness, and compatibility of materials and components, possible points and modes of failure, system operation, inspection, and maintenance.

5.6 System installation
RA/RR shall be performed for each installation of a system to evaluate appropriateness of the system for the intended use.

5.7 Mechanized systems
RA/RR for the machinery of mechanized performer flying systems shall follow, at a minimum, the procedures described in E1.6-1-2021, section 4.

5.8 Proximity
The RA/RR shall address all risks related to proximity and clearances of members of the public, show personnel, structures, and other effects to the flying performers during normal operations, foreseeable abnormal flight situations, all stop conditions, and during rescue operations.

5.9 Peak loads
The RA/RR shall address all risks associated with abnormal or peak loads, including those resulting from emergency stops of any kind. This shall include the consequences to the system, structures, and people.

5.10 Informed consent and training
All involved parties, including flying performers, shall be informed of, and consent as required, to the results of the RA/RR process, and how it relates to their roles in the performer flying system, including normal operation, potential abnormal conditions, and emergency response, or rescue. Where appropriate, specific training shall be provided to ensure the practicability and effectiveness of risk elimination, mitigation, and response measures.

5.11 Documentation
A written report of the RA/RR shall be recorded by the person or persons performing the assessment and made available by request to all involved parties. The report shall contain details describing:

5.11.1 Definitions of the limits of use.
5.11.2 Identification of the hazards associated with use.
5.11.3 Identification of hazards associated with reasonably foreseeable misuse.
5.11.4 Classification of the risks in terms of severity and probability of harm.
5.11.5 Methods used to mitigate the risks.
5.11.6 Classification of residual risks after mitigation.
5.11.7 Date of completion.

6 Performer flying system design
The intent of this section is to establish requirements for the design and engineering of performer flying systems and system components. Variations on the design requirements listed in sections 6, 7 (Engineering) and 8 (System Components) shall be permitted pursuant to RA/RR, or review and approval by a Professional Engineer

6.1 General guidelines
6.1.1 The performer flying system shall be designed by a qualified person.
6.1.2 The flying system designer shall use a process of RA/RR during the design phase to identify and mitigate hazards.
6.1.3 The flying system designer shall determine the anticipated operating cycles for the performer flying system.
6.1.4 The design shall include provisions for inspections, testing, assembly, installation, operational use, and rescue procedures.
6.1.5 The flying system design shall promote redundancy in design, where appropriate, to mitigate the likelihood of single point failure and cascading failures. In situations where single points or cascading failure

points of support are unavoidable, or where redundant systems may create additional hazards, the flying system designer shall use an increased design factor or other appropriate steps to mitigate risks based on RA/RR. (see annex note)

6.1.6 If the flying system designer determines that it is appropriate to use or attach to rigging equipment or other components considered by the manufacturer to be unsuitable for flying people as part of the performer flying system, the flying system designer shall take full responsibility for such use. In such cases, documentation of the rationale for such use based on RA/RR shall be included in system documentation.

6.1.7 A flying harness, ride-on prop, or acrobatic prop supports the flying performer's body weight throughout the flying routine from single or multiple pick-up points and not under the conditions normally associated with fall arrest equipment. When a person is supported by a performer flying system, fall arrest equipment is not needed and could present a safety hazard.

6.1.8 Subject to RA/RR and AHJ approval where required, flying performers' flight paths shall not bring the performer, acrobatic props, or ride-on props, or associated equipment within the reach of members of the public or into unintended contact with other show personnel.

6.1.9 All conditions of use in the design shall be explicitly outlined in the system design documentation.

6.2 Established performer flying systems

6.2.1 An Established performer flying system must be associated with a specific system supplier, i.e., a company or flying director. If a performer flying system is classified as Established for one entity (Company X), an identical set of flying equipment and procedures adopted by another entity (Company Y) is not deemed Established until Company Y independently satisfies the requirements. (see annex note)

6.2.2 An Established performer flying system shall satisfy all the following criteria:

6.2.2.1 The design has been in service for:

6.2.2.1.1 a minimum of one (1) year and a minimum of fifteen (15) separate documented installations, or

6.2.2.1.2 a minimum of two (2) years and a minimum of four (4) separate documented installations of regular use.

6.2.2.2 The design has not experienced any significant design related failures or significant design related safety issues that have not been mitigated.

6.2.3 An Established performer flying system may only be installed by, or under the supervision of, a qualified person, often filling the role of flying director, trained in accordance with requirements of the system supplier.

6.2.4 Documentation for the Established performer flying system shall include the following:

6.2.4.1 A risk mitigation report for the basic system design.

6.2.4.2 Records of in-service use locations, dates, personnel, and number of testing, rehearsal, and performance uses.

6.2.4.3 Records of inspection, maintenance, and testing.

6.2.4.4 Records of any incidents in use and any mitigation of deficiencies in the design.

6.2.4.5 Site specific risk assessment documents for each installation used to demonstrate requirements.

6.2.4.6 Protocol for training a flying director on the installation, testing, inspection, maintenance, operation, and use of an Established performer flying system.

6.2.4.7 Records of successful training of approved flying director(s).

6.2.5 Documentation shall be maintained by the system supplier. Copies shall be furnished to the user upon request.

6.2.6 System Components:

6.2.6.1 A system supplier may have multiple interchangeable components used in one or more performer flying systems as long as the components used match those specified for use in the Established performer flying system.

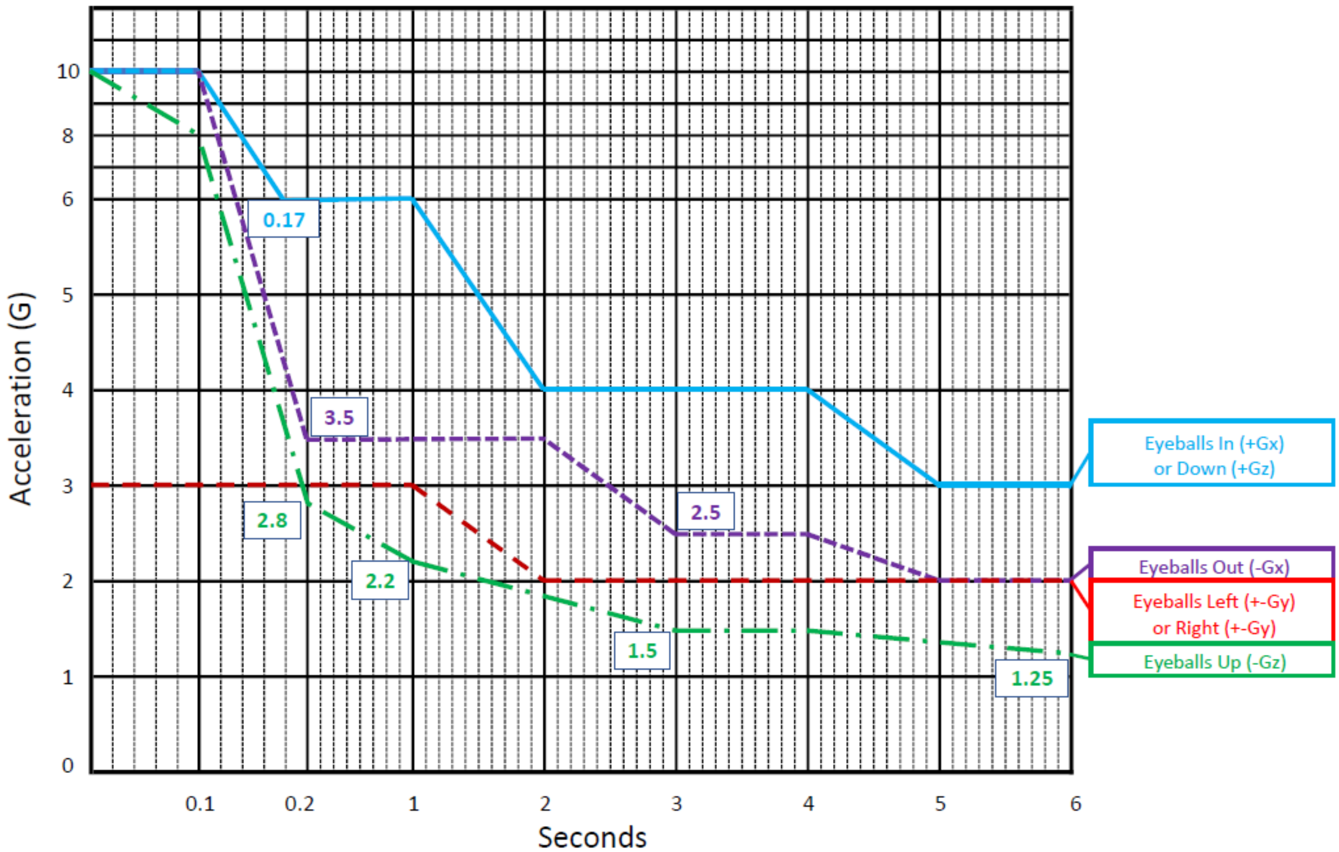
6.2.6.2 Any significant change, as determined by a qualified person, in component, assembly, or use shall require recertification of the established performer flying system.

6.2.6.2.1 A substitution in rated hardware or component may be allowed without being subject to the requirements of section 6.2.2.

6.3 Physiological limitations

6.3.1 The flying system designer shall evaluate effects of acceleration, deceleration, and other motion-based dynamics in load calculations as applied to the performer flying system and flying performers.

6.3.2 performer flying systems shall be designed such that loads imposed on the flying performer by the performer flying system (performer peak loads) are within the limits specified in the following graphs (Figures 1 through 5) based on definitions of Physiological Accelerations Systems in Table 1. [Graphs derived from ASTM F2291 “Standard Practice for Design of Amusement Rides and Devices” and NASA Memorandum “Human Tolerance to Rapidly Applied Accelerations” by A. Martin Eiband, June 1959.] The graphs indicate that acceleration/deceleration of 2.8G on the flying performer is allowed for a maximum duration of 0.2 seconds without regard to flying performer orientation relative to motion. (see annex note.)



Maximum Time Duration Limits for Acceleration and Deceleration Applied to a Typical Human Body

6.3.3 For multiple Axis (3D) performer flight systems, loads imposed on the flying performer by the harness shall comply with Figures 10-17 of ASTM F2291-20 “Allowable Combined Magnitude of (two or three axes) Accelerations.”

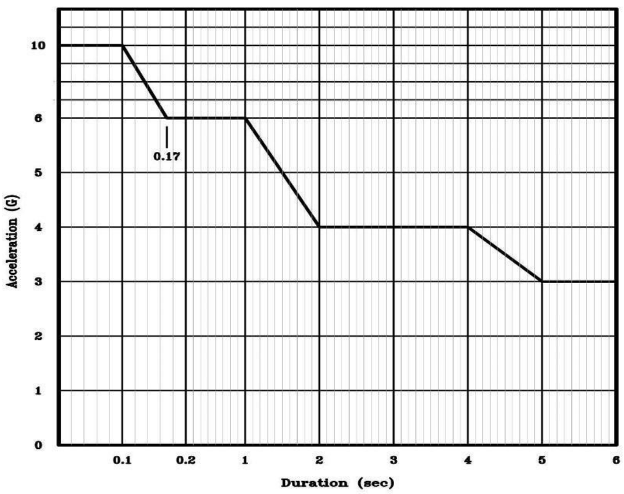
6.3.4 Higher performer loads than those specified in section 6.3.2 shall be permitted for acts using properly trained flying performers, only if validated by RA/RR.

6.3.5 The surface area pressure of the harness, acrobatic prop, or ride-on prop resisting the performer load shall be evaluated during design and selection in order to minimize performer discomfort and avoid injury when subjected to characteristic loads or peak loads. (see annex note)

6.3.6 peak load design factors included in this document pertain to all potential types of peak loads. (see annex note)

Vernacular Description	Pictorial Description	Verbal Definition	Descriptive Terms	AGARD Symbol	Heart Displacement	Other Terms	Other Terms
Eyeballs in		A force applied to the posterior part of the trunk, acting forward with respect to the subject and perpendicular to the mean spine produces a forward acceleration.	Forward acceleration or forward acting force	$+G_x$	Moves toward back	Forward Acceleration	Transverse A-P G Supine G Chest to back G Sternumward
Eyeballs out		A force applied to the anterior part of the trunk, acting backward with respect to the subject and perpendicular to the mean spine produces a backward acceleration.	Backward acceleration or backward acting force	$-G_x$	Moves toward front	Backward Acceleration	Transverse P-A G Prone G Back to chest G Spineward
Eyeballs left		A force applied to the left surface of the subject's body, acting in a rightward direction and essentially perpendicular to the subject's mean spine produces a rightward acceleration.	Rightward acceleration or rightward acting force	$+G_y$	Moves toward left	Right Lateral Acceleration	Left lateral G
Eyeballs right		A force applied to the right surface of the subject's body, acting in a leftward direction and essentially perpendicular to the subject's mean spine produces a leftward acceleration.	Leftward acceleration or leftward acting force	$-G_y$	Moves toward right	Left Lateral Acceleration	Right lateral G
Eyeballs down		A force applied to the buttocks, thighs, and/or feet, acting in a headward direction with respect to the subject and essentially parallel to the subject's mean spine produces a headward acceleration.	Headward acceleration or headward acting force	$+G_z$	Moves toward feet	Headward Acceleration	Positive G Headward
Eyeballs up		A force applied to the shoulders, thighs, and feet acting in a tailward direction with respect to the subject and essentially parallel to the subject's mean spine produces a tailward acceleration.	Tailward acceleration or tailward acting force	$-G_z$	Moves toward head	Tailward Acceleration	Negative G Tailward

Modified from Table 41: Physiological Acceleration Systems in Hugh W. Randel's *Aerospace Medicine, 2nd ed.*,
based on table compiled by Gerard J. Pesman in Dictionary of Technical Terms for Aerospace Use, edited by W.H. Allen, NASA SP-7, Washington, D.C., 1965


10
6
5
4
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Acceleration (G)
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1
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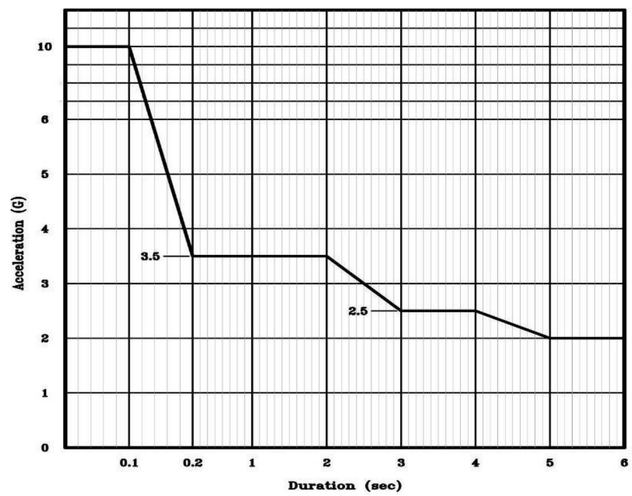
6
Duration (sec)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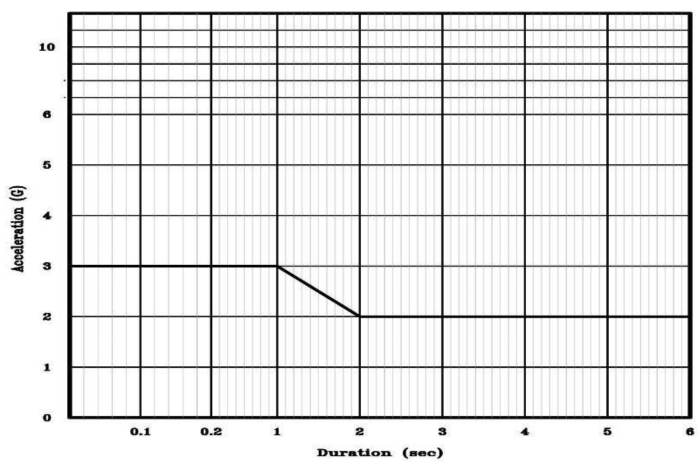
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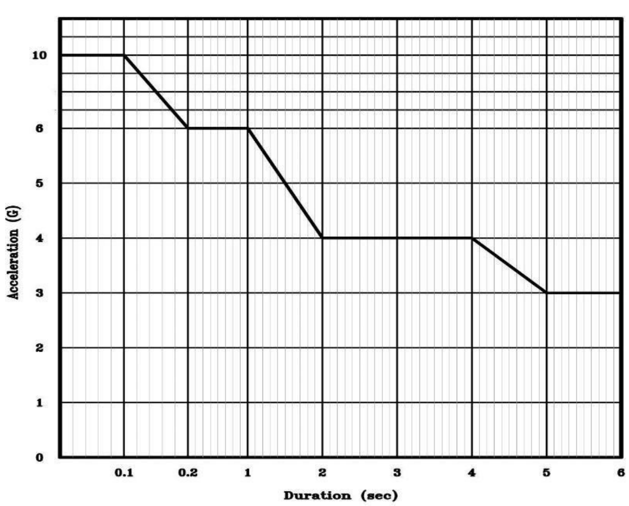
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Acceleration (G)
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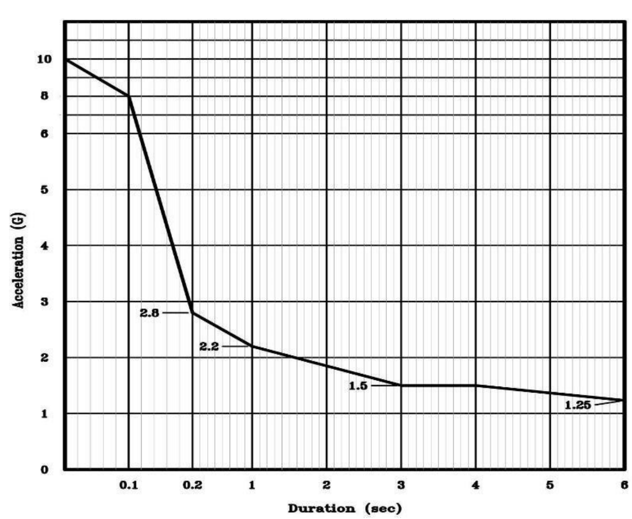
Duration (sec)


10
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6
5
4
3
2
1
0
2.8
2.2
1.5
1.25
Acceleration (G)
0.1
0.2
1
2
3
4
5
6
Duration (sec)

6.4 Tensioned cable track

Maximum tension in Tensioned Cable Tracks is determined using the catenary geometry, cable track pre-tension, weight of cable tracks, weight of supported performer flying system elements, and the dynamic forces. The selected design factor for supported performer flying system elements in Tensioned Cable Track systems should account for the ability to accurately calculate forces resulting from the often-sensitive variables involved in the geometry and forces in a catenary system, hazards caused by a failing tension line, as well as the difficulty often involved in inspecting these systems.

6.4.1 The flying system designer shall evaluate self-weight, characteristic loads and peak loads, and environmental variables imposed on Tensioned Cable Tracks.

6.4.2 flying system designer shall evaluate effects of peak load tension on Tensioned Cable Track attachments points.

6.4.3 The flying system designer shall determine the required design factor for Tensioned Cable Tracks for each performer flying system.

6.5 Electromechanical actuation

6.5.1 Mechanical

6.5.1.1 Mechanized and Automated performer flying systems shall incorporate all aspects of mechanical requirements herein, unless otherwise determined by RA/RR.

6.5.1.2 In addition to the provisions of this standard, all motorized Hoist systems shall conform to ANSI E1.6-1-2021. In the case of conflicts between the referenced standards and this document, this document shall take precedence.

6.5.1.3 The maximum force that can be produced by the electromechanical actuator shall be evaluated as part of the process to determine peak loads in the performer flying system.

6.5.1.4 If an electromechanical actuator is selected that can produce a force that would overload any of the elements in the load path based on the required design factor, then the flying system designer shall incorporate measures to reduce the maximum force from the actuator on the components in the load path so that the required design factors are satisfied.

6.5.2 Load-securing devices

6.5.2.1 As per E1.6-1-2021, Hoists shall include at least two independently functioning load-securing devices.

6.5.2.2 The purpose of the load securing devices shall be to independently secure the load at any position.

6.5.2.3 A gearbox alone shall not be considered as a load securing device.

6.5.2.4 Each load securing device shall be sized to hold at least 1.25 X WLL. The load securing system shall be designed to stop the WLL during a Category 0 stop, at Full Speed in both directions. Forces from a Category 0 stop may fall into the category of peak loads. Forces generated during a Category 0 stop from Full Speed shall be considered when calculating peak loads.

6.5.2.5 For machines where the drum or other termination point of the lifting medium is driven by a chain, belt or other articulating element, measures shall be taken to ensure that any failure of the articulating element shall cause the load securing devices to engage.

6.5.2.6 It shall be possible to disengage each of the load-securing devices without relying on facility power service by utilizing manual devices and/or readily available, locally stored power sources (such as batteries, generators, and the like).

6.5.2.7 It shall be possible to adjust one of the load-securing devices without relying on facility power service, in order to transition from secured load to controlled movement of the flying performer load to facilitate rescue operations.

6.5.2.8 If readily available battery back-up or uninterruptible power supply (UPS) are relied upon to release and/or control the load-securing devices as a primary rescue method, this back-up shall have the battery capacity and discharge rate that is sufficient for performing the rescue operation. Maintenance and inspection procedures shall ensure that the battery back-up and/or UPS are in proper operating condition at all times.

6.5.2.9 Design of load securing devices shall consider loads on the flying performer and on the performer flying system.

6.6 Electrical equipment and control systems

6.6.1 General

6.6.1.1 Mechanized and Automated performer flying systems shall incorporate all aspects of control requirements herein, unless otherwise determined by RA/RR.

6.6.1.2 Electrical equipment and control systems shall conform to ANSI E1.6-1-2021, “Entertainment Technology – Powered Hoist Systems.”

6.6.1.3 The electrical equipment covered by this standard commences at the point of power input into the control cabinet. The suitability of incoming power shall be verified before making the connection.

6.6.2 Control functions

6.6.2.1 Normal Limits shall not be utilized for positioning in cue-based operation of an Automated performer flying system.

6.6.2.1.1 For non-cued operation of Automated performer flying systems, such as by joystick or jog control, use of Normal Limits as a positioning limit shall be permitted.

6.6.2.1.2 For Mechanized performer flying systems, use of Normal Limits as a positioning limit shall be permitted.

6.6.2.1.3 Normal Limits may be used as part of a homing procedure without the flying performer attached to the system.

6.6.2.2 The control system shall have the ability to add local stop switches, interlocks, or enable switches as required by the flying system designer based on RA/RR.

6.6.2.3 When a flying operator’s direct line of sight is obstructed or compromised, remote means to stop or disable the system shall be provided, the locations and types of which shall be determined by a qualified person based on RA/RR.

6.6.2.4 The delivery of motive force shall be controllable in order to ensure safe flight and safe rescue. Electric motors, if used, shall have variable speed drives. Hydraulic or pneumatic systems, if used, shall have proportional valves and pressure relief valves.

6.6.2.5 Joystick control shall only provide motion after a hold-to-enable 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 is returned to the neutral position.

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

6.6.2.7 The maximum operating speed and acceleration of the system as determined by RA/RR shall be limited by a setting, or settings, in the variable speed controller. (see annex note)

6.6.2.8 The control system shall be secured against unauthorized use.

6.6.2.9 For automated performer flying systems, the control system shall have the ability to limit access to critical settings by use of a password, key operated switch, or other secure means. Such settings may include software limits, maximum speeds, acceleration/deceleration parameters, and torque/current settings.

6.6.2.10 When two or more actuators are used to perform an individual flying effect, and the fault of one of the actuators puts the flying performer at risk of harm, the actuators shall be linked by the control system so that any fault shall stop motion of all actuators for that individual effect.

6.6.3 Programmable control systems: For all programmable control systems for performer flying, the following shall be provided:

6.6.3.1 Each direction of travel shall have user assignable software limits which shall prevent further motion in the direction of travel. When the software limit is activated, movement in the opposite direction shall be allowed.

6.6.3.2 software limits should be functional in both joystick and run-cue operational modes.

6.6.3.2.1 The system may have different programmed software limit values based on operational mode.

6.6.3.2.2 Joystick operation of a system in "local" mode, i.e., operation in the absence of a functional programmable control system, might not require functional "soft" limits" based on RA/RR.

6.6.3.3 Each Axis shall have closed-loop feedback for position monitoring and control. (see annex note)

6.6.3.4 The control system shall compare set (“target”) values with actual values of speed, position or both, and fault if the difference exceeds the error tolerance as determined by the RA/RR.

6.7 Safety functions for mechanized and automated performer flying systems

6.7.1 Limits (see annex note)

6.7.1.1 For mechanized performer flying systems, Normal Limits and Ultimate Limits shall be incorporated at both ends of travel.

6.7.1.2 For automated performer flying systems, software limits shall also be incorporated at both ends of travel.

6.7.2 Emergency stop

6.7.2.1 The performer flying system shall have an emergency stop function that stops each Axis of motion by implementing either a Category 0 or a Category 1 stop. The choice of category shall be based on the

RA/RR and the functional needs of the performer flying system, with consideration of effects on the flying performer, machinery, and supports.

6.7.2.2 The emergency stop system shall include redundancy in the signals from each emergency stop device.

6.7.2.3 The emergency stop system shall be designed so that no single failure of an individual component or group of components shall cause the system to fail to an unsafe state.

6.7.2.4 The fault condition created by the initiation of an emergency stop shall only be reset by resetting the emergency stop device followed by a separate unique action by the flying operator.

6.7.2.5 Each flying operator control station shall be equipped with an emergency stop.

6.7.2.6 Activation of any of the emergency stops shall stop all machinery in the performer flying system unless otherwise determined by RA/RR.

6.7.2.7 Variable frequency drives (VFD) with integrated safety functions shall be utilized per the drive component manufacturer's instructions.

6.7.3 Backup operation

6.7.3.1 A secondary means of operating the system other than the primary operator interface shall be provided if failure of the primary operator interface would result in a hazard to the flying performer based on RA/RR.

6.7 3.2 The operation of the backup system shall not compromise primary safety functions except as needed to ensure safety of the flying performer as determined by RA/RR.

6.8 Rescue

The design of the performer flying system shall include a written rescue plan with rescue System(s), which should be coordinated with an overall emergency response plan.

6.8.1 Design responsibility: The rescue System shall be designed by a qualified person. The rescue plan shall include references to applicable reference standards employed in the rescue plan, based on the equipment and techniques used. Custom fabricated components used as part of the rescue System shall conform to section 8.2 (fabricated components).

6.8.2 Rescue systems

6.8.2.1 The rescue systems collectively shall accommodate safe rescue along the entire flight path and shall remain functional during the loss of power. There may be multiple rescue techniques and systems for a flight sequence depending on position, physical condition of the flying performer, availability of electromechanical power, and the like. The rescue systems shall be developed considering hazards to all persons in the area (the flying performer, rescuers, workers, audience members, and others). The rescue systems shall minimize time needed to perform the rescue to mitigate the risk to the flying performer.

6.8.2.2 Primary rescue - A primary rescue system is required. The primary rescue system shall be the first rescue method utilized unless there are situational restrictions to using the primary rescue system. The primary rescue system shall be designed with the safety of the flying performer, audience, and rescuers along with expediency as primary design parameters.

6.8.2.3 Secondary and subsequent rescue - Secondary and subsequent rescue systems are required. Secondary and any subsequent rescue systems shall be employed when situations arise that do not allow the safe use of the primary rescue system.

6.8.3 Rescue plan design considerations: The rescue plan shall allow a safe rescue to be performed throughout the flight path. (see annex note)

6.8.3.1 In order to mitigate the risks of restricted blood circulation and other health problems, the rescue plan shall include provisions to transport the flying performer to a safe location and shall minimize the time needed to perform the rescue for all reasonably foreseeable situations that can occur, including system failure, unconscious flying performer, and loss of power.

6.8.3.2 The rescue plan shall include protocols for communication during a rescue.

6.8.3.3 The rescue plan shall include readily available contact information for emergency medical personnel, and additional rescue personnel as may be required.

6.8.3.4 If the performer flying system rigging or hoist machinery is used for rescue operations, override devices shall be employed to enable rescuers to operate the equipment separately from the show cueing in a safe condition, which may include controlled descent for machinery operated by computerized controls. If determined by RA/RR, rescue may be performed using non-powered techniques with the machinery. In the case that safety devices are overridden to perform the rescue, operational procedures shall be put in place to mitigate risk.

6.8.4 Special rescue situations

6.8.4.1 Multiple flying performer rescue: The rescue plan and staffing of rescue Technicians and other technical personnel shall include provisions for safely and quickly rescuing flying performers in situations where multiple people require simultaneous rescue.

6.8.4.2 Rescue in audience or other public area: Where lowering of flying performers must occur in or near the audience, the rescue plan shall include provisions for protecting the audience, clearing a landing zone, protecting the flying performer from the audience or evacuating the audience, and for evacuating the flying performer to a protected location.

6.8.5 Rescue equipment

6.8.5.1 Rescue equipment components: The rescue system may include elements used for fall protection, assist-rescue and self-rescue systems, rope access systems, building maintenance and inspection access, ladders, movable stairs, personnel lifts, recreational climbing equipment, flying machinery, and/or rigging hardware. All such equipment shall meet applicable, nationally recognized industry standards. (see annex note.)

6.8.5.2 Fall protection equipment: If during a rescue, fall protection equipment is used as a fall protection component, it shall meet the requirements of ANSI Z359.1. If it is used as a rescue component, it shall meet the requirements of ANSI Z359.4.

6.8.5.3 Rescue rope: Rope used for rescue shall comply with NFPA 1983-2017: “Standard on Life Safety Rope and Equipment for Emergency Services” General-Use or Technical-Use (“Light-Use”) or shall comply with CI 1801-2007: “Low Stretch and Static Kernmantle Life Safety Rope” published by the Cordage Institute. Life safety rope shall be used with compatible rigging hardware, selected to suit the rescue scenarios that may be encountered in the performer flying system and the anticipated loads experienced during a rescue.

7 Engineering

7.1 Strength

7.1.1 The strength of individual components or assemblies can be established using either Load Resistance Factor Design (LRFD) or Allowable Stress Design (ASD) methods, or by physical testing in accordance with a recognized national standard and referenced in engineering documentation. Such engineering documentation may be furnished by the manufacturer. (see annex note)

7.1.2 Design factors shall be used as specified herein for different parts of the performer flying system. (see annex note)

7.1.2.1 For Allowable Stress Design, the minimum design factor specified shall replace the appropriate safety factor from the design code being applied. For Load Resistance Factor Design (LRFD), the LRFD live load factor divided by the minimum design factor specified, shall replace the resistance factor from the design code being applied.

7.1.2.2 For Allowable Stress Design, the minimum design factor against yield specified shall replace the appropriate safety factor from the design code being applied. For LRFD, the LRFD live load factor divided by the minimum design factor against yield specified, shall replace the resistance factor from the design code being applied. (see annex note)

7.1.2.3 In situations where the characteristic loads and peak loads are confirmed by documented empirical testing data supervised by a qualified person or by engineering calculations prepared by a qualified person, the flying system designer is permitted to reduce the working load design factor using a multiplier of 0.8.

7.2 Analysis

7.2.1 The analysis of structures for the intended load conditions shall be performed by calculation, modeling, physical testing, or a combination of these methods.

7.2.2 The analysis shall consider the governing combination, application, and configuration of loads and effects within the use guidelines.

7.2.3 Characteristic loads and peak loads shall be considered in determining the loads applied to the facility structure. See section 7.5 (Facility anchorage).

7.3 Environmental

7.3.1 The flying system designer shall evaluate and consider relevant environmental variables, such as wind, snow, ice, seismic, corrosion, temperature, and rain.

7.3.2 The flying system designer shall evaluate and consider additional prevailing forces for mobile venue application, such as ships, vessels, floats, and vehicles.

7.4 Strength design factors
(see annex note)

7.4.1 Elements in the load path other than flexible lifting media that are subject to single point or cascading failures shall be designed using the same design factors as rigid lifting medium. See section 8.5.4.3 (Rigid lifting medium).

7.4.2 Elements in the load path other than flexible lifting media that are not subject to single point or cascading failures shall be designed using the same design factors as static load bearing components. See section 8.6.1 (Static load bearing components, strength).

7.5 Facility anchorage

7.5.1 The flying system designer shall determine connection points interfacing with the facility structure and shall report associated reaction forces. The determination of appropriate locations and anchorage details for connecting to the facility structure shall be coordinated with the facility's technical representative.

7.5.2 If there is a load rating document for the facility certified by a professional engineer, then the flying system designer shall evaluate the reaction forces relative to the documented load ratings, if applicable. If the flying system designer cannot confirm that the facility structure can safely support the loads based on the load rating document, then the facility's technical representative shall be consulted as per section 7.5.3.

7.5.3 If a load rating document for the facility does not exist or does not pertain to the proposed loading, the facility's technical representative shall evaluate the reported reaction loads on the facility structure and shall determine if the facility structure can safely support the performer flying system. The performer flying system shall be implemented only if the facility's technical representative confirms that the facility structure will safely support the loads.

7.6 Engineering related to system installation and erection

The structural adequacy of the performer flying system during erection and installation shall be evaluated, including limitations imposed by weather.

7.7 Engineering documentation

7.7.1 Engineering drawings or equivalent technical documentation of the structural, mechanical, and electrical elements, and general arrangement drawings of the performer flying system, shall be developed by the flying system designer and maintained by the user.

7.7.2 Engineering drawings or equivalent technical documentation shall include the following:

- 7.7.2.1 Dimensions
- 7.7.2.2 Components
- 7.7.2.3 Subassemblies
- 7.7.2.4 Material types
- 7.7.2.5 Fastener types, specifications, and torque values
- 7.7.2.6 Weld sizes and types

7.7.3 Engineering calculations, design notes, and/or test results shall be developed and maintained.

7.7.4 The documentation package shall contain definitive statements about the operating limits of the system including physical forces, range of motion, speeds, and accelerations.

7.7.5 The documentation package shall clearly indicate where the performer flying system ends and how it interfaces with the support structure, including loads imparted to the support structure.

8 System Components

8.1 Purchased components

8.1.1 Selection of purchased components shall be based on performer flying system requirements.

8.1.2 Selection of purchased components shall be based on evaluation of component manufacturer's technical data and written guidelines.

8.1.3 Purchased components selected shall be supplied with a visible load rating mark from the manufacturer or certification of its load rating or strength by the manufacturer unless components meet the specifications of section 8.1.4.

8.1.4 The use of a purchased component without a visible load rating mark or certification of its load rating or strength shall be allowed only if approved by a professional engineer or validated by testing performed under the direction of a qualified person, subject to the requirements of section 7.1.

8.1.5 All screws, bolts, and nuts in the load path shall be non-malleable, steel construction, unless otherwise determined by RA/RR.

8.1.6 Open end terminations shall not be used in the performer flying system. (see annex note)

8.2 Fabricated components
Fabricated components shall be evaluated and approved by the flying system designer or validated by testing performed under the direction of a qualified person.

8.3 Personal flying components
For the purposes of this standard, personal flying components are considered system components with which the flying performer directly interacts or manipulates. The flying system designer shall categorize the personal flying component from the following list:

8.3.1 Flying harness

8.3.1.1 A flying harness shall be designed or selected by a qualified person solely for the specific purpose of creating flying effects in an entertainment performance environment.

8.3.1.2 Selection and design of the flying harness shall consider the suitability of the support provided by the harness as it relates to the intended flight body position (e.g., upright, lying down, prone or side position, inverted) and physical capabilities of the flying performer.

8.3.1.3 Selection and design of the flying harness and accessories shall consider the maximum period of time the flying performer is expected to be supported by the harness (e.g., leg straps, stirrups, chairs, and the like). (see annex note)

8.3.1.4 Performer flying harnesses shall be designed and selected with a minimum design factor of 10 X working load, 6 X characteristic load and 3 X peak load. When lower design factors are used in the design or selection of harnesses, the label shall clearly indicate usage limitations. Such harnesses may only be used if deemed acceptable by a qualified person based on RA/RR following the provisions of Section 7.4 (Strength design factors).

8.3.1.5 The harness shall have a permanently attached label, or labels, that include(s) the following information: (see annex note)

8.3.1.5.1 Manufacturer and contact information.

8.3.1.5.2 working load limit or recommended maximum flying performer weight.

8.3.1.5.3 Date of manufacture.

8.3.1.5.4 Serial number.

8.3.1.5.5 Applicable warnings.

8.3.1.5.6 Reference to user manual.

8.3.1.6 Harness manufacturer shall provide the following:

8.3.1.6.1 user manual

8.3.1.6.2 Factory quality control documentation

8.3.1.6.3 Inspection criteria

8.3.1.6.4 Retirement criteria

8.3.1.7 Connections to the lifting medium shall be secure under both load and slack conditions.

8.3.1.8 The application of costumes, paint, or any additional material to the harness shall not compromise the strength of the material, interfere with its operation, or impede the inspection of the stitching and connection hardware. Any application or addition shall be approved by the manufacturer or flying safety supervisor.

8.3.2 Ride-on prop

8.3.2.1 Any flying vessels, platforms, or props shall be designed by a qualified person.

8.3.2.2 Applicable design factors for ride-on props shall comply with section 7.4 (Strength design factors), unless otherwise determined by RA/RR.

8.3.3.3 Ride-on props shall be designed to comply with section 6.3 (Physiological Limitations).

8.3.3.4 Ride-on props shall be attached in a manner that in the event of a failure of the prop support lines the prop does not become supported by the flying performer, the flying performer's harness, or any point along the load path to the flying performer.

8.3.2.5 All flying performers riding on or in flying vessels, platforms, or ride-on props shall be tethered directly to the load path, unless other means are provided for protecting the Flying Performer as determined by RA/RR.

8.3.3 Acrobatic prop

8.3.3.1 Acrobatic props shall be designed or selected by a qualified person, who shall also determine the applicable section(s) within this standard with respect to design and engineering.

8.3.3.2 Applicable design factors for acrobatic props shall comply with section 7.4 (Strength design factors), unless otherwise determined by RA/RR.

8.3.3.3 Acrobatic props shall be designed to comply with section 6.3 (Physiological Limitations).

8.3.3.4 Regardless of the nature of the primary connection between the flying performer and the acrobatic prop, the flying system designer shall determine, based on RA/RR, whether the flying performers shall be mechanically attached or tethered to the performer flying system, either to the flying prop itself or to another load-bearing component in the load path. If such an attachment is made, the system designer shall ensure that it is capable of independently supporting the flying performer under all foreseeable characteristic load and peak load conditions.

8.4 Quick-connect hardware

8.4.1 All quick-connect hardware shall be designed such that its default state when in use is closed/locked.
8.4.2 All quick-connect hardware shall require at least two actions to open/unlock. These actions can be simultaneous or sequential. The number of required actions shall be determined by RA/RR.
8.4.3 Quick-connect hardware shall be selected to prevent unintended disconnection.
8.4.4 Purchased hardware used for quick-connect hardware shall bear a load rating that is permanently marked on the hardware or readily available as part of system documentation.
8.4.5 Quick-connect hardware shall be designed and selected with a minimum design factor of 10 X working load, 6 X characteristic load and 3 X peak load.
8.4.6 When multiple quick-connect hardware components are used to fly a flying performer, ride-on prop, or acrobatic prop, in the event of a failure of one quick-connect hardware component, the remaining hardware shall be capable of safely supporting the load. Reduced design factors may be used if determined by the flying system designer based on RA/RR.
8.4.7 Custom quick-connect hardware designs shall be reviewed and approved by a professional engineer or validated by testing performed under the direction of a qualified person.

8.5 Lifting medium

Lifting medium may take the form of steel wire or synthetic rope(s), synthetic or metallic webbing or band(s), physical structures such as beams and trusses, or other means of supporting or moving the flying performer.

8.5.1 Material: Material for the lifting medium shall be chosen by a qualified person based on the performer flying system's physical and performance requirements, and accepted engineering practices.
8.5.1.1 The lifting medium shall be of sufficient strength to withstand the expected characteristic loads and peak loads imposed by operation of the performer flying system. The strength shall be determined after the application of the appropriate de-rating factors if applicable.
8.5.1.2 The lifting medium selection shall consider the anticipated number of operating cycles and inspection and maintenance frequency.
8.5.1.3 Unless otherwise validated by testing performed under the direction of a qualified person, the material chosen for the lifting medium shall be furnished with mill or manufacturers certification documents detailing the base materials used in manufacturing, the origin and location of manufacture, and quality control and quality assurance testing methods and results. These documents shall be included in the documentation package maintained by the user.

8.5.2 Terminations and swivels
8.5.2.1 The lifting medium shall be securely terminated at both ends.
8.5.2.2 All terminations shall be made in accordance with the manufacturer's specifications. De-rated values of the lifting medium due to terminations shall be considered when calculating strength of medium when determining design factors and related strength data.
8.5.2.3 The use of swivels shall be in accordance with the rope manufacturer's recommendations and de-rated values of the lifting medium due to the use of swivels shall be considered when determining design factors and related strength data. (see annex note)

8.5.3 Manufacturing treatments
8.5.3.1 Strength and endurance reductions caused by finishes or coatings applied to lifting medium shall be considered.
8.5.3.2 De-rating factors for welding, heat treatments, bending, or other processes that affect the strength of the base material shall be applied prior to determining the final design factor.

8.5.4 lifting medium: lifting medium shall be sized to meet the following strength design factors.
8.5.4.1 Flexible lifting medium
8.5.4.1.1 Unless otherwise noted in this standard, flexible lifting medium (e.g., cable, rope, chain, band, webbing) shall be designed with a minimum design factor of 10 X working load, 6 X characteristic load, and 3 X peak load.
8.5.4.1.2 In situations where the characteristic loads and peak loads are confirmed by documented empirical testing data conducted under the supervision of a qualified person or by engineering

calculations prepared by a qualified person, the flying system designer is permitted to reduce the design factor to 5 X characteristic load and 2 X peak load.

8.5.4.2 In-view flexible lifting medium: In situations where it is desirable to minimize the visibility of the flexible lifting medium from the audience perspective, and the lifting medium does not travel over sheaves, drums, or other objects, lesser design factors may be used as determined by RA/RR, but not less than 5 X working load, 3 X characteristic load, and 1.5 X peak load. (see annex note)

8.5.4.3 Rigid lifting medium

8.5.4.3.1 Rigid lifting medium shall be designed with a minimum design factor of 8 X working load, 5 X characteristic load, and 2 X peak load.

8.5.4.3.2 Where design code equations include analysis of material yield stress and ultimate stress, analysis at Working Load is not required. Static Load Bearing Components shall be designed with a minimum Design Factor Against Yield of 3 X Characteristic Load and 1.5 X Peak Load and a minimum Design Factor per 8.5.4.3.1 for Characteristic Load and Peak Load.

8.5.4.4 Multiple lifting medium: In the event of a failure of one lifting medium element in a system where multiple lifting mediums are used to fly a flying performer, ride-on prop, or acrobatic prop, the remaining lifting medium shall be capable of safely supporting the load, including any peak load resulting from the failure. For non-3D flying systems, reduced design factors may be used if determined by the flying system designer based on RA/RR.

8.5.4.5 Durability: The design and selection of the lifting medium shall consider the following factors when making material selections: (see annex note.)

8.5.4.5.1 Cycles: Use the number of bend and loading cycles to determine the expected service life of lifting medium elements. Service life is determined by multiplying the number of bending/loading cycles on the lifting medium during each operation by the anticipated total number of operations, which include testing, rehearsal, maintenance, and performance.

8.5.4.5.2 Diameter and quantity of sheaves and rollers: In the case of flexible lifting medium, the quantity and relative position of the sheaves and rollers in the performer flying system shall be used to determine the number of bending fatigue cycles on the lifting medium during each operation. The number of bending fatigue cycles, the number of changes in bend direction, and the D:d ratios shall be considered when determining the effective service life.

8.5.4.5.3 Stress range: The stress range (differential loads) experienced by the lifting medium shall be determined to establish the expected service life.

8.5.4.5.4 Environment: The physical environment in which the performer flying system will be installed and utilized shall be considered for exposure to weather, corrosive materials, ultraviolet radiation, humidity, salt air, and other elements that may influence the service life or integrity of the lifting medium.

8.5.4.5.5 Wear or abrasion points: Idlers, glide plates, or other points of wear or abrasion to the lifting medium, as well as fleet angle, sheave alignment, groove profile, and D:d ratio shall be considered when determining its effective service life.

8.5.4.6 Inspection and replacement: The performer flying system design shall accommodate frequent and complete inspection of the full length of the lifting medium and its termination points. The performer flying system design shall accommodate full replacement of the lifting medium at regular intervals as determined by the flying system designer and detailed in the maintenance and inspection procedures.

8.6 Static load bearing components:

8.6.1 Strength

8.6.1.1 Static load bearing components shall be designed with a minimum design factor of 6.5 X working load, 4 X characteristic load and 2 X peak load.

8.6.1.2 Where design code equations include analysis of material yield stress and ultimate stress, analysis at Working Load is not required. Static Load Bearing Components shall be designed with a minimum Design Factor Against Yield of 2.5 X Characteristic Load and 1.25 X Peak Load and a minimum Design Factor per 8.6.1.1 for Characteristic Load and Peak Load.

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

8.6.3 Deflection of all static load bearing components shall not be detrimental to equipment operation.

8.7 Other load-bearing hardware

8.7.1 All load-bearing hardware shall be selected to prevent unintended disconnection.

8.7.2 Purchased load-bearing hardware shall either have a marked load rating, grade rating, or have an identifying marking that corresponds to catalog listed ratings, or be supplied with documentation of its

strength, working load limit, or breaking strength, unless the hardware meets the specifications of section 8.1.4.
8.7.3 Other load-bearing hardware shall be designed and selected with a minimum design factor of 10 X working load, 6 X characteristic load and 3 X peak load.

8.8 Blocks and drums

8.8.1 D:d ratio for sheaves and drums shall be determined by the flexible medium manufacturer's recommendation unless otherwise determined by RA/RR.
8.8.2 Fleet Angle shall not exceed 2 degrees for grooved drums and 1.5 degrees for smooth drums.
8.8.3 Sheave blocks and drums shall be designed or selected to prevent the lifting medium from coming out of the groove under all loading conditions.
8.8.4 The grooves in sheaves and drums shall be sized for the lifting medium being used. (see annex note)
8.8.5 The performer flying system design shall accommodate pendulum swings, when applicable, without exceeding Fleet Angle specifications.

8.9 Traveler track end stops

8.9.1 The system design shall include end of motion physical stops past the Ultimate Limit switches (if applicable) for moving mechanical elements.
8.9.2 The end stops shall be designed to take a full speed full load impact without causing catastrophic mechanical or structural failures that would result in an unsafe condition. (see annex note.)
8.9.3 End of travel protection for the flying performer shall be provided based on RA/RR.

9 Manufacturing

The intent of this section is to establish requirements for the manufacturing of components and subassemblies used in performer flying systems. Variations on the manufacturing requirements shall be permitted pursuant to RA/RR, or review and approval by a professional engineer.

9.1 Requirements

9.1.1 The system supplier shall ensure that all components are built, and materials are selected, for the performer flying system in accordance with flying system designer specifications.
9.1.2 Welding shall be performed in accordance with appropriate AWS standards by AWS certified welders.
9.1.3 Purchased components shall be used and assembled in accordance with component manufacturer's written specifications unless a specific deviation is approved in writing by the flying system designer and system supplier.
9.1.4 Assembly of all components of the performer flying system shall be in accordance with flying system designer specifications.
9.1.5 All raw materials and purchased parts shall be inspected for defects or damage and verification of material specification upon receipt.

9.2 Hardware

9.2.1 Fastener torque requirements and torque values shall be determined by the flying system designer.
9.2.2 Critical connections as defined by the flying system designer shall be marked with a tamper-resistant painted "witness mark" to indicate slippage or loosening in service.

9.3 Flexible lifting medium terminations

9.3.1 Terminations shall be made, inspected, and certified per the instructions provided by the manufacturer of the termination system or flying system designer.
9.3.2 Terminations shall be made by a person competent in the termination method.

9.4 Factory Acceptance Testing

9.4.1 The performer flying system shall be inspected to ensure compliance with the flying system designer's specifications.
9.4.2 A test weight shall be used for all Factory Acceptance Testing and before the attachment of any person.
9.4.3 All components in the performer flying system shall be load tested at 1.25 X WLL.
9.4.4 As applicable, operation of the control system including all limit switches, safety devices and interlock devices shall be confirmed. Mechanical over-speed braking devices may be excluded from this requirement when the brake manufacturer supplies written verification of a successful test of representative samples.
9.4.5 Mechanical flying performer Systems and Automated performer flying systems shall comply with the following:

9.4.5.1 Each hoist in the performer flying system shall undergo a static load test at 1.5 X WLL.
9.4.5.2 Each hoist in the performer flying system shall undergo a dynamic load test at 1 X WLL and maximum rated speed of the Hoist.
9.4.5.3 Each hoist in the performer flying system shall be tested for performance through the full range of accelerations, velocities, and decelerations.
9.4.5.4 Each hoist brake shall be tested individually to ensure that the brake will hold at least 1.25 X WLL.
9.4.5.5 Hoist brakes shall be tested in combination to ensure that the maximum applied braking force does not exceed the flying system designer's specification and does not exceed maximum allowable accelerations on the flying performer as specified herein. (see annex note)
9.4.5.6 The emergency stop function shall be tested at 1 X WLL and maximum rated speed of the system. This test shall be conducted in both the ascending and descending directions. Components shall be observed for indications of malfunction.
9.4.5.7 As applicable, the control systems shall be tested to verify positional accuracy.
9.4.5.8 Each hoist shall be tested for the intended loads as specified by the flying system designer.
9.4.6 The final assembly shall be tested for the intended loads as specified by the flying system designer.
9.4.7 Any additional tests required by the flying system designer shall be conducted.

9.5 Identification:
Critical components, as specified by the flying system designer, shall have a serial number or some other unique identifier. If the critical component is not furnished with a serial number from the manufacturer, then the system supplier, Installer, or user is permitted to affix an identifier to the component.

10 Documentation

10.1 General Requirements

10.1.1 The system supplier is responsible for maintaining a library of manufacturer specification sheets for all purchased components used in a performer flying system.
10.1.2 The system supplier shall furnish a system manual or manuals, or they shall exist electronically such as in PDF format.
10.1.3 The system manual shall contain, at minimum, an operation section and a maintenance section.
10.1.4 The system supplier shall maintain a library of general assembly drawings for assemblies or subassemblies in the performing flying system.
10.1.5 The system manual shall state the limits of use and include requirements that operation of the performer flying system shall be restricted to competent persons who are trained in the system operation.

10.2 Operation documentation

The system shall be clearly described in this section and shall include, at minimum:
10.2.1 A description of each safety function.
10.2.2 Descriptions of fault indications, including system responses and corrective procedures, when applicable.
10.2.3 Comprehensive operator instructions.
10.2.4 Capability of system specific components that may be used during rescue operations.

10.3 user's documentation package

The user shall keep a written record of the person or persons responsible for each role herein and shall update this record whenever there is a change in personnel.

10.4 Testing documentation

10.4.1 Factory Acceptance Testing (FAT)
10.4.1.1 FAT testing requirements and performance criteria shall be agreed upon between the system supplier and the user prior to a FAT.
10.4.1.2 Each component tested during FAT shall have its testing criteria recorded and saved with that component's serial number or other identifying data.

10.4.2 Destructive testing: All destructive testing documents shall be kept on file and made available to local AHJ's if requested.

10.5 Certification documents
Purchased components selected shall be supplied with a visible load rating mark from the manufacturer or certification of its load rating or strength by the manufacturer unless components meet the specifications of section 8.1 (Purchased components).

10.6 Reused components:
10.6.1 Prior to being furnished as part of a performer flying system, any used component(s) shall be inspected by a competent person and approved for the intended use by a qualified person.
10.6.2 When used component(s) are used as part of a new performer flying system, the system shall be tested using FAT guidelines as per section 9.4 (Factory Acceptance Testing).

11 Installation
This section is intended to ensure that the equipment used in performer flying is properly installed and commissioned in order to ensure the safety of flying performers and others potentially affected. Variations on the installation requirements shall be permitted pursuant to RA/RR, or review and approval by a professional engineer.

11.1 General guidelines
11.1.1 The user shall be responsible for complying with Authority Having Jurisdiction requirements.
11.1.2 It is not the intent of this standard to supersede local, state, or federal regulations.
11.1.3 The performer flying system shall be installed by or under the direct supervision of a qualified person.
11.1.4 The assembly shall be supported and braced to provide stability and prevent overloading during installation.

11.2 Installation training
The system supplier shall provide training to the system installer.

11.3 Control system commissioning
The system installer / Flight Sequence Programmer shall set control system operational parameters during installation.

11.4 Commissioning inspections
Upon completion of the system installation, the performer flying system shall be inspected as part of commissioning to ensure the integrity of the system. Commissioning inspection procedures shall be determined by the flying system designer and system supplier. (see annex note.)
11.4.1 The installing qualified person shall ensure that the harness is being used within its intended limits of usage.

11.5 Commissioning testing
The performer flying system shall be tested as part of commissioning to confirm proper behavior when the installation is complete.
11.5.1 Commissioning testing procedures shall be determined by the flying system designer and system supplier. In situations in which a performer flying system is touring, modified testing protocols may be performed on subsequent uses after commissioning first use, as determined by a qualified person based on RA/RR.
11.5.2 Testing shall be performed by, or under the supervision, of a qualified person.
11.5.3 Testing shall confirm compliance with system specifications.
11.5.3.1 Load tests shall be conducted with test weights or other mechanical means of applying force in a manner that does not put any personnel at risk.
11.5.3.2 The forces applied shall be at least equivalent to the characteristic load.
11.5.3.3 Tests shall include anticipated operational conditions over the entire flight path and shall test failure scenarios, including loss of electrical power if applicable. Multiple tests may be required to provide adequate data results.
11.5.3.4 For systems that include powered machinery, each of the following tests shall be performed on both new performer flying systems and on re-commissioned and repurposed machinery used in performer flying systems.

11.5.3.4.1 Load securing device proof load test: a minimum of 1.25 X WLL shall be tested with each load-securing device acting alone. For an Established performer flying system, a minimum of the 1 X WLL shall be tested with each load-securing device acting alone.
11.5.3.4.2 Static proof load test: a minimum of 1.5 X WLL shall be tested with both load-securing devices acting together. For an Established performer flying system, a minimum of the 1 X WLL shall be tested with both load securing devices acting together.
11.5.3.4.3 Dynamic proof load test: 1 X WLL with Category 1 stop if applicable, Full Speed in both directions. Distances traveled after initiation of stop shall be recorded and included with SAT documentation, unless determined by RA/RR to not be needed.
11.5.3.4.4 Power loss proof load test: 1 X WLL with Category 0 stop, Full Speed in both directions. Distances traveled after initiation of stop shall be recorded and included with SAT documentation.

11.5.4 Tests of Normal Limits and Ultimate Limits shall be conducted using both WLL and minimum anticipated load at Full Speed in both directions, except as follows:
11.5.4.1 In situations where a lower speed will produce confidence in safe operation of the limits as determined by a qualified person based on RA/RR.
11.5.4.2 In situations where the flying performer is descending to the stage or similar landing surface, limits shall be tested to ensure protection of the equipment. Testing at WLL is not required.

11.6 Site acceptance testing (SAT)

Such testing commences only after commissioning is complete. SAT may include some or all of the load testing described in section 11.5 (Commissioning Testing).

11.7 Documentation

All equipment used in a performer flying system shall have documentation demonstrating proper completion of installation and commissioning. The system supplier and flying safety supervisor or flying supervisor shall maintain and store documentation from the date of system commissioning acceptance to the date of decommissioning (load-out) of the system which shall include:
11.7.1 Name of installation supervisor and in-service date of system.
11.7.2 Commissioning inspection procedures, dates, and results.
11.7.3 Commissioning testing procedures, dates, results, and name of qualified tester(s).

12 Operational use

This section is intended to ensure that the equipment used in performer flying is properly used in order to ensure the safety of flying performers and others potentially affected. Variations on the operational use shall be permitted pursuant to RA/RR.

12.1 User’s documentation package

The system supplier shall supply a user’s documentation package to the user in a timely fashion prior to system commissioning, which shall include the following:
12.1.1 Description of the performer flying system.
12.1.2 Definitive statements about the operating limits of the system.
12.1.3 Indicate where the performer flying system ends and how it interfaces with the support structure, including loads imparted to the support structure.
12.1.4 Maintenance, inspection, and testing requirements for in-service use.

12.2 Operational documentation

A performer flying system shall have documentation describing the use and care of its equipment from the date of system commissioning acceptance to the date of decommissioning (load-out) of the system.
12.2.1 The flying safety supervisor or flying supervisor shall maintain and store documentation and shall provide copies to the user when major changes occur and at regular intervals.
12.2.2 For each activity, the name of the person performing the activity, date and results shall be recorded in the documentation.
12.2.3 Documentation shall include:
12.2.3.1 Maintenance procedures, dates performed, and results.
12.2.3.2 Daily inspection procedures performed by a competent person.
12.2.3.3 Periodic inspection procedures performed by a competent person.
12.2.3.4 Daily testing procedures performed by a qualified person.
12.2.3.5 Periodic testing procedures performed by a qualified person.
12.2.3.6 Record of usage cycles appropriate for the intended application.

12.2.3.7 Responsibilities of each person involved in the performer flying, including dates of such service.
12.2.3.8 Records of personnel training, including types of training, dates, and instructor name(s).
12.2.3.9 Removal from service date(s), reasons for removal, and by whom.

12.3 Rental documentation

12.3.1 When equipment is rented, the equipment owner shall keep documentation for the entire duration of the rental.
12.3.2 Documentation shall include:
12.3.2.1 Identification of the user and/or person or entity who rented the equipment.
12.3.2.2 Dates of the rental.
12.3.2.3 Inspections and tests performed prior to rental.
12.3.2.4 Any incidents reported during the rental period.
12.3.2.5 Notifications from user of damage or incidents involving equipment.
12.3.3 Operational documentation as per section 12.2 (Operational Documentation) for a particular user shall be furnished to the Owner if requested.

12.4 Maintenance

Routine maintenance service shall be performed to ensure that all equipment is in proper working order.
12.4.1 Such maintenance procedures and intervals shall be determined by the system supplier based on RA/RR.
12.4.2 The flying safety supervisor shall assign maintenance assignments to the technicians, and the flying supervisor or flying supervisor shall supervise the work.

12.5 In-service inspections

Periodic and daily inspections shall be performed to ensure the continued integrity of the system.
12.5.1 Such inspections shall be determined by the flying system designer, system supplier, flying safety supervisor, and user based on RA/RR.
12.5.2 The performer flying system shall be visually inspected daily, preferably before each use, regardless of whether it is being used for rehearsals or performances. The flying safety supervisor shall designate an inspector, and the flying safety supervisor or flying supervisor shall supervise such inspections. Any observation of note and any adjustments made shall be documented and submitted to the flying safety supervisor.
12.5.3 The flying equipment shall not be operated if concerns arise as a result of inspections regarding the safe use of the system. The performer flying system may be used only after the concerns are resolved and a test has been conducted yielding positive results.
12.5.4 The rescue equipment shall be visually inspected periodically, in accordance with ANSI Z359.1 and Z359.4 respectively, regardless of whether it is being used for rehearsals or performances. The flying safety supervisor shall designate an inspector, and the flying safety supervisor, flying supervisor, or Emergency Response Leader shall supervise such inspections.

12.6 In-service testing

Periodic testing shall be performed to validate the continued safety of the system. (see annex note)
12.6.1 Such testing procedures shall be determined by the flying system designer, system supplier and user based on a RA/RR.
12.6.2 The performer flying system is to be load tested at predetermined intervals, using the anticipated amount of load to be flown, regardless of whether it is being used for rehearsals or performances. Testing intervals shall be determined by the flying system designer, system supplier and user based on RA/RR. The flying safety supervisor shall designate or hire a tester, and the flying safety supervisor or flying supervisor shall supervise such testing.
12.6.3 The flying equipment shall not be used if deficiencies or concerns regarding the safe use of the system arise as a result of the testing. The performer flying system may be used only after the concerns or deficiencies are corrected and a test has been conducted resulting in positive results.

12.7 Training

12.7.1 All people directly or indirectly involved in the performer flying effects shall be appropriately informed and trained regarding the dangers, hazards, safety measures, operational requirements and procedures, communication protocols, rescue procedures, and responsibilities of the various participants involved in the use of the performer flying system. Training shall include safe access to and egress from all locations where a

flying performer connects to the performer flying system. Personnel directly involved in the use of the performer flying system shall be adequately trained to be competent in its proper and safe use.
12.7.2 All training shall be repeated at regular intervals to be determined by the flying safety supervisor.
12.7.3 The flying safety supervisor shall inform flying performers of the risks associated with flight, including risks associated with Flying System and those associated with potential actions of the flying performer, such as deviating from intended choreography.

12.8 Operation

12.8.1 General

12.8.1.1 Flying performers shall confirm that they have the physical capability to safely perform the intended aerial routine and withstand performer peak loads imposed on the body by the harness and/or performer's apparatus.
12.8.1.2 No member of the flying team shall participate in a flying effect if their ability to do their assigned job is impaired by alcohol, drugs, fatigue, physical or mental disability, or other causes.
12.8.1.3 Once the flying choreography is established, it shall only be changed by the Creative Designer in consultation with the flying safety supervisor. Choreography shall not be changed by the stage director, the choreographer, the performers, or any other individual who is not qualified or authorized to make these changes. Any substantial change in choreography, show order, or other element of the performance that may affect the safe operation of the performer flying system shall be subject to RA/RR.
12.8.1.4 Only a qualified person shall be allowed to modify control system operational parameters without the direct supervision of the system installer and the approval of the flying system designer.

12.8.2 flying operator

12.8.2.1 Flying operators shall have an unobstructed view of the flying performer's flight path while flying a performer. When a flying operator's direct line of sight is obstructed or compromised, the use of cameras and monitors, trained spotters, or infrared devices is acceptable as shall be determined through RA/RR.
12.8.2.2 The user shall provide the flying operators a clear, stable, non-distracting area in which to operate.
12.8.2.3 All personnel necessary for the safe operation of a flying sequence, as specified by the flying safety supervisor, shall be present for all rehearsals and performances when the system is to be used.

12.8.3 flying supervisor: The flying supervisor shall be in attendance at all times when a person flies on the performer flying system and shall confirm prior to each use that each flying performer is in a healthy mental and physical condition to perform flying.

12.8.4 Harnesses

12.8.4.1 Each Performer flying harness shall have a label designating the flying performer to which the harness is assigned.
12.8.4.2 Performer flying harnesses shall only be used as specified on the harness label or harness manual.
12.8.4.3 The initial harness fitting on the flying performer shall be done by a qualified person, whose qualifications shall include knowledge of risks associated with harnessed personnel flying. Harnesses shall be adjusted to each flying performer and should not cause undue discomfort when used in normal operation.
12.8.4.4 A competent person shall inspect each harness prior to each use.
12.8.4.5 A competent person shall check the fit and security of the harness prior to each use.

12.8.5 Communication

12.8.5.1 A predetermined chain of communication shall be established amongst all members of the flying team.
12.8.5.2 The flying performer shall be trained in communicating nonverbally with the Spotter or other designated flying team member.
12.8.5.3 Communication methods shall be secure and reliable.

12.8.6 Stops

12.8.6.1 If the Spotter, Observer, flying operator or flying performer identifies a problem that could affect the safety of the flying performer, they shall initiate a stop either directly or by informing the flying operator who will initiate a stop. An unplanned stop can also occur due to a fault in the performer flying system.
12.8.6.2 If a stop occurs, the flying operator shall inform the flying supervisor who will determine what action is to be taken. The flying supervisor shall inform the Stage Manager of the action to be taken and shall inform the Emergency Response Leader if a rescue is required.

12.9 Rescue

12.9.1 Rescue plan. Unless determined by RA/RR to be unnecessary, the flying safety supervisor shall prepare a written rescue plan prior to performer flying operations. The rescue plan shall include operational documentation and be disseminated to all personnel involved with flying operations, including relevant venue personnel. The scope of the rescue plan shall include both the safe and prompt retrieval of the flying performer and integration of rescue operations with any broader emergency response plans in effect.

12.9.2 Rescue team. The rescue plan shall designate specific competent personnel who shall be present whenever performer flying is taking place. Unless otherwise determined by RA/RR, personnel shall include, at a minimum, the roles outlined in section 3.16 (Emergency Response).

12.9.3 Rescue preparation

12.9.3.1 All involved personnel shall be trained in rescue operations.

12.9.3.2 All involved personnel shall be assigned specific duties for rescue scenarios.

12.9.3.3 rescue operations for all scenarios identified through RA/RR as necessary to rehearse shall be initially and periodically rehearsed by personnel involved. The need for, and risks associated with, rehearsal shall be considered and determined by RA/RR.

12.9.4 Rescue operations

12.9.4.1 The emergency response leader shall take overall command of the area and the rescue operation when a rescue is initiated.

12.9.4.2 Rescue operations shall follow the established rescue plan.

12.9.4.3 The emergency response leader shall exercise due diligence in adapting the rescue plan in the best interest of safety in the event of an unplanned-for incident.

12.9.5 Post rescue treatment of flying performers: Immediately after a flying performer is rescued and brought to a safe location, the emergency response leader shall assess the need for medical assistance for the flying performer and any person affected by rescue operations and shall contact/arrange for medical assistance when needed. (see annex note)

12.10 Inspection and testing after an incident

12.10.1 When any equipment in the system has sustained forces that exceed normal operational conditions or has been exposed to potentially harmful environmental situations (weather events, prolonged periods of inactivity, adverse storage conditions, or exposure to potentially harmful substances), such equipment shall be removed from service and fully evaluated by a qualified person.

12.10.2 The qualified person shall inspect for any damage or excessive wear, and shall recommend testing, if necessary.

12.10.3 The evaluation shall be documented noting the condition, inspections conducted, tests conducted, and resulting course of action taken.

12.11 Post-use

Upon completion of the system disassembly, all reusable components shall be thoroughly inspected, serviced (cleaned or otherwise maintained as per maintenance manual), documented, and stored in accordance with the system supplier's recommendations. Non-reusable components shall be discarded and or destroyed as per the system supplier's recommendations.

13 Storage

The intent of this section is to ensure that any equipment that is to be reused in performer flying systems is stored in a manner that retains the integrity of the system and its components.

13.1 Environmental conditions

Items shall be stored in an environment as per the system supplier's recommendations. All items shall be kept free from harmful exposure to high humidity and damp conditions, corrosive contaminants, ultraviolet radiation, abrasive wear, high temperatures for fiber materials, and high or low temperature extremes for plastic parts.

13.2 Documentation

Items that are to be reused and placed in storage or transported between applications shall be inspected for defects and documented by a competent person before being reused.

14 Repair and removal from service

The intent of this section is to ensure that any equipment unfit for service by damage, defect, or end of service life is repaired or disposed of in an appropriate manner.

14.1 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.

14.2 End of service life
Any equipment that has exceeded its lifespan as defined by the component manufacturer, flying system designer, or professional engineer shall be permanently removed from service.

14.3 Disposal
Any equipment that is to be permanently removed from service shall be appropriately disposed of in a manner that ensures it cannot be returned to service. This may require physical destruction of the item before being discarded.

14.4 Repair
14.4.1 Repair assessment: A qualified person shall determine whether the equipment removed from service is capable of being repaired.

14.4.2 Return to service: Returning an assessed component back into service shall be permitted if the assessment results show that the component does not lessen the strength and durability of the performer flying system.

14.4.3 Repairing a component: Repairing a component shall be permitted if the repaired component does not lessen the strength and durability of the performer flying system.

14.4.4 Repair procedures: Repairs shall be conducted according to the system supplier’s specifications or using details developed by a qualified person.

14.5 Documentation
14.5.1 When a piece of equipment has been removed from service, a report shall be created that documents the date of inspection, inspection results, date of removal, reasons for removal, date of disposal or repair, and method of disposal or repair.

14.5.2 If a qualified person determines that a piece of equipment is permitted to be returned to service, documentation of this assessment shall be created.

14.5.3 Records shall be kept by the flying safety supervisor or flying supervisor for the run of the show or by the equipment owner, as applicable.

14.5.4 When rental equipment is returned to its owner, the flying safety supervisor or flying supervisor shall provide copies of these records to the equipment owner.

Annex A, Commentary

This commentary is not part of the Standard and contains no mandatory requirements. It offers some explanatory information about the clauses in the standard. The relevant clauses have the same clause number, but without the "A" prefix. The clause numbering here is not continuous because no comments are offered on some of the clauses in the Standard.

Since no mandatory requirements are stated in this commentary, if there is any disagreement between the text of this annex and the requirements stated in the body of the standard, the requirements in the body of the standard shall prevail.

A.1 Scope

The term "performer flying system," as it is used in this Standard, is intended to be broadly inclusive, encompassing all forms and styles of performance activity where a human performer is "up in the air." This specifically includes effects that seek to simulate flight or weightlessness such as might be seen in theatrical performances such as Peter Pan, high-speed harnessed or prop-based flight as part of large-scale spectacles such as rock music shows, and what is increasingly called "aerial performance" such as acrobatic and circus performance, aerial dance, and related disciplines at all scales. These disciplines use a wide and varying range of approaches, equipment, terminologies, operational protocols, and risk management standards and cultures. Some have not traditionally thought of their disciplines as "Performer Flying." This revision of the original E1.43 standard recognizes that, regardless of the style of performance and associated historic practices, the underlying physics, much of the equipment used, and the relevant safety issues are all shared. The intent of this Standard is not to impose a single way of doing things, but rather to provide guidance that is relevant and useful to all.

A.2.3 Authority Having Jurisdiction (AHJ)

An AHJ is typically the governmental agency or sub-agency which regulates the work, such as a building department, fire marshal, department of labor, health department, OSHA, and the like. In most cases, the AHJ is defined by the municipality in which the performer flying installation is located.

A.2.4 Axis

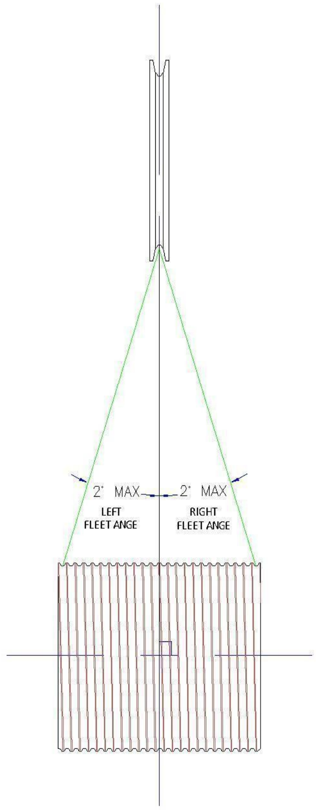
In automated systems axes are typically assigned effect numbers and names. Sometimes axes are called "effect" or "effect number" when referencing an Axis of motion.

A.2.6 Breaking strength

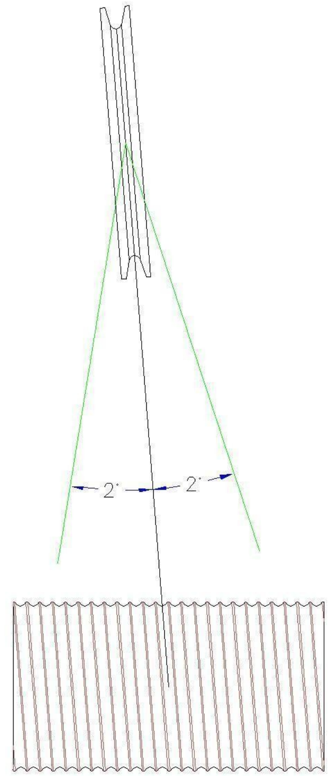
Breaking strength is the load at which the component fails. For example, for a steel member that will fail by fracturing rather than by becoming unstable, the breaking strength is directly related to the ultimate tensile stress, not the yield stress. The ultimate tensile stress is higher than the yield stress.

A.2.14 Fleet Angle

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 on the left 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 centerline of a groove as shown in the figure on the right below. In traditional drum applications and in situations with great distances between drum and sheave the difference is negligible. In some instances, typically with smaller diameter drums, calculation of the maximum fleet angle may be modified to take the helix angle into account. The actual fleet angle may be calculated by adding or subtracting the helix angle from the initially calculated fleet angle. For additional information see ISO 16625-2013 Cranes and Lifting Appliances and/or the US Navy Wire Rope Handbook Vol 1.



NOT TO SCALE



NOT TO SCALE

A.2.15 Full speed
For manual flying systems, full speed includes speeds achieved by mechanical advantage and increases in maximum acceleration and velocity achieved via change in operator position (such as jumping off of a ladder). For automated systems, full speed is typically the maximum speed of the hoist or winch as determined by the flying system designer.

A.2.18 Lifting medium
When lifting medium is a wire rope, sometimes also known colloquially as "aircraft cable," it is sometimes called a fly wire.

A.2.21.2 Characteristic load
Determination of the characteristic load begins with the working load (total static self-weight or "dead load" of who and what is flying, e.g., the flying performer, harness, ride-on prop or acrobatic prop, performer spreader bar if used, and lifting medium). The forces from this self-weight are then magnified by the anticipated dynamics of motion in normal planned use, often expressed in terms of G's (acceleration) in whatever directions are involved in the flying routine, in order to determine the characteristic load. This magnifying factor includes all forces resulting from system acceleration and deceleration, and acrobatic or other self-generated movements by the performer. characteristic loads are most accurately determined through the use of load-measuring devices such as digital load cells or digital dynamometers.

There is a growing body of research providing useful data on typically generated dynamic forces, especially in acrobatic and circus performance. Various methodologies and terminologies are used to express this, including "dynamic factors" and "body-weight multipliers." A recent peer-reviewed study addressing this may be found at: https://journals.publishing.umich.edu/circus/article/id/2776/?fbclid=IwAR1i3Ytf-JfLMCkkKeNimA6LcPuDTcHOcd0l7OgKOdhdkWIJRHyN42uADfU.

Relevant results are summarized in the chart set forth below.

Dynamic Forces
Circus Moves

Discipline	Max force (kN)	Max force (body weight)	Pre tension (kN)	Movement
Aerial straps [1]	5.3	7.9	-	Disloc layouts
Dance trapeze [1]	3.0	4.8	-	Tempo
Corde Lisse [2]	4.1	7.3	-	Slack drop
Aerial hoop [2]	3.1	4.8	-	Drop hip circle to front balance
Aerial silk [2]	3.0	5.6	-	Slack drop
Flying pole [2]	1.7	4.0	-	Bicep to back salto
Tight wire [2]	15.0	6.9	9.1	Salto
Chinese pole [*2] • Under the pole • Cable 1 • Cable 2 • Cable 4	-6.3 1.9 1.9 2.8	- - - -	-2.8 1.2 1.1 1.9	Front Salto
Swinging trapeze [**4]	3.7	5.6	-	Swing to ankles, ankles to seat
Solo fixed trapeze [**4]	3.7	6.8	-	Cross-back slack drop
Duo fixed trapeze [**4]	3.2	2.5	-	Big tempo back salto

The forces were measured using load cells located at the attachment points, in the wires, the cable or the ropes. The placement of the cells is described in scientific papers 1 and 2.

* The placement of the wires was asymmetrical. For the exact positions, please refer to the diagrams in article 1.
** The force for trapezes is the sum total of the forces on both ropes. For the duo trapeze, the force in body weight is calculated by taking the total mass of the two acrobats.

1. Cossin, M., Ross, A., & Gosselin, F. P. (2017). Making single-point aerial circus disciplines safer. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 231(4), 362-373.
2. Cossin, M., Bergeron-Parenteau, A., & Ross, A. (2022). Maximal dynamic forces exerted by acrobats on nine circus apparatuses. Circus: Arts, Life, and Sciences.

A.2.26 Performer flying system

The definition of a performer flying system does not differentiate between harnessed flight and harnessless flight where the connection for the flying performer ultimately relies on the strength or ability of the flying performer. Notwithstanding, this standard does not cover connections in the performer flying system that ultimately rely on the strength or ability of the flying performer.

A.3 Roles and Responsibilities

Performer flying is safest when the various roles and associated responsibilities are clearly understood by all persons involved. A primary intent of the standard is to clearly identify roles and responsibilities in order to ensure that all functions critical to safety are considered and covered. The specific job titles and assignment of responsibilities will vary from production to production.

The authors of this standard believe that there must be a party who is ultimately responsible for a specific flying rig. This responsible party must ensure that there is a qualified person serving as the flying system designer and other defined roles; for a small rig, this role and other roles could also be taken on by one person who might also be the end user.

The person performing the role of flying system designer will decide what rigging equipment to use, and this person might also play the role of system installer by taking the parts “out of the box” and assembling them according to the instruction manual. This person might also perform the roles of flying supervisor, flying safety supervisor, and user on a modest or small-scale production.

A person who makes a decision to select and assemble performer flying rigging, acrobatic apparatus or other associated gear is functioning as the flying system designer by making informed choices about the equipment to purchase and assemble. The person certainly needs to be qualified to make such choices, and in many cases in the aerial arts rigging industries, such qualification is often based on practical experience.

A.5.2 Personnel

RA/RR is often best performed by involved persons engaging in a discussion of the issues. While a qualified person should be fully capable of performing RA/RR alone, a discussion by two or more competent persons can produce satisfactory results. For example, a competent person on site can consult via telephone, email or video conference with a supervisor (competent or qualified) to address RA/RR.

A.6.1.5 Single point failure

Elements with single point failure conditions are common in performer flying, such as winch lines, carabiners, and swivels. Suitable design factors are used to mitigate these single point failure risks.

A.6.2.1 Established performer flying system

The established performer flying system concept was inspired by the service proven classification of amusement rides in ASTM F2291, to better accommodate performer flying systems that are reused repeatedly with success. An amusement ride is classified as service proven after it has demonstrated successful and safe use over a defined period of time. In contrast, a performer flying system achieves established performer flying system classification after it demonstrates compliance with the provisions of E1.43, is associated with specific flying director(s), and has demonstrated successful and safe use over a defined period of time and number of uses. A notable benefit of established performer flying system classification is that it allows a defined performer flying system to be rented or deployed repeatedly without needing the extensive documentation required by this standard for a new or bespoke performer flying system. It is important to repeat that the flying director, a qualified person, is considered part of the established performer flying system.

A.6.3.2 Performer peak load

Performer peak load refers to the pressure that the flying performer will experience through the body at the time of peak load in the performer flying system. Performer peak load may be higher than peak load on a performer flying system or component of a performer flying system, particularly in instances of multiple axis, 3D, or Flying V effects. G-Forces are influenced by:

- Load of flying performer, ride-on prop, and lifting medium
- Speed
- Negative and positive acceleration
- Brake onset time
- Power transmission system inertias
- Stiffness of equipment support frame and static load bearing components
- Stiffness of support structure

Maximum allowable G-Forces are determined by evaluating all of the following conditions:

- Physical fitness of the person experiencing the force
- Position of the body
- Duration of exposure to the forces

This section states that the flying system designer and the flying harness designer shall consider how performer peak forces are being distributed through the flying performer's body. These considerations should be made not only for characteristic loads but for peak loads generated during emergency stops, reasonably foreseeable misuse, and equipment or power failure situations. Flying effects and the harnesses created for flying effects differ from fall arrest harnesses. To state the obvious, the intent of flying effects is to support a flying performer in a manner that is consistently countering the effects of gravity. In fall arrest scenarios the period of "free fall" leading to sudden stopping can generate very large forces.

For effects requiring high speeds and for instances where flying performers are tethered to a performer flying system but not yet supported by the performer flying system, the flying harness could potentially see forces that are similar to fall arrest harnesses. For example, if an emergency stop occurs when traveling up on a flexible lifting medium, the flying performer will continue up, stop, and then free-fall, engaging the lifting medium at the same speed at which the emergency stop occurred, resulting in a shock-type load. The flying system designer and harness designer should consider all potential modes of use, emergency stops, reasonably foreseeable misuse, and equipment or power failure situations, and consider the forces due to rapid acceleration or deceleration.

Flying harness designers should determine not only the overall effects of G-forces, but the effects of localized impact force and pressure on the flying performer's body at the point of contact of the harness. These forces should be evaluated for both the positive and negative acceleration forces.

In writing this document, various research papers on the effects of G-Forces and their impact on the human body were reviewed. These documents include but are not limited to ASTM F2291 "Standard Practice for Design of Amusement Rides and Devices," NASA Memorandum "Human Tolerance to Rapidly Applied Accelerations" by A. Martin Eiband, June 1959; the Wayne State Tolerance Curve studies; research done by Colonel JP Stapp in the 1950's; and a comprehensive report prepared by Harry Crawford for the Health and Safety Executive of East Kilbride, Glasgow, UK in 2003. Research into the effects of G-force and body impact forces spans disciplines as varied as amusement rides, space flight, performance racing, military maneuvers, firefighting, fall arrest, boxing, and other sports. To sum up a vast and varied set of data, the human body can tolerate very large amounts of G-Forces for very short periods of time assuming the person being subjected to the force is physically fit & properly trained. (See Figure A3 below.)

When evaluating G-forces, performer flying system designers and flying harness designers should also consider the position of the body in relation to the direction of force with an evaluation of potential negative as well as positive G's. (See Figure A4 below.) Typically, negative G's occur when moving downward, where the blood is forced toward the brain. However, an upside-down oriented flying performer flying in the up direction could experience similar effects. High G's can be maintained in the horizontal direction but again, body position and whether you're forcing blood towards or away from the brain is of most concern.

flying system designers via a rigorous RA/RR process may establish allowable loads that vary from the values presented in this document. For instance, it is quite possible that a professional stunt person could withstand larger forces than a performer of flying effects in a small amateur production. Rigorous attention to maximum forces should be paid and measures should be taken to minimize Performer peak load.

Figure A3. Survivable abrupt positive G (+G_z) impact, from Eiband

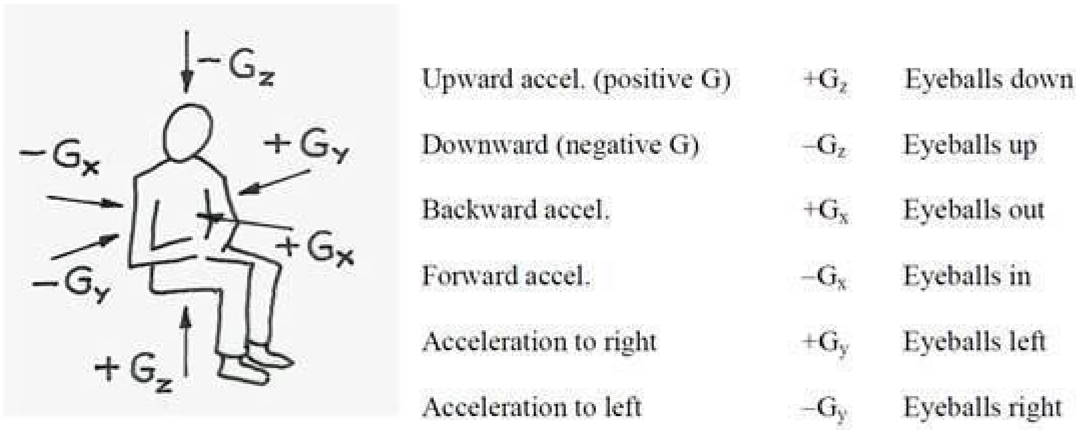
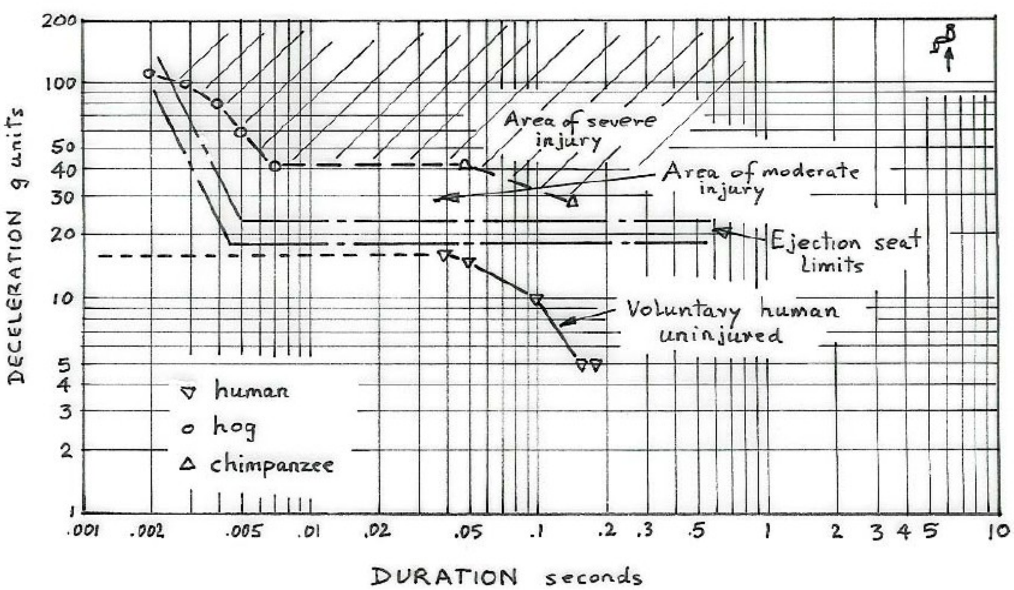


Figure A4. Direction of G-force relative to body position



A.6.3.5 Surface area pressure

This section states that in addition to the effects of G-forces, the flying system designer and flying harness designer shall consider the effects of pressure exerted on the human body due to point of contact with the harness. The intent being to limit, as much as is practicable, the performer's exposure to bruising, abrasion or general discomfort.

Current force values for body harnesses in other industries have been derived from studies of G-forces and the effects of rapid accelerations (both positive and negative) on the human body. Most of these studies were conducted over half a century ago and there is surprisingly little modern data available. Most modern studies, white papers and standards reference the Stapp studies conducted in the 1950's.

In an effort to determine a threshold of tolerance for the human body due to pressure exerted by forces transmitted through the harness, the Rigging Working Group referenced a variety of scientific studies and white papers listed below. Most notably this excerpt from a 1967 seat belt study that states:

> "Note that belt forces of 1518-3588 pounds (31.0-74.7 psi belt pressure at .001-.003 seconds duration at 15-23 G on abdomen were found in the Lewis and Stapp tests of volunteers. Only three of these subjects were reported (out of 19) to have received belt bruises in the impingement area, but two others were sore at the lower margin of the rib cage, one for four days, one for two weeks. However, these forces would probably be close to the subjective tolerance limits, since these subjects were all healthy young males. It is important to note that a difference was found in subjective tolerance not only between individuals, but within the same

individual on different runs. In similar tests a subjective limit of 9 G was found to be the highest voluntary level in the lateral position (97)."

In an attempt to put a maximum value on the pressure exerted by a harness, we looked at both allowable forces in fall arrest harnesses divided across an estimated surface area and compared it with the threshold values stated above. The result being a maximum suggested value of 75 PSI as derived from the force per area calculations and not exceeding the high end of the tolerance scale from the above referenced seatbelt study. This value is offered here as a high limit reference only. The language of this document does not disallow the manufacturer of flying harnesses from establishing higher or lower thresholds provided proper evaluations and testing is completed that supports the design intent.

Suggested Reading:

"Seat Belt Injuries in Impact" by R. G. Snyder, Ph.D., and J. W. Young, A. M. of *Ford Motor Company,* C. C. Snow, Ph.D. of *Federal Aviation Agency, and* P. Hanson, M. S. of *6571st Aeromedical Research Laboratory, USA F. Reprinted from* THE PREVENTION OF HIGHWAY INJURY *from The Proceedings of a Symposium held in honor of The University of Michigan's Sesquicentennial Celebration and sponsored by the University's' Medical School and Highway Safety Research Institute.* April 19-21, 1967. *Published by* HIGHWAY SAFETY RESEARCH INSTITUTE, The University of Michigan, 1*967.*

"Survivable Impact Forces on Human Body Constrained by Full Body Harness" HSL/2003/09, Prepared by Harry Crawford for the Health and Safety Executive (http://www.hse.gov.uk/)

"Human Tolerance and Crash Survivability" by Dennis F. Shanahan, M.D., M.P.H., Injury Analysis, LLC, 2839 Via Conquistador, Carlsbad, CA. *Paper presented at the NATO Research and Technology Organization Human Factors and Medicine Panel (RTO HFM) Lecture Series on "Pathological Aspects and Associated Biodynamics in Aircraft Accident Investigation," held in Madrid, Spain, 28-29 October 2004; Königsbrück, Germany, 2-3 November 2004, and published in RTO-EN-HFM-113.*

A.6.3.6 Peak load design factors

peak loads may include the following: emergency stops, uncontrolled stops, control system faults, equipment failure, free-fall shock loads, unplanned rapid acceleration, and other unplanned shock loading conditions that are not part of normal operations.

A.6.6.2.7 Maximum speed and acceleration settings

The control system critical settings may include:

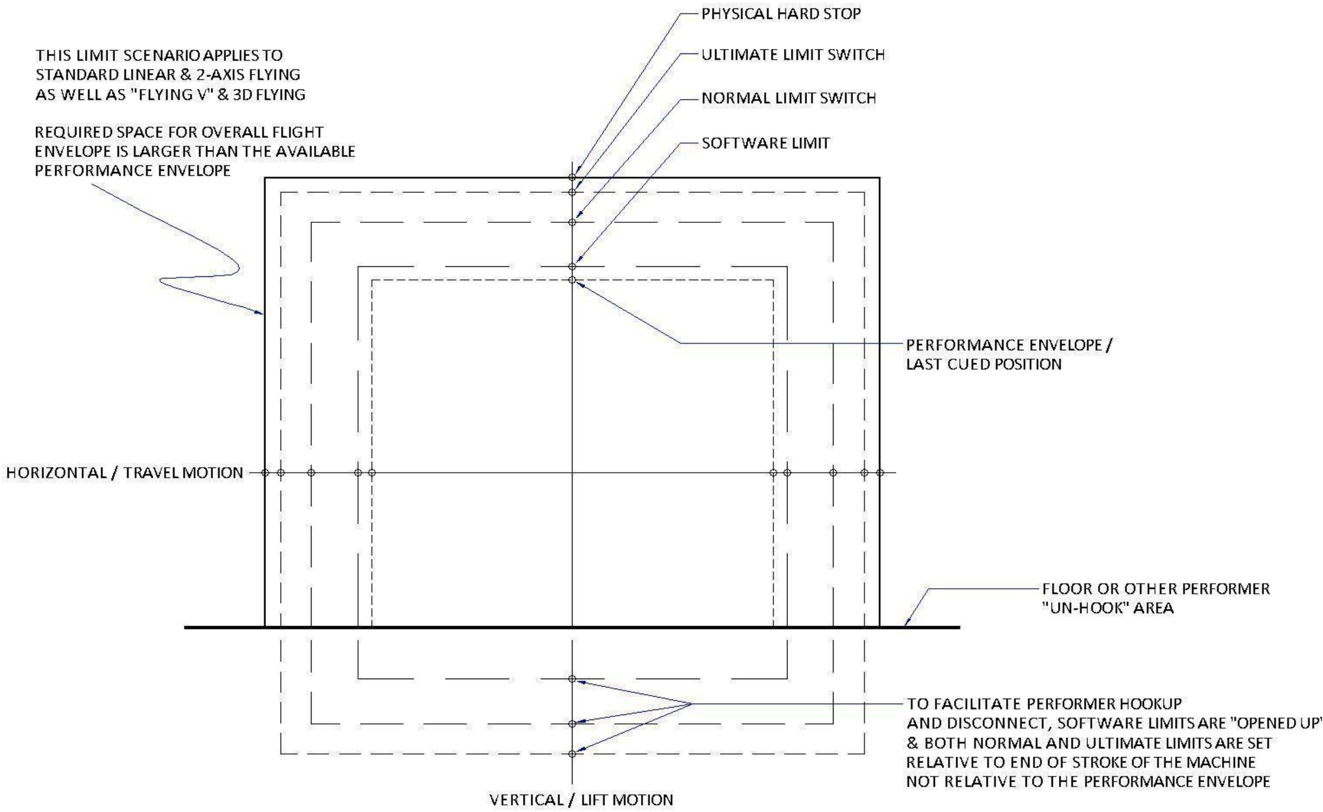
- Soft Limits
- Maximum Speeds
- Acceleration/Deceleration Limits
- Torque/Current Limits

A.6.6.3.3 Closed loop feedback

Dual position monitoring should be incorporated into each mechanized means of actuation. Use RA/RR to assess the safety of the flying performer. If dual position monitoring is used, the system should compare these position monitoring devices during operation and should stop motion if an unacceptable variance is detected. The category of stop should be determined by the RA/RR.

For simple, single Axis performer flying systems, the flying operator can close the loop with visual line of sight to the flying performer as determined by the flying system designer.

A.6.7.1 Limits



Schematic: Relative limit locations

To facilitate flying performer hookup and disconnect, software limits are extended beyond the floor level; Normal Limits and Ultimate Limits may be set relative to the end of stroke of the machine and not relative to the performance envelope.

A.6.8.3 Rescue plan design considerations
During performance, if an incident occurs requiring the flying performer to be removed immediately from flight, the first choice is to continue using primary fly rigging to transport the flying performer to the original intended stop position or to an alternative offstage exit position, if feasible for the flying performer. While rescuing the flying performer is the primary concern, if a stop must be performed mid-flight in view of the audience, it is advisable to obscure the flying performer as much as possible and/or to have attention drawn elsewhere, or by evacuating the audience. Such procedures should be planned and practiced in advance. rescue rigging and associated hardware should only be used when it is the only method available to perform a safe rescue. The condition of the flying performer is vital in determining the best course of action for quickly removing the flying performer from flight and providing care.

Typically, the Hierarchy of Fall Protection should be considered when creating the rescue Plan. Specifically:

1) Eliminate Hazard - Eliminate the risks by working from an existing area.
2) Passive Fall Protection - Collective measures involving the use of barriers such as guard rails to prevent personnel from reaching fall hazards.
3) Fall Restraint - Personnel wear harnesses with lanyards of limited length.
4) Fall Arrest - Personnel wear harnesses with lanyards designed to arrest their fall.
5) Administrative Controls - Minimize consequences through training instructions and signage.

A.6.8.5.1 Rescue equipment components
There are a number of nationally recognized standards for the potential equipment used for rescue Systems. Rope access rescue equipment and techniques are becoming more common. The following is suggested reading for rope access rescue:

"Safe Practices for Rope Access Work," published by Society of Professional Rope Access Technicians (SPRAT), USA, 2012. (http://www.sprat.org/resources/Safe_Practices%20-%20August%202012.pdf)

"Certification Requirements For Rope Access Work, Version 13," published by Society of Professional Rope Access Technicians (SPRAT), USA, 2013. (http://www.sprat.org/resources/SPRAT_Certification_Requirements_WebVersion.pdf)

"Technical rescuer: Rope Levels I and II" by Jeff Mathews, Published by Delmar - Cengage Learning, USA, 2009.

"CMC rescue Rope Manual, Revised 4th Edition," Edited by James A. Frank, published by CMC rescue, Inc.

"Rope rescue for Firefighting" by Ken Brennan, Published by PennWell Publishing, USA, 1998.

"The Essential Technical rescue Field Operations Guide, Edition 4," by Tom Pendley, Published by Desert rescue Research, USA, 2010."

A.7.1.1 Strength
When physical testing is used to determine the strength of a component or assembly, this section states that such testing shall be performed in accordance with a recognized national standard. Examples include, but are not limited to the following:

- International Building Code, latest edition, section 1709
- The Aluminum Association "Specifications & Guidelines for Aluminum Structures" – section 9 Testing
- ASTM E73 "Standard Practice for Static Load Testing of Truss Assemblies"

A.7.1.2 Design factors
References to design factor throughout this document refer both to specific code-based guidance and colloquial use of the term as a synonym for the commonly used term "safety factor." Fundamentally, the design factor is expressed as the ratio between a particular measure of applied force (such as working load, characteristic load, or peak load) and a defined point of failure of the component, system, or structure. The design factors for performer flying systems set forth in this Standard are typically greater than their counterparts in other entertainment industry standards such as ANSI E1.6-1-2021. In situations where there is substantial confidence in determining the characteristic load, this standard permits the use of reduced design factors based on RA/RR. This reduction may be beneficial in keeping components from being excessively large in situations where the dynamics are relatively low. Other relevant design codes include AISC 360-16 "Specifications for Structural Steel Buildings" and ADM1-20 "Aluminum Design Manual - Specifications for Aluminum Structures." The LRFD live load factor is typically 1.6.

design factors are included in the following sections:

Section	working load	characteristic load	peak load
8.3.1.4 Performer flying harnesses	10	6	3
8.4.5 Quick Connect Hardware	10	6	3
8.5.4.1.1 Flexible lifting medium	10	6	3
8.5.4.1.2 Flexible lifting medium where characteristic and peak loads are confirmed by testing or calculations		5	2
8.5.4.2 In-View Flexible lifting medium	5	3	1.5
8.5.4.3.1 Rigid lifting medium	8	5	2
8.6.1.1 Static Load Bearing Components	6.5	4	2

8.7.3 Other Load Bearing Hardware	10	6	3
8.5.4.3.2 Rigid lifting medium considering material yield		3	1.5
8.6.1.2 Static load bearing components including material yield		2.5	1.25

Reference	**WLL**
6.5.2.4 performer flying system design, load securing devices	1.25 X WLL
Section 9 - Factory Acceptance Test	
9.4.3 - All components shall be load tested at	1.25 X WLL
9.4.5.1 - Each hoist shall undergo a static load test at	1.5 X WLL
9.4.5.2 - Each hoist shall undergo a dynamic load test at maximum rated speed with	1 X WLL
9.4.5.4 - Each hoist brake, tested individually, will hold	1.25 X WLL
9.4.5.6 - Emergency stop function of the system at max speed tested at	1 X WLL
Section 11.5 - Commissioning Testing	
11.5.3.4.1 - Each hoist brake, acting alone, will hold	1.25 X WLL
11.5.3.4.1 - Established system - each hoist brake, acting alone, will hold	1 X WLL
11.5.3.4.2 - Static - both hoist brakes, acting together, will hold	1.5 X WLL
11.5.3.4.2 - Established system - static - both hoist brakes, acting together, will hold	1 X WLL
11.5.3.4.3 - Dynamic proof load test - full system full speed in both directions - Cat 1 stop	1 X WLL
11.5.3.4.4 - Dynamic power loss test - full system full speed in both directions - Cat 0 stop	1 X WLL

A.7.1.2.2 Design factor against yield
Equations in codes and standards involving material yield typically pertain to member sections, and not to fasteners, hardware, and flexible medium.

A.7.4 Strength design factors
Aesthetics and/or ergonomics of ride-on props and acrobatic props are often important factors in design, which may compete with satisfying strength design factors of members. A qualified person could determine that reduced design factors are acceptable for elements of ride-on props based on the RA/RR process, using other factors to compensate for the reduced design factors, such as enhanced maintenance and inspection procedures. For example, hand and foot holds should consider the risks associated with non-optimal shapes and sizes versus using reduced design factors.

A.8.1.6 Open end terminations
Open end terminations include hooks without spring latches. As per section 8.4 (Quick-connect hardware), any device that is opened on a regular basis (once or more per performance, rehearsal, or maintenance) shall have a redundant means of actuating that open movement. Use of hooks with spring latches or “gates” (for example on chain motors) should be evaluated as part of the RA/RR process and special attention should be paid to potential for slack conditions that may negate any protection the spring latch provides.

A.8.3.1.3 Suspension trauma

Suspension trauma, also known as harness hang syndrome (HHS), orthostatic intolerance, or orthostatic shock, is an effect which occurs when the human body is held upright without any movement for a period of time. If the person is strapped into a harness or tied to an upright object they will eventually suffer the central ischemic response (commonly known as fainting). If one faints but remains vertical, one risks death due to one's brain not receiving the oxygen it requires.

People at risk of suspension trauma include people using industrial harnesses (fall arrest systems, abseiling systems, confined space systems), people using harnesses for sporting purposes (caving, climbing, parachuting, and the like), stunt performers, aerial performers, and similar activities.

During rehearsals, the Spotters and flying supervisor should keep constant watch and communicate to the flying performers as needed to assure comfort and safety when suspended from harnesses.

If a flight during rehearsals or production is subject to stops and starts with the flying performer in the harness, it is advisable to have a suitable method to alleviate pressure in harness, such as ladders, bosun's chair, stirrups, tee bar, or other temporary support element.

A.8.3.1.5 Harness label

Warnings and/or user manual specifications should be used to clarify important requirements, e.g., that both sides of a hip harness must be used or built-in shock absorption mechanisms are included. Harnesses designed and constructed for a specific individual performing a specialized stunt should clearly denote the use.

A.8.5.2.3 Swivels

Swivels play an important role in most performer flying systems, both to mitigate unintended rotation of the flying performer and to facilitate intended rotation inherent to the performance. Swivels also frequently present a single point of potential failure requiring special consideration in system design and operation. The selection of the rope and swivel for the intended performer flying activity and loads should be assessed by a qualified person, who should determine the criteria and intervals for examining the rotating rope and swivel hardware.

The flying system designer should be aware that excessive rope rotation can compromise rope performance and can also cause a reduction in Ultimate Load Carrying Capacity of the rope. This reduction will depend on the characteristic load and the rotational properties of the selected rope.

A.8.5.4.2 In-View Flexible lifting medium

It is often desirable for creative reasons to make the in-view flexible lifting medium “invisible” from the audience perspective to the greatest extent possible. If the in-view flexible medium used for this application is not bent over sheaves or similar elements during use, the effects on the medium are less demanding than when flexed. As a result, lower design factors can produce a safe design for such elements, when combined with regular monitoring and/or frequent replacement of these in-view flexible mediums. Such reduced design factors are not appropriate for out-of-view elements, or for activities such as aerial acrobatics imposing significant dynamic forces on the system and performer.

A.8.5.4.5 Durability

All lifting medium materials are subject to fatigue over their useful life, and fatigue can affect the actual in-use strength of the material being utilized. The performer flying system maintenance procedures and schedules are determined partially by prediction of the fatigue life of these materials and the desired frequency of inspection and replacement of the lifting medium.

A.8.8.4 Groove sizing

Proper sizing of grooves in sheaves and drums should typically follow the lifting medium manufacturer’s recommendations and machining standards. Deviations may be permissible if determined by the flying system designer using RA/RR, with consideration of the lifting medium material and type, cycles, anticipated wear, maximum loads, and maximum operating speed and accelerations.

A.8.9.2 Traveler track end stops

Sacrificial damage to readily replaceable end stop elements not relied upon for structural support is acceptable. The system should not be used until damaged elements are replaced.

A.9.4.5.5 Hoist brake testing

Maximum braking torque will have an effect on emergency stop and peak stop G-forces as indicated in Annex note A.6.3.2. This force should be considered when examining characteristic (dynamic), and emergency stop and other peak load stop loads that can be transmitted to the flying performer, performer flying system equipment, and supporting structures. Excessive braking or too rapid deceleration can exert forces upon the flying performer that could cause injury or death.

Pull-through testing can be used to determine the amount of force on the line that will be generated before the load securing device will “slip” or back-drive and allow the load to continue moving, as well as to measure the resulting distances traveled after pull-through. The flying system designer may decide that this testing is appropriate for acceptance testing of a performer flying system. The flying system designer and/or system supplier should follow all manufacturer’s installation and testing guidelines and take into consideration the following mitigating factors:

- Machinery assembly tolerances
- Manufacturer’s listed +/- torque tolerances
- Relative age and torque reduction in older Brake pads
- Required “burn-in” period for new Brakes to ensure full or suitable capacity
- Environmental conditions

A.11.4 Commissioning inspections

Inspections may also include structural inspections, such as weld, high-strength fastener, and post-installed anchor inspections performed by a Certified Inspection Agency in accordance with the applicable building code.

A.12.6 In-service testing

Flying equipment should be tested according to frequency and type of application, so that defects and damage are detected in a timely fashion. The inspection intervals should be determined as part of the risk assessment, considering the component fabricators’ guidelines and the intended frequency of use of the equipment.
Testing may also include structural tests, such as non-destructive weld testing, performed in accordance with the applicable building code.

It is generally advisable to perform full load tests and/or non-destructive material tests of the performer flying system at least annually by a qualified person. performer flying systems in continuous use should be tested more frequently.

The inspection interval can be changed, if necessary, by the flying safety supervisor in consultation with the person responsible for the testing, considering the results of the risk assessment and the type and requirements of use. Relevant factors for changes might include the maintenance interval and the intensity of use. The flying safety supervisor should document the rationale for changes.

A.12.9.5 Post rescue treatment of flying performers

If there is the danger of suspension trauma or orthostatic shock, medical personnel should be contacted immediately and informed of the hazard. If the person is not breathing or has no heartbeat, then immediate resuscitation should be performed in the horizontal position.