



Designation: F2291 – 21

## Standard Practice for Design of Amusement Rides and Devices<sup>1</sup>

This standard is issued under the fixed designation F2291; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This practice establishes criteria for the design of amusement rides, devices and major modifications to amusement rides and devices manufactured after the effective date of publication except as noted in 1.2.

1.2 This practice shall not apply to:

1.2.1 Patron directed amusement rides or devices (for example, go karts, bumper cars, bumper boats),

1.2.2 Artificial climbing walls,

1.2.3 Air-supported structures,

1.2.4 dry slides,

1.2.5 coin operated rides,

1.2.6 Amusement rides or devices that involve the purposeful immersion of the patron's body partially or totally in the water and involves more than incidental patron water contact (for example, pools, water slides, lazy rivers, interactive aquatic play devices),

1.2.7 Amusement rides and devices whose design criteria are specifically addressed in another ASTM standard,

1.2.8 Portions of an amusement ride or device unaffected by a major modification,

1.2.9 Upgrades to electrical wiring, electrical motors and electrical components of amusement rides and devices provided the original design and safety criteria are maintained or enhanced, and

1.2.10 Pre-existing designs manufactured after the effective date of publication of this practice if the design is service proven or previously compliant and the manufacturer provides:

1.2.10.1 A historical summary of the amusement ride, device or major modification, and

1.2.10.2 A statement that the design is service proven or previously compliant as specified by Section 3.

1.2.10.3 Amusement rides and devices, and major modifications to amusement rides and devices may qualify as "previously compliant" for five years following the date of publication of this practice. Thereafter, amusement rides and devices, and major modifications to amusement rides and

devices must qualify as "service proven" or meet the requirements of this practice.

1.3 This practice includes an annex (mandatory), which provides additional information (for example, rationale, background, interpretations, drawings, commentary, and so forth) to improve the user's understanding and application of the criteria presented in this practice. The annex information shall be interpreted as mandatory design criteria.

1.4 This practice includes an appendix (non-mandatory), which provides additional information (for example, rationale, background, interpretations, drawings, commentary, and so forth.) to improve the user's understanding and application of the criteria presented in this practice. The appendix information shall not be interpreted as mandatory design criteria.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

**F770** Practice for Ownership, Operation, Maintenance, and Inspection of Amusement Rides and Devices

**F1159** Practice for Design of Amusement Rides and Devices that are Outside the Purview of Other F24 Design Standards

**F1193** Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices

**F2137** Practice for Measuring the Dynamic Characteristics of Amusement Rides and Devices

**F2374** Practice for Design, Manufacture, Operation, and

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee F24 on Amusement Rides and Devices and is the direct responsibility of Subcommittee F24.24 on Design and Manufacture.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

## Maintenance of Inflatable Amusement Devices

### 2.2 *ASTM Technical Publication:*<sup>3</sup>

**STP-1330 Composite Materials: Fatigue and Fracture, 7th Volume**

### 2.3 *ACI Standards:*<sup>4</sup>

**ACI-301 Specifications for Structural Concrete**

**ACI-318 Building Code Requirements for Structural Concrete (ACI-318) and Commentary (318R)**

### 2.4 *AFPA, American Wood Council Standard:*<sup>5</sup>

**NDS National Design Standard for ASD Design**

**NDS 2005 National Design Specification for Wood Construction**

### 2.5 *AISC Manuals:*<sup>6</sup>

**AISC 316 Manual on Steel Construction, Allowable Stress Design (ASD)**

**AISC M015 Manual on Steel Construction, Load & Resistance Factor Design (LRFD)**

### 2.6 *ANSI Standards:*<sup>7</sup>

**ANSI/AISC 360-05 Specifications for Structural Steel Buildings**

**ANSI B93.114M Pneumatic Fluid Power—Systems Standard for Industrial Machinery**

**ANSI B77.1 Passenger Ropeways—Aerial Tramways, Aerial Lifts, Surface Lifts, Tows and Conveyors—Safety Requirements**

**ANSI Y32.10 Graphic Symbols for Fluid Power Diagrams**

### 2.7 *ASCE Standard:*<sup>8</sup>

**ASCE 7 Minimum Design Loads for Buildings and Other Structures**

**ASCE 16 Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction**

**ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures**

### 2.8 *ASM Documents:*<sup>9</sup>

**ASM Atlas of Fatigue Curves**

### 2.9 *ASME Standards:*<sup>10</sup>

**ASME Boiler and Pressure Vessel Code**

**ASME B15.1 Safety Standards for Mechanical Power Transmission Apparatus**

**ASME A17.1 Safety Code for Elevators and Escalators**

### 2.10 *AWS Standards:*<sup>11</sup>

**ANSI/AWS D1.1/D1.1M Structural Welding Code—Steel**

### 2.11 *BSI Standards:*<sup>12</sup>

**BS 5400-10 Steel, Concrete and Composite Bridges—Code of Practice for Fatigue**

### 2.12 *Building Codes:*

**International Building Code Chapter 16, “Structural Design”**  
**National Building Code of Canada Companion-action load combinations**

### 2.13 *CDC (Center for Disease Control) Growth Charts:*<sup>13</sup>

**CDC Basic Body Measurements**

### 2.14 *DIN Standards:*<sup>14</sup>

**DIN 1055 Actions on structures, Parts 1–7**

**DIN 1055-100 Load combinations**

### 2.15 *EN Standards:*<sup>15</sup>

**EN 280 Mobile Elevating Work Platforms—Design Calculations, Stability Criteria, Construction, Safety, Examinations, and Tests**

**EN 1991 Eurocode 1: Actions on structures**

**EN 1992 Eurocode 2: Design of concrete**

**EN 1993 Eurocode 3: Design of steel structures**

**EN 1994 Eurocode 4: Design of composite steel and concrete structures**

**EN 1995 Eurocode 5: Design of timber structures**

### 2.16 *Factory Mutual Standard:*<sup>16</sup>

**FM6930 Flammability Classification of Industrial Fluids**

### 2.17 *Federal Documents:*

**FMVSS No. 213 Child Restraint Systems**<sup>17</sup>

**OSHA 29 CFR PART 1926.502 (d) Fall protection systems criteria and practices. Personal fall arrest systems.**<sup>18</sup>

**USDA-72 U.S. Dept. of Agriculture, The Wood Handbook—Wood As An Engineering Material, Forest Service, Forest Products Laboratory**<sup>19</sup>

### 2.18 *ISO Standards:*<sup>20</sup>

**ISO 4113 Road Vehicles – Calibration Fluid for Diesel Injection Equipment Second Edition**

**ISO 4413 Hydraulic fluid power – General rules relating to systems**

**ISO 4414 Pneumatic Fluid Power General Rules Relating to Systems**

**ISO 4406 Particle Count Chart**

**ISO 6149-1 Connections for hydraulic fluid power and general use – Ports and stud ends with ISO 261 metric threads and O-ring sealing – Part 1: Ports with truncated housing for O-ring seal**

<sup>3</sup> Available from ASTM International Headquarters, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.

<sup>4</sup> Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

<sup>5</sup> Available from American Forest and Paper Association (AF&PA), 1111 19th St., NW, Suite 800, Washington, DC 20036.

<sup>6</sup> Available from American Institute of Steel Construction (AISC), One E. Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

<sup>7</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<sup>8</sup> Available from The American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191.

<sup>9</sup> Available from American Society of Metals (ASM International), 9639 Kinsman Rd., Materials Park, OH 44073-0002.

<sup>10</sup> Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5900.

<sup>11</sup> Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

<sup>12</sup> Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K.

<sup>13</sup> Available from Centers for Disease Control & Prevention (CDC), 1600 Clifton Rd., Atlanta, GA 30333, website: <http://www.cdc.gov/> [Search: anthropometrics].

<sup>14</sup> Available from Beuth Verlag GmbH (DIN-- DIN Deutsches Institut für Normung e.V.), Burggrafenstrasse 6, 10787, Berlin, Germany.

<sup>15</sup> Available from European Committee for Standardization (CEN), 36 rue de Stassart, B - 1050 Brussels.

<sup>16</sup> Available from FM Global at <http://www.fmglobal.com/default.aspx>.

<sup>17</sup> Available from National Highway Traffic Safety Administration (NHTSA), 1200 New Jersey Ave., SE, West Building, Washington, DC 20590, <http://www.nhtsa.gov>.

<sup>18</sup> Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, <http://www.osha.gov>.

<sup>19</sup> Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

<sup>20</sup> Available from International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland.

**ISO 7250** Basic Human Body Measurements for Technological Design

**ISO 13850** Safety of Machinery – Emergency Stop – Principles for Design

2.19 *Military Standards:*<sup>21</sup>

**MIL 17** The Composite Materials Handbook

2.20 *NEMA Standard:*<sup>22</sup>

**NEMA 250** Enclosures for Electrical Equipment

2.21 *NFPA Standards:*<sup>23</sup>

**NFPA-79** Electrical Standard for Industrial Machinery

**NFPA-70** National Electric Code (NEC)

**NFPA-101** Life Safety Code

2.22 *National Fluid Power Association, Inc. Document:*<sup>24</sup>

**NFPA/JIC T2.25.1M** Pneumatic Fluid Power—Systems Standard for Industrial Machinery

**NFPA/T2.24.1** Hydraulic Fluid Power - Systems Standard for Stationary Industrial Machinery Supplement to ISO 4413; 1998 - Hydraulic Fluid Power - General Rules Relating to Systems

2.23 *SAE Standards:*<sup>25</sup>

**SAE 100R4**

**SAE J518** Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flange Type

**SAE J833** Human Physical Dimensions

**SAE J1926** Connections for General Use and Fluid Power-Ports and Stud Ends with ASME B1.1 Threads and O-Ring Sealing Part 3: Light-Duty (L-Series) Stud Ends

**SAE HS 4000** Fastener Standards

2.24 *SIA Standards:*<sup>26</sup>

**SIA 260** Basics of Planning Structural Design Projects

**SIA 261** Actions on Structures

2.25 *UL Standards:*<sup>27</sup>

**UL 508A** Industrial Control Panels

3.1.4 *designer/engineer*—party(s) that establishes and describes the configuration of the amusement ride or device, establishes strength and fatigue life, designs and develops electrical/electronic control systems, and defines inspection criteria.

3.1.5 *electrical (E)/electronic (E)/programmable electronic systems (PES) (E/E/PES)*—when used in this context, electrical refers to logic functions performed by electromechanical techniques, (for example, electromechanical relay, motor driven timers, and so forth), Electronic refers to logic functions performed by electronic techniques, (for example, solid state logic, solid state relay, and so forth), and Programmable Electronic System refers to logic performed by programmable or configurable devices (for example, Programmable Logic Controller (PLC)). Field devices are not included in E/E/PES.

3.1.6 *electro-sensitive protective equipment (ESPE)*—assembly of devices or components, or both, working together for protective tripping or presence-sensing purposes.

3.1.7 *fail-safe*—characteristic of an amusement ride or device, or component thereof, that is designed such that the normal and expected failure mode results in a safe condition.

3.1.8 *filter corner frequency (Fn)*—with reference to a low-pass filter, Fn is the frequency (specified in Hz) where the frequency response curve of the filter has magnitude of –3 dB.

3.1.9 *force limiting*—when pertaining to restraint devices, a characteristic that, regardless of the amount of force available from the system actuators, limits the amount of force applied to the patron(s).

3.1.10 *latching*—when pertaining to restraint devices, held secure against opening except by intentional action of the patron, operator, or other means. This can include restraints (for example, drop bars) held in place by gravity, detents or other means.

3.1.11 *locking*—when pertaining to restraint devices, held securely against opening except by intentional action of the operator or other means not accessible by the patron.

3.1.12 *manual release*—when pertaining to restraint devices, a hand or foot operated mechanism that allows for opening the patron restraint.

3.1.13 *manufacturer*—party producing the amusement ride or device, performing major modifications and can include the designer/engineer.

3.1.14 *operating mode*—a defined behavior of an amusement ride or device with a corresponding set of rules or interlocks that are implemented in control systems as required.

3.1.15 *patron clearance envelope*—patron reach envelope plus a margin of 3 in.

3.1.16 *patron containment*—features in an amusement ride or device that accommodate the patron for the purpose of riding the ride or device. This may include but is not limited to the seats, side walls, walls, or bulkheads ahead of the patron(s), floors, objects within the vicinity of the patron(s), restraint systems, and cages.

3.1.17 *patron reach envelope*—space a patron could reach during a ride cycle while properly positioned, as defined by the

### 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *acceleration, impact*—those accelerations with duration of less than 200 ms.

3.1.2 *acceleration, sustained*—those accelerations with duration greater than or equal to 200 ms.

3.1.3 *control station*—a location where buttons, switches or other controls are provided for the purpose of operating ride equipment.

<sup>21</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

<sup>22</sup> Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.

<sup>23</sup> Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.

<sup>24</sup> Available from National Fluid Power Association, Inc., 3333 N. Mayfair Rd., Milwaukee, WI 53222-3219.

<sup>25</sup> Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

<sup>26</sup> Available from Swiss Society of Engineers and Architects, Selnaustrasse 16, CH-8027 Zürich.

<sup>27</sup> Available from Underwriters Laboratories (UL), Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062.

ride analysis, in the amusement ride or device and limited only by the vehicle, seat geometry, and restraint system.

3.1.18 *previously compliant*—amusement ride or device, or major modification to an amusement ride or device, of which the design meets the ASTM Standard in place at the time of its design.

3.1.19 *primary circulation area*—areas leading directly to the entrance and exit of a ride that are normally traveled by patrons. These areas would not include emergency exit routes, maintenance areas, or other areas not normally on the route of the patron.

3.1.20 *restraint*—system, device, or characteristic that is intended to inhibit or restrict the movement of the patron(s) while on the amusement ride or device.

3.1.21 *safety-related control system (SRCS)*—an assembly of components that monitor and control the amusement ride or device such that it: (1) mitigates hazards to persons; or (2) has the capability to block or otherwise alter the performance of systems that implement safety features. Components may include without limitation electronic, electric, electro-mechanical, hydraulic, pneumatic or mechanical devices, or combinations thereof.

3.1.22 *service proven*—an amusement ride, device, or major modification to an amusement ride or device of which (1) unit(s) have been in service to the public for a minimum of five years, and (2) unit(s) that have been in service have done so without any significant design related failures or significant design related safety issues that have not been mitigated.

3.1.23 *service proven practice*—a policy or procedure used in association with an amusement ride or device, which (1) has been in service to the public for a minimum of five years, and (2) has done so without any significant safety related issues that have not been mitigated.

3.1.24 *supervising companion*—a person on a ride or device who is qualified by a reasonable age or other means to understand rider instructions, assist a patron or child under 48 in. in height in complying with rider instructions, and who meets all other criteria for riding.

3.1.25 *use case*—a purpose for which equipment is used by persons or external systems. Examples of common use cases include but are not limited to entertaining patrons, supporting routine maintenance, and programming for creative intent. Use cases and operating modes may or may not have a one-to-one correspondence.

3.1.26 *zone of operator awareness*—area defined by the sights, sounds, and other stimuli an operator can reasonably be expected to monitor from their specified location(s) relative to the amusement ride or device that they are operating. The zone of operator awareness could include multiple, noncontiguous portions of a ride-vehicle path. Information provided by remote audio or video monitoring devices may be part of the zone of operator awareness.

## 4. Significance and Use

4.1 The purpose of this practice is to provide designers, engineers, manufacturers, owners, and operators with criteria

and references for use in designing amusement rides and devices or a major modification for amusement rides or devices.

## 5. General Design Criteria

### 5.1 Ride Analysis:

5.1.1 The designer/engineer shall perform and document a ride analysis that illustrates how hazards to persons have been managed. The documentation shall include but not be limited to the following:

5.1.1.1 An identification of the scope of the analysis. The scope shall describe the equipment considered by the analysis. The scope shall identify the use cases of the amusement ride or device. The scope may be clarified by identifying excluded equipment or scenarios.

5.1.1.2 An identification of hazards that includes potential sources and consequences of harm.

5.1.1.3 An identification of hazardous scenarios.

(1) Hazardous scenarios shall consider physical areas where persons are expected to access.

(2) Hazardous scenarios shall consider exposure to hazards under all identified use cases.

(3) Hazardous scenarios related to maintenance personnel actions shall be restricted to routine, repetitive and essential procedures.

5.1.1.4 An assessment of hazards that includes a description of how identified hazards are mitigated to an acceptable level. Hazards are mitigated by reducing the severity of the hazard, reducing the probability of occurrence of related hazardous scenarios, or both. Not all hazards require mitigation. The assessment of hazards shall consider hazards that are created or aggravated by the means of mitigation and the potential for failure of the means of mitigation. This assessment shall include but not be limited to the following:

(1) *Patron Suitability Assessment*—A patron suitability assessment shall describe the suitability of the design of the amusement ride or device for the intended patrons, including anthropometric factors that relate age and physical size.

(2) *Patron Restraint and Containment Analysis*—A patron restraint and containment analysis shall be performed in accordance with Section 6.

(3) *Patron Clearance Envelope Analysis*—A patron clearance envelope analysis shall be performed in accordance with Section 6.

(4) *Load/Unload Areas Activities Analysis*—A load/unload areas analysis shall describe how the attraction's design addresses risk associated with activities that are performed in the primary load/unload areas of the amusement ride or device. (See [Appendix X9](#) for examples of strategies.)

(5) *Failure Analysis*—A failure analysis shall be performed on the safety related systems of the amusement ride or device. The failure analysis shall include either a Fault Tree Analysis, a Failure Mode and Effects Analysis (FMEA), or other accepted engineering practices.

(6) *Environmental Conditions*—The environmental conditions to which the amusement ride or device is designed to be subjected shall be included in the hazard assessment.

### 5.2 Hazard Mitigations:



### 5.2.1 Hazard mitigations shall consider:

5.2.1.1 The anticipated lifetime of safety related systems and components as identified in the Ride Analysis, based on their expected use;

5.2.1.2 The potential deterioration of safety-related components, as identified in the Ride Analysis, due to the environmental conditions identified in the hazard assessment; and

5.2.1.3 The means and methods for detecting component failures. Detection methods include but are not limited to automatic detection by a control system, periodic operational testing, and periodic inspection of components including non-destructive testing.

5.2.2 Hazard mitigations that involve safety-related control functions shall consider and identify:

5.2.2.1 System response/reaction time,

5.2.2.2 Tolerance limits for parameters (for example, speed, distance, force), and

5.2.2.3 Reliability, redundancy, and performance characteristics.

5.2.3 Hazard mitigations that involve operator responsibilities to perform actions shall:

5.2.3.1 Identify operator responsibilities and actions related to hazard mitigation and system responses to those actions.

5.2.3.2 Consider the specified operator responsibilities related to hazard mitigations in combination with other reasonably anticipated operator responsibilities.

5.2.4 Hazard mitigations that involve operator procedures, or involve routine, repetitive, and essential maintenance procedures shall:

5.2.4.1 Identify the frequency of the procedures, and

5.2.4.2 Define the elements that must be included in the documented procedures in order to make those procedures effective with respect to associated hazards.

5.2.5 The design shall identify appropriate devices that allow the operator(s) to enable, intercept, or affect amusement ride or device operation considering the operator's specified responsibilities, specified location, and identified zone of operator awareness.

### 5.3 Design and Calculations:

5.3.1 The designer/engineer shall perform calculations showing compliance with the design criteria of this practice. Calculations and assessments of the following types are required.

5.3.1.1 Calculations verifying the adequacy of structural, mechanical, and electrical components.

5.3.1.2 Calculations of significant and predictable acceleration that is generated by the ride or device when operated as reflected in the manufacturer's provided operating and maintenance manuals or written instructions.

5.3.1.3 Performance and functional characteristics of control systems.

5.3.1.4 Calculations shall be performed using coordinate axis and load paths as defined by Practice F2137 or the EN equivalent.

5.4 Other Design Considerations—Where water is a design element of the ride or of related ride effects and is intended to contact the equipment of the ride, the designer/engineer should

consider water quality maintenance and treatment when determining materials for use in manufacture.

### 5.5 Units:

5.5.1 Units of measurement shall be clearly specified in all documentation.

5.5.2 The coordinate system shown in Fig. 1 shall be used as the standard reference for acceleration directions, including the application of the different means of restraint in accordance with the criteria of the restraint diagram shown in Fig. 2.

### 5.6 Drawings and Records:

5.6.1 The designer/engineer or manufacturer shall produce and retain as-built drawings, calculations, and control software that depict the amusement ride, device, or major modification details. These drawings and calculations shall be retained for a minimum of 20 years from the date of last manufacture. In the case of a major modification, only the records associated with that major modification, and not the entire ride or device, must be retained for a minimum of 20 years.

5.6.2 Documents deemed proprietary and confidential by the manufacturer shall include a statement of such on each document. Use of the manufacturer's documentation and records should be limited, where possible, to the installation, maintenance, inspection, and operation of the ride or device. All other dissemination should be limited.

5.6.3 Documentation supplied to the buyer, owner, or operator shall be complete and adequate for proper installation, maintenance, inspection, and operation of the amusement ride, device, or major modification.

5.6.4 Drawings and documents shall illustrate and define all important dimensions and tolerances. Dimensions, tolerances, and other important characteristics shall be clearly depicted in appropriate views and cross sections. The following shall be included:

5.6.4.1 General drawings or diagrams in plan, elevation, and section views showing the general arrangement of components, including patron clearance envelope as described in Section 6 of this practice.

5.6.4.2 Assembly and subassembly drawings providing additional views of areas not clearly discernible from the general drawings and providing clear identification and specification of all included components, their locations, and other information as applicable, for example, proper adjustment(s), fastener tightening specifications, descriptions of any other materials or lubricants used, and other important information.

5.6.4.3 Detailed drawings of all components specifically manufactured for use in the amusement ride, device, or major modification.

### 5.7 Regulatory Body Review Documents:

5.7.1 When the approval of the amusement ride, device, or major modification design is required by a regulatory authority, the following documents are typically made available for review:

5.7.1.1 General assembly drawings,

5.7.1.2 Facility interface drawings and related load calculations,

5.7.1.3 Operations, maintenance, and assembly instructions, and

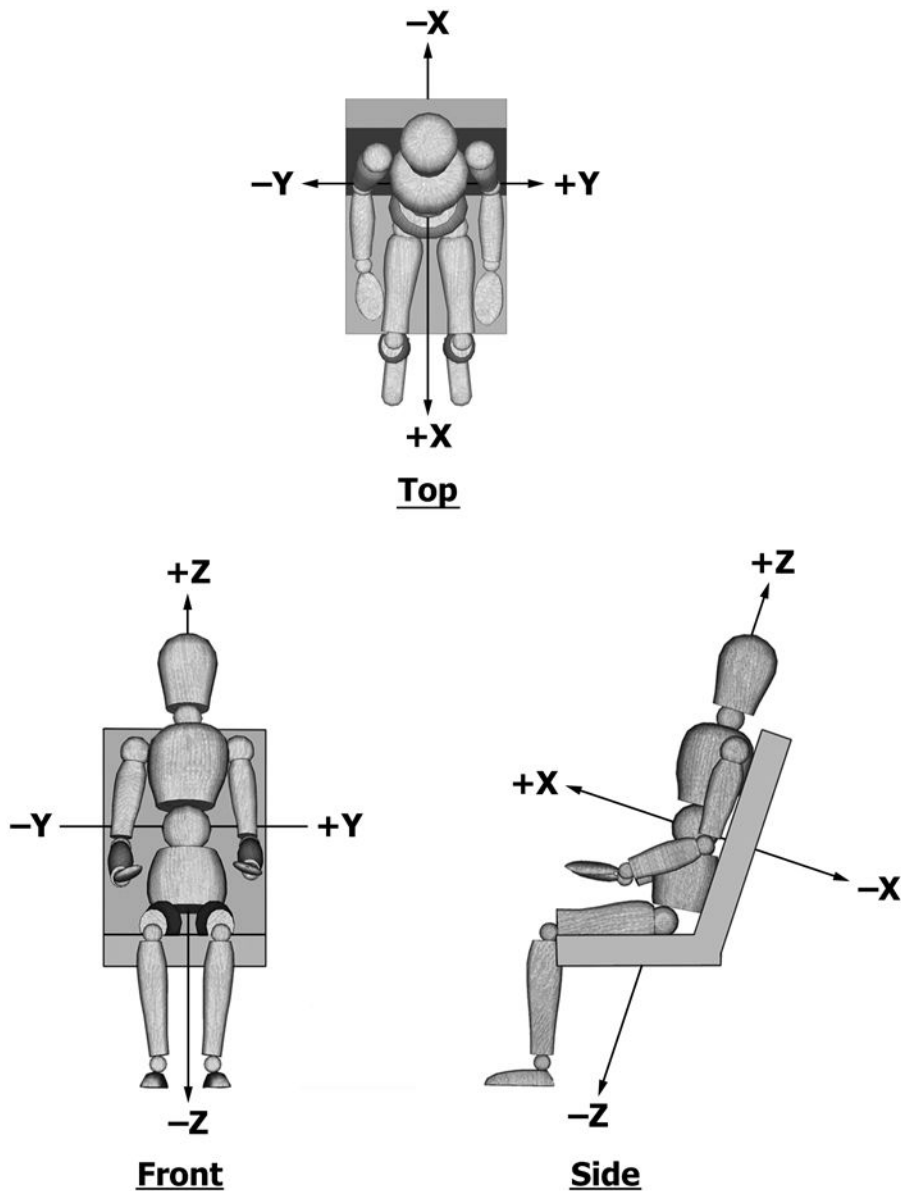


FIG. 1 Patron Coordinate System

5.7.1.4 Information otherwise called for in accordance with the guidelines in Practice F1193.

5.7.2 Use of the manufacturer's documentation and records should be limited to the regulatory approval process and dissemination shall be limited to minimize disclosure of proprietary and confidential documents.

## 6. Patron Restraint, Clearance Envelope, and Containment Design Criteria

### 6.1 Patron Containment:

6.1.1 The amusement ride or device shall be designed to support and contain the patron(s) during operation. This support and containment, that is, the patron containment, shall be consistent with the intended action of the ride or device.

6.1.2 Parts of amusement rides and devices that patrons may reasonably be expected to contact shall be smooth; free from unprotected protruding studs, bolts, screws, sharp edges and

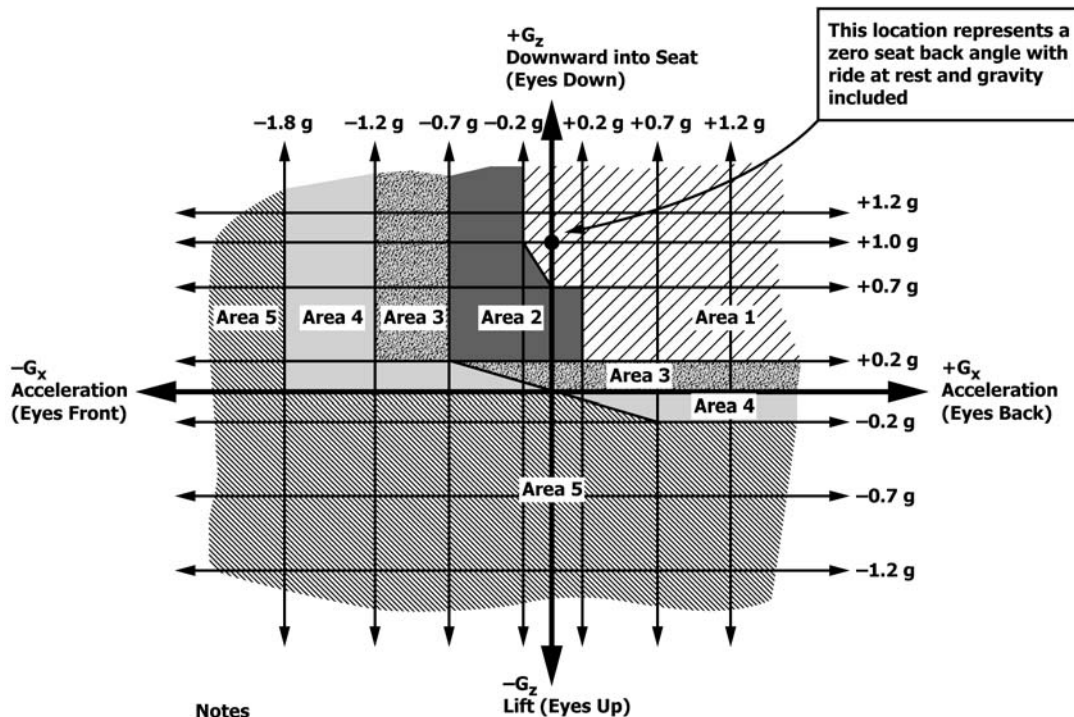
corners, and rough or splintered surfaces; and considered for padding as appropriate.

6.1.3 For devices lacking a ride vehicle or patron carrier, consideration shall be given to measures that prevent or mitigate injuries potentially caused by collisions as determined by the ride analysis and patron restraint and containment analysis.

### 6.1.4 Ride or Device Vehicle Doors:

6.1.4.1 When amusement ride or device patron vehicles are provided with doors, measures shall be taken to ensure that the doors do not open during operation, failure, or in case of emergency, unless otherwise determined by the ride analysis.

6.1.4.2 Powered doors shall be designed to minimize pinch points and entrapment areas. The doors' (opening and closing) movement shall be controlled, and the maximum exerted force, measured on the edge of the door at the furthestmost point from the hinge or pivot, shall not exceed 30 lb (133 N).



**Notes**

- 1) For cases on a boundary, the lower category may be chosen.
- 2) Accelerations are limited to the sustained values in section 7.
- 3) This diagram is intended for use with restraint systems where the patron begins the ride in the sitting or standing position (that is, spine nearly aligned with gravity).

FIG. 2 Restraint Determination Diagram—Accelerations in Design Stage

## 6.2 Security of Patron Containment System:

6.2.1 Any system or systems used to support and contain the patron(s) shall be securely fixed to the structure of the ride or device and shall have adequate strength for the intended forces produced by the ride or device and the reasonably foreseeable actions of the patron(s).

## 6.3 Patron Restraints:

6.3.1 Patron restraints shall be provided as determined by the designer/engineer. This determination shall be based on the patron restraint and containment analysis performed in accordance with criteria defined in this practice and shall take into consideration the nature of the amusement ride or device and the intended adult or child patron physical characteristics, based on recognized and published anthropometric data such as Dreyfuss Human Scale 4/5/6 (1),<sup>28</sup> 7/8/9 (2), SAE J833, ISO 7250, or Center for Disease Control Growth Charts. The specific anthropometric data utilized shall be documented in the ride analysis. When evaluating anthropometric data to be used in design, the designer/engineer shall consider that the patron height requirement will be enforced as stated in Practice F770.

6.3.2 The patron restraint and containment analysis may identify the need for a restraint system for reasons other than acceleration or seat inclination. The analysis shall also evaluate the need for locking or latching functions when restraints are required.

6.3.3 The manufacturer shall take into consideration the evacuation of patrons from any reasonably foreseeable position or situation on the ride or device, including emergency stops and stops in unplanned locations. The patron restraint and containment analysis shall address whether individual or group restraints releases are appropriate.

6.3.4 The manufacturer shall specify the state, locked or unlocked, of the restraint system in the event of unintended stop, for example, emergency stop or loss of power. This specification shall be based on the results of the ride analysis performed in 5.1.

6.3.5 Restraints shall be designed such that the opportunity for pinching or unintentional trapping of fingers, hands, feet, and other parts of the patron's body is minimized.

6.3.6 The maximum exerted force produced by any powered patron restraint device while opening or closing shall not be more than 18 lb (0.08 kN), measured on the active surfaces contacting the patron. Force limiting systems, if used to

<sup>28</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard.