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.

Designation: F2291 – 23

Standard Practice for Design of Amusement Rides and Devices[1]

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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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.*

1.7 *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:*[2]

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

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

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

[1] 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, Manufacture, Installation and commissioning.

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

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F2374 Practice for Design, Manufacture, Operation, and Maintenance of Inflatable Amusement Devices

2.2 *ASTM Technical Publication:*[3]

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

2.3 *ACI Standards:*[4]

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:*[5]

NDS National Design Standard for ASD Design

NDS 2005 National Design Specification for Wood Construction

2.5 *AISC Manuals:*[6]

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:*[7]

ANSI/AISC 360-16 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:*[8]

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 7-22 Minimum Design Loads for Buildings and Other Structures

2.8 *ASM Documents:*[9]

ASM Atlas of Fatigue Curves

2.9 *ASME Standards:*[10]

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:*[11]

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

2.11 *BSI Standards:*[12]

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

2.12 *Building Codes:*

International Building Code (2018) Chapter 16, "Structural Design"

National Building Code of Canada (2015) Companion-action load combinations

2.13 *CDC (Center for Disease Control) Growth Charts:*[13]

CDC Basic Body Measurements

2.14 *EN Standards:*[14]

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

EN 1990 Eurocode 0: Basis of structural design

EN 1991 Eurocode 1: Actions on structures

EN 1993 Eurocode 3: Design of steel structures

EN 1995 Eurocode 5: Design of timber structures

2.15 *Factory Mutual Standard:*[15]

FM6930 Flammability Classification of Industrial Fluids

2.16 *Federal Documents:*

FMVSS No. 213 Child Restraint Systems[16]

OSHA 29 CFR PART 1926.502 (d) Fall protection systems criteria and practices. Personal fall arrest systems.[17]

USDA-72 U.S. Dept. of Agriculture, The Wood Handbook—Wood As An Engineering Material, Forest Service, Forest Products Laboratory[18]

2.17 *ISO Standards:*[19]

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

ISO 7250 Basic Human Body Measurements for Technological Design

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

[3] Available from ASTM International Headquarters, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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

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

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

[8] Available from The American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191.

[9] Available from American Society of Metals (ASM International), 9639 Kinsman Rd., Materials Park, OH 44073-0002.

[10] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[11] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

[12] Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K.

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

[14] Available from European Committee for Standardization (CEN), 36 rue de Stassart, B - 1050 Brussels.

[15] Available from FM Global at http://www.fmglobal.com/default.aspx.

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

[17] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

[18] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

[19] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland.

2.18 *Military Standards:*[20]
MIL 17 The Composite Materials Handbook

2.19 *NEMA Standard:*[21]
NEMA 250 Enclosures for Electrical Equipment

2.20 *NFPA Standards:*[22]
NFPA-79 Electrical Standard for Industrial Machinery
NFPA-70 National Electric Code (NEC)
NFPA-101 Life Safety Code

2.21 *National Fluid Power Association, Inc. Document:*[23]
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

2.22 *SAE Standards:*[24]
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

2.23 *UL Standards:*[25]
UL 508A Industrial Control Panels

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.

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 *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.

3.1.6 *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.

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

3.1.8 *latching*—when pertaining to restraints, 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.

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

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

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

3.1.12 *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.

3.1.13 *patron clearance envelope*—patron reach envelope plus a margin of 3 in. (76 mm).

3.1.14 *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.

3.1.15 *patron reach envelope*—space a patron could reach during a ride cycle while properly positioned, as defined by the ride analysis, in the amusement ride or device and limited only by the vehicle, seat geometry, and restraint system.

3.1.16 *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.

3.1.17 *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.

3.1.18 *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.

3.1.19 *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, electromechanical, hydraulic, pneumatic or mechanical devices, or combinations thereof.

[20] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098
[21] Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.
[22] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.
[23] Available from National Fluid Power Association, Inc., 3333 N. Mayfair Rd., Milwaukee, WI 53222–3219.
[24] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.
[25] Available from Underwriters Laboratories (UL), Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062.