



Designation: ~~F2376--17a~~ F2376 – 21

Standard Practice for Classification, Design, Manufacture, Construction, and Operation of Water Slide Systems¹

This standard is issued under the fixed designation F2376; 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 applies to the classification, design, manufacture, construction, major modification, and operation of water slide systems. Water slide systems shall be defined as rides intended for use by riders in bathing attire where the action of the ride involves possible and purposeful immersion of the rider's body either in whole or in part in water, and uses circulating water to mobilize or lubricate the rider's transportation along a purpose built path. This includes slides used with or without vehicles as defined below. The terms water slides, waterslides, and slides shall be considered equivalent when used in this practice.

1.1.1 Owner/operator requirements of this standard are required of all water slide systems regardless of date of construction.

1.1.2 The design, manufacture and construction of an existing water slide or portions of a water slide system unaffected by a major modification shall meet the standard requirements in existence at the time of the construction.

1.2 For the purposes of this practice, a water slide system includes:

1.2.1 The flume,

1.2.2 The water-circulation system,

1.2.3 The starting platform with associated means of access and egress,

1.2.4 The structural supports,

1.2.5 Vehicles or other aquatic accessories that are part of the water slide as defined by the manufacturer, and

1.2.6 Means of slide termination.

1.3 This practice shall not apply to:

1.3.1 Any water slides installed in private residences,

1.3.2 Water flume amusement rides where contact with water is merely incidental (for example, log flume rides, shoot-the-chutes),

¹ This practice is under the jurisdiction of ASTM Committee F24 on Amusement Rides and Devices and is the direct responsibility of Subcommittee F24.70 on Water Related Amusement Rides and Devices.

Current edition approved Dec. 1, 2017; May 1, 2021. Published January 2018; June 2021. Originally approved in 2006. Last previous edition approved in 2017 as F2376 – 17; F2376 – 17a. DOI: 10.1520/F2376-17A; 10.1520/F2376-21.

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

1.3.4 Lazy river type attractions operating at constant elevation, constructed in the ground, ~~and~~

1.3.5 Inflatable water slides (constant air supply) that are mounted on land (refer to Practice F2374-19 for the requirements of these types of water slides), and

1.3.6 Inflatable water slides (captured air) that are floating on a body of water (refer to EN/ISO 25649, parts 1 through -7).

1.4 Pre-existing designs manufactured after the effective date of publication of this practice if the design is service proven or previously compliant, as defined in ~~Section 3.1.26 of Practice Terminology F2291F747,-15,~~ and the manufacturer provides:

1.4.1 A historical summary of the water slide, or major modification as defined in Terminology F747,-15, and

1.4.2 A statement that the design is service proven or previously compliant. Water slides and major modifications to water slides may qualify as previously compliant for five years following the date of publication of this practice. Thereafter, water slides and major modifications to water slides must qualify as service proven or meet the requirements of this practice.

1.4.3 Service proven or previously compliant designs shall comply with Section 84.

1.5 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

NOTE 1—The conversion factor from inch-pound to metric units is 1 in. = 25.4 mm, and 1 lb = 4.4482 N.

1.6 This practice includes an Appendix, which provides additional information to enhance the user's understanding of and application of the criteria presented in this practice, for example, rationale, background, drawings, interpretation, or commentary. The information in the Appendix shall not be considered a mandatory part of this practice.

1.7 *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.*

1.8 *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

[D570 Test Method for Water Absorption of Plastics](#)

[D638 Test Method for Tensile Properties of Plastics](#)

[D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials](#)

[F747 Terminology Relating to Amusement Rides and Devices](#)

[F770 Practice for Ownership, Operation, Maintenance, and Inspection of Amusement Rides and Devices](#)

~~[F846 Guide for Testing Performance of Amusement Rides and Devices \(Withdrawn 2013\)](#)~~³

~~[F853 Practice for Maintenance Procedures for Amusement Rides and Devices \(Withdrawn 2014\)](#)~~³

~~[F893 Guide for Auditing Amusement Rides and Devices \(Withdrawn 2013\)](#)~~³

[F1193 Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices](#)

~~[F1305F2291 GuidePractice for ClassificationDesign of Amusement Ride and Device Related Injuries and IllnessesRides and Devices \(Withdrawn 2011\)](#)~~

~~[F2291F2374 Practice for Design of Amusement Rides and Design, Manufacture, Operation, and Maintenance of Inflatable Amusement Devices](#)~~

2.2 ACI Standard:³

[ACI-318 Building Code Requirements for Structural Concrete](#)

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.

³ Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

2.3 ASCE Standard:⁴

[ANSI/ASCE 7-ASCE/SEI 7-16 Minimum Design Loads for Buildings and Other Structures](#)

2.4 EN/ISO Standard:⁵

[EN/ISO 25649 Floating leisure articles for use on and in the water](#)

2.5 USDA Document:⁶

[USDA-72 The Wood Handbook](#)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *fall distance*—vertical distance between the terminus of the slide surface and the water surface of the landing pool.

3.1.2 *flume riser (splashguard)*—extension of the side wall of an open flume to contain riders or water and is capable of use as a riding surface.

3.1.3 *landing pool*—pool intended to receive riders from a water slide.

3.1.4 *landing zone*—area in a landing pool intended for receiving riders from a particular slide.

3.1.5 *lifeguard*—individual specially trained in lifesaving and emergency procedures, responsible for monitoring patrons and responding to aquatic and other emergencies.

3.1.6 *owner/operator*—person or organization that is responsible for the maintenance and operation of a water slide system.

3.1.7 *run-out section*—flume surface of a water slide where riders are intended to decelerate or come to a stop, or both.

3.1.8 *slide height*—difference in elevation from the centerline of the flume at the slide exit to the centerline of the flume at slide entry, measured at the riding surface.

3.1.9 *slide path*—geometric layout of the flume sections that make up the water slide.

4. Slide Classification

4.1 Water slides are classified by their physical and intended use characteristics. The classification may be a combination of the specific rider vehicle used the type of geometric path, often serpentine or straight, and the designation as a speed slide if the rider's velocity exceeds 25 ft/s. The following are definitions of the types of water slides:

4.1.1 *body slides*—water slide used without a vehicle.

4.1.2 *children's slides*—Water slides generally intended only for use by persons under the height of 48 in. Water slide has a maximum fall distance of 3 in. from slide exit where the rider enters the water and water depth is no greater than 24 in.

4.1.3 *mat slides*—water slide used with a designated mat as a vehicle.

4.1.4 *serpentine slide*—curved path as viewed in geometric slide path.

4.1.5 *specialty slides*—proprietary water slide design, such as an uphill, half-pipe, or bowl ride, which does not conform to standard classification.

4.1.6 *specialty vehicle slides*—water slide used with a proprietary vehicle specified by the manufacturer.

⁴ Available from The American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191.

⁵ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

⁶ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

4.1.7 *speed slide*—water slide where the rider(s) achieve a velocity of 25 ft/s or more during the course of the ride.

4.1.8 *tube slides*—water slide used with a single or multi-person water slide tube.

5. Materials

5.1 *Flume Material*—Any material that has the following basic properties and that meets all other requirements of this practice may be used to construct water slides:

5.1.1 Flumes riding surfaces shall be constructed to be smooth.

5.1.2 Flume material shall be demonstrated as strong enough to support specified loads as defined in Section 8.

5.1.3 Flume components, maintained using the manufacturer's instructions, shall not deteriorate over time in such a way that a hazard will develop.

5.2 *Support Materials*—Any material that has the following basic properties and that meets all other requirements of this practice may be used to construct water slide supports:

5.2.1 Supports for water slides shall be constructed from durable materials such as wood, metal, concrete, or engineered composites.

5.2.2 Supports for water slides fabricated from metal shall be either inherently corrosion resistant, or be finished in such a way as to provide protection from corrosion.

5.2.3 Wood materials shall be finished in such a way to provide protection against deterioration.

5.2.4 Support material shall be demonstrated as strong enough to support specified loads as defined in Section 7.

5.2.5 Supports shall be constructed to accommodate regular inspection and maintenance for structural integrity, material deterioration, or corrosion, or a combination thereof.

6. Notification Requirement

<https://standards.iteh.ai/catalog/standards/sist/66cebd26-9060-46d2-955f-4915ed27a1f3/astm-f2376-21>

6.1 A water slide system shown to comply with this practice shall meet all applicable requirements specified in this practice. Anyone representing compliance with this practice shall keep such essential records as are necessary to document any claim that the requirements within this specification have been met.

6.2 The owner/operator of a water slide shall notify the appropriate manufacturer(s) of any known incident as specified in Guides F1305 and F893.

6.3 The manufacturer shall notify the appropriate owner(s)/operator(s) of similar water slides of an incident that resulted in a serious injury promptly upon the determination by the manufacturer that the incident is significantly repeatable.

6.3.1 Such manufacturer notification shall be a bulletin as specified in Sections 4.1.14.3 through 4.1.14.8 of Practice F853.

7. Structural Design of Water Slides

7.1 This section defines the loading and strength criteria that shall be used in the structural engineering of water slide flumes and supporting structures. The strength and stability of the water slide system shall be demonstrated by generally accepted engineering methods certified by a professional engineer.

7.2 *Dead Loads (symbol DL)*—Forces resulting from weight of all components of the ride and includes all loads that do not fluctuate with respect to time.

7.3 *Operational Loads*—Forces from water, riders, or vehicles, or a combination thereof, in the ride under normal operations.

7.3.1 *Water Load (symbol WL)*—In free flowing water slides where water does not collect in pools or streams greater than 2 in. deep, the water load shall be a minimum of 15 lbs/linear ft for every 1000 gal/min of flow. Where the flow is such that water collects in pools or streams greater than 2 in. deep, the actual maximum water load shall be determined and used in calculation, design, or load tests, or a combination thereof.

7.3.2 *Rider Load (symbol RL)*—The manufacturer shall specify the rider vehicle and the maximum number of riders that are to ride in the flume at one time.

7.3.2.1 For water slides intended for multiple rider use, the weight assigned to each rider shall be, at a minimum, the weight specified for an adult rider in Section 8.6.1 of Practice F2291.

7.3.2.2 For single rider water slides, the rider weight shall be a maximum of 300 lb.

7.3.2.3 For water slides intended for use by children only, the weight assigned to a child shall be as specified in Section 8.6.2 of Practice F2291.

7.3.2.4 Ride loads shall be so arranged to cause the greatest realistic operational load to the system.

7.3.2.5 Lateral centripetal forces shall be considered in curved sections of flume. Predicted rider speeds should be used to calculate these forces. If speeds cannot be predicted, then a minimum of 15 ft/s for flumes under 15 % slope and 30 ft/s for all other flumes shall be used.

7.3.2.6 If the manufacturer places maximum rider total weight limits on a slide, then that restricted load may be used.

7.3.2.7 The weight of the rider vehicle shall be included in determining rider load.

7.4 *Environmental Loads*—Forces from environmental conditions of the site such as wind, precipitation, earthquake, and changes in temperature.

7.4.1 Loads and forces due to environmental conditions shall be in accordance with applicable local code requirements or ANSI/ASCE 7, or other equivalent national standard.

7.4.2 The manufacturer/designer shall clearly indicate the environmental loads the water slide was designed for in the operating and maintenance instructions as specified in the sections on Manufacturer's Responsibility of Practices F770 and F853. In addition to the environmental load information, any restriction, limitations, or special procedures associated with water slides exposed to these environmental loads shall be included.

7.4.3 *Lateral Wind Load (symbol LWL)*—For outdoor slides, the minimum wind load for all types of water slides shall be calculated based on 100-mph wind (3-s gust) for non-operational conditions. Lateral wind load may be reduced by an importance factor of less than 1.0, where appropriate, for water slide structures that are unoccupied during extreme weather.

7.4.4 *Reduced Lateral Wind Load (symbol RLWL)*—For outdoor slides, the minimum wind load for all types of water slides shall be calculated based on Section 8.13.1 of Practice F2291 for operational conditions.

7.4.5 *Other Lateral Loads (symbol OLL)*—A minimum lateral load equivalent to 10 % of the dead weight of the structure shall be included.

7.4.6 *Snow Load (symbol SL)*—The snow load for all types of water slides shall be calculated in accordance with the relevant local ground snow load(s).

7.5 *Overload*—Forces from water, riders, or vehicles, or a combination thereof, under extraordinary operational conditions due to user overload.

7.5.1 Calculations for extraordinary operational conditions that consider user overload shall be based on conditions specified by the manufacturer and need not consider any other live load in combination with such overload.

~~7.6 Load Combinations—Engineering calculations may use either allowable stress methods (ASD) or load and resistance factor methods (LRFD). Engineering calculations shall consider load conditions and combinations of loads in accordance with generally accepted engineering methods. Calculations shall consider that water slide systems may not be occupied during extremes of weather.~~

~~7.7 Metal Structures—Strength of steel structures under or above noted loads shall be designed in accordance with current AISC, ASCE standards,⁵ or equivalent national standards.~~

~~7.8 Wood Structures—Strength of timber structures under or above noted loads shall be designed in accordance with current USDA-72, ASCE standards,⁵ or equivalent national standards.~~

~~7.9 Concrete Structures—Strength of concrete structures under above noted loads shall be designed in accordance with current ACI-318 or equivalent national standards.~~

~~7.10 Plastic and Plastic Composite Structures:~~

~~7.10.1 Strength of plastic structures under above noted loads shall be designed in accordance with generally accepted engineering methods. Assessment shall be performed in a manner suitable for the specific material and structure.~~

~~7.10.2 Fiberglass reinforced plastic or other composite materials used structurally shall have samples tested for strength with accelerated aging in accordance with Test Methods D570, D638, and D790.~~

~~7.10.3 Loads from normal operational conditions shall demonstrate a minimum of 5 to 1 factor of safety against rupture for fiberglass reinforced plastic or other composite materials.~~

~~7.10.4 Calculations for extraordinary operational conditions from user overload shall demonstrate a minimum of 2 to 1 factor of safety against rupture of fiberglass reinforced plastic or other composite materials.~~

4. Performance RequirementsDesign

~~4.1 General Requirements:~~Slide Classification:

~~8.1.1 The following are minimum requirements and should not be substituted where manufacturer experience suggests more acrimonious values.~~

~~8.1.2 Surfaces in reach by slide attendants and riders shall be made in such a way as to reduce the potential for injury.~~

~~4.1.1 A water slide shall be designed and constructed so that forces on riders allow the rider to use the slide in accordance with the rules and instructions under normal operating conditions. Water slides are classified by their physical and intended use characteristics. The classification may be a combination of the specific rider vehicle used the type of geometric path, often serpentine or straight, and the designation as a speed slide if the rider's velocity exceeds 25 ft/s. The following are definitions of the types of water slides.~~

~~4.1.1.1 body slides—water slide used without a vehicle.~~

~~4.1.1.2 children's slides—Water slides generally intended only for use by persons under the height of 48 in. Water slide has a maximum fall distance of 3 in. from slide exit where the rider enters the water and water depth is no greater than 24 in.~~

~~4.1.1.3 mat slides—water slide used with a designated mat as a vehicle.~~

~~4.1.1.4 serpentine slide—curved path as viewed in geometric slide path.~~

~~4.1.1.5 specialty slides—proprietary water slide design, such as an uphill, half-pipe, or bowl ride, which does not conform to standard classification.~~

~~4.1.1.6 specialty vehicle slides—water slide used with a proprietary vehicle specified by the manufacturer.~~

4.1.1.7 *speed slide*—water slide where the rider(s) achieve a velocity of 25 ft/s or more during the course of the ride.

4.1.1.8 *tube slides*—water slide used with a single or multi-person water slide tube.

4.2 *Slide Access: Notification Requirement*—

8.2.1 *General*—Fencing, guardrails, and handrails shall be installed in accordance with Section 14 of Practice F2291. A water slide system shown to comply with this practice shall meet all applicable requirements specified in this practice. Anyone representing compliance with this practice shall keep such essential records as are necessary to document any claim that the requirements within this specification have been met.

8.2.2 If the water slide system includes a starting platform and the platform is more than 21 in. above surrounding terrain, the platform shall provide at least 36 in. in distance between the slide entry and the top of stairs or ramp. Sufficient space shall be provided on the platform for slide attendant workspace, signage, and any communication devices needed for operation. Except where a stair or ramp or slide entry joins it, the platform shall be surrounded on all sides by a guardrail in accordance with Section 14 of Practice F2291.

8.2.3 Surface of steps, access ramp, and deck shall be slip-resistant and self-draining.

8.2.4 Slide entry section should interface with the platform guardrail so that a 4 in. sphere cannot pass between the slide entry component and the adjacent guardrail component.

4.3 *Structural Design of Water Slides:*

4.3.1 This section defines the loading and strength criteria that shall be used in the structural engineering of water slide flumes and supporting structures. The strength and stability of the water slide system shall be demonstrated by generally accepted engineering methods certified by a professional engineer.

4.3.1.1 Basic load descriptions are provided below and within Appendix X2.

4.3.1.2 In the absence of a recognized national building code, the basic loads defined below shall be combined with guidance provided by Practice F2291-19^{e1}, with the exception that ASCE/SEI 7-16 shall be used.

4.3.1.3 The ASCE/SEI 7-16 and later calculates basic wind loads as ultimate wind loads. This document provides the ultimate wind speeds for use with the load combinations provided in Appendix X2.

4.3.1.4 Basic loads are forces, pressures, movements, etc. defined by a magnitude, direction, and application location. Basic loads are not yet combined with other loads.

4.3.1.5 Basic load case values such as wind, live, and dead shall be combined using pre-defined Load Combinations within ASCE/SEI 7-16 when no other load combination guidance is required by the jurisdiction. Some of these load combinations are provided within Appendix X2 as they appear within ASCE/SEI 7-16. Load combinations are defined for allowable stress design (ASD) and ultimate strength design (USD) methodologies, respectively. The engineer will ensure that load combinations are used consistently with matching resistance levels.

4.3.2 *Dead Loads (symbol D)*—Forces resulting from weight of all components of the ride and includes all loads that do not fluctuate with respect to time.

4.3.2.1 *Ice Loads (symbol D,i)*—Forces resulting from the calculated accumulation of ice on exterior water slide components that correspond to the location's ice risk category.

4.3.3 *Live Loads (symbol L)*—Forces resulting from live load occupancy requirements including, but not limited to egress corridors, public assembly, queuing areas, maintenance platforms or catwalks. Also, forces from water, riders, rider vehicles, or a combination thereof, in the slide system, are defined herein.

4.3.3.1 *Slide Live Load (symbol L,s)*—Forces from water, riders, rider vehicles, or a combination thereof, in the system under its pre-established and defined normal operations. $L_s = \text{water loads}(L,f) + \text{rider loads}(L,p)$.

4.3.3.2 Water Load (symbol L_f)—One component of the slide live load. In free flowing water slides where water does not collect in pools or streams greater than 51 mm (2 in.) deep, the water load shall be a minimum of 0.35 kN/m (22.5 pounds per linear foot) for every 100 liters per second (1500 gallons per minute) of flow. Where the flow is such that water collects in pools or streams greater than 51 mm (2 in.) deep, the actual maximum water load shall be determined and used in calculation, design, or load tests, or a combination thereof.

4.3.3.3 Rider Load (symbol L_p)—One component of the slide live load. The manufacturer shall specify the rider vehicle weight and the maximum number of riders that are to slide in the flume at one time to the designer/engineer.

(1) For water slides intended for multiple rider use, the weight assigned to each rider shall be, at a minimum, the weight specified for a rider within 4.3.3.3(2).

(2) Each water slide rider shall be modeled as a 1.33 kN (300 lb) point load rationally distributed by the rider vehicle stiffness, or over a 762 by 762 mm (30 by 30 in.) area for an individual rider with no vehicle.

(3) Rider loads shall be so arranged to cause the greatest realistic stress on each structural element within the water slide system.

(4) Lateral centripetal forces shall be considered in curved sections of flume using live loads. Predicted rider speeds should be used to calculate these forces. If speeds cannot be predicted, then a minimum of 4.6 m/s (15 ft/s) for flumes under 15 % slope and 9.1 m/s (30 ft/s) for all other flumes shall be used.

(5) If the manufacturer allows rider loads in excess of those defined herein, then the designer/engineer shall design for the higher load provided by the manufacturer.

(6) The weight of the rider vehicle shall be added to and included in determining rider load.

4.3.3.4 Live loads are loads produced by the intended use, occupancy, reasonably expected operations, maintenance, and person rescue applied to the water slide structural system. Live loads shall never be less than the loads required within this specification, even if operational limitations may justify a lesser load.

4.3.4 Environmental Loads—Forces from environmental conditions of the site such as wind, precipitation, earthquake, and changes in temperature.

4.3.4.1 Loads and forces due to environmental conditions shall be applied consistently in accordance with the applicable building code requirements or guidance provided by this standard.

4.3.4.2 The manufacturer and designer/engineer shall clearly indicate the design environmental loads within the water slide system's operating and maintenance instructions, as specified in the sections on manufacturer's responsibility within Practices F770-18 and F1193-18. In addition to the environmental load information, any restriction, limitations, or special procedures associated with water slides exposed to these environmental loads shall be included.

4.3.4.3 Wind Load (symbol W)—For outdoor slides, the minimum wind load for all types of water slides shall be calculated based on the local jurisdiction's minimum wind speed velocity using the following:

- Duration equal to 3-s gust.
- Height equal to (10.06 m) 33 ft above grade.
- Exposure C is defined as open terrain with scattered obstructions.
- The return interval (of 300, 700, and 1700 years) is based on the water slide systems' risk category.

(1) Non-operational in the wind (symbol W_n)—In the absence of a local building code, the wind load shall be calculated based on a minimum 3-s gust, 700-year MRI basic wind speed of 58 m/s (130-mph) during non-operational conditions.

(2) Operational in the wind (symbol W_s)—For outdoor slides the operational wind load for all types of water slides shall be calculated based on a minimum 3-s gust, 700-year MRI wind speed of 25 m/s (60-mph) during operational conditions.

4.3.4.4 Other Lateral Loads – for example, Notional Loads (symbol N)—A minimum lateral load equivalent to 10 % of the dead weight and superimposed D of the structure shall be included or minimum notional load required by structural material specifications (whichever is larger).

4.3.4.5 Snow Load (symbol S)—The snow load for all types of water slides shall be calculated in accordance with the relevant local ground snow load(s).

4.3.4.6 Rain Load (symbol R)—The rain load shall be calculated for outdoor slides and incorporated into operational and non-operational load combinations.

4.3.4.7 Temperature Change Loads (symbol T)—The temperature change load shall be calculated for outdoor/exposed water slides and incorporated into operational and non-operational load combinations.

4.3.4.8 Seismic Loads (symbol E)—The seismic load shall be calculated for all slides and incorporated into load combinations for operational and non-operational load combinations. Seismic loads shall be considered during both operational and non-operational conditions.

4.3.4.9 The environmental loads during operation shall always conform to the minimum requirements within this document and Practice F2291-19^{e1} regardless of operational manual limitations. However, when the operations manual dictates operational limits that are higher (or more severe) than this document and Practice F2291-19^{e1}, the environmental loads during operations shall be increased to those written within the operations manual.

4.3.5 Overload—Forces from water, riders, or vehicles, or a combination thereof, under extraordinary operational conditions due to user overload.

4.3.5.1 Calculations for extraordinary operational conditions that consider user overload shall be based on conditions specified by the manufacturer and need not consider any other live load in combination with such overload.

4.3.5.2 Chain Load (symbol L_p)—A required overload case where multiple ride vehicles (or single riders) slide down the flume connected. This load case shall be considered regardless of operational limitations. The chain load shall be applied within load combinations as a live load in place of the slide live load, using the same live load factors. Apply the chain load as a moving load that starts at the top of the flume and ends at the flume's bottom. This load is defined as a 1.5 kN/m (103 plf) over a 5.0 m (16.4 ft) length segment.

4.3.5.3 Jam Load (symbol A)—An overload case where a ride vehicle or individual rider stops or is stuck on the slide. Subsequent ride vehicles or individual riders accumulate behind the blockage. This load shall be used in place of the slide live load using a 1.0 load factor for service (ASD) combinations, and a 1.3 load factor for ultimate (USD) combinations. The load is defined as a 1.5 kPa (31 psf) over the projected plan area of the entire length of the flume. This load may be omitted where there is a 20 % or more vertical slope.

4.3.6 Load Combinations—Shall be calculated according to Practice F2291-19^{e1}, Section 8. Engineering calculations may use either service level (ASD) or ultimate level methods (LRFD). Whichever load combination method is used, the subsequent analysis and material resistance calculations shall be performed consistent with the load combination method chosen. Engineering calculations shall consider load conditions and simultaneous occurrence of loads in accordance with generally accepted engineering methods. Calculations shall consider load combinations when water slide systems are not occupied and may experience extreme (or maximum design) weather.

4.3.6.1 Operational Load Combinations—For guidance on operational load combinations refer to Practice F2291-19^{e1}, Section 8.

4.3.7 Metal Structures—Strength of steel structures under or above noted loads shall be designed in accordance with current AISC, ASCE standards,⁴ or equivalent national standards.

4.3.8 Wood Structures—Strength of timber structures under or above noted loads shall be designed in accordance with current USDA-72, ASCE standards,⁴ or equivalent national standards.

4.3.9 Concrete Structures—Strength of concrete structures under above noted loads shall be designed in accordance with current ACI-318 or equivalent national standards.

4.3.10 Plastic and Plastic Composite Structures:

4.3.10.1 Strength of plastic structures under above noted loads shall be designed in accordance with generally accepted engineering methods. Assessment shall be performed in a manner suitable for the specific material and structure.

4.3.10.2 Fiberglass reinforced plastic or other composite materials used structurally shall have samples tested for strength with accelerated aging in accordance with Test Methods D570, D638, and D790.

4.3.10.3 Loads from normal operational conditions shall demonstrate a minimum of 5 to 1 factor of safety against rupture for fiberglass reinforced plastic or other composite materials.

4.3.10.4 Calculations for extraordinary operational conditions from user overload shall demonstrate a minimum of 2 to 1 factor of safety against rupture of fiberglass reinforced plastic or other composite materials.

4.4 *Open Flume Geometry: Performance Requirements:*

4.4.1 Flume cross-section shape shall be configured to contain the rider(s) or vehicle, or both, under all reasonable operating conditions. Total depth of section and shape of cross-section of a flume may be created in a single piece or more than one piece. *General Requirements:*

4.4.1.1 The following are minimum requirements and should not be substituted where manufacturer experience suggests more acrimonious values.

4.4.1.2 Surfaces in reach by slide attendants and riders shall be made in such a way as to reduce the potential for injury.

4.4.1.3 A water slide shall be designed and constructed so that forces on riders allow the rider to use the slide in accordance with the rules and instructions under normal operating conditions.

4.4.2 Open water slide flumes shall be kept clear of obstacles within the water slide clearance envelope as shown in Figs. 1 and 2. Flume riser sections may be added to block access to anything encroaching in the area. *Slide Access:*

4.4.2.1 *General*—Fencing, guardrails, and handrails shall be installed in accordance with Section 14, Fencing, Guardrails, Handrails, Gates, and Walkways for Amusement Rides and Devices, of Practice F2291-19^{e1}.

4.4.2.2 If the water slide system includes a starting platform and the platform is more than 21 in. above surrounding terrain, the platform shall provide at least 36 in. in distance between the slide entry and the top of stairs or ramp. Sufficient space shall be provided on the platform for slide attendant workspace, signage, and any communication devices needed for operation. Except

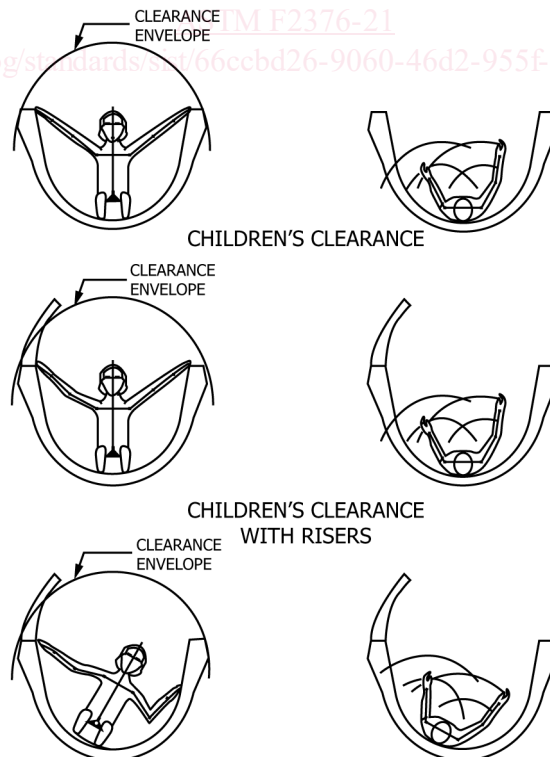


FIG. 1 Water Slide Clearance Envelope

where a stair or ramp or slide entry joins it, the platform shall be surrounded on all sides by a guardrail in accordance with Section 14, Fencing, Guardrails, Handrails, Gates, and Walkways for Amusement Rides and Devices, of Practice F2291-19^{e1}.

4.4.2.3 Surface of steps, access ramp, and deck shall be slip-resistant and self-draining.

4.4.2.4 Slide entry section should interface with the platform guardrail so that a 4 in. sphere cannot pass between the slide entry component and the adjacent guardrail component.

4.4.3 Water slides shall have additional sidewall height provided by a flume riser section on the outside part of all horizontal curves to contain the rider. This flume riser shall be concave facing the center of the cross-section. The flume riser may be an integral or separate part from the main flume component. *Open Flume Geometry:*

4.4.3.1 *Flume Riser Transition*—Flume riser parts shall be transitioned from sections without flume risers to sections with flume risers with a maximum angle of 45° from the horizontal. See cross-section shape shall be configured to contain the rider(s) or vehicle, or both, under all reasonable operating conditions. Total depth of section and shape of cross-section Fig. 3 of a flume may be created in a single piece or more than one piece.

4.4.3.2 Open water slide flumes shall be kept clear of obstacles within the water slide clearance envelope as shown in Figs. 1 and 2. Flume riser sections may be added to block access to anything encroaching in the area.

4.4.3.3 *Other Additions*—Where a cover, a tube entrance, or a flume riser is fitted other than at the beginning of the slide, the sides of the slide shall have a smooth transition from horizontal to vertical. Maximum angle of transition will be 45°. The inside height of the entrance to the cover or Water slides shall have additional sidewall height provided by a flume riser section on the outside part of all horizontal curves to contain the rider. This flume riser shall be at least 48 in. concave facing the center of the cross-section. The flume riser may be an integral or separate part from the main flume component.

(1) *Flume Riser Transition*—Flume riser parts shall be transitioned from sections without flume risers to sections with flume risers with a maximum angle of 45° from the horizontal. See Fig. 3.

(2) *Other Additions*—Where a cover, a tube entrance, or a flume riser is fitted other than at the beginning of the slide, the sides of the slide shall have a smooth transition from horizontal to vertical. Maximum angle of transition will be 45°. The inside height of the entrance to the cover or flume riser shall be at least 48 in.

4.4.3.4 Body slides with curved bottom flume sections such that the cross-section of the bottom and the sides are a continuously curving surface shall have:

- (1) Minimum inside width of 30 in., minimum sidewall height of 15 in., and
- (2) The top 1 in. of curved sidewalls shall be within 10° of vertical.

4.4.3.5 Tube slides with flat bottom flume sections shall have:

- (1) Minimum width of 48 in. inside sidewalls,
- (2) Minimum sidewall height of 24 in., and
- (3) Sidewalls that are straight may diverge from vertical a maximum of 2 in. measured at 24 in. from bottom.

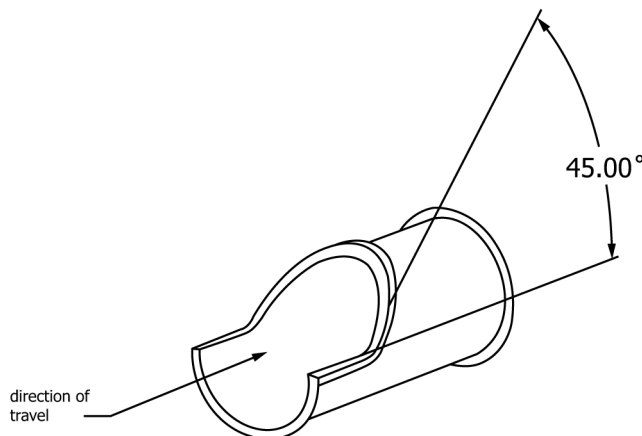


FIG. 3 Flume Riser