



AEROSPACE STANDARD

AS8994™

Issued

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Emergency Evacuation Slides, Ramps, Ramp/Slides, and Slide/Rafts

RATIONALE

The S-9A committee was informed that the FAA is planning to revise TSO-C69c in the near future, and it was requested that the committee develop an aerospace standard (AS) that would establish the minimum performance requirements for emergency evacuation devices. The intent of this AS is to update the requirements from TSO-C69c based on lessons learned and to clarify certain requirements that are considered to be vague or in need of updating.

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1. SCOPE

This AS provides the minimum performance requirements for the following types of inflatable emergency evacuation devices (hereinafter referred to as device[s]):

1. Type I - Inflatable Slide: A device suitable for assisting occupants in descending from a floor-level airplane exit or from an airplane wing to the ground. A Type I off-wing slide is a device that does not include a ramp.
2. Type II - Inflatable Slide/Raft: A device suitable for assisting occupants in descending from a floor-level airplane exit or an airplane wing to the ground that is also designed to be used as a life raft. A Type II off-wing slide/raft is a device that does not include a ramp.
3. Type III - Inflatable Exit Ramp: A device suitable for assisting occupants in descending from certain overwing exits to an airplane wing.
4. Type IV - Inflatable Ramp/Slide: A device suitable for assisting occupants from an overwing exit or airplane wing to the ground. It is a combination ramp and wing-to-ground device.
5. Type V - Inflatable Ramp/Slide/Raft: A device suitable for assisting occupants from an overwing exit or airplane wing to the ground. It is a combination ramp and wing-to-ground device that is also designed to be used as a life raft.

1.1 Purpose

This document provides the minimum performance standards for inflatable emergency evacuation slides, overwing exit ramps, ramp/slides, slide/rafts, and ramp/slide/rafts. However, in addition to the requirements in this AS, the deployment and erection characteristics for these devices as installed on airplanes are also addressed in regulatory requirements such as FAA 14 CFR § 25.810 (EASA CS § 25.810). These regulatory requirements shall be complied with prior to the device being approved for installation on an airplane.

1.2 Alternate Means of Compliance

For requirements defined herein that specify the compliance to be shown by test, compliance shall be demonstrated by test unless it can be shown that a combination of testing and analysis will provide equivalent results. If a combination of testing and analysis is used, the test data shall be shown to be applicable to the design being qualified. If an analysis is presented as the sole means of compliance, the validation of the analysis method shall also be provided.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of a conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption or Equivalent Level of Safety (ELOS) has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS-STD-595® Colors Used in Government Procurement

ARP1282B Survival Kit - Life Rafts and Slide/Rafts

AS1241 Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft

2.1.2 AATCC Publications

Available from American Association of Textile Chemists and Colorists, 1 Davis Drive, Research Triangle Park, NC 27709-2215, Tel: +1 919-549-8141, www.aatcc.org.

AATCC 183 Test Method for Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D1141-98 Standard Practice for Preparation of Substitute Ocean Water

ASTM D1434-82 Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting

ASTM D1894-14 Standard Test Method for Determining Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting

NOTE: ASTM D1894-14 was withdrawn by ASTM with no replacement in March 2023.

2.1.4 FAA Airworthiness Standards

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-0000, www.gpoaccess.gov.

14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes

14 CFR Part 91 General Operating and Flight Rules

49 CFR Part 178 Specifications for Packagings

2.1.5 FAA Publications - Other

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 21-46A Technical Standard Order Program

AC 25-17A Aircraft Interiors Crashworthiness Handbook

TSO-C13 Life Preservers

TSO-C69c Emergency Evacuation Slides, Ramps, Ramp/Slides, and Slide/Rafts

TSO-C85a Survivor Locator Lights

Aircraft Materials Fire Test Handbook (available online at <https://www.fire.tc.faa.gov/Handbook>.)

2.1.6 EASA Airworthiness Standards

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

CS-25 Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes

2.1.7 EASA Publications - Other

EASA ETSO-C13 Life Preservers

EASA ETSO-C69c Emergency Evacuation Slides, Ramps, Ramp/Slides, and Slide/Rafts

EASA ETSO-C85a Survivor Locator Lights

2.1.8 EPA Publications

Available from U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, Tel: 202-564-4700, www.epa.gov.

EPA-570/9-76-003 National Interim Primary Drinking Water Regulations

2.1.9 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment

2.1.10 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-DTL-5624 Detail Specification: Turbine Fuel, Aviation, Grades JP-4 and JP-5

MIL-PRF-23699 Performance Specification: Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number O-156

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AS4492 Survivor Locator Lights

2.2.2 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

14 CFR Part 21 (Subpart O) Technical Standard Order Approvals

14 CFR Part 121 Operating Requirements: Domestic, Flag and Supplemental Operations

2.3 Definitions

AIRCRAFT: Any machine that can fly. Airplanes, hot air balloons, helicopters, or even flying platforms are considered aircraft.

AIRPLANE: A specific type of aircraft that has fixed wings and is heavier than air that is capable of sustained, powered flight.

AMBIENT TEMPERATURE: 77 °F ± 18 °F (25 °C ± 10 °C)

CRITICAL FLOTATION CHAMBER: The chamber in a dual chamber slide/raft that, when deflated, results in the lowest single freeboard measurement on the slide/raft.

CRITICAL WIND ANGLE: The angle(s) at which winds have the greatest adverse effect upon the device's ability to convey evacuees safely to the ground (e.g., where there is the greatest lateral and/or torsional displacement or buckling or tendency for the device to float above the ground).

DARK-OF-NIGHT CONDITIONS: Exterior lighting conditions measured at the ground end of the assisting device and at the exit shall not exceed 0.005 foot-candle (0.05 lx).

DEPLOYMENT TIME: Time from the initiation of the door opening means or deployment mechanism (e.g., the point of no return of the deployment mechanism) to when the device is fully extended and ready for use. Refer to 14 CFR § 25.810(a)(1)(i), (a)(1)(ii), (b), and (d)(4).

DITCHING SILL HEIGHT: Planned and Unplanned - "Planned" is the nominal exit sill height above the water corresponding to a planned ditching event where there has been sufficient time available to prepare the airplane for the ditching by reducing the airplane weight as much as possible by jettisoning and/or consuming fuel and there is no damage to the airplane. "Unplanned" is the lowest exit sill height above the water corresponding to an unplanned ditching event where an airplane has entered the water without damage at its maximum takeoff weight (MTOW).

FLOOR (DECK): That portion of the slide/raft which is the walking or sliding surface or the seating area within the raft.

GIRT: The typical means by which a device is attached to an airplane. It consists of a strong fabric that is attached to the airplane via a girt bar or other structural means at one end and is attached to the inflatable device at the other end.

HIGH VISIBILITY COLOR: International orange-yellow or a bright orange-yellow color similar to color numbers 28915 or 38903 of AMS-STD-595®.

INFLATION TIME: Time from the initiation of the inflation system to when the device is fully extended and ready for use. Refer to 14 CFR § 25.810(a)(1)(i), (a)(1)(ii), (b), and (d)(4).

MAX OPERATING PRESSURE: The maximum pressure (in each/every chamber) that may be reached after the device has reached a usable attitude. Typically, this pressure is determined during the device developmental process when evaluating all test conditions.

MAXIMUM SILL HEIGHT: The maximum height above the ground of the exit sill corresponding to the collapse of one or more of the airplane landing gear legs accounting for airplane pitch and roll.

MIN OPERATING PRESSURE: The minimum pressure (in each/every chamber) at which the evacuation rate requirement of 4.6.4.1 can be met.

MIN RAFT MODE PRESSURE: The minimum pressure required to meet the minimum design buoyancy requirements of 4.3.2.

MINIMUM SILL HEIGHT: The lowest height above the ground of the exit sill corresponding to the collapse of one or more of the airplane landing gear legs accounting for airplane pitch and roll.

MIN DISPATCH PRESSURE: The minimum reservoir pressure required to comply with the test conditions defined in this standard. This typically demonstrates that this inflation system pressure will inflate the device to at least minimum operating pressure under the cold soak test protocol described in Appendix H.

NOMINAL OPERATING PRESSURE: The mid-point of the range of pressures (in each/every chamber) obtained following an ambient deployment where the pressure is taken within 1 minute of the completion of the deployment.

NORMAL SILL HEIGHT: The nominal height above the ground of the exit sill with all airplane landing gear extended.

POTABLE WATER: Water suitable for drinking that does not contain minerals, chemical substances, or microorganisms in amounts that would be hazardous to health.

SLIDE USABILITY: An escape slide is considered usable when it is fully formed and extended at or below horizontal, and it is capable of being safely used by evacuees. In addition, the unoccupied slide, when viewed from the exit, shall appear to be safe for use.

USABLE SITTING AREA: The interior area of the device, i.e., the floor, defined by the innermost points of the uppermost buoyancy tube, or other inflatable support structure(s), with the device inflated to Nominal Operating Pressure and occupied at its rated capacity in fresh water.

2.4 Mandating and Recommending Criteria

SHALL: Indicates a mandatory criterion.

SHOULD: Indicates a criterion for which an alternative, including non-compliance, may be applied if it is documented and justified.

2.5 Abbreviations

AC	advisory circular
AS	aerospace standard
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
CS	certification specification
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
TSO	technical standard order
ELOS	Equivalent Level of Safety

3. MATERIALS

The materials used shall be of a quality which tests have demonstrated to be suitable for use in inflatable emergency slides, ramps, ramp/slides, slide/rafts, and ramp/slide/raft devices.

3.1 Nonmetallic Materials - General

3.1.1 Finished Device

The finished device shall be clean and free from any defects that might affect its function.

3.1.2 Materials Subject to Deterioration

Coated fabrics and other items that are subject to deterioration shall have been manufactured not more than 18 months prior to the date of manufacture of the finished product. However, these materials may be retested and recertified for use in manufacture of the finished product for an additional 18 months if they pass the requirements of 3.1.4, 3.1.5, 3.1.8, 3.1.9, and 3.1.10, as applicable. Alternate shelf-life recommendations may be considered if data and/or analysis can be provided which show that the material (or item) under consideration will meet its minimum design requirements for the service life of the device as defined by the manufacturer.

3.1.3 Fungus Resistance

Fabrics and other textile or elastomeric materials shall not support fungus growth, as demonstrated by successful completion of tests conducted in accordance with RTCA DO-160G, Section 13. Upon completion of the 28-day test, the test sample substrate shall be devoid of microbial growth. If the test samples exhibit only scattered, sparse, or very restricted microbial growth (trace amounts), testing of the samples shall be continued for an additional 56 days. If, at the end of the 84 days, the test sample substrate is devoid of microbial growth, the test is considered successfully completed. If there are still indications of microbial growth, the test is considered failed.

3.1.4 Accelerated Aging Susceptibility

Coated fabrics, including seams, which are subject to deterioration and are used in either air retentive or structural applications, shall retain at least 90% of their original physical properties when tested per the following sections (as applicable) after being subjected to the accelerated aging test specified in Appendix A.

a. Coated fabric strength (see 3.1.5)

b. Seam strength (see 3.1.8)

In addition, the post-accelerated aging test results shall be no less than the minimum values defined in 3.1.5 and 3.1.8.

3.1.5 Coated Fabric Strength

Coated fabrics shall conform to the following minimum strengths after being subjected to the accelerated aging test method in Appendix A.

3.1.5.1 Tensile Strength (Grab Test Per Test Method in Appendix B)

Warp: 190 pounds (86.4 kg)

Fill: 190 pounds (86.4 kg)

3.1.5.2 Tear Strength (Trapezoid or Tongue Test Per Test Method in Appendix C)

Non-walking/sliding surface: 13 x 13 pounds (5.9 x 5.9 kg)

Walking/sliding surface: 50 x 50 pounds (22.7 x 22.7 kg)

3.1.5.3 Puncture Strength (Per Test Method in Appendix D)

Walking/sliding surface: 67 lbf (15.1 N)

3.1.6 Permeance

For coated fabrics used in the manufacture of inflation chambers, the maximum permeance to helium or its equivalent using hydrogen shall not exceed 10 L/m²/atm in 24 hours at 73.4 °F ± 3.6 °F (23 °C ± 2 °C), when tested per ASTM D1434-82, Procedure V, except the coated fabric sample shall be pressurized to slide Nominal Operating Pressure. The permeameter shall be calibrated for the gas used.

3.1.7 Hydrolysis

Coated fabrics used in the manufacture of inflation chambers, including seams, shall be shown to be resistant to hydrolysis. It shall be shown that the porosity of the basic pressure holding material is not increased as a result of the material being subjected to hydrolysis conditioning in accordance with the test method specified in Appendix E. Seam peel and seam shear strength shall not be reduced more than 20% and shall not fall below the minimums prescribed in 3.1.8 as a result of hydrolysis conditioning.

3.1.8 Seam Strength

Seams used in the manufacture of the device shall meet the following minimum strength requirements after being subjected to the accelerated aging test method in Appendix A:

3.1.8.1 Seam Shear Strength (Per Test Method in Appendix F):

140 lb/in (2500.1 kg/m) width at 70 °F (21.1 °C)

60 lb/in (1071.5 kg/m) width at 160 °F (71.1 °C)

3.1.8.2 Seam Peel Strength (Per Test Method in Appendix G):

5 pounds (89.3 kg) at 70 °F (21.1 °C)

3.1.9 Flammability

Devices designed to be installed on an airplane inside the pressurized cabin shall be constructed of materials (including material constructions) that comply with the requirements of 14 CFR § 25.853(a).

The flammability requirement does not apply to devices that are designed to be installed on an airplane outside of the pressurized cabin.

For Type II and Type V devices that include a survival kit, the survival kit contents need not meet the flammability requirement provided that they are fully enclosed within a container that successfully completes the 12-second vertical burn test defined in 14 CFR Part 25, Appendix F, Part 1(b)(4).

3.1.10 Radiant Heat Resistance

The pressure holding materials in the device, including material constructions and stenciled/marked materials in the device, shall meet a 90-second minimum time to failure requirement and a 180-second average time to failure when subjected to the escape slide radiant heat resistance test specified in FAA Aircraft Materials Fire Test Handbook, Chapter 9.

3.1.11 Fuels, Oils, Hydraulic Fluid Resistance

Materials used in the construction of Inflatable chambers and floors shall resist the detrimental effects of jet fuel, oil, and hydraulic fluid.

- a. Fabric and seam samples used to demonstrate this capability shall be representative of the material and construction used in the device and shall be preconditioned per (b.) before testing for strength.
- b. Immerse separate samples in jet fuel (refer to MIL-DTL-5624), oil (refer to MIL-PRF-23699), and hydraulic fluid (refer to AS1241) for 5 minutes minimum (only the outside surfaces shall be soaked). For Type II and V devices, seal in separate airtight containers/enclosures for at least 24 hours at room temperature. Materials used in Type I, III, and IV devices do not require the 24-hour exposure time after the 5-minute soak time.

c. Fabric and seam samples shall meet minimum strength requirements and at least 80% of its original strength when tested for the following physical properties defined in 3.1.5 and 3.1.8 when tested for the following:

1. Tensile strength
2. Tear strength
3. Seam peel strength
4. Puncture strength (deck/sliding lane material only)
5. Seam shear strength

3.2 Nonmetallic Materials - Type II and V Devices

3.2.1 Flotation Chamber and Floors

Material used in the construction of buoyancy chambers and floors (exposed surfaces, including seams) shall resist the detrimental effects of sea water.

After 1-hour minimum exposure to sea water (e.g., synthetic sea water per ASTM D1141-98), the wetted samples shall be sealed in a plastic cover for at least 15 days. After excess sea water is drained off and then blotted dry, fabric and seam samples shall meet the minimum strength requirements defined in 3.1.5 and 3.1.8 when tested for the following:

- a. Tensile strength
- b. Tear strength
- c. Puncture strength (floor material only)
- d. Seam shear strength
- e. Seam peel strength

3.2.2 Canopy

Canopy fabrics shall be waterproof and resistant to sun penetration (provide a mean ultraviolet protection [UPF] of 30 or greater, as determined using AATCC Test Method 183-2000, or equivalent).

Canopy fabric shall not affect the potability of collected water, as determined by taking a 9-ft² (0.84-m²) fabric sample per 1 gallon (3.79 L) of distilled water ratio and combining for 16 hours. After removing sample, collected water shall not exceed the maximum contamination levels for inorganic and organic chemicals defined in EPA-570/9-76-003.

In addition, canopy fabric shall meet the following strength and color requirements:

3.2.2.1 Minimum Strength Requirements

- a. Tensile strength (Grab Test per test method in Appendix B):

Warp: 75 pounds (34.0 kg)

Fill: 75 pounds (34.0 kg)

In lieu of meeting the tensile strength requirements, a fabricated canopy erected on the device may be demonstrated to withstand sustained wind velocities of 35 kts (64.9 km/h) and 52 kts (96.4 km/h) gusts, as defined in 4.3.10.

- b. Tear strength (Trapezoid or Tongue Test per test method in Appendix C):

4 x 4 pounds (1.8 x 1.8 kg)

3.2.2.2 Canopy Color

Canopy surface visible from air shall be an international orange-yellow or an equivalent high-visibility color per AMS-STD-595®.

3.3 Protection of Materials

All inflatable chambers and load carrying fabrics shall be protected in such manner that non-fabric parts do not cause chafing or abrasion of the material during any phase of device use (e.g., packed, inflated, or during deployment) to the extent that the chafing or abrasion would impair proper function.

4. DETAIL REQUIREMENTS

4.1 System Requirements - General

The following requirements apply to all devices (Type I, II, III, IV, and V) unless otherwise noted.

4.1.1 System Operation

The operation of the device shall be simple enough so that brief, easily understood, posted instructions can be followed by the user.

4.1.2 Temperature

4.1.2.1 Operating Temperature

The device, including its inflation system, shall be demonstrated to be capable of fully functioning when subjected to temperatures from -40 to +160 °F (-40.0 to +71.1 °C). If the device is intended for installation outside the pressurized cabin, the device shall be capable of functioning after being stowed at -65 °F (-53.9 °C). The function of the device shall be demonstrated in accordance with the Hot and Cold Soak Test Protocol described in Appendix H, Section H.2.

4.1.2.2 Ground Survival Temperature

The device, including its inflation system, shall be demonstrated to be capable of fully functioning after prolonged exposure to temperatures ranging from -65 to +185 °F (-53.9 to +85.0 °C). The function of the device after exposure shall be demonstrated in accordance with the Ground Survival Temperature Test Protocol described in Appendix H, Section H.3.

4.1.3 Elimination of Static

The device, including its sliding surface and its fastening, shall be so constructed that static electricity shall not be generated in sufficient quantity to cause a spark which would create a hazard if there is any fuel spillage nearby. Resistance measured from the fastening to the airplane to where the inflatable contacts the ground shall be less than 2 MΩ.

4.1.4 Damage Resistance and Usage

4.1.4.1 Type I, II, IV, and V devices shall be constructed in a manner that permits their intended use as a non-inflatable device (with the assistance of persons on the ground) in the event of puncture or tear which may render the device incapable of holding air and sustaining inflation.

4.1.4.2 If the device has multiple inflatable compartments, the loss of any one compartment shall not render the device totally unusable.

4.1.5 Elimination of Encumbrances

The device shall have no components or features that are found to be encumbrances that impede the evacuation capability of the device. This shall be demonstrated during successful completion of the Evacuation Rate testing in 4.6.4.1 and Dark-of-Night testing in 4.6.4.2.

4.1.6 Hardware and Attaching Means Strength

- 4.1.6.1 The means used to attach the device to the airplane (including the packboard/enclosure/girt bar if part of the girt load path) shall withstand the maximum applicable loads with a safety factor of not less than 1.5X the highest design load, as defined in Appendix M.
- 4.1.6.2 All other straps, grips, handholds, and cords/webbings not associated with the attachment to the airplane, and not defined by a fixed load requirement, shall be designed and tested for their intended function in the system, and shall withstand the maximum applicable loads with a safety factor of not less than 1.5.

4.1.7 Inflation System

- 4.1.7.1 The inflation system shall be connected to the evacuation device and ready for instant use. After inflation, the system shall prevent any leakage that would adversely impact proper device function.
- 4.1.7.2 Gas storage reservoirs (cylinders) shall comply with 49 CFR Part 178, or DOT-approved equivalent, such as Special Permits issued by the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration.

4.1.8 Inflation Time

- 4.1.8.1 Type I (non-off-wing), Type II, and Type III devices shall meet a 6-second Inflation Time under Ambient Temperature conditions. For extreme temperature tests per 4.1.2.1, adverse attitude tests per 4.6.3, 25-kt (46.3-km/h) wind tests per 4.6.7, or ditching tests per 4.6.12, a 10-second Inflation Time is acceptable.
- 4.1.8.2 Type I (off-wing), Type IV, and Type V devices shall meet a 10-second Inflation Time under Ambient Temperature conditions. For extreme temperature tests per 4.1.2.1, adverse attitude tests per 4.6.3, 25-kt (46.3-km/h) wind tests per 4.6.7, or ditching tests per 4.6.12, a 16-second Inflation Time is acceptable.

4.1.9 Device Length Extensions

- 4.1.9.1 The device extension shall be capable of being inflated at any time during or after inflation of the basic device has been initiated. If inflated after the basic device, the time to inflate the extension device shall not exceed 4 seconds as measured from the time the extension device is actuated to when it is inflated to a usable condition.
- 4.1.9.2 Inflation of the extension can be initiated by separate controls from those used for the basic device. If actuated by separate controls, the controls shall be clearly identified, and they shall be located separate from the manual inflation actuation controls of the basic device to minimize the possibility of inadvertent actuation. The pulling force required shall not exceed 30 pounds (13.6 kg).

4.1.10 Multiple Lane Devices

- 4.1.10.1 A multiple lane device shall provide space for evacuees sliding simultaneously in each lane. Each sliding surface, if separated by a raised divider not considered to be a part of the sliding surface, shall be at least 20 inches (50.8 cm) wide. The combined width of two sliding surfaces not separated by a raised divider shall be at least 42 inches (106.7 cm), and there shall be a clear indication that there is more than one sliding lane. The multiple lane device with no raised lane divider shall enable evacuees to jump side-by-side into each slide lane simultaneously and reach the ground safely.
- 4.1.10.2 A multiple lane device shall resist adverse twisting or deflecting when subjected to maximum asymmetrical loading represented by evacuees traversing each lane of the device individually at the evacuation rate prescribed in 4.6.4.1. Test conditions shall be as specified in Appendix N, Section N.2, except that only Nominal Operating Pressure shall be tested.
- 4.1.10.3 When used, a raised divider or center median shall be constructed to prevent injury to evacuees and not to throw from the device evacuees who jumped into it astraddle or partly astraddle the divider or median. Multiple lane devices, if canted, shall have features to minimize the potential of evacuees crossing lanes due to the canting.

4.1.11 Overpressure Test - Design Margin

At least one specimen of the inflatable device model (e.g., lefthand or righthand, presuming inflatable is mirror image design) shall be demonstrated by test to withstand a pressure at least 2X the Maximum Operating Pressure without failure for at least 1 minute. Devices so tested shall be clearly identified and not be used for any evacuee-related testing.

4.1.12 Static Pressure Retention Test

Under static conditions and when inflated and stabilized at the Nominal Operating Pressure, the pressure in each inflatable chamber of Type II and Type V devices shall not fall below the Minimum Raft Mode Pressure in less than 24 hours. This shall be demonstrated by test.

For Type I, Type III, and Type IV devices, the pressure in each inflatable chamber shall not fall below 50% of the Nominal Operating Pressure in less than 12 hours. This shall be demonstrated by test.

4.2 System Requirements - Type I Devices

In addition to the system requirements identified in 4.1, the following requirements apply to Type I devices.

4.2.1 Buoyancy

Devices shall be designed to have positive buoyancy (freeboard > 0 inches or 0 cm) when extended so that they can be used as emergency flotation devices following an unplanned (or planned) ditching deployment.

4.2.2 Disconnect Means

4.2.2.1 A means to disconnect the device from the airplane shall be provided. The means shall be a readily apparent flexible cloth/webbing loop that is capable of being operated by untrained persons, and it shall be covered until ready for use.

4.2.2.2 Devices having airplane mounted inflation systems shall have means for rapid detachment from the airplane in a manner that does not result in loss of pressure that would adversely affect the device's use as an emergency flotation device.

4.2.2.3 The method of disconnecting the device from the airplane shall be conspicuously and clearly indicated by brief instruction placards.

4.2.3 Mooring Line

Devices shall be equipped with a mooring line so that the deployed device will automatically remain secured to the airplane when it is used as an emergency flotation device. The following shall also apply.

- a. The mooring line shall not endanger the device, cause the device to spill occupants if the airplane sinks, or interfere with the operation of the device.
- b. The knotted or assembled mooring line shall have a minimum length of 20 feet (6.1 m) and have a breaking strength of not less than 500 pounds (226.8 kg).
- c. The attachment to the evacuation device shall be stronger than the mooring line and shall comply with 4.1.6.2.
- d. The moored device shall be quickly and easily disconnected from the airplane.
- e. The mooring release means shall be readily apparent and operable by untrained evacuees.

4.2.4 Lifeline

Devices shall be equipped with a lifeline. The following shall also apply.

- a. The lifeline size shall be greater than or equal to 3/8-inch (0.95-cm) diameter or 1/2-inch (1.27-cm) width, 0.060-inch (0.15-cm) minimum thickness, and of a color that contrasts with the device.
- b. The lifeline shall be attached along at least 80% of the length of both sides of the device.
- c. The lifeline shall not interfere with the device's inflation or adversely compromise the use of the device as a slide.
- d. The lifeline and its attachment shall be capable of withstanding a minimum load of 500 pounds (226.8 kg).

4.3 System Requirements - Type II and V Devices

In addition to the general system requirements identified in 4.1, the following requirements apply to Type II and Type V devices.

4.3.1 Raft Capacity

4.3.1.1 Rated Capacity

The rated capacity shall be the Usable Sitting Area on the Floor surface of not less than 3.6 ft² (0.33 m²) per occupant.

4.3.1.2 Overload Capacity

The overload capacity shall be the Usable Sitting Area on the Floor surface of not less than 2.4 ft² (0.22 m²) per occupant.

4.3.1.3 Capacity - Alternate Rating Methods

In lieu of the rated capacity prescribed in 4.3.1.1, one of the following methods may be used:

- 4.3.1.3.1 The rated capacity of a device may be determined by the number of seating spaces which can be accommodated within the occupiable area exclusive of the perimeter structure (such as inflation/buoyancy chambers) without overlapping of the occupant seating spaces. The occupant seating spaces may not be dimensionally different than the following trapezoid (see Figure 1).

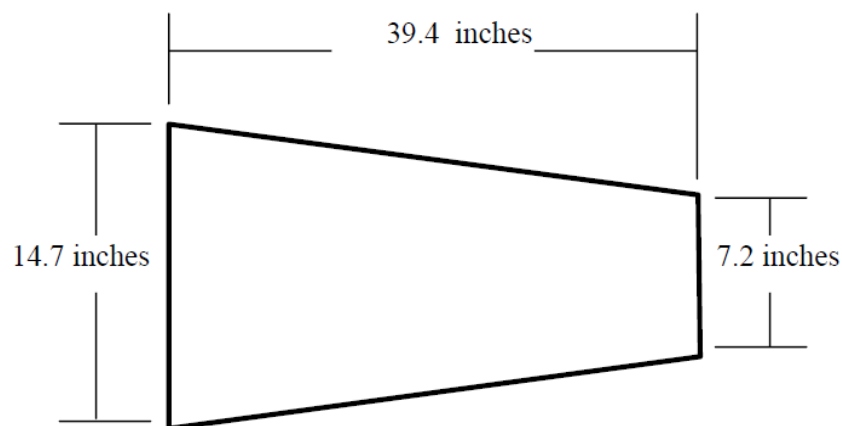


Figure 1 - Reprinted from 4.26.3.1 of FAA TSO-C69c

4.3.1.3.2 The rated capacity may also be determined by a controlled pool or freshwater demonstration which includes conditions prescribed in Appendix I and the following:

- a. The Usable Sitting Area on the raft floor may not be less than 3.0 ft² (0.28 m²) per occupant.
- b. At least 30% but no more than 50% of the participants shall be female.
- c. A raft commander, acting in the capacity of a crewmember, may direct occupant seating to the extent necessary to achieve reasonable weight distribution within the device.

4.3.2 Buoyancy

The device shall have two independent inflatable flotation chambers. If either chamber is deflated, the other chamber and the device floor shall be capable of supporting the rated and overload capacities in fresh water.

4.3.2.1 It shall be shown by tests conducted in accordance with Appendix I, Section I.1, that the device, loaded to rated capacity, has a freeboard of at least:

- a. 12 inches (30.48 cm) with both flotation chambers at Minimum Raft Mode Pressure; and
- b. 6 inches (15.24 cm) with the Critical Flotation Chamber deflated and the remaining flotation chamber at Minimum Raft Mode Pressure.

4.3.2.2 It shall be shown by tests conducted in accordance with Appendix I, Section I.1, that the device loaded to its overload capacity has a measurable freeboard with the Critical Flotation Chamber deflated and the remaining flotation chamber inflated to Minimum Raft Mode Pressure.

4.3.3 Inflation System

- a. Inflation systems for devices shall be designed so that failure of one inflatable chamber or manifold will not result in loss of gas from the other chamber.
- b. The inflation equipment shall be located so as not to interfere with boarding operations.

4.3.4 Mooring Line

- a. Devices shall be equipped with a mooring line so that the deployed device, loaded to rated capacity, will remain secured to the airplane.
- b. The mooring line shall not endanger the device, cause the device to spill occupants if the airplane sinks, or interfere with the operation of the device.
- c. The knotted or assembled mooring line shall have a minimum length of 20 feet (6.1 m) and have a breaking strength of not less than 500 pounds (226.8 kg).
- d. The attachment to the evacuation device shall be stronger than the mooring line and shall comply with 4.1.6.2.
- e. The moored device shall be quickly and easily disconnected from the airplane.
- f. The mooring release means shall be readily apparent and operable by untrained evacuees.

4.3.5 Lifeline

Devices shall be equipped with a lifeline. The following shall also apply:

- a. The lifeline size shall be greater than or equal to 3/8-inch (0.95-cm) diameter or 1/2-inch (1.27-cm) width, 0.060-inch (0.15-cm) minimum thickness, and of a color that contrasts with the device.
- b. The lifeline shall be attached along at least 80% of the length of both sides of the device.
- c. The lifeline shall not interfere with the device's inflation or adversely compromise the use of the device as a slide.
- d. The lifeline and its attachment shall be capable of withstanding a minimum load of 500 pounds (226.8 kg).

4.3.6 Capsize Resistance

The device shall be resistant to capsizing when empty or in any condition of raft load (e.g., with one or more occupants). The effectiveness of the capsize resistant design shall be demonstrated by a single test participant boarding in calm water in compliance with 4.3.8 and by compliance with the Sea Performance Test in 4.3.17.

4.3.7 Righting

Unless it is shown that there is no tendency for the device to become inverted during loading in compliance with 4.3.6 and release from the airplane in compliance with Appendix J, Section J.2, the device shall comply with the righting tests specified in Appendix I, Section I.2.

4.3.8 Boarding Aids

4.3.8.1 Boarding aids shall be provided at two opposing positions on the device.

4.3.8.2 Boarding aids shall permit unassisted entry from the water into the unoccupied device.

4.3.8.3 Boarding aids, when in use, shall not adversely affect the rigidity of the device.

4.3.8.4 If a boarding aid is inflatable, the puncturing of the boarding aid shall not affect the buoyancy of the device flotation chambers.

4.3.8.5 Boarding handles and/or stirrups used in conjunction with the boarding aids shall withstand a pull of 500 pounds (226.8 kg).

4.3.8.6 Boarding aids shall be demonstrated to comply with the test requirements of Appendix I, Section I.3.

4.3.9 Heaving-Trailing Line

At least one, floating, heaving-trailing line, not less than 75 feet (22.9 m) in length and at least 250 pounds (113.4 kg) strength, shall be accessible to device occupants and shall comply with 4.1.6.2.

4.3.10 Canopy

A canopy shall be packed with or attached to the device. The following shall also apply:

4.3.10.1 The erected canopy shall be capable of withstanding sustained wind velocities of 35-kt (64.9-km/h) and 52-kt (96.4-km/h) gusts without damage that would compromise canopy attachment or function, when demonstrated as follows:

4.3.10.2 Average 35-kt (64.9-km/h) wind speed shall be directed at the windward (sea anchor attachment) side of the device for 45 seconds $\pm$ 5 seconds. The wind velocity shall be increased to 52 kts (96.4 km/h) minimum for no more than 15 seconds followed by a return to the average 35 kts (64.9 km/h) steady state wind in less than 5 seconds. This wind cycle shall be completed at least three times.

- 4.3.10.3 The installed canopy shall provide openings at two opposing positions on the device. An opening is a path to enter the device at a boarding location (where boarding aids exist).
- 4.3.10.4 The canopy shall provide adequate headroom. This shall be demonstrated by showing there is a minimum clearance of 1 inch (2.54 cm) for a 95th percentile male (seated height) in at least 75% of the seating area of the device and a minimum clearance of 1 inch (2.54 cm) for a 50th percentile male (seated height) in the remaining 25% of the seating area.
- 4.3.10.5 Means shall be provided to close the canopy in a manner that resist the wind and rain from entering the device.
- 4.3.10.6 If the canopy is not integral with the device, it shall be capable of being erected by occupants following instructions provided with the device.
- 4.3.10.7 The canopy shall be capable of being erected by one occupant of an otherwise empty device and by occupants of a device filled to rated capacity.

4.3.11 Sea Anchor

A sea anchor, or anchors, or other equivalent means shall be provided to maintain the device, with rated capacity and canopy installed, on a substantially constant heading relative to the wind and shall have the ability to reduce the drift to 2 kts (3.7 km/h) maximum when subjected to winds of 17 to 27 kts (31.5 to 50.0 km/h).

- 4.3.11.1 The line securing a sea anchor to the device shall have a minimum breaking strength of 500 pounds (226.8 kg). The attachment of the line to the device shall be capable of withstanding a load of 1.5X the line rated strength without damaging the device.
- 4.3.11.2 The line shall be at least 25 feet (7.6 m) in length and shall be protected or positioned away from the mooring line detachment means to prevent it from being inadvertently cut (if a knife is used for mooring line release) by device occupants.

4.3.12 Emergency Inflation Equipment

A means readily accessible to occupants of the device shall be provided to manually inflate the device and maintain the raft mode minimum operating pressure.

- 4.3.12.1 The manual inflation means shall have a displacement of at least 32 in³ (524.4 cm³) per full stroke.
- 4.3.12.2 Manual inflation valves, with a non-return opening adequate for the size and capacity of the inflation means, shall be readily accessible and located to permit inflation of all chambers.
- 4.3.12.3 The inflation means and valves shall have provisions to prevent inadvertent removal and loss when either stowed or in use.

4.3.13 Knife

A hook-type knife secured by a retaining line shall be sheathed and attached to the device adjacent to the point of mooring line attachment. It shall be so installed that it cannot injure persons using the evacuation device in a normal manner.

4.3.14 Markings

Suitable markings in contrasting colors that are not detrimental to the fabric shall be provided to denote the use and location of the inflation systems, raft equipment, boarding aids, and righting aids. Legibility of markings shall not be affected by the sea water exposure test in Appendix I, Section I.4. The letters used for such markings shall be at least 2 inches (5.1 cm) high, except the details and miscellaneous instructions may be of smaller lettering. Applicable markings shall take into account persons boarding or righting the raft from the water. Markings shall comply with Radiant Heat Resistance requirements of 3.1.10.

4.3.15 Emergency Lights

A TSO-C85a, or later revision, approved survivor locator light shall be provided at or near each boarding station. The light shall be automatically activated upon device inflation in the water and release from the airplane, and a light shall be visible from any direction by persons in the water.

4.3.16 Actuation Means

If the device, as a slide, requires an additional operation to make it usable as a raft, the means for initiating the additional operation shall be designed to preclude inadvertent actuation but be readily available for use. If a pull motion is used, the force required shall not be more than 30 pounds (13.6 kg).

4.3.17 Sea Performance

The device shall be shown to be seaworthy in an open sea condition with maximum sustained winds of 17 to 27 kts (31.5 to 50.0 km/h) and waves of 6 to 10 feet (1.8 to 3.1 m), by meeting the requirements in Appendix J.

4.3.18 Survival Kit

The device shall be equipped with a survival kit per 14 CFR 91.509(e). The minimum survival kit contents shall be in accordance with the requirements of ARP1282B, Section 5. The survival kit shall also incorporate one pyrotechnic signaling device per 14 CFR 91.509(b)(3) or regulatory agency approved equivalent. If the survival kit is stored remotely from the device, the survival kit shall have the capability of being attached to the device prior to - or once it has been deployed in - a ditching situation.

4.4 System Requirements - Type III Device

There are no additional requirements specific to Type III devices.

4.5 System Requirements - Type IV Device

In addition to the general system requirements identified in 4.1, the following requirements apply to a Type IV device unless it can be shown that the device will not fully deploy in the airplane's range of foreseeable ditching sill heights.

4.5.1 Buoyancy

The device shall be designed to have positive buoyancy (freeboard > 0 inches or 0 cm) if extended so that it can be used as emergency flotation device.

4.5.2 Disconnect Means

4.5.2.1 A readily apparent disconnect means shall be provided to allow the inflated device to be released from the airplane. The means shall be capable of being operated by untrained persons and shall be covered until ready for use.

4.5.2.2 Devices having airplane mounted inflation systems shall have means for rapid detachment from the airplane in a manner that does not result in loss of pressure that would adversely affect the devices' use as an emergency flotation device.

4.5.2.3 The method of disconnecting the device from the airplane shall be conspicuously and clearly indicated by brief instruction placards.

4.6 System Requirements That Are Airplane and Door Type and/or Location Dependent

The following requirements, which apply to all devices (Type I, II, III, IV, and V) unless otherwise noted, shall be applied at each specific airplane location that they are intended to be used. As such, an airplane or airplane representative mockup(s) shall be used when demonstrating compliance to requirements in this section.

Airplane representative mockups, if used, shall meet the minimum requirements specified in Appendix K.

4.6.1 Deployment Time

The device shall be demonstrated to meet the applicable automatic deployment and inflation requirements of 14 CFR § 25.810 (a)(1)(i), (a)(1)(ii), (b), and/or (d)(4) in Ambient Temperature conditions at Normal Sill Height. This Deployment Time requirement only applies to testing conducted under 4.6.9.

4.6.2 Strength

4.6.2.1 Beam Strength

The structural integrity of the device during and after the dynamic challenge of multiple sandbag loading of the device (to simulate loading by three tightly bunched evacuees entering each lane of the device) shall be demonstrated to be adequate by test in accordance with the procedures defined in Appendix L.

4.6.2.2 Attachment Means Strength

The means by which the device is attached to the airplane, typically the girt, shall not fail and shall remain intact and suitably attached to both the airplane and the device during and after the severe loading tests simulating normal evacuation. The device shall withstand the applicable static tensile load tests defined in Appendix M (see Section M.2 for girts, or Section M.3 for non-girts, and Section M.4 for evacuees inadvertently entering pontoon areas), as appropriate. Separate girt specimens may be used in the two tests required in Section M.2.

4.6.3 Length

With the airplane landing gear extended, the device (Type I, II, IV, and V) shall be of such length after full deployment that the lower end is self-supporting on the ground. If necessary, the application of 100 pounds (45.4 kg) weight (maximum) can be used to demonstrate the device lower end contact with the ground.

The device shall provide safe evacuation of occupants to the ground when the airplane is on the ground with the landing gear extended and after collapse of one or more legs of the landing gear.

4.6.4 Evacuation Capability

4.6.4.1 Evacuation Rate

The device shall be demonstrated by tests conducted under the conditions described in Appendix N, Section N.2, to be capable of safely accommodating evacuees at an average rate of at least 70 evacuees per minute per lane. The evacuees shall exit the device without assistance.

4.6.4.2 Dark-of-Night

Evacuation capability under the test conditions described in Appendix N, Section N.3, shall be demonstrated to confirm the acceptability of the device and its and/or the associated airplane's emergency lighting system for use by evacuees under dark-of-night conditions. An evacuation rate based upon the rating of the exit (see Appendix N, Section N.3, [j.]) to which the device will be attached shall be achieved.

4.6.4.3 Usability

For devices which support evacuation from Type III exits where there is no cabin crew, the deployed device shall be usable and appear usable from the Type III exit.

4.6.5 Manual Inflation Actuation Controls

4.6.5.1 A manual means of actuating inflation shall be provided. The manual means of actuation of the inflation system may be mechanical or electrical. However, the manual inflation actuating means shall be neither visible nor presented for use until the device has been deployed.

- 4.6.5.2 If the means is an integral part of the device, the inflation controls shall be equipped with a rigid cross member as an actuation handle. The handle shall be red in color, marked with the word "PULL" (or other appropriate instruction) in high-visibility reflective letters at least 1/2 inch (1.27 cm) high and of a contrasting color. In addition, there shall be the words "PULL TO INFLATE" (or other appropriate instruction) located as close to the handle as possible.
- 4.6.5.3 When the inflation actuation controls are exposed for use, they shall be visible to an airplane occupant, standing at the doorsill, under the minimum emergency lighting conditions specified in 14 CFR § 25.812.
- 4.6.5.4 Unless a rational analysis is provided to locate them elsewhere, or if there is no girt attachment, inflation actuation controls shall be on the right side of the girt as seen by an airplane occupant looking out of the airplane door.
- 4.6.5.5 Inflation actuation controls shall be so designed that the maximum required pulling force will not pull the deployed device back into the doorway. The pulling force required shall not exceed 30 pounds (13.6 kg).
- 4.6.5.6 Inflation actuation controls shall be constructed so they cannot trip or entangle evacuees during evacuation testing. This shall be demonstrated during successful completion of the Evacuation Rate testing in 4.6.4.1 and Dark-of-Night testing in 4.6.4.2.
- 4.6.5.7 When actuated, the manual inflation actuation controls shall function in a manner that does not result in detrimental rotation or twist of the deployed device.

4.6.6 Device Illumination

- 4.6.6.1 Integral device illumination shall be designed so the illumination means is activated automatically during deployment or inflation and the level of illumination meets the appropriate requirements in 14 CFR § 25.812.
- 4.6.6.2 The illumination means shall not interfere with the safe evacuation of persons using the device.

4.6.7 Wind

The device shall be demonstrated, in 25-kt (46.3-km/h) winds directed from the Critical Wind Angle, to deploy and, with the assistance of only one 170-pound (77.1-kg) (maximum) evacuee who has evacuated down the device, to remain usable after full deployment to evacuate occupants safely to the ground. The device shall be usable and appear usable to the evacuee from the doorway.

The device shall be tested while it is properly attached to the exit or location on the airplane on which installation is intended or on an equivalent mockup. The function of the device shall be demonstrated in accordance with the wind test protocol described in Appendix O. Requirements for airplane representative mockups are addressed in Appendix K.

For all evacuation devices that are installed in a location outside of the pressurized cabin, the applicable wind and usability requirements shall be demonstrated in combination with a -65 °F (-53.9 °C) cold soak temperature. The cold soak protocol defined in Appendix H, H.2, (b.) and (c.), shall apply except the time from device removal from chamber to conducting the deployment shall be no more than 15 minutes.

4.6.8 Device Sliding/Walking Surface

- 4.6.8.1 The sliding/walking surface of the device, including its coating, shall be suitable and safe for use in a rainfall of 1 in/h (2.54 cm/h) minimum. The evacuation rate achieved in demonstrating suitability and safety of the device sliding/walking surface under rainfall conditions shall be no less than that shown in Appendix N, N.2.2.2, (g.). Evacuees shall meet the requirements of Appendix N, N.2.1, (e.). The device is installed at its Normal Sill Height.
- 4.6.8.2 Each device sliding lane, including its coating, shall provide safe and rapid evacuation for at least 200 adult persons without detrimental erosion or deterioration and without any rework of the surface when tested according to 4.6.10 and meeting the evacuee demographics of Appendix N, N.2.1, (e.).

4.6.9 Device Performance

At least five consecutive deployment and inflation tests shall be conducted without failure, and at least three tests of each such five-test series shall be conducted using a single representative sample of the device. If any part of the system fails or does not function properly during the required tests, the cause of the failure or malfunction shall be corrected by positive means and, after that, the full series of five consecutive deployment and inflation tests shall be conducted without failure. The full series of five consecutive deployment tests is required for each installation on an airplane (i.e., if the device is designed for use at more than one exit location, the five deployments are required for each of the intended exit locations).

4.6.10 Dynamic Pressure Retention Test

The device shall maintain adequate pressure to satisfactorily accomplish its intended function throughout an emergency evacuation in which:

- a. The device is installed at its Normal Sill Height.
- b. The device initial pressure will be established by deploying the device with the inflation system pressure set at the minimum of its design range (Minimum Dispatch Pressure) and recording the resulting deployed device pressure. This device initial pressure will then be used for the Dynamic Pressure Retention Test.
- c. If the device is designed to have pressure relief valve(s), the pressure relief valve(s) must be installed and operable.
- d. At least 200 evacuees meeting the evacuee demographics of Appendix N, N.2.1, (e.), in no more than ten separate demonstrations, use each slide lane of the device at an average rate of not less than 60 evacuees per lane per minute.

At the completion of the testing per (a.) through (d.), the slide pressure shall not be below the Minimum Operating Pressure.

4.6.11 Metallic Parts

- 4.6.11.1 Metallic components and fittings of the device shall be made of corrosion-resistant material, or shall be suitably protected from corrosion, including galvanic corrosion.
- 4.6.11.2 Metallic parts and fittings of the device installed inside the pressurized cabin shall not exhibit any corrosion that would affect their functionality after being subjected to the Salt Spray Test in RTCA DO-160G, Section 14, Category S.
- 4.6.11.3 Metallic parts and fittings of the device installed outside the pressurized cabin shall not exhibit any corrosion that would affect their functionality after being subjected to the Salt Spray Test in RTCA DO-160G, Section 14, Category T. For some metallic parts and fittings, demonstrating functionality within 1 hour of removal from chamber per Category T test may not be realistic. In these cases, functionality should be demonstrated as soon as possible after test.

4.6.12 Ditching Deployments - Type II and V Devices

- 4.6.12.1 The device shall be demonstrated to be usable as a raft when deployed at Planned and Unplanned Ditching Sill Heights for the exit at which the device is installed. The device shall be fully erected within the applicable time requirement of 4.1.8. Manual actuation of the inflation system is an acceptable actuation means for ditching deployments.
- 4.6.12.2 Portable Type II devices shall be usable as a raft at an alternate exit(s) in accordance with 14 CFR § 25.1411(d)(4).

4.6.13 Disconnect Means - Type II and V Devices

A means shall be provided to disconnect the device from the airplane.

- 4.6.13.1 Device disconnect from an airplane, whether by automatic or manual means, shall not be restricted by the critical conditions of floor sill height above the water, wind velocity and direction, or occupant load.

- 4.6.13.2 Devices having airplane mounted inflation systems shall have means for rapid detachment from the airplane in a manner that does not result in loss of pressure that adversely affects raft function.
- 4.6.13.3 Release means shall be a readily apparent flexible cloth/webbing loop capable of being operated by untrained persons. The release means shall be covered until ready for use.
- 4.6.13.4 The method of disconnecting the device from the airplane shall be conspicuously and clearly indicated by brief instruction placards.

5. NOTES

5.1 Revision Indicator

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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