EASA
European Union Aviation Safety Agency

Load factors in Emergency Landing and Crashworthiness

SC VTOL.2325, SC VTOL.2270

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Overview

- Crashworthiness of SC-VTOL is covered in 2 paragraphs
- SC-VTOL.2270 “Emergency Conditions”
  - **occupant protection in case of an emergency landing**
- SC-VTOL.2325 “Fire Protection”
  - Fire initiation
  - Fire propagation
  - **Post crash fire/hazard protection**

SC-VTOL.2270 Emergency Landing

- Protect each occupant against injury that would preclude egress when
  - Using safety features (seat belts…)
  - Experiences ultimate static inertia loads likely to occur
  - Items of mass experience ultimate static inertia loads
- Must include dynamic conditions
- Baggage compartment
  - Prevent items of mass to shift or become a hazard
  - Protect flight controls, wires… which damage could become a hazard

SC-VTOL.2325 Fire Protection

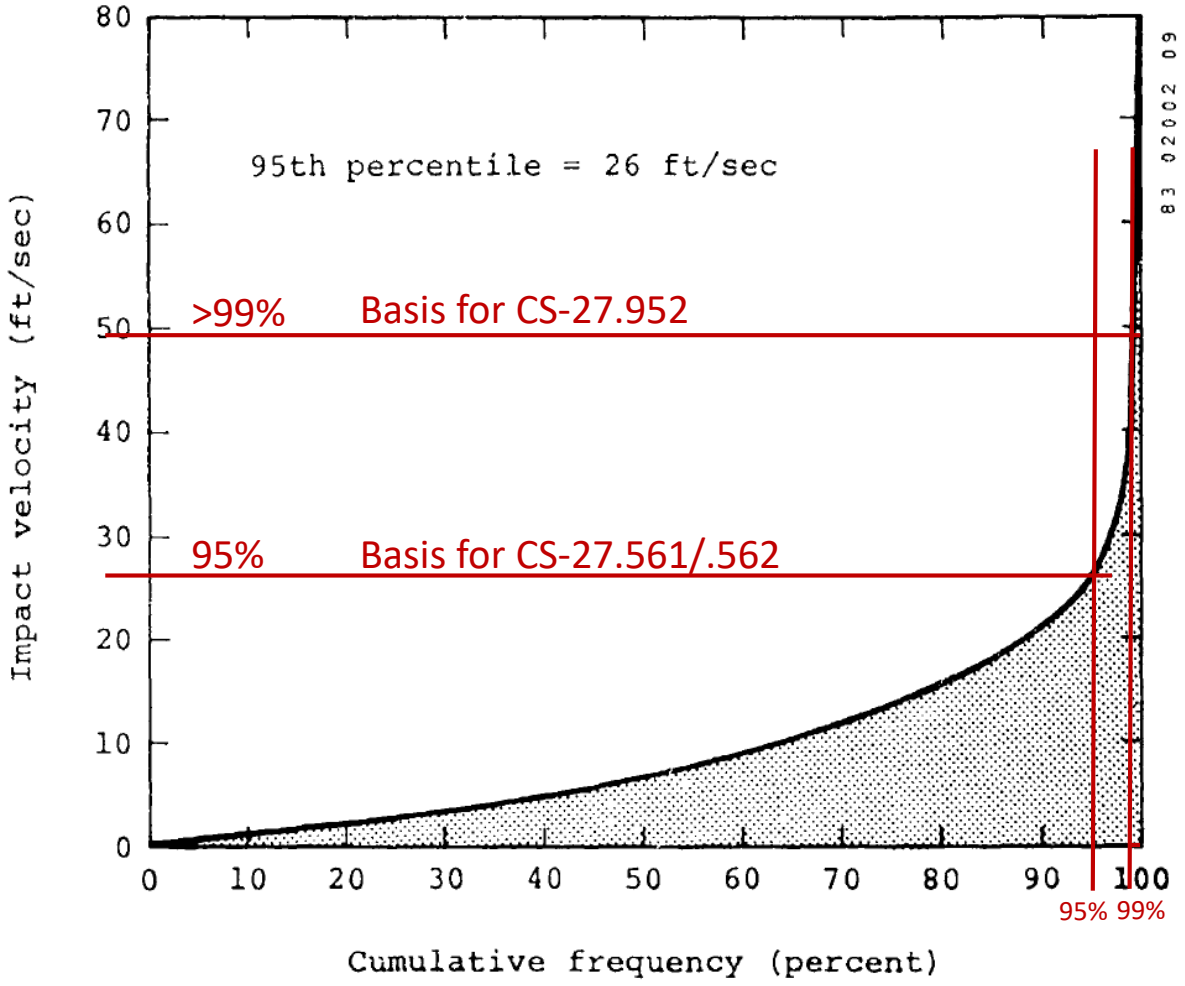
- Minimize the risk of fire initiation due to
  - Systems failures, overheat, energy dissipation
  - Ignition of flammable fluids, gases or vapours
  - Oxygen system
  - **Survivable emergency landing**
- Minimize the risk of fire propagation by
  - Providing adequate smoke and fire awareness
  - Use of self-extinguishing, flame-resistant or fireproof material
  - Specifying designated fire zones

Basis for Crashworthiness AMC: CS-27

- → VTOL can be operated similar to a rotorcraft
- → BUT it can be more diverse:
  - → Speed range could be wider than for rotorcraft
  - → VTOLs might have CTOL (conventional take-off and landing) capability
- → AMC will be based on
  - → CS-27.561 General Emergency landing conditions
  - → CS-27.562 Emergency landing dynamic conditions
  - → CS-27.952 Fuel System Crash resistance
  - → Complemented by CS-23.561/.562 requirements for CTOL

History of CS-27 Crashworthiness

- Crashworthiness requirements are based on the FAA study DOT/FAA/CT-85/11 by Coltman/Balukbasi/Laananen "Analysis of Rotorcraft Crash Dynamics for Development of Improved Crashworthiness Design Criteria"
- Review of 1351 rotorcraft accidents between 1974 and 1978
- Main outcome:
  - Vertical impact velocity and Survivability
  - Impact scenarios



DOT/FAA/CT-85/11 "Analysis of Rotorcraft Crash Dynamics for Development of Improved Crashworthiness Design Criteria"

Crash Scenarios – 2 Layers of protection

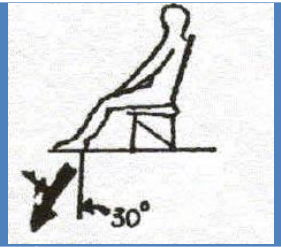
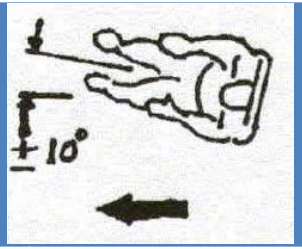
- CS-27.561/.562
  - **Minor** emergency (crash) landing
  - 9.1 m/s (30 ft/s) impact velocity, covering 95% of crashes
  - Loads should not exceed 30 g on seat attachment level
  - Occupants must be able to evacuate themselves after the impact
- CS-27.952
  - **Survivable** emergency (crash) landing
  - 15.2m (50ft) drop test height
  - Exceeds (deliberately) the 99% survivable impact velocity envelope
  - Occupants should be protected from post crash fire / post crash hazard

AMC for VTOL.2270 based on CS-23/27.561

→ Give each occupant every reasonable chance of escaping serious injury under static ultimate inertial load factors

Direction	Occupants Items in cabin	Items adjacent Cabin	Structure in area near energy storage system
Upward	4 g	1.5 g	1.5 g
Forward	16 g (CTOL: 18 g)	12 g	4 g
Sideward	8 g	6 g	2 g
Downward	20 g	12 g	4 g
Rearward	1.5 g	1.5 g	-

AMC for VTOL.2270 based on CS-23/27.562

77 kg Test Dummy	Test 1 (downward) 60° canted upwards 		Test 2 (Forward) 10° yaw 	
	VTOL	CTOL	VTOL	CTOL
Min. Velocity	9.1 m/s 30 ft/s		12.8 m/s 42 ft/s	
Min. G Force	30 g		18.4 g	1st row: 26 g Other: 21 g
Max peak floor deceleration after	0.031 s		0.071 s	0.05 s
Floor deformation	Degrees Roll: 10° / Degrees Pitch: 10°			

AMC VTOL.2325 Energy Storage Drop Test

- → Based on CS-27.952 „Fuel system crash resistance “
- → **Minimize** hazards to occupants caused by the energy storage system in an otherwise **survivable crash landing**
- → Written to address liquid, gaseous and solid (battery) energy storage systems
- → Self-insulations means have to be provided
- → For electrical systems, a manual insulation means is requested

Energy Storage System Drop Test

- Test conditions:
  - Energy storage system should be tested in a representative surrounding structure → Full scale drop test is an option
  - The entire energy storage system, or the most critical one, needs to be dropped
  - Must be filled or charged to the most critical condition
  - 15.2 m drop height on non-deformable surface
  - Must be dropped freely
  - Impact in a horizontal position ±10°

Energy Storage System Drop Test

- Pass/fail criteria
  - No leakage of flammable fluids or gases which could cause a fire
  - Leakage of harmful fluids, fumes or gases only in non-occupied areas and outside the evacuation path
  - For pressurized energy storage systems: No structural damage that could lead to injuries of occupants or persons on ground

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Battery Drop Test from 55m