

# **Pyrotechnic Pretensioner Requirements and Validation**

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## PYROTECHNIC PRETENSIONER REQUIREMENTS AND VALIDATION

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## 1. INTRODUCTION

### 1.1 Scope

This specification establishes the minimum required performance and validation for the seatbelt pyrotechnic pretensioners integrated into retractors, buckles, and/or anchors. It also includes pyro for switchable load limiters. This specification is intended to focus on the performance of the tensioner function integrated into the aforementioned devices and NOT the entirety of the device integrated into the vehicle.

See Figure 1 in 2.2.

### 1.2 Definitions

- 1.2.1 **Seat Belt (Seatbelt) Assembly:** Any strap, webbing, or similar device designed to secure a person in a motor vehicle in order to mitigate the results of any accident, including all necessary buckles and other fasteners, and all hardware designed for installing such seat belt assembly in a motor vehicle.
- 1.2.2 **Retractor:** A device for storing part or all of the webbing in a seat belt assembly.
- 1.2.3 **Automatic-Locking Retractor (ALR):** A retractor incorporating adjustment hardware by means of a positive self-locking mechanism which is capable of withstanding restraint forces when locked.
- 1.2.4 **Emergency-Locking Retractor (ELR):** A retractor incorporating adjustment hardware by means of a locking mechanism that is activated by vehicle acceleration, webbing movement relative to the vehicle, or other automatic action during an emergency and is capable of withstanding restraint forces when locked.
- 1.2.5 **Anchor:** Hardware designed for securing the webbing of a seat belt assembly to a motor vehicle.
- 1.2.6 **Buckle:** Quick release connector which fastens a person in a seat belt assembly.
- 1.2.7 **Latch Plate (Tongue):** Hardware designed for securing the webbing of a seatbelt assembly by coupling into the buckle.
- 1.2.8 **Pretensioner (Tensioner, PT):** For the purposes of this specification a pretensioner (tensioner) is a device that delivers a defined quantity or volume of gas with a defined mass flow at a required reliability and repeatability to the retractor, buckle, anchor, and/or device intended to remove belt length in the seat belt system, thereby providing increased occupant restraints as defined by the intended customer engineering group(s). Any information in this specification for pretensioners is intended as reference only and does not set vehicle level performance and/or content requirements.
- 1.2.9 **Load Limiter:** A seat belt assembly component or feature that controls tension on the seat belt to modulate the forces that are imparted to occupants restrained by the belt assembly during a crash.
- 1.2.10 **Pyro-Switchable Load Limiter:** A seat belt assembly component or feature that allows additional selectable controls of Load Limiter feature using a pyrotechnic charge device. It may be referred to or “also known as” (aka) switchable, selectable, or adaptive load-limiting.
- 1.2.11 **Degradation:** The term “degraded” refers to a change in performance that falls outside of the reference window established by a virgin control group to meet any other requirement as stated in this document after environmental conditioning shall also be defined as degradation. Environmental conditioning cycle is defined in accordance with OEM specific requirement.
- 1.2.12 **Strap:** A narrow non-woven material used in a seat belt assembly in place of webbing.
- 1.2.13 **Shall Requirements:** The tensioner is required to meet all “shall” requirements. The use of “shall” in this document denotes a binding provision that must be met.

1.2.14 Should Requirements: "Should" requirements provide criteria for a preferred condition, where absolute compliance is NOT required. The use of "should" in this document denotes a preference or desired conformance.

1.2.15 OEM: Original equipment manufacturer, such as vehicle manufacturer or seatbelt assembly manufacturer.

1.2.16 NCAP: New car assessment program.

1.2.17 ATD: Anthropomorphic test device (crash test dummy).

## 2. APPLICABLE DOCUMENTS

### 2.1 List of Applicable Documents

SAE/USCAR-28, Initiator Technical Requirements and Validation  
 SAE/USCAR-24, Inflator Technical Requirements and Validation  
 MIL-STD-810G, Environmental Engineering Considerations and Laboratory Tests  
 SAE J211-1, Instrumentation for Impact Test–Part 1: Electronic Instrumentation  
 SAE J211-2, Instrumentation for Impact Test–Part 2: Photographic Instrumentation  
 ISO 17025, General requirements for the competence of testing and calibration laboratories

In the case of new releases of the listed reference documents, the latest version shall be applicable except where direct conflicts with this document takes place. In the case of a direct conflict, this document shall supersede, and the previous version of the referenced document(s) shall be applicable.

### 2.2 Boundary Diagram

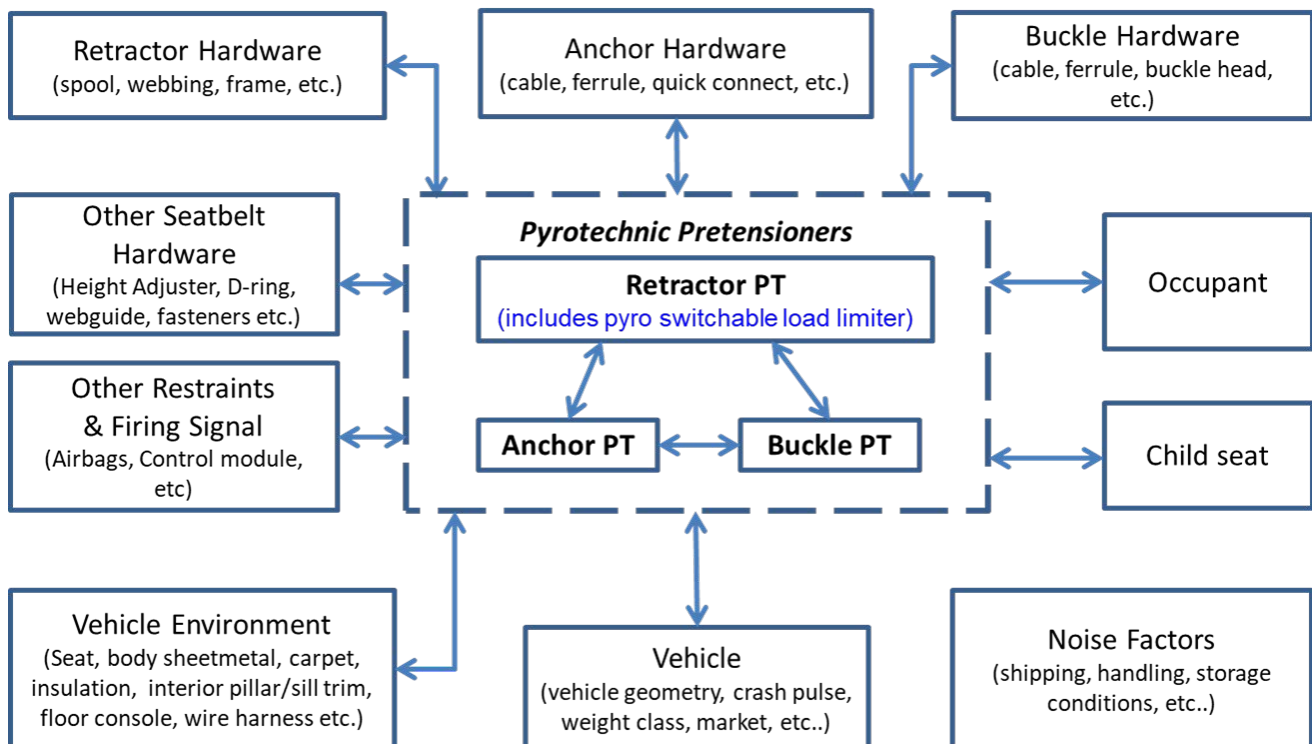


**Figure 1 - Pyrotechnic pretensioner system boundary diagram**

### 3. REQUIREMENTS

#### 3.1 General Requirements

##### 3.1.1 Micro Gas Generators (MGGs)

All MGGs for seat belt pretensioners used in retractors, buckles, or outboard anchors and other similar devices shall conform to USCAR-28 for initiators.

##### 3.1.2 Tensioner Operating Temperature

Pretensioner is expected to function after exposure and storage within the entire temperature range from -35 to 100 °C. Tensioning performance requirements are demonstrated in the range of -30 to 85 °C.

##### 3.1.3 Tensioner Emission of Energy

All pretensioner devices in the vehicle, when deployed at -30 °C, +23 °C, and +85 °C shall NOT:

- 3.1.3.1 Have flames of any length or duration.
- 3.1.3.2 Have burning particles or sparks.
- 3.1.3.3 Display any gas leakage residue beyond distance of 6 mm from the initiator, around the micro gas generator (MGG) housing or case, except for minimal witness marks.
- 3.1.3.4 Have burning of effluents, gasses and propellants occur outside of the energetic device, including in presence of an external ignition source.
- 3.1.3.5 Produce "incandescence" that is visible in standard and/or highspeed video as specified in the test methods.
- 3.1.3.6 Ignite surrounding materials in the environment in which the device is packaged.

##### 3.1.4 Emission of Particulates or Gases

Pretensioner devices shall have no emission of flammable particulates or flammable gases upon deployment under any expected vehicle or test conditions, including:

- 3.1.4.1 Over-pressure relief features.
- 3.1.4.2 At temperature extremes.
- 3.1.4.3 With and without deployment resistance (blocked/unblocked).
- 3.1.4.4 When used in conjunction with other/additional pretensioner for the same seating position.

##### 3.1.5 Effluent (Emissions) Flammability

All pretensioner devices, when deployed in a chamber with an external ignition source applied repeatedly during the time immediately post deployment (0 to 2 minutes minimum duration), at temperatures of -30 °C, +23 °C, and +85 °C, 750 mm webbing on spool over a stationary 50th percentile ATD and with webbing blocked as defined in 5.3, shall meet requirements outlined in 3.1.3.

### 3.1.6 Cotton Wrap Evaluation for Emissions

All pretensioner devices, when deployed wrapped in cotton material (defined in 5.4.2.4), at temperatures of -30 °C, +23 °C and +85 °C, 750 mm webbing on spool over a stationary 50th percentile ATD and with webbing blocked as defined in 5.4, shall meet requirements outlined in 3.1.3.

In addition, post deployment, the cotton materials shall be removed from the devices and visually inspected and photographed. The cotton packing shall be free of evidence of burning fibers. Some discoloration and deposits from exhaust are acceptable.

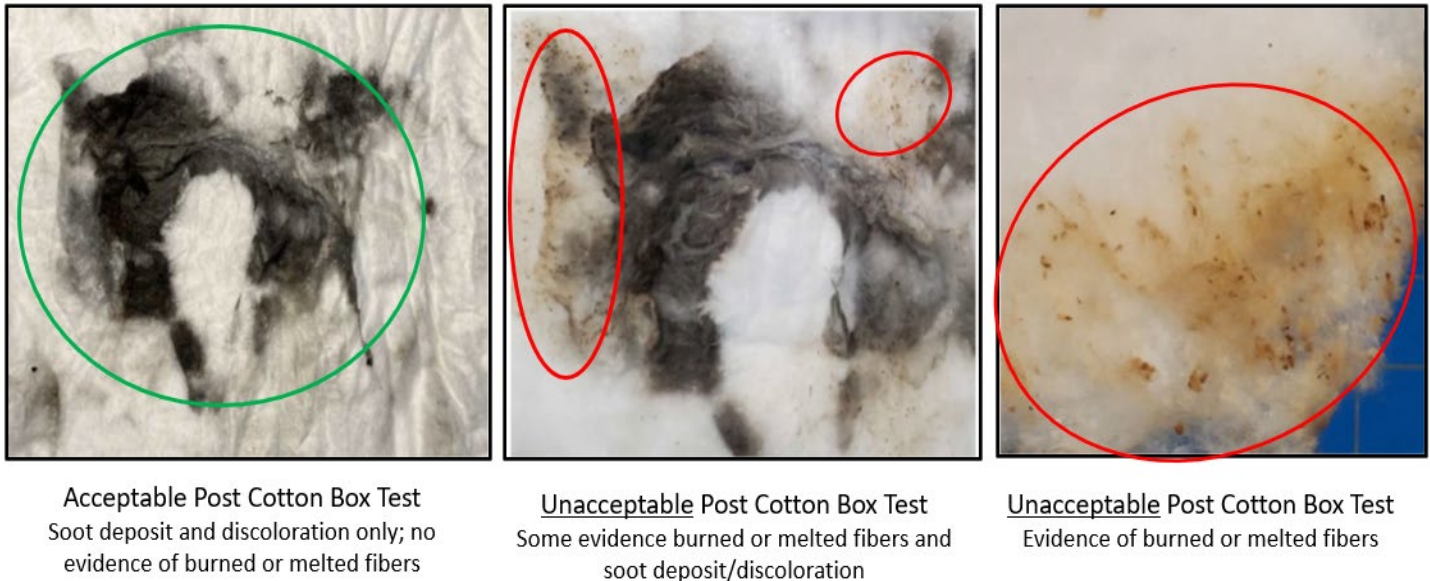


**Figure 2 - Post-cotton box testing acceptable criteria**

### 3.1.7 Pressure Vessel Structural Integrity

The pressure vessel portion of tensioner, under all conditions, shall prevent unwanted venting of gas, particulates, or fragmentation. When tensioning within a functional temperature range between -35 and 85°C, the parts must not burst, detach, or leave the original outer contour of the entire unit.

Safety tests/detachment of parts:

- 3.1.7.1 Must comply to pressure vessel requirement per FMVSS 208 Section 9.1 (if applicable) and 9.2 with safety factor (SF)  $\geq 1.7$ .  
To calculate safety factor, refer to SAE/USCAR-24 Appendix C. Maximum expected operating pressure (MEOP) is determined with physical test per 5.3.4 at worst case temperature for the device.
- 3.1.7.2 When tested per 5.3.3.
- 3.1.7.3 When tested per 5.3.5.

### 3.1.8 Tensioner Cable Robustness to MGG Gas

- 3.1.8.1 The tensioner cable (if equipped) shall be thermally protected (i.e., material, composition, or protective coating) that resists degradation from the deploying gas during a crash event. Any thermal damage to the cable shall be evaluated and approved by responsible vehicle engineering organizations (OEM). This includes both static and dynamic deployments over the full temperature range from -30 to +85 °C.
- 3.1.8.2 Suppliers shall demonstrate the robustness capability of the cable material to MGG output temperature via correlated analytical and/or physical methods when deployed under any expected vehicle or test conditions, including temperature extremes, with and without deployment resistance to ensure the cable(s) are protected from the MGG output.

## 3.2 General Requirements for Lap/Buckle Pretensioner Devices

### 3.2.1 Structural Integrity Requirements

The following shall be met in any test mode, during and after tensioning deployment event.

- 3.2.1.1 Tensioner device shall not expel gas and/or particulates to the environment.
- 3.2.1.2 Tensioner device shall not exhibit any separation, cracks, fragmentation, or breakage of any component.
- 3.2.1.3 All parts shall remain within the operational package envelope of the tensioner device defined by design. Operational package envelope may include, additional package space required for components that protrudes past the end of the tube post deployment.
- 3.2.1.4 Tensioner device shall not cause damage to other seatbelt system components (such as webbing, belt guides, D-ring, tongue, etc.).
- 3.2.1.5 The initiator electrical connector may disconnect as a result of the tensioning event provided it does not inhibit or degrade performance or function of the tensioner and/or adjacent systems.

### 3.2.2 Static Evaluation Requirements

The lap/buckle pretensioners, when evaluated per 5.5.4 or 5.5.5 on static deployment test rig (see Figure 5) test setup, shall demonstrate a minimum pretensioning stroke ("pull in") at 6 ms (from deployment signal), expressed as a % ratio of the stroke performance and the maximum stroke travel allowed by design.

| Static Pull-in             | @ 100 mm Belt Slack | @ 0 mm Belt Slack |
|----------------------------|---------------------|-------------------|
| New Parts @ 23 °C          | 70%                 | 50%               |
| Conditioned Parts @ -30 °C | 50%                 | 30%               |

Condition tensioners as required per 5.2.3.1.

### 3.2.3 Dynamic Evaluation Requirements

The lap/buckle pretensioners, when evaluated per 5.5.4 or 5.5.5 on static deployment test rig (see Figure 5) test setup, with tensioner deployed at 16 ms, shall demonstrate a minimum pretensioning stroke ("pull in") at 6 ms (from deployment signal) expressed as a % ratio of the stroke performance to the tube length (maximum stroke travel allowed by design).

| Dynamic Pull-in            | @ 100 mm Belt Slack | @ 0 mm Belt Slack |
|----------------------------|---------------------|-------------------|
| New Parts @ 23 °C          | 50%                 | 30%               |
| Conditioned Parts @ -30 °C | 30%                 | 20%               |

Condition tensioners as required per 5.2.3.1.

### 3.2.4 Tensioner Static Strength When Integrated into an Ancho

3.2.4.1 Shall meet a minimum load of 14.7 kN statistically demonstrated (0.95R at 0.90C) after deployment, per test method 5.6.

3.2.4.2 Shall meet a minimum load of 14.7 kN statistically demonstrated (0.95R at 0.90C) without deployment, per test method 5.6.

Note: For anchor/buckle tensioner strength, OEMs may have additional requirements beyond stated above in 3.2.4.

### 3.2.5 Tensioner Static Strength When Integrated into a Buckle

3.2.5.1 Shall meet minimum load of 18 kN statistically demonstrated (0.95R at 0.90C) strength requirements after deployment, per test method 5.6.

3.2.5.2 Shall meet minimum load of 18 kN statistically demonstrated (0.95R at 0.90C) strength requirements without deployment, per test method 5.6.

Note: For anchor/buckle tensioner strength, OEMs may have additional requirements beyond stated above in 3.2.5.

### 3.2.6 Tensioner Under Compressive Loading (Back Drive)

A buckle tensioner or lap tensioner subject to compressive loading:

3.2.6.1 Shall not allow more than 2 mm of permanent stroke of the piston down the pretensioner tube when a minimum specified force of 450 N is applied to the top of the buckle or anchor downward along the axial direction of the cable.

### 3.2.7 Tensioner Deployment Locking

3.2.7.1 Shall demonstrate that, after tensioner deployment, and during a static tensile test, its locking distance (pay back) is less than 10 mm from maximum stroke reached during deployment.

3.2.7.2 Shall payout less than 15 mm from maximum stroke reached during deployment when deployed and dynamically loaded to 11 kN minimum in 60 ms (see graph based on R16 test with 95th percentile ATD). Statistically demonstrate 0.95R at 0.50C.

Note: Correlation to a pendulum or drop silo impact test with PT deployment and subsequent static tensile test can be used to demonstrate performance and support statistical requirements.

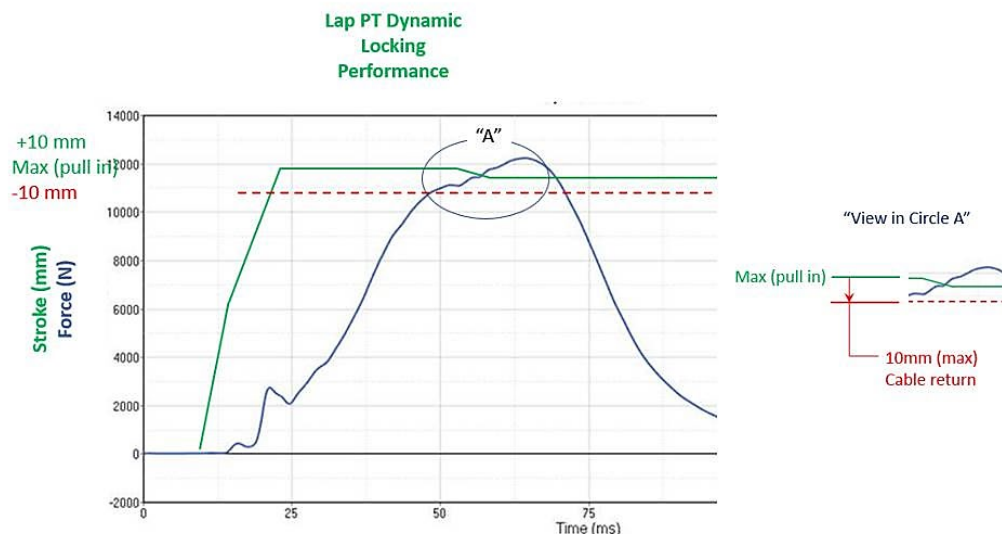


**Figure 3 - Pyrotechnic pretensioner retraction and locking performance**