# USCAR Inflator Technical Requirements and Validation



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USCAR INFLATOR TECHNICAL REQUIREMENTS AND VALIDATION

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# 1. INTRODUCTION

## 1.1 Scope

This specification establishes the performance and validation requirements for the inflator assembly used in airbag modules.

## 1.2 Preface Definitions

Inflator: For the purposes of this specification, an Inflator is a device that delivers a defined quantity or volume of gas with a defined rate of mass flow to a cushion or chamber, to directly provide occupant restraints as defined by the intended customer engineering group(s). Specific design elements are not limited except by the performance and reliability requirements contained herein.

Degradation *(following environmental conditioning)*: Refers to a change in ballistic performance that falls outside of the reference window established by a virgin control group per 3.2.9, Inflator Performance and Variability Limits (i.e., DV/PV baseline group). In addition, a failure of the Inflator to meet any other requirement as stated in this document after environmental conditioning shall also be defined as degradation.

Tailorability: The ability to tune slope, onset, output (peak pressure), and output ratio (dual stage Inflators) independently to meet the various program requirements.

Variability: Refers to performance variation within a group of Inflators that falls outside of the reference window established by a virgin control group (i.e., DV/PV baseline group) per 3.2.9, Inflator Performance and Variability Limits.

Shall Requirements: The Inflator is required to meet all shall requirements. The use of "shall" in this document denotes a binding provision that must be met unless a deviation is granted by the Responsible Vehicle Engineering Organization. Deviations to "shall" requirements will only be considered and, if approved, granted by the Responsible Vehicle Engineering Organization after evaluating appropriate available technologies and balancing all Module and restraint system performance considerations.

Should Requirements: Should requirements are to provide preferred requirements where absolute compliance is not required. "Should" denotes a preference or desired conformance which, if not met, require acceptance by the Responsible Vehicle Engineering Organization. The final determination of the subject performance requirement shall be made by the Responsible Vehicle Engineering Organization.

Responsible Vehicle Engineering Organization (RVEO): Intended vehicle manufacturer; OEM responsible for approving Inflator technology for use in their vehicles.

QFS: Refers to 'Qualified for Sourcing' and is synonymous with 'Bookshelving.' The procedure for attaining QFS status for an Inflator is detailed in Appendix A, Pre-Source Qualification (QFS) Requirements.

For additional definitions see Appendix E, Glossary.

## 1.3 Changes to this Document

This document is to be considered a living document. Revisions are to be based on relevant experience and changes to the application environments of the participating OEMs. All changes to the document are to be decided upon by a joint USCAR committee as appointed by the participating OEMs and ratified by their respective organizations.

## 2. APPLICABLE DOCUMENTS

| | |
|---|---|
| SAE J211-2 | Instrumentation for Impact Test - Part 2: Photographic Instrumentation |
| SAE J1794 | SAE Restraint Systems Effluent Test Procedure |
| SAE J2238 | Airbag Inflator Ballistic Tank Test Procedure, Gas Generating Devices Used in Inflatable Restraint Systems |
| SAE/USCAR-28 | Initiator Technical Requirements and Validation |
| ISO 9001:2015 | Quality management systems - Requirements |
| ISO 17025 | General Requirements for the competence of testing and calibration laboratories |
| MIL-STD-810G | Environmental Engineering Considerations and Laboratory Tests |
| IATF 16949:2016 | Automotive Quality Management System Standard |
| ASTM B117 | Standard Practice for Operating Salt Spray (Fog) Apparatus |

999-U-002-1-Z02 USCAR Standard Connector Pocket Chart Drawing



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

## 3. REQUIREMENTS

### 3.1 General Requirements

#### 3.1.1 General

The Inflator supplied under this specification shall meet all functional requirements outlined in this specification. The Inflator shall meet these requirements both before and after the environmental conditioning specified and over the deployment temperature range. This specification represents a minimum set of requirements. Any technology that presents functional, quality and/or durability issues that are not addressed in this specification shall be required to complete additional testing. Test requirements of such systems shall be proposed by the inflator supplier and agreed to by the RVEO. All testing shall be based on supporting a 15-year vehicle life.

#### 3.1.2 Quality

All structural and performance related features shall be manufactured and/or processed in accordance with automotive industry accepted quality requirements (PPAP per AIAG or IATF 16949 process) for purchased materials and shall be done with the concurrence of the RVEO Supplier Quality Assurance group(s).

#### 3.1.3 Production Requirements

As a general assumption, Inflators qualified to this specification will meet this specification on an ongoing production basis unless specifically excepted by the RVEO. All prototype parts must be representative of production intent. Any differences must be identified with rationale for equivalence.

#### 3.1.4 Reliability

The Inflator shall demonstrate, through successful completion of the PV test matrices, a reliability of 99% at 99.9999% confidence without any failures during deployment, degradation as defined in this specification, or failure to meet any shall requirements of this specification.

3.1.5 Heavy Metal Compounds Reporting and Recyclability Requirements

The Inflator Supplier shall provide timely information verifying product compliance with current OEM requirements regarding the use of Heavy Metals or Heavy Metal Compounds in the manufacture of the Inflator. The Inflator supplier shall provide, at the request of the RVEO, a breakdown of the materials in the Inflator for recycling purposes.

3.1.6 Informational Requirements

The Inflator Supplier shall provide the information as defined in the following subsections prior to, or in conjunction with, the DV report. Use of the 'QFS Checklist' is highly recommended for organization and completeness of the information. The Inflator DV shall not be considered complete without prior or joint submission of the informational requirements.

3.1.6.1 Inflator Pre-Source Qualification (QFS)

The Inflator Supplier shall provide the information outlined in Appendix A, Inflator Pre-source Qualification (QFS) Requirements.

3.1.6.2 Inflator Soak Back Heat

In addition to the information supplied in the QFS, and for the specific Inflator output in consideration, a temperature trace of the external surface of the Inflator after deployment shall be provided after hot deployment per 5.2.2.7, Open Air Test Procedure. The measurements shall be taken from the highest temperature area of the Inflator, showing the peak temperature reached immediately and throughout the full cool down cycle of the Inflator. The data shall be provided as part of the DV and PV reports. Placement of the temperature measuring probe(s) shall be based on temperature mapping for the worst-case location and approved by the RVEO.

3.1.6.3 Inflator Performance Envelope and Characteristics

In addition to the information supplied in the QFS, and for the specific Inflator output(s) in consideration, the Inflator Supplier shall supply Inflator vented tank test (or equivalent test method) curves (if specifically requested), closed tank test curves, mass flow and gas temperature curves, and moles of gas for the output tested. In addition, the Inflator Supplier shall provide the Inflator initial onset rate (e.g., using a small vented tank, initial onset chamber, nozzle exit pressure, or other equivalent method) if requested by the RVEO. The Inflator Supplier shall demonstrate tailorability criteria and repeatability. The Inflator Supplier shall make available on an ongoing basis, information and data to demonstrate lot-to-lot variability during production is minimized, controlled, and meets the requirements of this specification.

3.1.6.4 Shipping Classification

The Inflator Supplier shall provide evidence of shipping 'Competent Authority' approval for target jurisdictions and programs. In addition, the test data utilized to comply with all applicable government shipping regulations, including auto-ignition regulations, in countries where the Inflator(s) are manufactured and transported, shall be summarized (with conclusions) and provided to the RVEO through submission as a subsection of the QFS/DV report (i.e., DOT, CTC, TUV, BAM, CE, UKCA, etc.).

3.1.6.5 Module Performance

Examples of the Inflator performance in a baseline module shall be demonstrated if requested by the RVEO. This demonstration shall be done in a dynamic test configuration (i.e., drop tower, pendulum, linear impactor, or other equivalent device) in an existing and well characterized module that meets the criteria of Appendix A, Pre-source Qualification (QFS) Requirements, Section IV G, Table 1, Module Configuration. Modifications to the baseline module are acceptable and encouraged to enhance the new Inflator's performance, so long as they are thoroughly documented. Alternate configurations with documented differences can also be used to show typical design modifications from the established baseline modules to enhance performance.

#### 3.1.6.6 Electrical Isolation of Pyrotechnic Materials

Pyrotechnic materials in the Inflator shall not have direct contact with the external metallic surfaces of the initiator charge cup and header assembly.

### 3.1.7 Testing and Reporting

#### 3.1.7.1 Ethics in Testing and Reporting

Inflator Supplier shall adhere to the highest levels of ethical standards in all aspects of engineering testing, analysis, and reporting of data.

#### 3.1.7.2 Test Sample Control

All Inflators produced for the sole purpose of validation testing and evaluations (including “extra”/mistake protection stock) shall be serialized in original planned sequence, secured, and stored as “validation parts” and shall not be intermingled with production stock.

All test parts shall be saved for review and shall not be scrapped without prior approval from the RVEO.

#### 3.1.7.3 Testing/Evaluation Errors

If a testing error occurs, validation shall be stopped and a thorough engineering analysis of the “root cause” of the error shall be performed. RVEO review and approval is required before proceeding with validation testing utilizing “extra”/mistake protection stock. Examples of testing errors include (but are not limited to) samples conditioned at the incorrect temperature, reversed firing lines, and instrumentation malfunction. Testing errors do not include sample failures / non-conformances to this performance specification.

#### 3.1.7.4 Data Integrity

All data gathered for all tested Inflators shall be reported, including any testing / evaluation errors as described in 3.1.7.3, Testing / Evaluation Errors. Data shall be communicated in its “native collection form” upon request. No truncation or exclusion of data is permitted.

### 3.1.8 Electrical Connection Interface

The Inflator electrical connection interface shall conform to the USCAR Standard Connector Pocket Chart Drawing 999-U-002-1-Z02 and USCAR-2 Performance Specification for Automotive Electrical Connector Systems.

## 3.2 Functional Requirements

This section describes the functional and performance requirements of the Inflator. For the environmental conditioning and testing required to validate these performance characteristics, see Section 5, Test Requirements.

### 3.2.1 General Inflator Requirements

Inflator(s) shall demonstrate the ability to successfully complete a ‘Proof of Concept’ test series as outlined in Appendix A, Pre-source Qualification (QFS) Requirements.

For dual-stage Inflators utilizing either two separate pressure chambers or a single pressure chamber inflator with an internal segmenting partition, the Inflator and all Inflator segments shall meet all applicable performance requirements and validation conditions singly and in combination, referenced in this specification.

For Inflators to be considered ‘Pre-Qualified’ (QFS) the Inflators should use only approved initiators (PPAP per AIAG process or equivalent) at the time of pre-qualification. Inflators shall use an initiator that has, as a minimum, met all DV requirements per SAE/USCAR-28 Initiator Technical Requirements and Validation of current issue at the time of Inflator DV. Inflators shall use only approved initiators (PPAP per AIAG process or equivalent) at the time of Inflator PV.

### 3.2.2 Inflator Structural Integrity

Inflator(s) shall maintain structural integrity when deployed in and after exposure to the conditioning environments described in Section 5, Test requirements. An Inflator shall not eject any components or fragments during any portion of DV and PV testing. Burst foil pieces are not considered fragments based on the lack of risk as a potential hazard, however, burst diaphragm fragments from pressurized Inflators are considered fragments.

#### 3.2.2.1 Inflator Burst Safety Factor

Over the temperature range of -40 to +85 °C, the Inflator burst safety factor, when tested per 5.2.3.1, Structural Burst Test, and calculated per Appendix C, Statistical Structural Margin Calculations, shall be greater than 1.7 for all pressurized chambers. The reliability and confidence interval shall be reported on the data used to calculate the safety factor and shall have a d-value greater than 4.753, indicating 99.9999% reliability with 99% confidence.

MEOP shall be calculated using data at each deployment temperature for each group of Inflators (i.e., baseline and environmentally conditioned). The maximum MEOP from all data sets shall be used for the safety factor calculation of the Inflator.

All pressure vessel testing shall be conducted with as-designed/produced Inflator components, including exit orifices. Specially designed components shall not be used in any structural testing. Alterations may be made to production parts to accommodate testing; however, these alterations shall not influence the Inflator structural integrity (i.e., no welding exit orifices closed). A detailed description of the structural testing procedure shall be provided at QFS, DV, and PV. Pictures of failure modes for each tested part shall be included in all reports.

The Inflator shall exhibit a ductile failure mode insofar that the Inflator shall not fragment or eject any part of the structural components during the burst test. The Inflator Supplier and RVEO shall jointly determine the burst test configuration. The RVEO shall be the final arbiter of the burst test configuration.

Inflators with multiple structural, dynamically independent, pressurized chambers shall meet the required Inflator burst safety factor for all pressurized chambers tested independently and together. Structural failure in a common component or wall is allowed only if such a failure is the standard operating mode of the component and does not eject components or fragments. External crimps, curls, swages, press-fits such as end closure and initiator retaining features shall be loaded during testing and shall not fail during burst testing. Welds shall not fail in the fusion area.

Design and process parameters of all crimp, curl, swage, press-fit, and weld joint design and process parameters shall be verified by margin studies and/or FEA. Propagation of the primary failure from the parent material into external welds, crimps, curls, or swages is allowed.

The Inflator structure shall comply with all applicable government regulations, including pressure vessel burst regulations, in countries where the Inflator is manufactured and transported, as well as the countries where the vehicle is manufactured and sold as directed by the RVEO.

NOTE: Dynamic burst testing may be used when no reasonable alternative can be found. Prior agreement of the RVEO to the specific test method and pass/fail criteria shall be obtained.

### 3.2.3 Effluents

The RVEO shall be the final arbiter for each application for all effluent requirements. The limits and requirements listed in this section are subject to change as effluent knowledge evolves.

#### 3.2.3.1 General Effluents

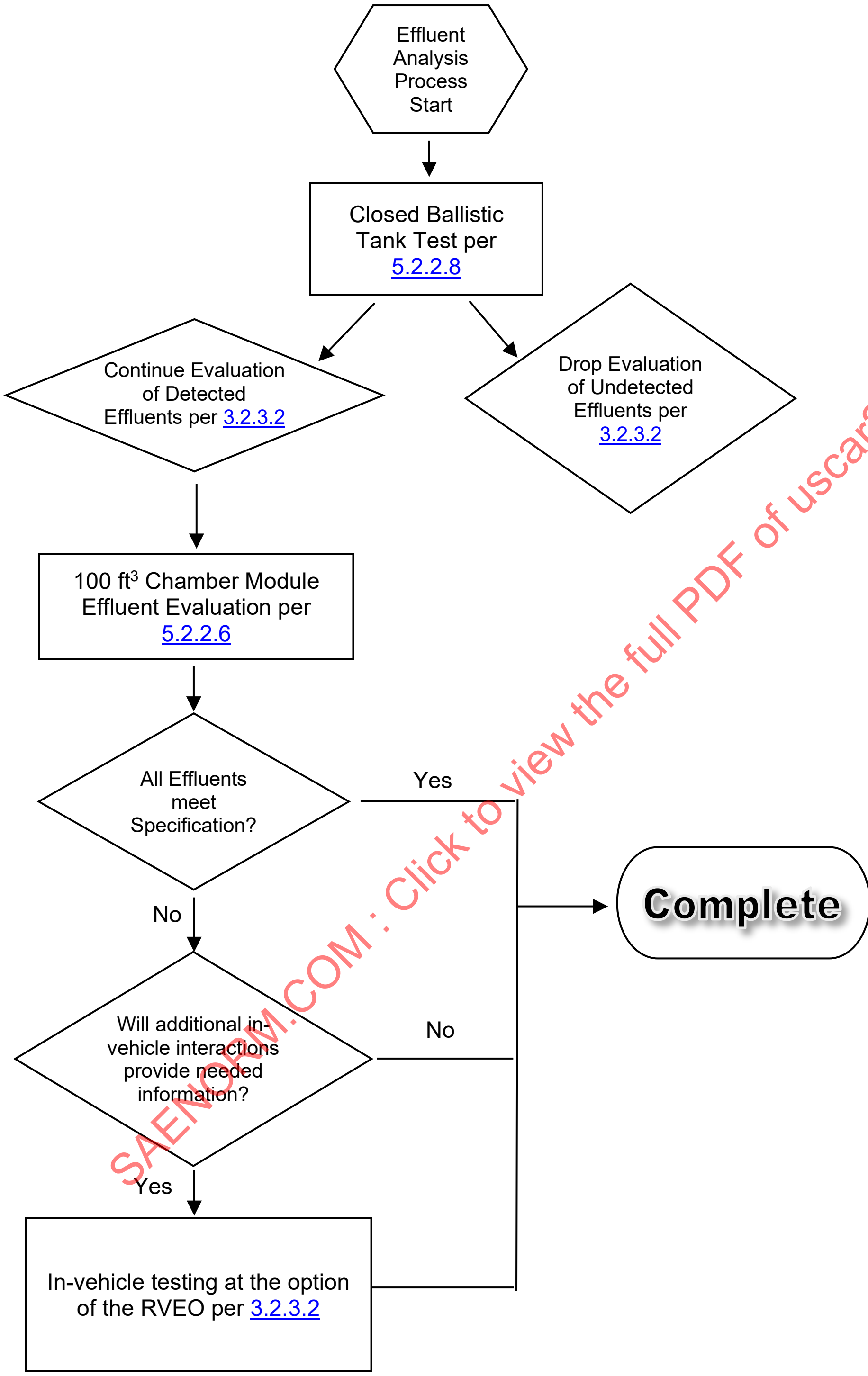
The Inflator Supplier shall characterize and report the presence of all chemical constituents, both listed and unlisted gasses and particulates according to the following sections. Follow Table 3.2.3.1.A, Flow Chart of Effluent Evaluation. All gasses and particulate levels (generated by the Inflator, labels, paints, glues, inks, cushions, housings, deflectors, and other Module components) shall be reviewed with the vehicle manufacturer's engineering and health effect support organization(s). Joint agreement of the Inflator Supplier and responsible vehicle engineering and health effect support organization shall establish vehicle level limits for any gasses or materials not specified or exempted herein. Synergistic effects of the mixture of effluents shall be identified in so far as possible and may be cause to alter the published limits of any listed compound (see Table 3.2.3.2.3.B, Effluent Compound Limits). Allowable levels may be subject to modification based on the specific vehicle requirements (vehicle interior volume, bag configuration, etc.).

Those effluents defined as 'Unlisted' are all other effluents, gasses, and particulates, generated by the Inflator, labels, paints, glues, inks, cushions, housings, deflectors, and other Module components not specifically listed in this document. Unlisted compounds exclude normal, nonhazardous levels of atmospheric gasses.

The RVEO may add to the effluent gas and particulate list as information becomes available and may alter the specified component level allocations to achieve overall vehicle safety system effluent and particulate limits. However, program specific Inflators should be consistent with the information provided in the QFS package.

The reporting of effluent results shall use the tables provided in Appendix D, Gas and Particulate Reporting Tables and Analysis Methods.

***Table 3.2.3.1.A - Flow Chart of Effluent Evaluation***



#### 3.2.3.2 Gasses

All gas concentrations defined in this section as 'Listed' and those defined as 'Unlisted,' but determined to be present, shall be measured in a tank size per Table 5.2.1.A, Closed Tank Sizes. The results of the gas analysis of the ballistic tank shall be reported as part of QFS package. The results of the ballistic tank evaluation are for reference only. Those compounds detected in the ballistic tank sample at concentrations that exceed 25% of the apportioned vehicle limit as calculated per Table 3.2.3.2.3.A, Effluent Apportionment (based on calculated dilution factors), and all gasses known to be substantially soluble in water, shall be analyzed in all subsequent effluent tests.

Effluent tests in a 100 ft$^3$ tank should be conducted in modules and at outputs that are consistent with the requirements of Appendix A, Section IV-G Table 1, Standard Module Configurations. 'In-vehicle' tests, conducted in a representative vehicle, may be accepted on a case-by-case basis at the discretion of the RVEO. All parameters of the module configuration (bag size, vents, inflator output, etc.) shall be recorded and reported with the data.

Effluents measurements should be corrected to STP for the dilution effects of tests done at higher altitudes.

Upon deployment, the 'in-vehicle' gaseous and particulate effluent levels from the Frontal System or Side System shall not exceed the vehicle limits and should not exceed apportioned fractions (per Table 3.2.3.2.1.A, Effluent Apportionment) established for listed compounds (per Table 3.2.3.2.1.B Effluent Compound Limits), unlisted compounds (where determined to be present), and airborne particulates.

NOTE: Compliance of the effluent data shall be evaluated by use of the average(s) of each group of tests (minimum of three data points for each series). Each data point shall also be reported, and shall not exceed 150% of the respective apportioned limits.

##### 3.2.3.2.1 Gas Sampling and Analysis

Effluent testing shall be performed per 5.2.2.6, Effluent Test Procedure, without any devices or materials (in the test tank or in the gas sampling tube) that may alter results or otherwise 'scrub' the gas prior to analysis.

***Table 3.2.3.2.1.A - Effluent Apportionment***

| **Frontal** | | |
|---|---|---|
| **Driver Airbag** | **Passenger Airbag** | **Knee Airbags (<0.75 mole)** |
| 1/3 | 2/3 | |
| 1/4 | 1/2 | 1/8 |
| **Side (per-bag basis)** | | |
| **Head Thorax or Head Thorax Pelvis (>0.75 mole)** | **Thorax or Thorax Pelvis or Pelvis or CSIAB (<0.75 mole)** | **Curtain (assumes non-vented bag)** |
| 1/4 | | |
| | 1/8 | 1/8 |

NOTE: Due to the nature of most crashes, Frontal and Side restraint systems will not fire together without substantial 'opening' occurring to the occupant compartment. This opening (or ventilating) of the occupant compartment allows the combined side and frontal apportionment to be considered separately.

NOTE: In cases where the sum of the frontal or side restraint systems apportionments will exceed 1, the apportioned fractions shall be normalized by adding the smallest fractions for each airbag noted above and then normalizing to equal 1, as approved by the RVEO.

***Table 3.2.3.2.1.B - Effluent Compound Limits***

| Effluent Compound | Vehicle Level Limit (ppm, maximum) |
|---|---|
| Ammonia ($NH_3$) | 50.0 |
| Benzene ($C_6H_6$) | 22.5 |
| Carbon Monoxide (CO) | 461 |
| Carbon Dioxide ($CO_2$) | 30000 |
| Chlorine ($Cl_2$) | 1.0 |
| Formaldehyde (HCHO) | 2.0 |
| Hydrogen Chloride (HCl) | 5.0 |
| Hydrogen Cyanide (HCN) | 4.7 |
| Hydrogen Sulfide ($H_2S$) | 15.0 |
| Nitric Oxide (NO) | 75.0 |
| Nitrogen Dioxide ($NO_2$) | 5.0 |
| Phosgene ($COCl_2$) | 0.3 |
| Sulfur Dioxide ($SO_2$) | 5.0 |
| Acetylene | 25000 (LEL) |
| Ethylene | 27000 (LEL) |
| Methane | 50000 (LEL) |
| Hydrogen | 40000 (LEL) |

3.2.3.3 Inflator Particulate

For each Inflator technology, the Inflator Supplier should demonstrate that airborne particulate from the 100 $ft^3$ chamber meet the following requirements. In addition, the Inflator shall show no evidence of internal filter failure over the deployment temperature range specified in 5.2.2.5, Conditioning of Inflators.

3.2.3.3.1 Airborne Particulate Measurement and Analysis

Inflators shall meet the following airborne particulate effluent levels when tested in a closed tank and determined per 5.2.2.6, Effluent Test Procedure:

1. Total vehicle particulate shall not exceed those limits specified in Table 3.2.3.3.1.A, Effluent Airborne Particulate Limits. Each Inflator should not exceed the apportioned limits determined per Table 3.2.3.2.1.A Effluent Apportionment.

2. Particulate fraction of less than 10 micron shall be determined per SAE J1794 Restraint Systems Effluent Test Procedure, section 6.2, and reported.

***Table 3.2.3.3.1.A - Effluent Airborne Particulate Limits***

| | Vehicle Level Limit |
|---|---|
| Total Particulate | 125.0 $mg/m^3$ |
| Sub 10-micron particulate | Fraction to be reported only |

3.2.3.3.2 Tank Wash Particulate Measurement and Analysis

The particulate effluent levels shall be determined from samples collected per 5.2.2.8.3 Sampling Tank Contents (Tank Wash) Procedure. The following information shall be supplied from the sample(s).

1. Large particle weight (see 5.2.2.8.4 Tank Wash Solution and Particulate Analysis), Water Soluble and Water Insoluble fractions of the particulate shall be individually determined and reported.

2. Total particulate (excluding large particulate) shall be determined and reported.

3. Total tank wash particulate from each deployment shall not exceed 1.0 g, at room temperature.

4. The pH of the tank wash solution, diluted to 1000 mL, shall be measured and reported. The pH shall fall in the range of 4 to 10.5.

5. Full speciation including metals, soluble salts and mass balance, accounting for a minimum of 90% of the measured sample weight, shall be determined per 5.2.2.8.5, Tank Wash Solution and Particulate Speciation, and reported.

6. The speciation of the tank wash solution shall include a full metals scan, cation analysis, and anion analysis. A mass balance of the speciation analysis shall be provided (calculated fractional weights of each species found verses the total particulate sample mass).

7. Chemical species that have reacted post deployment, such as some carbonates and hydrated salts, etc., shall be corrected and reported as the un-reacted original weight.

NOTE: Tank wash particulate measurement and analysis shall be reported using the tables found in Appendix D, Gas and Particulate Reporting Tables and Analysis Methods.

3.2.4 Inflator Flaming

For the purposes of this test, deflectors, diffusers, shrouds, housings, etc., used as a standard component for applications of the Inflator to suppress external flaming, redirect gasses, minimize bag damage, and/or modify system performance, may be utilized. Components that block clear photographic documentation of the Inflator's performance (i.e., closed bags) shall not be allowed. The configuration of the device under test shall be clearly documented as part of the test report.

Testing shall be conducted per 5.2.3.8, Flaming Test with a minimum high speed video frame rate of 1000 fps.

Inflator Supplier shall provide digital video files showing the actual during-deployment and post-deployment flaming tests (high speed video for during-deployment and standard speed video for post-deployment flames).

Inflators deployed at +23 °C:

a. shall not have flames of any length or duration other than item c,

b. shall not have burning particles other than item c,

c. shall not have flames/sparks exceeding 5 ms in duration at or around the initiator, inclusive of the connector interface pocket or adjacent area.

d. shall not have any gas leakage residue at or around the initiator, excepting minimal witness marks caused by item c.

e. Burning of gasses and propellants shall not occur outside of the Inflator.

f. When directed by the RVEO, the Inflator shall not produce 'bag luminescence' visible in standard video (standard frame rate), using an uncoated bag per program direction, or Appendix A, Table IV G-1, other than item c.

Inflators deployed at +85 °C:

a. should not have flames of any length or duration other than item e,

b. shall not have flames exceeding 50 mm in length,

c. shall not have flames exceeding 20 ms in duration,

d. shall not have burning particles other than item e,

e. shall not have flames/sparks exceeding 5 ms in duration at or around the initiator, inclusive of the connector interface pocket or adjacent area.

f. shall not have any gas leakage residue at or around the initiator, excepting minimal witness marks caused by item e.

g. Burning of gasses and propellants shall not occur outside of the Inflator.

h. When directed by the RVEO, the Inflator shall not produce 'bag luminescence' visible in standard video (standard frame rate), using an uncoated bag per program direction, or Appendix A, Table IV G-1, other than items b, c, and e.

Inflators, during the time immediately post-deployment (10 s to 2 min minimum), with an external ignition source applied:

a. shall not have flames of any length or duration due to ignition of residual gases by the applied external ignition source,

b. shall not have burning particles.

The RVEO shall be the final arbiter of acceptable configurations and results of all flaming testing.

### 3.2.5 Auto-Ignition Performance

The Inflator(s) shall maintain structural integrity, shall not fragment or have any separation of components, and Inflator traceability identifier shall be legible (excepting components that melt or are consumed) when auto-ignition is induced by external heating per 5.2.3.2 High Temperature Oven (HTO) Test, 5.2.3.3 Bonfire Test or 5.2.3.4 Slow Heat/Autoignition Test.

#### 3.2.5.1 High Temperature Oven (HTO) and Auto-Ignition Performance

Additionally, Inflator(s) shall retain all stored gas (pressurized inflators) and shall not deploy during +107 °C heat soak environment. Gas venting for each pressurized Inflator shall be >+130 °C, or the mean-3σ gas venting temperature shall be >+115 °C. All pyrotechnic mixtures (such as propellants, auto-igniting materials, combustible gasses, etc.) of the Inflator shall have an auto-ignition temperature >+130 °C (as measured from the surface of the Inflator nearest the thermal path to the specific pyrotechnic mixture in question) when the Inflator is tested per 5.2.3.2, High Temperature Oven (HTO) Test. Additional quantities of Inflators can be used to minimize σ as required.

### 3.2.6 Accelerated Heat Aging

After exposure to environments as specified per 5.2.3.5 Accelerated Heat Aging Test, the Inflators:

a. shall not leak per 5.2.2.1, Leak Test Procedure,

b. shall maintain an initiator bridge wire resistance as specified per SAE/USCAR-28 Initiator Technical Requirements and Validation Specification of current issue, or as approved by the RVEO,

c. shall not show any loss in the measured strength or ballistic integrity of the propellant as demonstrated by ballistic performance and/or accepted break or crush strength measurement methods of live teardown Inflators (limited dusting that does not appreciably affect ballistic performance is excepted).

In addition, those Inflators deployed in a closed tank or open air:

a. shall deploy as intended when tested per 5.2.2.8, Closed Tank Test or 5.2.2.7, Open Air Test Procedure,

b. should meet tank wash requirements per 3.2.3.3.2, Tank Wash Particulate Measurement and Analysis,

c. shall meet all requirements per 3.2.9, Inflator Performance and Variability Limits, where ballistic curves are obtained.

3.2.7 High Humidity/Heat Age

After exposure to environments as specified in 5.2.3.6, High Humidity/Heat Age Test, the Inflators:

a. shall not leak per 5.2.2.1, Leak Test Procedure,

b. shall maintain an initiator bridge wire resistance as specified per SAE/USCAR-28 Initiator Technical Requirements and Validation Specification of current issue, or as approved by the RVEO,

c. shall not show any loss in the measured strength or ballistic integrity of the propellant as demonstrated by ballistic performance and/or accepted break or crush strength measurement methods of live dissection Inflators (limited dusting that does not appreciably affect ballistic performance is excepted).

In addition, those Inflators deployed in a closed tank or open air:

a. shall deploy as intended when tested per 5.2.2.8, Closed Tank Test or 5.2.2.7, Open Air Test Procedure,

b. should meet tank wash requirements per 3.2.3.3.2, Tank Wash Particulate Measurement and Analysis,

c. shall meet all requirements per 3.2.9, Inflator Performance and Variability Limits, where ballistic curves are obtained.

3.2.8 Sequential Test Series

After the completion of the Sequential conditioning series (or any individual or combination of environmental conditionings), the Inflator(s):

a. shall not leak per 5.2.2.1, Leak Test Procedure,

b. shall maintain an initiator bridge wire resistance as specified per SAE/USCAR-28 Initiator Technical Requirements and Validation Specification of current issue, or as approved by the RVEO,

c. shall not show any loss in the measured strength or ballistic integrity of the propellant as demonstrated by ballistic performance and/or accepted break or crush strength measurement methods of live dissection Inflators (limited dusting that does not appreciably affect ballistic performance is excepted).

In addition, those Inflators deployed in a closed tank or open air:

a. shall function as intended when deployed per 5.2.2.8, Closed Tank Test or 5.2.2.7, Open Air Test Procedure,

b. should meet tank wash requirements per 3.2.3.3.2 Tank Wash Particulate Measurement and Analysis,

c. shall meet all requirements per 3.2.9, Inflator Performance and Variability Limits where ballistic curves are obtained.

Inflators shall be exposed to environmental conditions in the following sequence for DV/PV:

1. Thermal Shock
2. Dynamic Shock (Low G/High G)
3. Vibration - Temperature Cycle
4. Humidity Resistance
5. Salt Spray
6. Drop Test

Inflators shall be exposed to environmental conditions in the following sequence for QFS:

1. Dynamic Shock (Low G/High G)
2. Vibration - Temperature Cycle
3. Humidity Resistance
4. Drop Test

3.2.8.1 Thermal Shock Resistance

Expose Inflators to environments per 5.2.3.7.1, Thermal Shock Resistance Test.

3.2.8.2 Dynamic Shock Resistance

Expose Inflators to the shock profile per 5.2.3.7.2, Dynamic Shock Test.

3.2.8.3 Vibration/Temperature Resistance

Expose Inflators to the environments per 5.2.3.7.3, Vibration - Temperature Cycle Test.

3.2.8.4 Humidity Resistance

Expose Inflators to the environments per 5.2.3.7.4, Humidity Resistance Test.

3.2.8.5 Salt Spray Resistance

Expose Inflators to the environments per 5.2.3.7.5, Salt Spray Test.

NOTE: Corrosion of the components is acceptable, unless the corrosion impacts the Inflator ability to meet functional requirements stated in 3.2.9, Inflator Performance and Variability Limits.

3.2.8.6 Drop Resistance

Expose Inflators to the environments per 5.2.3.7.6, Drop Test.

3.2.9 Inflator Performance and Variability Limits

When Inflators are tested per 5.2.2.8, Closed Tank Test, the following requirements shall be met:

1. Ballistic curves per the following shall be provided to the RVEO by the Inflator Supplier for all tests:

    a. Baseline deployments at each temperature (full and staged output for dual-stage Inflators).

    b. Scatter plots for each group with overlays of the mean curve, mean ±3σ curves and performance windows (see Appendix F, Ballistic Examples for examples).

    c. Data tables showing performance against the specified windows established per Table 3.2.9.A, Inflator Variability Limits.

    d. Environmentally conditioned Inflators deployed at each temperature, with comparison plots for each group with overlays of the mean baseline curve and performance windows.

2. The tolerances shown in Table 3.2.9.A, Inflator Variability Limits, shall be met at room temperature, hot temperature, and cold temperature by the baseline Inflators full and staged output(s). Mean±3σ of the baseline deployment groups at each temperature shall fall within each defined window, except TTFG, which shall be evaluated for each individual curve.

3. The tolerances shown in Table 3.2.9.A, Inflator Variability Limits, shall be met at room temperature, hot temperature, and cold temperature by environmentally conditioned Inflators full and staged output(s). The individual ballistic curves of each Inflator shall fall within each defined window.

4. A program specific closed tank mean curve shall be determined from an appropriate 'baseline inflator tank deployment' series, such as the baseline tests of the PV or other appropriate data set and approved by the RVEO. Dual-stage Inflators shall have full and staged output curves defined. Ongoing production Lot Acceptance Tests (LAT) shall be measured against the tolerances determined from Table 3.2.9.A, Inflator Variability Limits for the vehicle specific baseline mean curve(s). Each individual LAT Inflator curve shall fall within each defined window.

***Table 3.2.9.A - Inflator Variability Limits***

| **Inflator Variability Parameters (for Closed Tank Tests)** | | **Attribute Limits** |
|---|---|---|
| Slope calculated using the best fit line along the curve as calculated from a minimum of nine equally spaced points from 10 to 50% pressure | | Nominal ±12.5% |
| Time to First Gas (TTFG) (attribute based only) | TTFG | Ambient / Cold:<br>Passenger <5 ms / <7 ms<br>Driver <4 ms / <6 ms<br>Side <2 ms / <4 ms<br>Knee (recommended) <2 ms / <4 ms |
| Time at P=10% of peak | $T_{10\% \text{ of peak}}$ | $T_{(10\% \text{of peak})} \pm (30\% * T_{(10\% \text{ of peak})})$ |
| Time at P=25% of peak | $T_{25\% \text{ of peak}}$ | $T_{(25\% \text{of peak})} \pm (20\% * T_{(25\% \text{ of peak})})$ |
| *Pressure at P=50% of peak | $P_{50\% \text{ of peak}}$ | $P_{(50\% \text{ of peak})}$ + $(15\%* P_{(50\% \text{ of peak})})$ / - $(12.5\%* P_{(50\% \text{ of peak})})$ |
| *Alternative Time at P=50% of peak | $T_{50\% \text{ of peak}}$ | $T_{(50\% \text{ of peak})} \pm (12.5\% * T_{(50\% \text{ of peak})})$ |
| *Pressure at P=75% of peak | $P_{75\% \text{ of peak}}$ | $P_{(75\% \text{ of peak})} \pm (12.5\% * P_{(75\% \text{ of peak})})$ |
| *Alternative Time at P=75% of peak | $T_{75\% \text{ of peak}}$ | $T_{(75\% \text{ of peak})} \pm (12.5\% * T_{(75\% \text{ of peak})})$ |
| *Time at P=90% of peak | $T_{90\% \text{ of peak}}$ | $T_{(90\% \text{ of Peak})} \pm (12.5\% * T_{(90\% \text{ of peak})})$ |
| *Alternative Pressure at P=90% of peak | $P_{90\% \text{ of peak}}$ | $P_{(90\% \text{ of peak})} \pm (12.5\% * P_{(90\% \text{ of peak})})$ |
| Peak Pressure | $P_{max}$ | $P_{max} \pm (10\% * P_{max})$ |

**Evaluation of either P=50%, 75%, and 90% or T at P=50%, 75%, and 90% is allowed at the Inflator Supplier's discretion (based on curve slope at P=50%, 75%, and 90%). Only one attribute (P or T) at each percent is required to meet the criteria.*

*The RVEO shall have the option to modify the ± tolerance variability requirements if acceptable module performance can be demonstrated across the full range of ballistic variability. The RVEO shall be the final arbiter of acceptable Inflator variability.*

*Important Note: Care should be taken to compare the 'Time' based windows to the "Time at pressure x" calculated from each individual curve. It is not correct to construct an acceptance bar and to plot the curves graphically judging pass/fail on the curve breaking the acceptance bar as has been customary. Although true for all time-based windows, this is most apparent in the T at P90 (Time to 90% pressure) window where a horizontal bar would be evaluated against a pressure curve that is flattening and may be shifted up or down depending on the maximum pressure achieved. The T at P90 acceptance window creates a column of time. The calculated mean of the baseline deployments at 90% pressure, ±3σ column of time, must be evaluated against the calculated T at P90 point for each inflator ballistic curve. In the case of the environmentally conditioned inflator curves, each individual curve's calculated T at P90 point must fall in the baseline's T at P90 ± 10% column of time. It is much easier to evaluate the compliance of data by charting the acceptance windows and comparing the calculated values. Plotted curves and acceptance bars are of great value for other evaluations and should continue to be provided.*

3.2.9.1 Additional LAT Evaluation

The performance of each production LAT Inflator is to be evaluated against the program compliance windows as follows:

1. Calculate the specified Time and Pressure points for each curve as described in 3.2.9 Inflator Performance and Variability Limits.

2. Evaluate the Time and Pressure points of the LAT against the Time and Pressure windows for compliance.

In the event one or more pressure or time points fall outside of any of the defined LAT limits, the following additional evaluation can be done at the discretion of the Inflator Supplier with the concurrence of the RVEO supplier quality group:

1. Randomly select a minimum of 15 additional Inflators from the lot in question for each temperature where a LAT evaluation did not meet the defined limits.

2. Condition each group of Inflators at the appropriate temperature and deploy in a closed tank.

3. Perform the following two evaluations:

   Evaluation 1:

   a. Calculate mean curve from each group of deployed Inflators.

   b. From the mean curve, calculate the Time and Pressure points for each required acceptance criteria.

   c. Recalculate the accepted program Time and Pressure windows to ±33% of their original value.

   d. Compare the Time and Pressure points calculated from the mean curve of the lot in question to the recalculated program Time and Pressure windows for all points.

   Successful evaluation to this criterion is demonstrating a mean shift of less than 33% of the original program windows for each Time and Pressure window.

   Evaluation 2:

   a. Using the mean curve from each group of Inflators, calculate the specified Time and Pressure windows per Table 3.2.9.A, Inflator Variability Limits.

   b. Calculate the mean±3σ values for each Time and Pressure point for each group of deployed Inflators.

   Successful compliance to the specification is to have all mean±3σ Time and Pressure values (Step 2) fall within the calculated limits (Step 1).

   NOTE: Evaluation 1 is intended to evaluate the mean centeredness of the lot in question. Evaluation 2 is to evaluate the individual lot's variability. In both cases the intent is to provide an ongoing measurement of the inflator's ability to perform to output characteristics consistent with those that were agreed to in the specific program development and validation.

3.2.10 Propellant Stability

The Inflator Supplier shall supply test data showing that all propellants, gasses, and pyrotechnic materials contained within the Inflator will remain within the specified performance requirements per 3.2.9, Inflator Performance and Variability Limits, for a minimum of an Inflator target life of 15 years. This shall be demonstrated by the successful completion of the informational requirements of Appendix A, Pre-Source Qualification (QFS), Sections III-G and IV-K, a DV, and PV per this specification.

The Inflator Supplier shall provide basic ESD, Friction and Thermal Shock data in the unaged and aged conditions of all propellants, gasses (if applicable) and pyrotechnic materials contained within the Inflator.

Prior to conducting an inflator-level PV, the evaluation of Propellant Stability in Simulated Regions of High Absolute Humidity (see Appendix A, IV-K) shall be performed on propellant produced with mass production equipment at the production-intent facility and has been PPAP approved per AIAG or IATF 16949 process. The results of this evaluation shall be provided to the RVEO for review.

Requirements as described in Appendix A, Pre-Source Qualification (QFS) Requirements, are an attempt to assess the risk associated with stability over the lifetime of a propellant system; however, Inflator Suppliers are obligated to understand if the propellant will change in such a manner that causes risk of Inflator rupture or other safety issues to customers. This may include other testing protocols not included in this specification.



3.2.11 Hermeticity

For pyrotechnic Inflators, hermeticity (leak) limits shall be defined by successful completion of an ‘Induced Moisture Margin Study.’ The acceptable ‘leak’ limit is calculated based on the following assumptions:

1. daily respiration of +33 °C, 80% RH air (refer to MIL-STD-810G),

2. differential pressure based on a diurnal temperature range of +38 °C (refer to MIL-STD-810G),

3. all water is retained (i.e., no water is expired on each cycle),

4. cycles (one per day for 15 years),

5. instantaneous min to max temperature change,

6. 6-hour duration at each condition,

7. circular duct of the shortest possible length.

The calculated leak rate shall allow less moisture intrusion into the Inflator than is demonstrated by the Induced Moisture Margin Study to degrade the Inflator performance by less than or equal to 10%.

The leak rate limit shall be set at a maximum of the calculated requirement, or 1 x $10^{-4}$ $^{cc}/_{atm.sec}$ (assuming 100% Helium) or equivalent, whichever is less.

For stored gas inflators, hermeticity limits shall be determined by considering both an induced moisture margin study for any pyrotechnics not inside the pressurized region and the gas loss of the pressure vessel(s). The overall hermeticity limit shall be set at the resulting calculated value limiting the potential degradation of the Inflator performance over the 15 year vehicle life to less than or equal to 10%.

3.2.11.1 Leak Detection

All inflator(s) shall contain helium or an equivalent substance which shall be detectable if a leak is present in the pressure vessel or pyrotechnic chamber per 5.2.2.1, Leak Test Procedure. Alternate procedures are acceptable (i.e., bombing, etc.) where process reliability and sensitivity are demonstrated to the RVEO.

3.2.11.2 Pressurized Inflators

All stored gas pressure bearing components (body, welds, burst disk(s), etc.) shall remain intact with no cracks, fractures, or mechanical failures and shall not leak at a rate greater than that determined per 3.2.11, Hermeticity, after exposure to pressure cycling per 5.2.3.9, Pressure Cycle Durability Test and tested per 5.2.2.1, Leak Test Procedure. The Inflator burst disk(s), body, and all welds under high pressure shall be evaluated.

3.2.12 Dual-Stage Inflator - Additional Requirements

3.2.12.1 Dual-Stage Inflator Tunability

Following deployment of the primary stage of dual-stage Inflators, the Inflator's secondary stage shall have the capability of being delay deployed over a range of 0 to 150 ms.

The Inflator's primary to secondary output ratio should be tunable from 50/50 maximum to 80/20 minimum of the total available ballistic output.

3.2.12.2 Sympathetic Ignition of Secondary Stage

When deployed at any temperature from -40 to +85 °C, the secondary stage of a dual-stage Inflator shall not sympathetically ignite or otherwise inadvertently deploy from 0 to 150 ms, or during the restraint cycle of the primary stage, whichever is greater.

The secondary stage of a dual-stage Inflator shall be allowed to ignite or deploy as a result of residual heat or some other repeatable and reliable method, from 150 ms to a maximum of 150 seconds based on an ambient test. Repeatable and reliable automatic or sympathetic ignition of the second stage shall be demonstrated over the full operational temperature and output range of the Inflator. This demonstration shall include a minimum of six tests at each temperature -40 °C, +23 °C, and +85 °C. The mean deployment time +3σ shall be less than 30 seconds at +23 °C.

Any automatic or sympathetic ignition of the second stage shall be well characterized to provide no potential for increased injury to an occupant in a representative module by a minimum of three worst-case static occupant position tests using a primary/secondary output split as agreed to by the RVEO.

Following deployment of the primary stage, a delayed ignition (or deactivation) of the secondary stage beyond 150 seconds in an ambient test (in a manner that will not cause hazard, decrease the protection of the system to the occupant(s), or cause audible alarm to occupants or emergency personnel) shall be permissible only as agreed to by the RVEO.

3.2.12.3 Dual-Stage Inflator Offset

Unless otherwise specified, for dual-stage Inflators, tests shall be conducted by deploying both the primary and secondary stages simultaneously (0 ms offset).

4. VALIDATION

Any change to a DV- or PV-qualified Inflator's structure, part configuration, propellant load (increased), manufacturing method, or any other change that could alter the outcome of any tests included in the DV or PV test (series) contained herein shall require re-validation. Re-validation may be accomplished through a subset of the requirements (delta DV or PV) containing only tests where the outcome is influenced by those changes. Any delta DV or PV shall be agreed to in advance by all affected parties at the RVEO.

Laboratory and test facilities shall be accredited by the American Association for Laboratory Accreditation (A2LA), the Standards Council of Canada (SCC), ISO or other locally accepted laboratory accreditation program.

## 4.1 Design Verification/Production Validation Report Format

DV and PV Test reports shall include as a minimum the following items:

1. Summary: The summary shall include a clear and complete description of the device in test, cut away drawings of the device in test, indented bill of materials (including part numbers, rev. levels, etc.), a summary description of tests, ballistic summary charts (scatter plots, mean and variability plots, tabular performance charts as defined in 3.2.9, Inflator Performance and Variability Limits), and analysis of test results.

2. Deviations: All deviations from the specified test protocol and performance requirements, design issue resolutions and any other relevant supporting information generated during the execution of the DV or PV shall be included or summarized in a subsection of the completed test report. All deviations and agreements or approvals by the RVEO that alter the requirements of this document shall be documented and included as a subsection/appendix titled, 'Deviations' in the DV or PV report.

3. Test Plan: The test plan shall include a configuration document detailing the exact configuration tested, future product changes not included in the current test configuration (if applicable), test schedule (projected or actual dates), and test plan (including test location and equipment).

4. Appendices: Appendices should include detailed build records, conditioning records, detailed test results, equipment description and certification (if required), and any other supporting data. Appendices may be bound as a separate volume.

## 4.2 Deviations From Test Procedure

Deviations from specified test requirements and procedures shall be approved in writing by the RVEO prior to beginning the test procedure. In the case that the deviation occurs during the conditioning and/or testing of the device, the RVEO shall be notified as soon as practical, verbally and in writing, as to the circumstances of the deviation. The RVEO shall determine if further testing is required to maintain the intent of the test requirements. All deviations and supporting information shall be included in the test report.

## 4.3 Design Verification Process

### 4.3.1 DV Program Sequence

Following is the recommended Design Verification (DV) process:

1. Inflator Supplier completes requirements as outlined in Appendix A, Pre-Source Qualification (QFS) Requirements and reviews with the RVEO for approval.

2. Inflator Supplier completes configuration document/test plan and makes them available to the RVEO for review.

3. The RVEO reviews the QFS information and DV test plan. All proposed changes to the plan should be submitted for review to the RVEO for agreement prior to implementation.

4. DV Build proceeds. The RVEO should be given the opportunity to attend the DV Build and subsequent testing.

NOTE: Proceeding with a DV without RVEO review and approval is at the supplier's own risk and may result in refusal to accept the test report and/or additional testing.

### 4.3.2 DV Test Plan

The DV test plan shall be structured in accordance with Appendix B, DV/PV Test Matrix.

Any delta DV report shall clearly reference the previously completed DV report(s) containing the surrogate data used to fulfill all DV requirements.

Copies of the original data should be included in the DV report along with a detailed description of the source and applicability of the data.

## 4.4 Production Validation Process

### 4.4.1 PV Program Sequence

The production validation (PV) process shall proceed according to the following sequence:

1. Inflator Supplier prepares package for Supplier Quality Assurance and/or RVEO showing compliance with design and manufacturing requirements (including PFMEA) as required by PPAP.

2. Inflator Supplier completes configuration document, test plan, and time schedule and provides completed documents to Supplier Quality Assurance and/or RVEO for review and agreement.

3. Supplier Quality Assurance and/or RVEO approves documentation including PFMEA and PV test plan. Once the PV test plan has been approved, any additional changes to the plan shall be submitted to Supplier Quality Assurance and/or RVEO for approval prior to implementation.

4. PV build proceeds. The PV build shall be built at production capacity planned cycle time. The RVEO shall be given the opportunity to attend the PV build and all subsequent testing.

### 4.4.2 PV Test Plan

PV test plan shall be structured from three lots of Inflators that contain three different lots of main propellant (a, b, and c) in accordance with Appendix B, DV/PV Test Matrix.

Any delta PV report shall clearly reference the previously completed PV report(s) containing the surrogate data used to satisfy all PV requirements.

Copies of the original data should be included in the PV report along with a detailed description of the source and applicability of the data.

# 5. TEST REQUIREMENTS

## 5.1 General Requirements

### 5.1.1 Measurement Tolerances

Measurement tolerances shall be as follows:

| | |
|---|---|
| Time | ±1% (except where minimums are stated) |
| Temperature | ±2 |
| Relative Humidity | ±10% of RH |
| pH | ±0.1 pH |
| Force | ±4 N |
| Vacuums | ±10 mm of Hg |
| Height | ±0.05 m |
| Frequency | ±4% or ±2 Hz, whichever is greater |
| Current | ±0.01 A |
| Voltage | ±5% |
| Resistance | ±1.0% |
| Tank Volume | ±5.0% as measured per SAE J2238 |
| Firing Pulse | ±25% |
| Mass | ±0.01 g |

All test conditions shall be within the above stated tolerances at the time of test. These tolerances shall not be used independently.



## 5.2 General Tests

### 5.2.1 Test Equipment

Test equipment shall be utilized as specified by the indicated test procedures, standards, and specifications.

All Inflators tested in a closed ballistic tank shall be attached to a sealed tank with chemically inert internal surfaces and of appropriate volume per Table 5.2.1.A, Closed Tank Sizes. The attachment shall allow the Inflator to discharge all gases (all gases shall be collected in the tank after deployment) into the tank when activated and shall position the Inflator so the gas jets are not aimed directly at the pressure transducer(s).

***Table 5.2.1.A - Closed Tank Sizes***

| Inflator Type | Tank Size (Liters) |
|---|---|
| Passenger | 60 |
| Driver | 60 |
| Side, Knee | 28.3 (1 $ft^3$) |
| Curtain | 28.3 or 60 (as appropriate) |

#### 5.2.1.1 Calibration of Equipment

Calibration of all equipment shall be done at an appropriate time interval as determined by the usage or recommendation of the equipment manufacturer. Records of the calibration shall be maintained and made available at the request of the RVEO.

### 5.2.2 General Procedures

#### 5.2.2.1 Leak Test Procedure

The Inflator Supplier shall adhere to leak check procedure(s) compatible with the Inflator technology(s). The leak checking procedure shall be demonstrated capable of detecting leaks from 'gross' through one order of magnitude more sensitive than the leak rate established in 3.2.11, Hermeticity.

#### 5.2.2.2 Weight Inspection Procedure

All Inflators shall be weighed, with weights reported in grams to a minimum of two decimal places (i.e., xxx.xx g). The weights shall be recorded along with the Inflator serial number for comparison to manufacturing, pre-environmental, post-environmental, and post-test weights. All weights shall be reported in chart form in the QFS, DV, and PV reports.

5.2.2.3 Visual Inspection Procedures

5.2.2.3.1 Pre-Deployment Inspection

All Inflators shall be carefully examined, taking note of all external physical features such as nozzle holes present, seal integrity, weld or crimp appearance and integrity, as well as any other physical characteristics that can be noted by external physical examination. Post environmental examination shall include any changes to the physical appearance of the inflator as well as the presence or absence of normal features. All visual observations shall be reported in chart form and included in the QFS, DV, and PV reports.

5.2.2.3.2 Post-Deployment Inspection

All Inflators shall be carefully examined after testing, taking note of the presence or absence of normal features as compared to pre-deployment condition. Inflators tested at +85 °C (full output only for dual stage) in a closed tank or tested for auto-ignition compliance shall have the amount of physical deformation incurred during deployment characterized in manner relevant to the module/vehicle and can be statistically evaluated. An example of measurements for a disk-style Inflator is shown in Figure 5.2.2.3.2.A, Inflator Deformation Measurements. Values for each tested Inflator should be correlated with IOP values collected during the test and shall be reported in chart form in the QFS, DV, and PV reports.

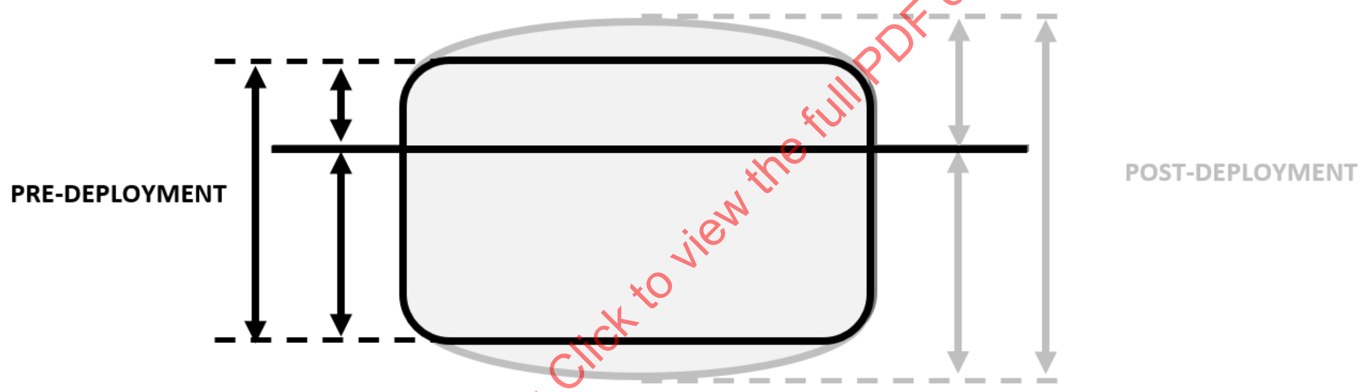



***Figure 5.2.2.3.2.A - Inflator Deformation Measurements***

Deployed Inflators that require internal inspection shall be opened in an appropriate manner that minimizes damage to the internal components and carefully examined, taking note of any characteristics of components/assembly (i.e., filter burn, deformation, etc.) and significant differences between parts, if any. High resolution X-ray or CT scans of the tested Inflators prior to opening should be utilized as appropriate to get a clear understanding of how internal components interact during deployment.

5.2.2.4 Electrical Check Procedure

All Inflators shall be evaluated for proper electrical isolation and continuity requirements per appropriate safety procedures. All electrical measurements shall be recorded along with the Inflator serial number for comparison to manufacturing, pre-environmental, and post-environmental measurements. All electrical measurements shall be reported in chart form in the test reports.

5.2.2.5 Conditioning of Inflators

1. Condition Inflator at appropriate temperature for minimum of 4 hours or 125% of the demonstrated time for the Inflator core temperature to reach equilibrium with the conditioning temperature. The time to equilibrium temperature shall be demonstrated with the worst-case positioning and maximum number of Inflators in the conditioning chamber.

2. Inflators shall be deployed within 3 minutes of removal from the conditioning chamber. Other methods where 'at temperature' deployments are demonstrated are acceptable as approved by the RVEO are allowed. On occasions an Inflator cannot be deployed within the required 3 minutes, the Inflator shall be returned to the conditioning chamber within 5 minutes and reconditioned for a minimum of 1 hour or 125% of the time required for the Inflator core temperature to reach equilibrium at the required deployment temperature.

5.2.2.6 Effluent Test Procedure

The gaseous and particulate effluent levels shall be measured and analyzed per SAE J1794 Restraint Systems Effluent Test Procedure, with the following additions:

1. Airborne particulate effluent shall be sampled at the rate of 5.0 L/min or greater (as appropriate for the analytical method(s) used) with a tolerance of ±10% L/min for 20 minutes.

2. Gaseous effluents shall be sampled at the rate of 10 L/min ± 0.25 L/min or a rate deemed to be appropriate for the analytical method being used. Gas samples shall be taken at 1, 5, 10, 15, and 20 minutes minimum. It is acceptable to sample gases directly into analysis cell on a continuous basis or at the above intervals. It is also acceptable to use Tedlar bags for sample collection. If Tedlar bags are used, the collection shall be started in a timely fashion (less than 5 minutes from the time of the deployment). It is acceptable to use a single continuous (20 minutes) sample for analytical techniques where appropriate (i.e., absorbing/adsorbing of organics, etc.).

3. Gas concentrations shall be reported in PPM as 20-minute time weighted averages (TWA). A 20-minute TWA concentration for each gas shall be calculated using an appropriate mathematical formulation, i.e., the following equation if 1-, 5-, 10-, 15-, and 20-minute samples are used:

$$TWA_{20} = (1C_1 + 4C_5 + 5C_{10} + 5C_{15} + 5C_{20})/20$$

4. A maximum of the lesser of 5% or 141.5 L total of gas volume of the test chamber shall be removed from the chamber for sampling purposes. Return lines for continuous sampling loops and particulate filters shall be used if sampling flow rates would otherwise exceed 5% of the chamber volume or 141.5 L total gas.

5.2.2.7 Open Air Test Procedure

Inflators that require open air deployment shall use the following (or equivalent) equipment and procedure.

Purpose: To define procedure for testing Inflator assemblies on an open-air stand.

Equipment:

Constant Current/Voltage Supply
Actuation equipment and Ohmmeter
Approved Data Acquisition and Camera Systems
Temperature chamber(s) capable of maintaining -40 °C, +23 °C, or +85 °C as required

Procedure:

1. Condition Inflators as required per 5.2.2.5, Conditioning of Inflators.

2. Verify ready condition of all cameras, lighting, transducers, etc., for the deployment.

3. Remove Inflator from conditioning chambers and make all necessary preparations for deployment.

4. Deploy the Inflator using the all-fire pulse within the proper time interval per 5.2.2.5, Conditioning of Inflators.

5. The results including any residue, flame observed, and a visual post deployment test and/or inspection of the Inflator shall be reported in a clear concise manner in the test reports.



5.2.2.8 Closed Tank Test

Inflators that require Closed Tank deployment shall use the following (or equivalent) equipment and procedures.

5.2.2.8.1 Closed Tank Test Procedure

Purpose: To define procedure for testing Inflator assemblies in a closed tank.

Equipment:

Constant Current/Voltage Supply
Actuation equipment and Ohmmeter
100 to 200 psi Pressure Transducer (or as appropriate)
Sealed Test Tank per Table 5.2.1.A, Closed Tank Sizes
Approved Data Acquisition System
Temperature chamber(s) capable of maintaining -40 °C, +23 °C, or +85 °C as required

Procedure:

1. Where tank content samples are required, clean the test tank per 5.2.2.8.1, Tank Cleaning Procedure. Tank shall be at ambient temperature and pressure prior to deployment.

2. Remove Inflator from conditioning chambers and make all necessary preparations for deployment.

3. Deploy the Inflator using the all-fire pulse within the proper time interval per 5.2.2.5, Conditioning of Inflators, collecting all appropriate data from the test. For tests that require sampling of tank contents, see 5.2.2.8.3 Sampling Tank Content (Tank Wash) Procedure.

4. Using appropriate PPE, remove the Inflator from the tank. Visually inspect the Inflator for any abnormalities and note any findings. Record post-test weight.

Data Processing and Reporting:

1. Standard data shall include:

   a. All pressures to be reported in kPa

   b. Time to first gas (TTFG)

   c. Pressure versus Time curve (Data filtered with SAE Class 60 filter per SAE J2238).

   d. Slope using the best fit line along the curve as calculated from a minimum of nine equally spaced points from 10 to 50% peak pressure

   e. Time at 10% peak pressure

   f. Time at 25% peak pressure

   g. Pressure and Time at 50% peak pressure

   h. Pressure and Time at 75% peak pressure

   i. Pressure and Time to 90% peak pressure

   j. Pressure and Time to Peak pressure

2. All ballistic charts shall include test description (title), test temperature, test number(s), tank size, company name, and any other information required to identify the specific test. For sample data formatting, see Appendix F, Ballistic Examples. For all mean curves, include the number of deployments used.

3. Report any anomalies, residue, etc., in the test report.

5.2.2.8.2 Tank Cleaning Procedure (pre-test and post-test with no sampling)

Purpose: To define the general procedure for washing test tanks and purging them prior to sampling tank contents.

Equipment:

Distilled or deionized water
Mild, nonabrasive detergent
Clean brush
Spray gun
Clean, dry, lint-free cloth

Procedure:

1. Use spray gun (or equivalent) to spray and wash the residue off the tank walls, lid, and fixtures with deionized or distilled water.

2. Using a nonabrasive detergent (if any oily substances are present) and a clean brush, scrub the entire interior surface of the tank. Make sure all openings, bulkheads, and seals of the tank are clean and free of deposits.

3. Drain the tank completely through the appropriate tank opening.

4. Thoroughly flush the tank, openings, fittings and fixtures a final time with deionized or distilled water. Drain the tank and allow for the tank to dry completely. A clean, dry, lint-free cloth or clean dry lab air can be used to dry the tank.

5.2.2.8.3 Sampling Tank Contents (Tank Wash) Procedure

Purpose: To define a general procedure for sampling tank contents after an Inflator deployment.

Equipment:

1000 mL deionized or distilled water
1 L chemically inert bottle or flask
30 to 40 psi spray gun (or equivalent)

Procedure:

1. After the completion of data collection, allowing time for suspended particulate to settle (up to 1 min or as required), vent the gases from the tank via the bleed valve into the exhaust system.

2. Using appropriate PPE, remove the Inflator from the tank. Visually inspect the Inflator for any abnormalities and note any findings.

3. Use spray gun (or equivalent) to spray and wash the residue off the tank walls, lid, and fixtures using approximately 500 mL of deionized or distilled water.

4. Capture all liquid and residue in an appropriate clean container.

5. Repeat step 1 with an additional approximately 500 mL of deionized or distilled water to equal less than 1000 mL of total liquid. Take special care to assure all openings, bulkheads, seals, and internal walls of the tank are thoroughly rinsed and clean.

6. Add the second 500 mL of liquid and residue into the sample from item 3 (i.e., 1 L chemically inert bottle or flask). Analyze entire 1000 mL sample per 5.2.2.8.4, Tank Wash Solution and Particulate Analysis, and 5.2.2.8.5, Tank wash Solution and Particulate Speciation, if required.



5.2.2.8.4 Tank Wash Solution and Particulate Analysis

Purpose: To describe general requirements for the analysis of the tank wash solution and particulate from the Inflator closed tank tests.

Determination of the pH, Particulate Weight, and Soluble/Insoluble Fractions:

1. Measurement of the pH of the tank wash solution:

   a. Volumetrically dilute the sample to 1000 mL. Transfer an aliquot of the sample to a clean beaker, measure and report the pH of the tank wash solution.

   b. The pH meter calibration shall be verified before and after the measurement using a buffered standard within two pH units of the measured value.

2. Particulate Analysis (Large, Soluble, Insoluble and Total weight of particulate):

   a. Using the sample from part 1, filter the sample through a 10 mesh (or less, i.e., larger) medium. Determine weight and origin of large particulate removed by the medium.

   b. Filter the insoluble material from the sample using a clean pre-weighed filter paper.

   c. Dry the filter paper and determine the weight of the insoluble material.

d. Evaporate the entire filtered (or an aliquot of a minimum 200 mL) sample to dryness in a drying oven at a temperature that will not decompose the sample. Total dissolved solids method is acceptable where controlled experiments have demonstrated their accuracy.

e. Weigh and report the full soluble particulate weight and the sample size analyzed.

f. Report the sum of the soluble and insoluble particulate fractions as the Total particulate weight.

5.2.2.8.5 Tank Wash Solution and Particulate Speciation

Purpose: To describe the general requirements for the full species analysis of the tank wash solution and particulate from the Inflator closed tank tests. Specific situations may require additional procedures.

Test Requirements:

Elemental and/or molecular composition (salts) of the soluble and insoluble fractions of particulate shall be determined and reported per the tables supplied in Appendix D, Gas and Particulate Reporting Tables and Analysis Methods. In addition to providing a full analysis of all major components, the concentration and calculated mass of the following elements in the particulate shall be determined: aluminum, cadmium, chromium, copper, iron, lead, nickel, mercury, arsenic, and zinc. A single set of analysis for each Inflator family with a specific chemistry is acceptable for DV and PV.

1. Insoluble Fraction analysis

   a. Dissolve the insoluble particulate fraction from a tank wash in an appropriate carrier to prepare for analysis (i.e., aqua regia.) Note: Use approximately 2 mL per 1 mg of sample weight.

   b. Perform elemental analysis for metals and report the mass concentration for each element.

2. Soluble Fraction analysis

   a. Perform elemental analysis for metals.

   b. Perform ionic analysis for anionic and cationic (where applicable) soluble species.

   c. Report the concentration and calculated mass for each element.

Calibration Check or Routine Calibration:

1. The general calibration of instrumentation and the analysis specific calibration shall be consistent with common analytical practices for each type of analysis.

2. A minimum of one calibration check shall be performed for each group of analysis. The calibration check shall include all reported elements. The concentrations of each element in the standard shall bracket the range of the measured concentration for that element in the sample.

3. For all analyses, where applicable (AA, ICP, HPLC, etc.), a (matrix) blank shall be carried through the entire analytical procedure along with the actual samples to account for background concentrations, matrix effects and potential losses during sample handling. Results from the background sample analyses shall be reported along with that for the actual samples.

5.2.2.9 Live Dissection Procedure

Purpose: To provide a general procedure for evaluation of Inflator internal components.

Procedure:

1. Fixture the Inflator and vent any stored gas per appropriate safety protocol.

2. Open body chamber(s) of Inflator per appropriate safety protocol, in a way that minimizes disturbance of the internal components of the Inflator.

3. Remove and document any degradation, deformation, or other changes to the internal components. Analysis of all propellant formulations shall include density, moisture, crush strength, burn rate, DSC, and sieve range masses for all propellant formulations. Pictures documenting every step in the teardown process and of each component/subassembly shall be reported. Retain components for review of the RVEO for a minimum of 1 year after submission of the DV or PV report (consult with the RVEO for any additional retention requirements). Where hazardous components are clearly documented to be within normal requirements and such documentation is immediately available, those components can be discarded with approval from the RVEO.

5.2.3 Specific Tests

5.2.3.1 Structural Burst Test

Purpose: To evaluate Inflator burst strength and to determine the burst mode of Inflator.

Equipment:

Hydrostatic (or fluid) pressure equipment.

Procedure:

1. The Inflators shall be tested at +23 °C per 5.2.2.5, Conditioning of Inflators.

2. Seal Inflator gas ports.

3. Increase pressure gradually (i.e., <150 psi/ms) until burst occurs. Pressure values shall be recorded throughout the entire test. For dual-stage Inflators, conduct structural burst of each pressure vessel separately and all chambers simultaneously by pressurizing in parallel.

4. Document burst mode with a description and pictures clearly depicting failure mode.

5.2.3.2 High Temperature Oven (HTO) Test

Purpose: Verify that the Inflator will not deploy at, or below, +115 °C or auto-ignite below +130 °C.

Equipment:

Temperature chamber or equipment, capable of maintaining +107 °C. The same equipment or other as required to raise the inflator temperature at a rate of ≤14 °C/min until the inflator deploys.

Procedure:

1. Inspect all Inflators for gas leaks (pressure vessel type Inflator).

2. Condition Inflators for minimum of 4 hours at +107 °C.

3. The temperature of the Inflators shall then be increased at a rate not to exceed 14 °C/min until all gas and pyrotechnic materials are spent. Event times and pictures of post-test samples shall be included in the test report.

5.2.3.3 Bonfire Test

Purpose: Verify that the Inflator will deploy and not fragment when subjected to a bonfire per USDOT requirements.

Equipment:

Bonfire test equipment
Video recording equipment

Procedure:

1. Conduct Bonfire test per USDOT requirements on the subject Inflators. Event times and pictures of post-test samples shall be included in the test report.

5.2.3.4 Slow Heat/Autoignition Test

Purpose: Verify that the Inflator will deploy and not fragment when subjected to a surface heating rate of ≤14 °C/min.

Equipment:

Slow Heat equipment capable of ≤14 °C/min controlled heating of the Inflator surface
Protective enclosure
Video recording equipment

Procedure:

1. Starting at +23 °C, raise the temperature of the inflator at a rate not to exceed 14 °C/min, until deployment of the Inflator.

2. Heating shall continue until all energetic materials in the Inflator deploy. Event times and pictures of post-test samples shall be included in the test report.

5.2.3.5 Accelerated Heat Aging Test

Purpose: Evaluate Inflator resistance to temperature aging in a dry condition.

Equipment:

Temperature chamber, capable of maintaining +90 °C or +107 °C, as required.

Procedure:

1. Condition Inflators at +90 °C for minimum 1000 hours* or +107 °C for minimum 408 hours, with maximum 20% RH.

2. Inspect Inflator for gas leaks (pressurized Inflator).

3. Verify Inflator terminal-to-terminal resistance after each conditioning.

4. Perform testing as required per appropriate Test Matrix.

*NOTE: Acceptance of 1000 hours at +90 °C should be verified for each RVEO. All participants in this specification may not accept 1000 hours at +90 °C as an alternate method of testing in equal measure.

5.2.3.6 High Humidity/Heat Age Test

Purpose: Evaluate Inflator resistance to temperature aging in an environment of high humidity.

Equipment:

Temperature/Humidity chamber capable of maintaining 95% RH at +70 °C.

Procedure:

1. Condition Inflators at +70 °C with a minimum of 95% RH for minimum of 408 hours.

2. Inspect Inflator for gas leaks (pressurized Inflator).

3. Perform visual inspection of each Inflator. All discrepancies shall be documented and included in the test report.

4. Verify Inflator terminal-to-terminal resistance.

5. Perform testing as required per appropriate Test Matrix.



5.2.3.7 Sequential/Environmental Tests

Purpose: To evaluate Inflator performance in a series of different environmental conditions.

5.2.3.7.1 Thermal Shock Resistance Test

Purpose: To evaluate performance effect on Inflator components due to rapid temperature changes.

Equipment:

Temperature chamber(s), capable of maintaining cycling between -40 to +90 °C as required.

Procedure:

1. Beginning and ending at +23 °C, apply 200 temperature cycles, where one temperature cycle consists of the sequence illustrated in the figure below.

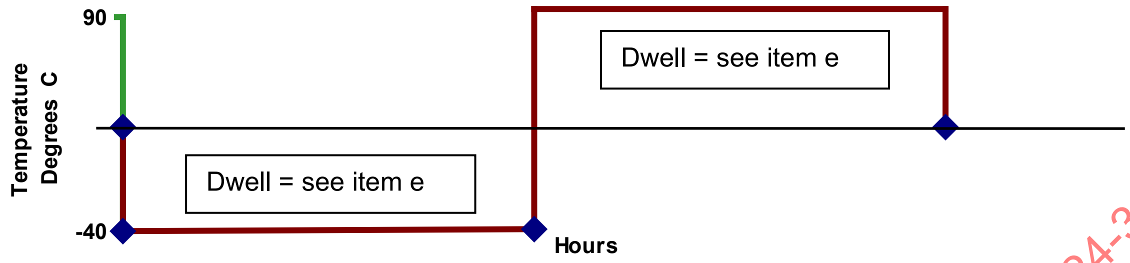
2. Perform visual inspection of each Inflator. All discrepancies shall be documented and included in the test report.

3. Inspect Inflator for gas leaks (pressurized Inflator).

4. Optional: Verify Inflator terminal-to-terminal resistance.

5. Perform testing as required per appropriate Test Matrix.

**Temperature Cycle**
**Inflator core temperature shall reach the specified conditioning temp**
**Duration of a cycle may vary with inflator size (see note e)**




*a- Place Inflator into -40 °C chamber within 120 seconds.*
*b- Condition Inflator at -40 °C.*
*c- Place Inflator into +90 °C chamber within 120 seconds.*
*d- Condition Inflator at +90 °C.*
*e- Dwell shall be four hours or 125% of the time the core temperature of all inflators require to equilibrate in the test chamber, using the actual mounting method and quantity of inflators under test.*
*Note: Temperature overshoot of up to 10 °C with a worst-case instrumented control inflator is acceptable.*

5.2.3.7.2 Dynamic Shock Test

Purpose: To evaluate the effects of mechanical shocks such as potholes, steering wheel adjustment (25 g), and high impacts (60 g) on Inflator performance.

Equipment:

Rigid fixture to mount Inflator
Shaker

Procedure:

1. Condition Inflators at +23 °C per 5.2.2.5, Conditioning of Inflators.
2. Complete dynamic shock test per the schedule in the following table.
3. Perform visual inspection of each Inflator. All discrepancies shall be documented and included in the test report.
4. Inspect Inflator for gas leaks (pressurized Inflator).
5. Optional: Verify Inflator terminal-to-terminal resistance

| ***LOW g Test*** | ***HIGH g Test*** |
|---|---|
| Acceleration: Minimum of 25 g<br>Nominal Shock Duration: 6 ms<br>Nominal Shock Shape: Half Sine<br>Number of Shocks Per Axis: 3 (18 total)<br>Three axes (X, Y, Z) in both positive and negative directions<br><br>**Test Method:**<br><br>a. Apply 25 g, three times<br>b. Change axis and repeat step 1<br>c. Continue step 1 and step 2 until all six axes are tested | Acceleration: Minimum of 60 g<br>Nominal Shock Duration: 11 ms<br>Nominal Shock Shape: Half Sine<br>Number of Shocks Per Axis: (18 total)<br>Three axes (X, Y, Z) both positive and negative directions<br><br>**Test Method:**<br><br>a. Apply 60 g, three times<br>b. Change axis and repeat step 1<br>c. Continue step 1 and step 2 until all six axes are tested |

5.2.3.7.3 Vibration - Temperature Cycle Test

Purpose: To evaluate the effect of vibration and temperature on Inflator performance.

Equipment:

Temperature chamber, capable of cycling between -40 to +90 °C as required
Rigid fixture to mount Inflator
Shaker

Procedure:

1. Condition Inflators at +23 °C per 5.2.2.5, Conditioning of Inflators.

2. Apply the random vibration profile for a minimum of 22 hours along each axis. The Inflator X-axis is an axis parallel to the centerline of the initiator's pins or lead wire. Y- and Z-axes are mutually perpendicular to this axis. The vibration profile is shown in Table 5.2.3.7.3.A.

***Table 5.2.3.7.3.A - Vibration Profile***

| **Frequency range: 5 - 1000 Hz** | | ***Driver Inflators*** | ***Passenger/Side Inflators*** |
|---|---|---|---|
| **PSD Level at:** | **5 Hz** | 20 $m^2 / s^3$ = 0.21 $g^2$/Hz | 8.7 $m^2 / s^3$ = 0.09 $g^2$/Hz |
| | **30 Hz** | 20 $m^2 / s^3$ = 0.21 $g^2$/Hz | 8.7 $m^2 / s^3$ = 0.09 $g^2$/Hz |
| | **200 Hz** | 0.5 $m^2 / s^3$ = 0.0052 $g^2$/Hz | 1.1 $m^2 / s^3$ = 0.011 $g^2$/Hz |
| | **1 kHz** | 0.1 $m^2 / s^3$ = 0.001 $g^2$/Hz | 0.22 $m^2 / s^3$ = 0.0023 $g^2$/Hz |
| **Maximum acceleration:** | | 33 m / $s^2$ = 3.365 g RMS | 30 m / $s^2$ = 3.053 g RMS |

3. Apply temperature cycle of 11 hours total twice during each axis of vibration testing. One temperature cycle consists of the following steps (see Figure 5.2.3.7.3.B):

   a. Drop temperature to -40 °C at the rate of 2 °C/min

   b. Condition Inflator for a minimum of 270 ± 5 min at -40 °C

   c. Raise temperature to +90 °C at the rate of 2 °C/min

   d. Condition Inflator for a minimum of 270 ± 5 min at +90 °C

   e. Bring inflators to +23 °C at the rate of 2 °C/min

4. Condition Inflator at +23 °C per 5.2.2.5, Conditioning of Inflators. Change vibration direction to Y-axis (Inflator's axis) repeat steps 3 and 4.

5. Condition Inflator at 23 °C per 5.2.2.5, Conditioning of Inflators. Change vibration direction to Z-axis (Inflator's axis), repeat steps 3 and 4.

6. Perform visual and audio inspection of each Inflator during and after the conditioning procedure. All visual and audio discrepancies shall be documented and included in the test report.

7. Inspect Inflator for gas leaks (pressurized Inflators).

8. Optional: Verify Inflator terminal-to-terminal resistance.

NOTE: For symmetrical Inflators, the vibration-temperature cycle can be performed on two axes. However, the vibration duration shall be increased to 33 hours per axis (3 cycles).

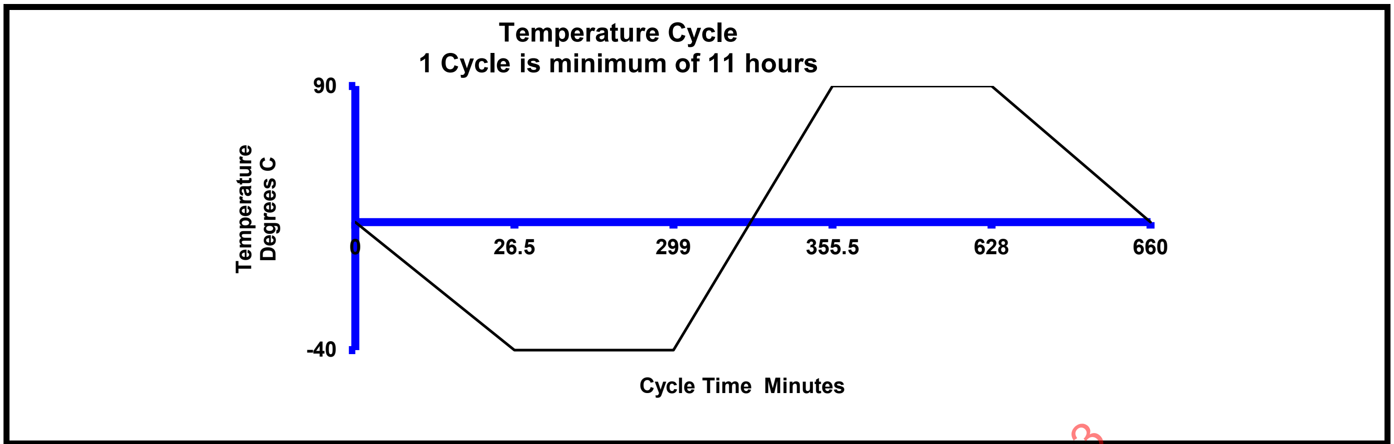



*Figure 5.2.3.7.3.B - Temperature Cycle*

5.2.3.7.4 Humidity Resistance Test

Purpose: To evaluate the effect of humidity on Inflator performance

Equipment:

Temperature chamber(s), capable of maintaining -40 °C and +90 °C, and up to 95% RH.

Procedure:

1. Condition Inflator for a minimum of 288 hours with temperatures of -40 °C, +23 °C, and +90 °C and with 95% minimum RH according to Figure 5.2.3.7.4.A.

2. Inflator shall complete 24 cycles of conditioning, as shown in Figure 5.2.3.7.4.A. The relative humidity shall be at least 95% where the temperature is above freezing, except during temperature transitions.

3. The transition shall be at a minimum 5 °C/min and maintain a minimum of 80% RH where the temperature is above freezing.

4. Perform visual inspection of each Inflator. All visual damage shall be documented and included in the test report.

5. Inspect Inflator for gas leaks (pressurized Inflators).

6. Optional: Verify Inflator terminal-to-terminal resistance.

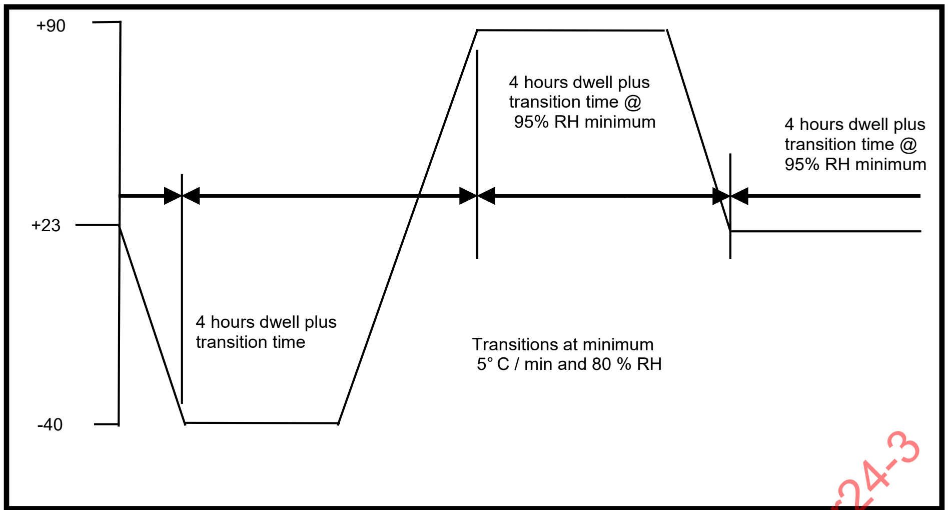



***Figure 5.2.3.7.4.A - Humidity/Thermal Cycle***



5.2.3.7.5 Salt Spray Test

Purpose: To evaluate the corrosion resistance of the Inflator

Equipment:

Chamber capable of maintaining +23 °C while providing 5% salt solution spray to all surfaces of the Inflator.

Procedure:

1. Condition Inflators at +23 °C, per 5.2.2.5, Conditioning of Inflators.
2. Condition Inflators for minimum of 24 hours in a salt spray at 5% solution and +23 °C per ASTM B117.
3. Rinse all residual salt solution with clean water and air-dry inflators prior to continuing test sequence or storing inflators. Cleaning to enhance ballistic performance is not acceptable.
4. Perform visual inspection of each Inflator. The Inflator serial number shall be identifiable (enhancing by scraping, chemical washing, etc., is acceptable). All discrepancies shall be documented and included in the test report.
5. Inspect Inflator for gas leaks (pressurized Inflators).
6. Optional: Verify Inflator terminal-to-terminal resistance.

5.2.3.7.6 Drop Test

Purpose: To evaluate the effects of drop impacts on the Inflator performance.

Equipment:

Fixtures to drop Inflators from 1.2 m onto a steel plate.

Procedure:

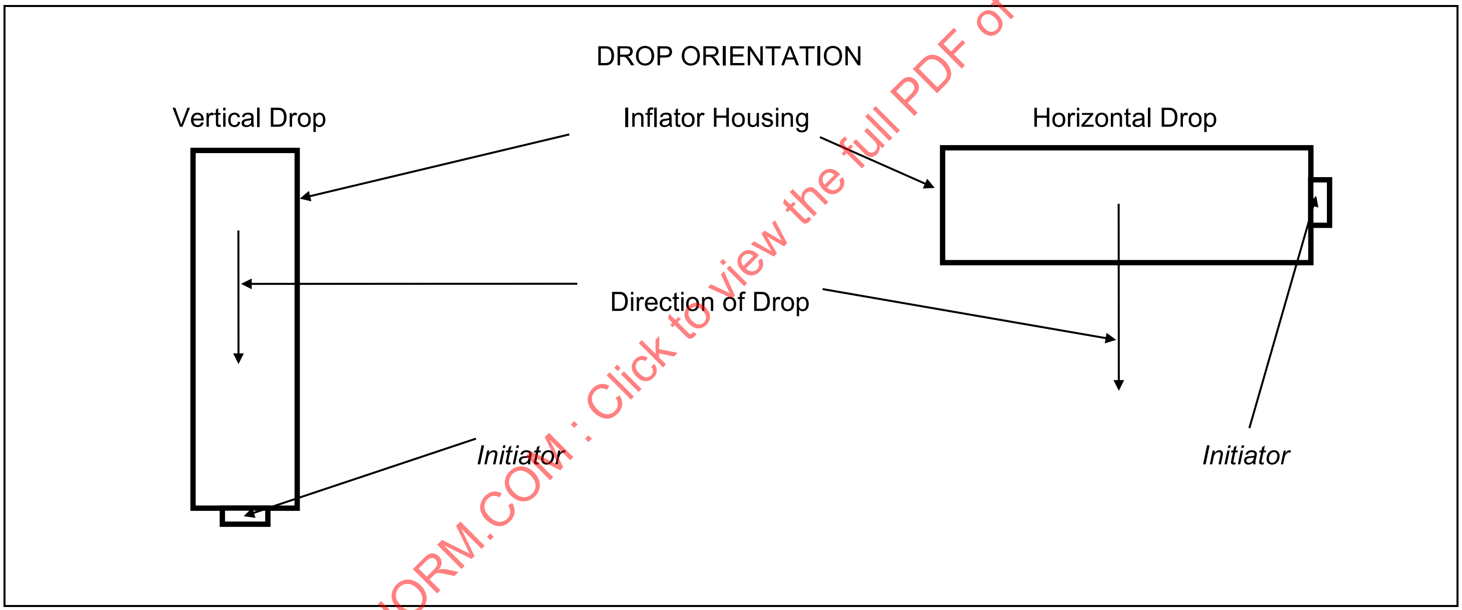
1. Condition Inflators at +23 °C per 5.2.2.5, Conditioning of Inflators.

2. Perform all drops at +23 °C, from 1.2 m (lowest point of the Inflator shall be at a 1.2 m height) on to a steel plate. Dimension of the plate shall be greater than the Inflator size. Each unit shall be dropped a total of six times: twice with the initiator up, twice with the initiator down and twice on the axis perpendicular to the axis of the previous two orientations. For dual-stage Inflators with initiators located at opposite ends of the Inflator, perform drop twice with each initiator in down position. The third orientation shall be in the direction perpendicular to the axis of both initiators (center pin to center pin) for a total of six drops.

3. Inspect for visual damage of the Inflator, electrical connector, and lead wire. All visual damage shall be documented and included in the test report.

4. Inspect Inflator for gas leaks (pressurized Inflator).

5. Verify Inflator terminal-to-terminal resistance.






5.2.3.8 Flaming Test

Purpose: To evaluate Inflator flaming characteristics

Equipment:

Temperature chamber, capable of maintaining +85 °C.
High Speed Camera with a minimum speed of 1000 fps.
Real time video for post deployment flaming analysis with external flame source.

Procedure:

1. Condition Inflators with deflectors, diffusers, shrouds, housings, etc., as allowed by 3.2.4 Inflator Flaming, at +85 °C and +23 °C per 5.2.2.5, Conditioning of Inflators.

2. Following the setup guide per Appendix G, Shadowgraph Procedure - Inflator Flaming Testing, with a minimum RH of 50%. Actuate the inflator per 5.2.2.7, Open Air Test Procedure. Record the entire deployment using a High-Speed Camera with the nozzle area(s) of the inflator in full view.

3. Provide external ignition source (flame) using charcoal grill lighter or equivalent all around the Inflator (at gas exhaust port) within 15 seconds after deployment and maintain the flame for 5 seconds. Reapply the flame for 5 seconds every 30 seconds until a total of 1.5 minutes have elapsed. Record video of the nozzle area(s) of the inflator with real time video camera following deployment when external flame source is applied.

4. Measure and record flame length and duration (if any) and highlight any burning particles using video analysis.

5.2.3.9 Pressure Cycle Durability Test

Purpose: Evaluate integrity of stored gas (pressurized) Inflators under a pressure cycle.

Equipment:

The fixture(s) shall be able to provide required pressure using only dry air or water. (However, water may not be used for carbon steel Inflator vessels due to corrosion concerns, unless corrosion inhibitor is used in the water. Inflator Supplier shall provide the name and amount of corrosion inhibitor used in this test.)

Procedure:

1. Determine maximum and minimum stored pressure inside the Inflator at extreme temperatures. Use equations and gas property methods (such as Van der Waal's, Redlich-Kwong, NIST Mixture Property Database, or any equivalent method) to determine Pmax and Pmin.

$$P_{max} = (P_{nominal} + P_{tolerance}) \text{ at } 85\ °C$$

$$P_{min} = (P_{nominal} - P_{tolerance}) \text{ at } -40\ °C$$

2. Condition all Inflators at +23 °C per 5.2.2.5, Conditioning of Inflators.

3. Perform 4500 pressure cycles on all Inflators. One pressure cycle consists of pressure fluctuation between the pressure extremes ($P_{max}$ - to - $P_{min}$ - to - $P_{max}$) in 7 ± 2 s.

   NOTE: For dual-stage Inflators, conduct pressure cycle test for each chamber separately where applicable.

4. Inspect Inflator body, all welds, and burst disk(s) (if possible) for any cracks, fractures, or mechanical failures. All findings shall be recorded and included in the test report.

5. Clean the Inflator as necessary.

6. Fill the Inflator with the nominal gas charge, including the normal pressure proofed test.

7. Determine the leak rate for the Inflator. The Inflator shall remain in a gas-spectrometer for a minimum of 10 min to determine the equilibrium gas leak rate. Time duration in a gas-spectrometer is supplier specific and shall be approved by the RVEO. Actual leak rate for each Inflator shall be recorded and included in the test report.

# APPENDIX A - PRE-SOURCE QUALIFICATION (QFS) REQUIREMENTS

## I. INTRODUCTION:

Qualified for Sourcing (QFS)

The QFS process provides a consistent method for evaluating new airbag inflator technologies prior to sourcing. The requirements within this specification are a minimum for Pre-Source qualification and does not imply approval by all RVEOs that subscribe to this specification. Each RVEO may have additional processes/requirements and the Inflator Supplier shall work with each individually to gain approvals.

Production Considerations

For those Inflators in production prior to QFS approval, all related design and production control documents shall be made available as requested by the RVEO.

The QFS Process

1. Informational Review (including underlined items in the Review Outline in Section III) with the RVEO. Reference QFS Checklist at the end of this appendix.

2. Successful Completion of Section IV, Performance Requirements or Successful Completion of Section IV, items G, H, and I of the Performance Requirements, and successfully completing a DV or PV to the requirements of this specification.

3. Close all Action Item Requests from the RVEO.

*Note: The tests as outlined here represent the minimum required. Suppliers are encouraged to supply additional data where possible.*

## II. GUIDELINES:

Complete the testing according to the following:

a. Use production design intent parts (production tooling not required) from one lot with maximum (worst case or most difficult to achieve) ballistic output and slope.

b. Inflator Suppliers shall not be approved for sourcing above the tested output!

c. Perform validation tests according to test procedures within this specification.

d. For dual-stage Inflators, a primary/secondary ratio in the range of 70/30 to 60/40 shall be used for any testing where the ratio is not specifically called out.

## III. INFORMATIONAL REVIEW REQUIREMENTS:

Review Outline:

**III A** Inflator Cutaway Model

**III B** General Inflator Information

Labeled Cutaway Drawing (top and side views)
Vital statistics, i.e., Size, Weight, dimensions, etc.
Standard output chart(s) or curves
Envelop Drawing with intended mounting flanges
General Information and Description of all features

**III C** Standard Deployment Sequence

**III D** Auto Ignition Sequence — 3.2.5 Auto-Ignition…

**III E** Dual-Stage Deployments — 3.2.12 Dual-Stage Inflators…
Section IV H

**III F** Chemistry Information

Formulation and quantity of all pyrotechnic materials
Standard Toxicity of all pyrotechnic materials
100 ft$^3$ Chamber Evaluation — 3.2.3 Effluents

Tank Wash: Total, Soluble, and Insoluble fractions — 3.2.3.3.2 Tank Wash Particulate Measurement and Analysis

Speciation with mass balance of Tank Wash Particulate (to include metal scan and salt components) — 3.2.3.3.2 Tank Wash Particulate Measurement and Analysis
5.2.2.8.5 Tank Wash Solution and Particulate Speciation

Any component materials expected to be consumed by the inflator deployment (coatings, polymers, etc.)

**III G** Performance Data

Baseline Tank Tests including the following analysis and information: — 3.1.6.3 Inflator Performance Envelope and Characteristics

1. Gas conversion percentage
2. Gas composition
3. Total moles of gas

Structural Evaluation/Safety Factor Calculations — 3.2.2.1 Inflator Burst Safety Factor
Conditioned deployment results (see QFS or DV test matrix)
*Note: All conditioned inflator data is not required for a Formal Review.*

Safety test data of all pyrotechnic materials. Minimum tests to include ESD, Friction, Impact and Cap Sensitivity of non-aged and aged samples. — 3.2.10 Propellant Stability

Provide mechanical stability data for all propellants containing Ammonium Nitrate including: — 3.2.10, Propellant Stability

1. DSC traces.
2. Dimensional, pellet strength and ballistic evaluation after extended dwell/ramp thermal cycling per 3.2.8.1, Thermal Shock Resistance, using the following profile: 2 hours dwell at 100 °C, 4 hours dwell at -40 °C, 4-hour transition time (approximately 35 °C/h ramp rate), 40 cycles minimum.
3. Literature to support stabilization method.

Propellant Stability in Simulated Regions of High Absolute Humidity — Appendix A, Section IV-K

Mass Flow of Primary Stage (for dual level) and Full output (computation shall include Avg. Temperature of gas assumption, Time to 95% of mass flow and be presented in a format consistent with Appendix F *Ballistic Examples*). Shall include the following information:

Vented Tank, Tunability, and max/min ratio Tests per Sections IV-H and VI- I — 3.1.6.3 Inflator Performance Envelope and Characteristics
3.2.12 Dual-Stage Inflators…

**III H** Specifications
List all component materials and material specifications — 3.1.6.5 Heavy Metal Compounds…
Indented Parts List
Differences between Test Configuration and intended Production Configuration
Shipping Classification Competent Authority or equivalent — 3.1.6.4 Shipping Classification

**III I** DFMEA
Top Ten RPNs
All 10 Severity
List of all Margin Test Series completed, in process and/or identified

**III J** Manufacturing Processes
Proposed Process Flow Chart with Quality Checks identified
Proposed Traceability System

## IV. PERFORMANCE REQUIREMENTS:

### IV A. Baseline

Deploy 43 Inflators and sample tank contents of 9 per 5.2.2.8, Closed Tank Test. IOP shall be collected on all tests.
11 @ -40 °C (tank wash sampling of 3)
11 @ +23 °C (tank wash sampling of 3)
18 @ +85 °C (tank wash sampling of 3)

Dissect three Inflators per 5.2.2.9, Live Dissection Procedure.

Note: *Where the measurement of internal pressures could affect the baseline performance, a separate series of Inflators can be utilized for deployments with IOP measurements.*

Dual-Stage Added Requirement(s):

See Guidelines II, Item c for ratio requirements
Deploy Full output Inflators with 0 ms offset
Deploy 21 Additional Inflators (total of 63)
5 @ -40 °C, Primary Output (100 ms or 150 ms offset)
5 @ +23 °C, Primary Output (100 ms or 150 ms offset)
5 @ +85 °C, Primary Output (100 ms or 150 ms offset)
3 @ +23 °C, Staged Output (Driver @ 10 ms offset, Passenger @ 20 ms offset)
3 @ +23 °C, Primary Only

**Requirement**: The Inflators shall meet the functional requirements of 3.2.9, Inflator Performance and Variability Limits.

### IV B. Thermal Shock Resistance

Condition 23 Inflators per 5.2.3.7.1, Thermal Shock Resistance Test.
- Deploy 20 Inflators per 5.2.2.8, Closed Tank Test. IOP shall be collected on all tests.
  5 @ -40 °C
  5 @ +23 °C
  10 @ +85 °C
- Dissect three Inflators per 5.2.2.9, Live Dissection Procedure

Dual-Stage Added Requirement(s):

Deploy Full Output Inflators with 0 ms offset.
Condition an additional 15 Inflators per 5.2.3.7.1, Thermal Shock Resistance Test (total of 38).
- Deploy 15 Inflators per 5.2.2.8, Closed Tank Test
  5 @ -40 °C, Primary Output (100 ms or 150 ms offset)
  5 @ +23 °C, Primary Output (100 ms or 150 ms offset)
  5 @ +85 °C, Primary Output (100ms or 150 ms offset)

**Requirement**: The Inflators shall meet the functional requirements of 3.2.8.1 Thermal Shock Resistance.

### IV C. Accelerated Heat Aging

Condition 29 Inflators per 5.2.3.5, Accelerated Heat Aging Test.
- Test 3 Inflators per 5.2.3.3, Bonfire Test.
- Test 3 Inflators per 5.2.3.2, High Temperature Oven Test
- Deploy 20 Inflators per 5.2.2.8, Closed Tank Test
  - 5 @ -40 °C
  - 5 @ +23 °C
  - 10 @ +85 °C
- Dissect three Inflators per 5.2.2.9, Live Dissection Procedure

Dual-Stage Added Requirement(s):

Deploy Full Output Inflators with 0 ms offset.
Condition an additional 15 Inflators per 5.2.3.5, Accelerated Heat Aging Test (total of 44).
- Deploy 15 Inflators per 5.2.2.8, Closed Tank Test
  - 5 @ -40 °C, Primary Output (100 ms or 150 ms offset)
  - 5 @ +23 °C, Primary Output (100 ms or 150 ms offset)
  - 5 @ +85 °C, Primary Output (100 ms or 150 ms offset)

**Requirement**: Inflators shall meet the functional requirements of 3.2.6, Accelerated Heat Aging.

### IV D. Sequential/Environmental

Condition 23 Inflators per 3.2.8, Sequential Test Series: 10 Dynamic Shock - Low g & 13 Dynamic Shock - High g.
- Deploy 20 Inflators per 5.2.2.8, Closed Tank Test. IOP shall be collected on all tests.
  - 3 low g and 2 high g @ -40 °C
  - 3 low g and 2 high g @ +23 °C
  - 5 low g and 5 high g @ +85 °C
- Dissect three Inflators per 5.2.2.9, Live Dissection Procedure

Dual-Stage Added Requirement(s):

See Guidelines II, Item c for ratio requirements
Deploy Full Output Inflators at 0 ms offset.
Condition an additional 18 Inflators: 12 with Dynamic Shock - Low g & 6 with Dynamic Shock High g (total of 41)
- Deploy 18 Inflators per 5.2.2.8 Closed Tank Test. IOP shall be collected on all tests.
  - 3 low g and 2 high g @ -40 °C, Primary Output (100 ms or 150 ms offset)
  - 3 low g and 2 high g @ +23 °C, Primary Output (100 ms or 150 ms offset)
  - 3 low g and 2 high g @ +85 °C, Primary Output (100 ms or 150 ms offset)
  - 3 low g @ +23 °C, Staged Output (Driver 10 ms offset, Passenger 20 ms offset)

**Requirement**: The Inflators shall meet the functional requirements of 3.2.8, Sequential Test Series.

### IV E. Structural Integrity

Burst 15 Inflators per 5.2.3.1, Structural Burst Test and calculate the Safety Factor per 3.2.2.1, Inflator Burst Safety Factor.

Dual-Stage Added Requirement(s):

Burst 15 Inflators for each structural chamber and calculate structural safety margin on each Structural Unit separately. Use MEOP from worst case firing of Primary stage first, Secondary stage first, or 0 ms offset firing at +85 °C, -40 °C, and +23 °C.

**Requirement**: The Inflators shall meet the requirements of 3.2.2, Inflator Structural Integrity.

### IV F. Pressure Cycle Durability (pressurized Inflators only)

Condition 3 Inflators per 5.2.3.9, Pressure Cycle Durability Test and then inspect.

Dual-Stage Added Requirement(s):

Three additional Inflators shall be evaluated for each additional pressurized chambers that are part of the dual-stage configuration (if applicable).

**Requirement**: The Inflators shall meet the requirements of 3.2.11.2, Pressurized Inflators.

### IV G. Effluent Tests

Deploy 3 Inflators in representative vented bag modules (see Table IV G-1, Standard Module Configurations) per 5.2.2.6, Effluent Test Procedure, and measure airborne particulate and gaseous effluents per 3.2.3, Effluents.

Dual-Stage Added Requirement(s):

See Guidelines II, Item c for ratio requirements
Deploy Full Output Inflators with 0 ms offset
Deploy 6 additional Inflators:
    3 @ +23 °C, Primary Output (100 ms or 150 ms offset)
    3 @ +23 °C, Primary Only

**Requirement**: The airborne particulate and gaseous effluent levels shall meet the requirements of 3.2.3, Effluents.

***Table IV G -1 - Standard module configurations***

| Type | Bag Size (L) | Vent Size | Inflator Output |
|---|---|---|---|
| **Passenger** | 120-140 | 1 X 42 mm | 550-650 kPa (60 L tank) |
| **Driver** | 55-65 | 2 X 25 mm | 180-220 kPa (60 L tank) |
| **Curtain** | 25-30 | none | 200-250 kPa (1 ft$^3$ tank) |
| **Side Impact** | 18-22 | 1 X 20 mm | 180-200 kPa (1 ft$^3$ tank) |
| **Knee** | 14-19 | 1 X 20 mm | 150-200 kPa (1 ft$^3$ tank) |

## IV H. Tailorability and Hot/Cold Spread Ballistic Tank Tests



Deploy an additional 12 Inflators according to the following table:

***Table IV H-1 - Tunability matrix***

| Temp. | Min. Ballistic Output & Slope (Closed Tank) | Nom. Ballistic Output & Slope (Closed Tank) | Max. Ballistic Output & Slope[4] (Closed Tank) |
|---|---|---|---|
| -40 °C | 3 | 0 | (8) |
| +23 °C | 3 | 3 | (8) |
| +85 °C | 3 | 0 | (8) |

[4] *Note: These are the Baseline Ballistic Tank tests.*

Dual-Stage Added Requirement(s):

Deploy Full Output Inflators with 0 ms offset
Deploy 5 Inflators of maximum output and slope, with a ratio between 70/30 and 60/40 @ +23 °C with 0, 5, 10, 20, and 30 ms offsets (provide curves on a single plot).
Deploy an additional 2 Inflators of maximum ballistic output and slope @ +23 °C, secondary Stage only.
Deploy an additional 2 Inflators of maximum ballistic output and slope @ +23 °C in reverse order (i.e., second stage first) with 10 ms offset (if previous 2 second stage only deployments ignite the primary stage in <10 ms this test need not be run).
Deploy an additional 12 Inflators @ +23 °C, one each with 0, 10, and 30 ms offset, according to the following table.

***Table IV H-2 - Dual stage output definitions for tunability matrix***

| Inflator Configuration | Combination of Stored Gas (where applicable) and propellant to provide: | |
|---|---|---|
| | Primary Stage | Secondary Stage |
| 3 @ Min/Max Ratio | Minimum Output | Maximum Output |
| 3 @ Max/Min Ratio | Maximum Output | Minimum Output |
| 3 @ Max/Max Ratio | Maximum Output | Maximum Output |
| 3 @ Min/Min Ratio | Minimum Output | Minimum Output |

*Note: Configurations that match those included in Table IV H-1, Tunability Matrix, are not required to be re-tested.*

**Requirement**: The Inflators shall function as intended and shall not fail structurally.

*Note: Clearly state ratio, output of each stage and total output of each configuration on the ballistic plots.*

## IV I. Equivalence Data and Testing

*Note: Equivalence Data and Testing are optional unless requested by the RVEO. The RVEO will specify the tank size to be used for the vented tank test based on the comparative data available.*

Supply gas conversion percentage, gas composition, total moles of gas, gas temperature (at Inflator nozzle), and millisecond by millisecond mass flow data of the following tests. Mass flow calculation methodology shall be provided to the RVEO upon request.

Deploy 6 Inflators according to Table IV I-1 Vented Tank Test Configurations and Table IV I-2 Vented Tank Size

***Table IV I-1 - Vented tank test configurations***

| Temperature | Min. Ballistic Output & Slope (Vented Tank) | Nom. Ballistic Output & Slope (Vented Tank) | Max. Ballistic Output & Slope (Vented Tank) |
|---|---|---|---|
| +23 °C | 3 | 0 | 3 |

**Requirement**: The Inflators shall function as intended and shall not fail structurally.

Dual Stage Added Requirement(s):

Deploy Full Output Inflators with 0 ms offset.
No additional Inflators required.

***Table IV I-2 - Vented tank size***

| Tank Size (L) | Vent Size |
|---|---|
| 100 | 2 X 2 inch NPT |
| 60 | 2 X 1 1/2 inch NPT |
| 28.3 (1 $ft^3$) | 2 X 1 inch NPT |

## IV J. Inflator Flaming

Deploy 3 Inflators at +23 °C and 3 Inflators at +85 °C per 5.2.3.8, Flaming Test.

Dual Stage Added Requirement(s):

No additional Inflators required. Deploy Full Output Inflators with 0 ms offset.

**Requirement**: The Inflators shall deploy as intended and shall not fail structurally. Results shall be evaluated per 3.2.4, Inflator Flaming.

## IV K. Propellant Stability in Simulated Regions of High Absolute Humidity

The purpose of this testing is to understand end of life behavior of a propellant technology based on simulated environment that mimics the range of conditions observed by a pyrotechnic Inflator in regions of high absolute humidity (HAH). The testing is not intended to predict the time to end of life.

Upon completion of the field simulation environment testing:

a. The Inflators shall be tested per 5.2.2.8, Closed Tank Test.
b. Data shall be reviewed by the RVEO.



### K.1 High Absolute Humidity and Thermal Cycling with Punctured Seal

*Purpose:* To simulate the conditions an Inflator could experience when inside a vehicle exposed to thermal cycling via solar exposure while in regions of high absolute humidity (HAH). The Inflator hermetic seal is compromised to accelerate the time to moisture equilibrium.

*Test Fixtures and Equipment:*

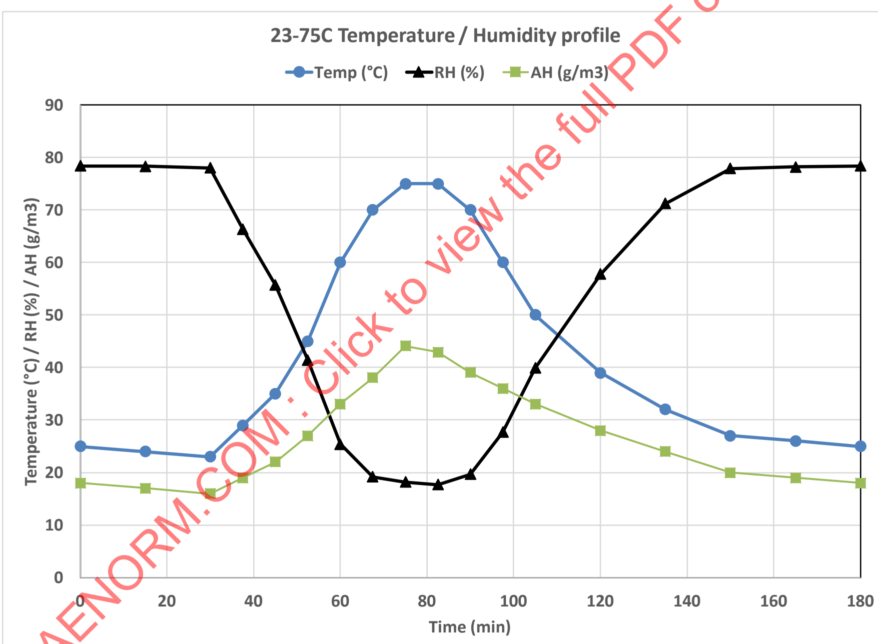
Temperature/Humidity chamber capable of maintaining specified conditions per Table IV K-1.

*Test Procedure:*

1. Pierce the tape seal in one Inflator gas exit port using a 25-gauge needle (diameter 0.5 mm ± 0.2 mm) so that the seal is fully broken and path for moisture mass transfer is free of barriers into propellant chamber(s). If required, additional leak paths within an Inflator should be made using the same tool to ensure vapor contact between propellant chambers (main propellant/booster/AI material - if applicable).
2. Beginning and ending at +25 °C, condition Inflators per Table IV K-1 for 2000 cycles. Remove defined quantity of Inflators at the proper intervals per appropriate test matrix.
3. Upon removal of conditioning chamber, seal the pierced hole and store Inflators at +23 °C for 5 days to ensure internal equilibrium is attained.
4. Test per appropriate PROPELLANT STABILITY IN SIMULATED REGIONS OF HIGH ABSOLUTE HUMIDITY TEST MATRIX. Ballistic testing shall include IOP measurement.

***Table IV K-1***

| Step # | Initial Temp | Initial RH | Final Temp | Final RH | Duration (min) |
|---|---|---|---|---|---|
| 1 | 25 | 78.4 | 24 | 78.3 | 15 |
| 2 | 24 | 78.3 | 23 | 78.0 | 15 |
| 3 | 23 | 78.0 | 29 | 66.3 | 7.5 |
| 4 | 29 | 66.3 | 35 | 55.7 | 7.5 |
| 5 | 35 | 55.7 | 45 | 41.4 | 7.5 |
| 6 | 45 | 41.4 | 60 | 25.4 | 7.5 |
| 7 | 60 | 25.4 | 70 | 19.2 | 7.5 |
| 8 | 70 | 19.2 | 75 | 18.2 | 7.5 |
| 9 | 75 | 18.2 | 75 | 17.7 | 7.5 |
| 10 | 75 | 17.7 | 70 | 19.7 | 7.5 |
| 11 | 70 | 19.7 | 60 | 27.7 | 7.5 |
| 12 | 60 | 27.7 | 50 | 39.9 | 7.5 |
| 13 | 50 | 39.9 | 39 | 57.8 | 15 |
| 14 | 39 | 57.8 | 32 | 71.2 | 15 |
| 15 | 32 | 71.2 | 27 | 77.9 | 15 |
| 16 | 27 | 77.9 | 26 | 78.2 | 15 |
| 17 | 26 | 78.2 | 25 | 78.4 | 15 |
| **Total time** | | | | | **180 min** |






## K.2 Constant High Absolute Humidity Exposure with Punctured Seal (no cycling)

*Purpose:* To simulate the conditions an Inflator could experience when inside a vehicle at constant temperature while in regions of high absolute humidity. The Inflator hermetic seal is compromised to accelerate the time to moisture equilibrium.

*Equipment:*

Temperature/Humidity chamber capable of maintaining +30 °C with 75% Relative Humidity.

*Test Procedure:*

1. Pierce the seal tape in one Inflator gas exit port using a 25-gauge needle (diameter 0.5 mm ± 0.2 mm) so that the seal is fully broken and a path for moisture mass transfer is free of barriers into propellant chamber(s). If required, additional leak paths within an Inflator should be made using the same tool to ensure vapor contact between propellant chambers (main propellant/booster/autoignition material - if applicable).
2. Place Inflators in humidity chamber set to +30 °C with 75% relative humidity.
3. Upon removal from conditioning chamber, seal the pierced hole and store Inflators at +23 °C for 5 days to ensure internal equilibrium is attained.
4. Test per appropriate PROPELLANT STABILITY IN SIMULATED REGIONS OF HIGH ABSOLUTE HUMIDITY TEST MATRIX. Ballistic testing shall include IOP measurement.

PROPELLANT STABILITY IN SIMULATED REGIONS OF HIGH ABSOLUTE HUMIDITY TEST MATRIX
SINGLE STAGE INFLATOR

| Test Sequence | | Specification Section | Qty A | Qty B | Qty C | Qty 54 Total |
|---|---|---|---|---|---|---|
| **Initial Checks** | | | | | | |
| Leak Inspection | | 5.2.2.1 | 6 | 24 | 24 | |
| Weight Inspection | | 5.2.2.2 | 6 | 24 | 24 | |
| Visual Inspection | | 5.2.2.3.1 | 6 | 24 | 24 | |
| Electrical Checks | | 5.2.2.4 | 6 | 24 | 24 | |
| **Environmental Simulation/Conditioning** | **Cycles / Hours** | | | | | |
| High Absolute Humidity with Thermal Cycling (# of 3-hour cycles) | 500 | Appendix A, IV-K1 | | 6 | | ***Inflator seal tape pierced in one gas port prior to conditioning** |
| | 1000 | | | 6 | | |
| | 1500 | | | 6 | | |
| | 2000 | | | 6 | | |
| Constant High Absolute Humidity Exposure (hours) | 500 | Appendix A, IV-K2 | | | 6 | |
| | 1500 | | | | 6 | |
| | 3000 | | | | 6 | |
| | 6000 | | | | 6 | |
| **Post Conditioning Inspection** | | | | | | |
| Weight Inspection | | 5.2.2.2 | | 24 | 24 | |
| Visual Inspection | | 5.2.2.3.1 | | 24 | 24 | |
| Electrical Checks | | 5.2.2.4 | | 24 | 24 | |
| **Inflator Testing** | | | | | | |
| Live Dissection | | 5.2.2.9 | 3 | 3 | 3 | |
| **Closed Tank Tests** | | 5.2.2.8 | | | | ***Tested w/ Internal Chamber Pressure Measurement** |
| +23 °C w/ Internal Chamber Pressure | | | 3 | 3 | 3 | |
| Visual Inspection<br>Post Test Documentation | | 5.2.2.3.2 | 6 | 6 | 6 | |

PROPELLANT STABILITY IN SIMULATED REGIONS OF HIGH ABSOLUTE HUMIDITY TEST MATRIX
DUAL STAGE INFLATOR

| Test Sequence | | Specification Section | Qty A | Qty B | Qty C | Qty 78 Total |
|---|---|---|---|---|---|---|
| **Initial Checks** | | | | | | |
| Leak Inspection | | 5.2.2.1 | 6 | 36 | 36 | |
| Weight Inspection | | 5.2.2.2 | 6 | 36 | 36 | |
| Visual Inspection | | 5.2.2.3.1 | 6 | 36 | 36 | |
| Electrical Checks | | 5.2.2.4 | 6 | 36 | 36 | |
| **Environmental Simulation/Conditioning** | **Cycles / Hours** | | | | | |
| High Absolute Humidity with Thermal Cycling (# of 3-hour cycles) | 500 | Appendix A, IV-K1 | | 9 | | ***Inflator seal tape pierced in one gas port prior to conditioning** |
| | 1000 | | | 9 | | |
| | 1500 | | | 9 | | |
| | 2000 | | | 9 | | |
| Constant High Absolute Humidity Exposure (hours) | 500 | Appendix A, IV-K2 | | | 9 | |
| | 1500 | | | | 9 | |
| | 3000 | | | | 9 | |
| | 6000 | | | | 9 | |
| **Post Conditioning Inspection** | | | | | | |
| Weight Inspection | | 5.2.2.2 | | 36 | 36 | |
| Visual Inspection | | 5.2.2.3.1 | | 36 | 36 | |
| Electrical Checks | | 5.2.2.4 | | 36 | 36 | |
| **Inflator Testing** | | | | | | |
| Live Dissection | | 5.2.2.9 | 3 | 3 | 3 | |
| **Closed Tank Tests** | | 5.2.2.8 | | | | ***Tested w/ Internal Chamber Pressure Measurement** |
| Full Output (0 ms), +23 °C | | | 3 | 3 | 3 | |
| Delayed Output (150 ms), +23 °C | | | 3 | 3 | 3 | |
| Visual Inspection<br>Post Test Documentation | | 5.2.2.3.2 | 9 | 9 | 9 | |

QFS MATRIX AND POST DEPLOYMENT PLAN
SINGLE STAGE INFLATOR

| Test Sequence | Spec. Section | Qty A | Qty B | Qty C | Qty D | Qty E | Qty F | Qty G | Qty H | Qty I | Qty J | Qty K | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Document Part #, Serial # | | 43 | 29 | 23 | 23 | 15 | 3 | 3 | 12 | 6 | 6 | 78 | 241 inflators total |
| **INITIAL CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | • | • | • | • | | • | • | • | • | • | • | |
| Weight Inspection | 5.2.2.2 | • | • | • | • | | • | • | • | • | • | • | |
| Visual Inspection | 5.2.2.3.1 | • | • | • | • | • | • | • | • | • | • | • | |
| Electrical Checks | 5.2.2.4 | • | • | • | • | | • | • | • | • | • | • | |
| **CONDITIONING** | | | | | | | | | | | | | |
| **Accelerated Heat Aging** | 5.2.3.5 | | • | | | | | | | | | | |
| **Thermal Shock** | 5.2.3.7.1 | | | • | | | | | | | | | |
| **Sequential Environments** | 5.2.3.7 | | | | • | | | | | | | | *(sequence)* |
| Dynamic Shock (1) | 5.2.3.7.2 | | | | • | | | | | | | | *3 High g, 6 Low g* |
| Vibration - Temperature Cycle (2) | 5.2.3.7.3 | | | | • | | | | | | | | |
| Humidity Resistance (3) | 5.2.3.7.4 | | | | • | | | | | | | | |
| Drop Test (4) | 5.2.3.7.6 | | | | • | | | | | | | | |
| **Pressure Cycle** | 5.2.3.9 | | | | | | • | | | | | | |
| **Propellant Stability** | A, IV-K | | | | | | | | | | | • | |
| **POST CONDITIONING CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | | • | • | • | | • | | | | | | |
| Weight Inspection | 5.2.2.2 | | • | • | • | | | | | | | | |
| Visual Inspection | 5.2.2.3.1 | | • | • | • | | | | | | | | |
| Electrical Checks | 5.2.2.4 | | • | • | • | | | | | | | | |
| **INFLATOR TESTING** | | | | | | | | | | | | | |
| **Structural Burst** | 5.2.3.1 | | | | | 15 | | | | | | | |
| **Auto-Ignition** | | | | | | | | | | | | | |
| High Temperature Oven Test | 5.2.3.2 | | 3 | | | | | | | | | | |
| Autoignition/Bonfire | 5.2.3.3 | | 3 | | | | | | | | | | |
| Slow Heat/Autoignition | 5.2.3.4 | | | | | | | | | | | | |
| **Flaming** | 5.2.3.8 | | | | | | | | | | | | |
| Open Air +23 °C | | | | | | | | | | | 3 | | |
| Open Air +85 °C | | | | | | | | | | | 3 | | |
| **Live Dissection** | 5.2.2.9 | 3 | 3 | 3 | 3 | | | | | | | | |
| **Closed Tank** | 5.2.2.8 | | | | | | | | | | | | **w/ IOP Measurement** |
| Full Output -40 °C | | 11 | 5 | 5 | 5 | | | | | | | | |
| Full Output +23 °C | | 11 | 5 | 5 | 5 | | | | | | | | |
| Full Output +85 °C | | 18 | 10 | 10 | 10 | | | | | | | | |
| Tunability Matrix | A, IV-H | | | | | | | | 12 | | | | |
| **100 ft³ Tank** | 5.2.2.6 | | | | | | | | | | | | |
| Full Output +23 °C | | | | | | | | 3 | | | | | |
| **Vented Tank (optional)** | A, IV-I | | | | | | | | | 6 | | | |
| **SUPPLEMENTAL EVALUATIONS** | | | | | | | | | | | | | |
| *Sampling Tank Content* | 5.2.2.8.3 | | | | | | | | | | | | |
| Closed Tank Full Output -40 °C | | 3 | | | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 3 | | | | | | | | | | | |
| Closed Tank Full Output +85 °C | | 3 | | | | | | | | | | | |
| *Tank Wash Chemical Speciation* | 5.2.2.8.5 | | | | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 2 | | | | | | | | | | | |
| *Tank Effluents (gas analysis)* | 3.2.3 | | | | | | | 3 | | | | | |
| *Post Deployment Internal Insp.* | 5.2.2.3.2 | | | | | | | | | | | | |
| Full Output +85 °C | | 15 | 10 | 10 | 10 | | | | | | | | |
| Auto-Ignition | | | 6 | | | | | | | | | | |
| Visual Insp./Post Test Doc. | 5.2.2.3.2 | 64 | 39 | 33 | 41 | 15 | 3 | 3 | 12 | 6 | 6 | 78 | |

• Indicates all samples within the group.

QFS MATRIX AND POST DEPLOYMENT PLAN
DUAL STAGE INFLATOR

| Test Sequence | Spec. Section | Qty A | Qty B | Qty C | Qty D | Qty E | Qty F | Qty G | Qty H | Qty I | Qty J | Qty K | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Document Part #, Serial # | | 64 | 44 | 38 | 41 | 15 | 3 | 9 | 31 | 12 | 6 | 78 | 341 inflators total |
| **INITIAL CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | |
| Weight Inspection | 5.2.2.2 | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | |
| Visual Inspection | 5.2.2.3.1 | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | |
| Electrical Checks | 5.2.2.4 | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | |
| **CONDITIONING** | | | | | | | | | | | | | |
| **Accelerated Heat Aging** | 5.2.3.5 | | ● | | | | | | | | | | |
| **Thermal Shock** | 5.2.3.7.1 | | | ● | | | | | | | | | |
| **Sequential Environments** | 5.2.3.7 | | | | ● | | | | | | | | *(sequence)* |
| Dynamic Shock (1) | 5.2.3.7.2 | | | | ● | | | | | | | | *3 High g, 6 Low g* |
| Vibration - Temperature Cycle (2) | 5.2.3.7.3 | | | | ● | | | | | | | | |
| Humidity Resistance (3) | 5.2.3.7.4 | | | | ● | | | | | | | | |
| Drop Test (4) | 5.2.3.7.6 | | | | ● | | | | | | | | |
| **Pressure Cycle** | 5.2.3.9 | | | | | | ● | | | | | | |
| **Propellant Stability** | A, IV-K | | | | | | | | | | | ● | |
| **POST CONDITIONING CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | | ● | ● | ● | | ● | | | | | | |
| Weight Inspection | 5.2.2.2 | | ● | ● | ● | | | | | | | | |
| Visual Inspection | 5.2.2.3.1 | | ● | ● | ● | | | | | | | | |
| Electrical Checks | 5.2.2.4 | | ● | ● | ● | | | | | | | | |
| **INFLATOR TESTING** | | | | | | | | | | | | | |
| **Structural Burst** | 5.2.3.1 | | | | | 15 | | | | | | | |
| **Auto-Ignition** | | | | | | | | | | | | | |
| High Temperature Oven Test | 5.2.3.2 | | 3 | | | | | | | | | | |
| Autoignition/Bonfire | 5.2.3.3 | | 3 | | | | | | | | | | |
| Slow Heat/Autoignition | 5.2.3.4 | | | | | | | | | | | | |
| **Flaming** | 5.2.3.8 | | | | | | | | | | | | |
| Open Air +23 °C | | | | | | | | | | | 3 | | |
| Open Air +85 °C | | | | | | | | | | | 3 | | |
| **Live Dissection** | 5.2.2.9 | 3 | 3 | 3 | 3 | | | | | | | | |
| **Closed Tank** | 5.2.2.8 | | | | | | | | | | | | **w/ IOP Measurement** |
| Full Output -40 °C | | 11 | 5 | 5 | 5 | | | | | | | | |
| Full Output +23 °C | | 11 | 5 | 5 | 5 | | | | | | | | |
| Full Output +85 °C | | 18 | 10 | 10 | 10 | | | | | | | | |
| Primary Output -40 °C | | 5 | 5 | 5 | 5 | | | | | | | | |
| Primary Output +23 °C | | 5 | 5 | 5 | 5 | | | | | | | | |
| Primary Output +85 °C | | 5 | 5 | 5 | 5 | | | | | | | | |
| Primary Only Output +23 °C | | 3 | | | | | | | | | | | Do not deploy secondary |
| Staged Output +23 °C | | 3 | | | 3 | | | | | | | | Driver 10 ms, Pass. 20 ms |
| Second Stage Only Output +23 °C | | | | | | | | | 2 | | | | |
| Reverse Firing Order Output +23 °C | | | | | | | | | 2 | | | | |
| Tunability Matrix | A, IV-H | | | | | | | | 27* | | | | |
| **100 ft³ Tank** | 5.2.2.6 | | | | | | | | | | | | |
| Full Output +23 °C | | | | | | | | 3 | | | | | |
| Primary Only Output +23 °C | | | | | | | | 3 | | | | | Do not deploy secondary |
| 100 ms Offset Output +23 °C | | | | | | | | 3 | | | | | |
| **Vented Tank (optional)** | A, IV-I | | | | | | | | | 12 | | | |
| **SUPPLEMENTAL EVALUATIONS** | | | | | | | | | | | | | |
| *Sampling Tank Content* | 5.2.2.8.3 | | | | | | | | | | | | |
| Closed Tank Full Output -40 °C | | 3 | | | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 3 | | | | | | | | | | | |
| Closed Tank Full Output +85 °C | | 3 | | | | | | | | | | | |
| *Tank Wash Chemical Speciation* | 5.2.2.8.5 | | | | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 2 | | | | | | | | | | | |
| *Tank Effluents (gas analysis)* | 3.2.3 | | | | | | | 9 | | | | | |
| *Post Deployment Internal Insp.* | 5.2.2.3.2 | | | | | | | | | | | | |
| Full Output +85 °C | | 5 | | | | | | | | | | | |
| 100 ms Delay Output +85 °C | | 5 | | | | | | | | | | | |
| Visual Insp./Post Test Doc. | 5.2.2.3.2 | 64 | 39 | 33 | 41 | 15 | 3 | 9 | 31 | 6 | 6 | 78 | |

*This number assumes 0 ms offset, Max/Max and Min/Min match tunability matrix.
● Indicates all samples within the group.

QFS CHECKLIST

| Inflator Name | Status | Output (Maximum) | Date |
|---|---|---|---|
| Review Status | | | |
| Open Issues Status | | | |
| Information Section | | | |
| General | | | |
| Inflator Cutaway and hardware | | | |
| Inflator Cutaway Drawings (plan and side view) | | | |
| Size, Wt, moles, gas mass, and Output Chart | | | |
| Envelope Drawing with mounting flange | | | |
| General Description | | | |
| Standard Deployment Sequence | | | |
| Autoignition Sequence | | | |
| Chemistry | | | |
| Formulation with gas yield and percentages | | | |
| Toxicity | | | |
| Stored Gas Composition | | | |
| 100 $ft^3$ Chamber evaluation | | | |
| Tank Particulate soluble/insoluble % | | | |
| Tank wash Speciation | | | |
| Part Coatings, etc. | | | |
| Propellant Hazard Testing (Before Aging) | | | |
| Propellant Hazard Testing (After Aging) | | | |
| Propellant Stability in Simulated Regions of High Absolute Humidity | | | |
| Specifications | | | |
| Indented Parts List (with Drawing Rev. #) | | | |
| Component and Materials List (with Spec #'s) | | | |
| Differences of QFS to Production | | | |
| Shipping Classification (or Schedule) | | | |
| DFMEA | | | |
| Top ten | | | |
| All 10 PNs | | | |
| Margin Testing (or Schedule) | | | |
| Manufacturing | | | |
| Process Flow Chart | | | |
| Redundant Checks of all actions | | | |
| Poke yoke (error proofing) | | | |
| Production Status (schedule) | | | |
| Traceability System Description | | | |
| Initial Bar Code application | | | |
| Station to Station part tracking | | | |
| Lot control at each station | | | |
| Lot Control in plant | | | |
| Performance Data and/or Test Matrix | | To be submitted as scatter plots with $\pm 3\sigma$ and USCAR windows | |
| Baseline | | | |
| Conditioned Deployments | | | |
| Thermal Shock | | | |
| Heat Age | | | |
| Bonfire | | | |
| Sequential | | | |
| Structural Margin | | | |
| Pressure Cycle | | | |
| Tunability | | | |
| Vented Tank or FINAL Tank (if required) | | | |
| Mass Flow | | | |
| Gas Temperature | | | |
| Dual Stage Specific | | | |
| Full Power | | | |
| Primary Only | | | |
| Secondary Only | | | |
| Second Stage Disposal | | | |
| Delay Series (0,5,10,20,30, primary only) | | | |
| Max/Min Ratio Demonstration | | | |

## APPENDIX B - DV/PV TEST MATRIX

**Test Matrix and Post Deployment Plan**

The test matrices defined in the following tables shall be a minimum set of tests and minimum quantity sample size for the Design Verification (DV) and Production Validation (PV) of Inflators. It shall be the supplier's responsibility to evaluate this plan and allow for additional testing based on the Inflator design's unique characteristics. This table shall not replace the supplier's responsibility, based on the DFMEA and PFMEA to define and complete appropriate margin testing to establish a final robust design. Any deviations from these test matrices shall be reviewed and approved by the RVEO. Subscripts (a, b, and c) refer to three different main propellant lots used in the specific groups.

*Note:* Where Pre-source (QFS) testing has not been completed, testing from Appendix A, Sections IV-H shall be provided with the DV or PV report. Testing from Appendix A, Section IV-I shall be provided with the PV report where specifically requested by the RVEO.

## DV MATRIX AND POST DEPLOYMENT PLAN - DUAL STAGE

| Test Sequence | Spec. Section | Qty A | Qty B | Qty C | Qty D | Qty E | Qty F | Qty G | Qty H | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Document Part #, Serial # | | 120 | 56 | 71 | 81 | 81 | 22 | 8 | 12 | 451 Inflators total |
| **INITIAL CHECKS** | | | | | | | | | | |
| Leak Test | 5.2.2.1 | ● | ● | ● | ● | ● | | ● | ● | |
| Weight Inspection | 5.2.2.2 | ● | ● | ● | ● | ● | | ● | ● | |
| Visual Inspection | 5.2.2.3.1 | ● | ● | ● | ● | ● | ● | ● | ● | |
| Electrical Checks | 5.2.2.4 | ● | ● | ● | ● | ● | | ● | ● | |
| **CONDITIONING** | | | | | | | | | | |
| **High Humidity/Heat Aging** | 5.2.3.6 | | ● | | | | | | | |
| **Accelerated Heat Aging** | 5.2.3.5 | | | ● | | | | | | |
| **Sequential Environments** | 5.2.3.7 | | | | ● | ● | | | | *(sequence)* |
| Thermal Shock (1) | 5.2.3.7.1 | | | | ● | ● | | | | |
| Dynamic Shock - Low g (2) | 5.2.3.7.2 | | | | ● | | | | | |
| Dynamic Shock - High g (2) | 5.2.3.7.2 | | | | | ● | | | | |
| Vibration - Temperature Cycle (3) | 5.2.3.7.3 | | | | ● | ● | | | | |
| Humidity Resistance (4) | 5.2.3.7.4 | | | | ● | ● | | | | |
| Salt Spray (5) | 5.2.3.7.5 | | | | ● | ● | | | | |
| Drop Test (6) | 5.2.3.7.6 | | | | ● | ● | | | | |
| **Pressure Cycle** | 5.2.3.9 | | | | | | | ● | | |
| **POST CONDITIONING CHECKS** | | | | | | | | | | |
| Leak Test | 5.2.2.1 | | ● | ● | ● | ● | | ● | | |
| Weight Inspection | 5.2.2.2 | | ● | ● | ● | ● | | | | |
| Visual Inspection | 5.2.2.3.1 | | ● | ● | ● | ● | | | | |
| Electrical Checks | 5.2.2.4 | | ● | ● | ● | ● | | | | |
| **INFLATOR TESTING** | | | | | | | | | | |
| **Structural Burst** | 5.2.3.1 | | | | | | 22 | | | |
| **Auto-Ignition** | | | | | | | | | | |
| High Temperature Oven Test | 5.2.3.2 | 3 | | 3 | 3 | | | | | |
| Autoignition/Bonfire | 5.2.3.3 | 6 | | 6 | 6 | | | | | |
| Slow Heat/Autoignition | 5.2.3.4 | 6 | | 6 | 6 | | | | | |
| **Flaming** | 5.2.3.8 | | | | | | | | | |
| Open Air +23 °C | | | | | | | | | 6 | |
| Open Air +85 °C | | | | | | | | | 6 | |
| **Live Dissection** | 5.2.2.9 | 3 | 3 | 3 | 3 | 3 | | | | |
| **Closed Tank** | 5.2.2.8 | | | | | | | | | **w/ IOP Measurement** |
| Full Output -40 °C | | 15 | 15 | 15 | 15 | 18 | | | | |
| Full Output +23 °C | | 20 | 15 | 15 | 15 | 21 | | | | |
| Full Output +85 °C | | 25 | 15 | 15 | 15 | 21 | | | | |
| 100 ms Delay Output -40 °C | | 5 | | | 5 | 5 | | | | |
| 100 ms Delay Output +23 °C | | 5 | 5 | 5 | 5 | 5 | | | | |
| 100 ms Delay Output +85 °C | | 5 | | | 5 | 5 | | | | |
| Staged Output -40 °C | | 5 | | | | | | | | |
| Staged Output +23 °C | | 5 | 3 | 3 | 3 | 3 | | | | Driver 10 ms, Pass. 20 ms |
| Staged Output +85 °C | | 5 | | | | | | | | |
| **100 ft³ Tank** | 5.2.2.6 | | | | | | | | | |
| Full Output +23 °C | | 6 | | | | | | | | |
| Primary Only Output +23 °C | | 3 | | | | | | | | Do not deploy secondary |
| 100 ms Offset Output +23 °C | | 3 | | | | | | | | |
| **SUPPLEMENTAL EVALUATIONS** | | | | | | | | | | |
| *Sampling Tank Content* | 5.2.2.8.3 | | | | | | | | | |
| Closed Tank Full Output -40 °C | | 5 | | | | 3 | | | | |
| Closed Tank Full Output +23 °C | | 10 | | | | 6 | | | | |
| Closed Tank Full Output +85 °C | | 10 | | | | 6 | | | | |
| *Tank Wash Chemical Speciation* | 5.2.2.8.5 | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 3 | | | | | | | | |
| *Tank Effluents (gas analysis)* | 3.2.3 | 12 | | | | | | | | |
| *Post Deployment Internal Insp.* | 5.2.2.3.2 | | | | | | | | | |
| Full Output +85 °C | | 10 | 3 | 3 | 3 | 3 | | | | |
| 100 ms Delay Output +85 °C | | 5 | | | | | | | | |
| Auto-Ignition | | 15 | | 15 | 15 | | | | | |
| Visual Insp./Post Test Doc. | 5.2.3.3.2 | 120 | 56 | 71 | 81 | 81 | 22 | 8 | 6 | |

● Indicates all samples within the group.

PV MATRIX AND POST DEPLOYMENT PLAN
DUAL STAGE INFLATOR

| Test Sequence | Spec. Section | Qty $A_1$ | Qty $A_2$ | Qty $A_3$ | Qty $B_1$ | Qty $C_1$ | Qty $D_1$ | Qty $D_2$ | Qty $E_3$ | Qty $F_1$ | Qty $G_1$ | Qty $H_1$ | Notes ← *(GROUP $_{LOT\#}$)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Document Part #, Serial # | | 110 | 110 | 110 | 66 | 81 | 74 | 74 | 81 | 22 | 8 | 12 | 758 Inflators total |
| **INITIAL CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | |
| Weight Inspection | 5.2.2.2 | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | |
| Visual Inspection | 5.2.2.3.1 | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | |
| Electrical Checks | 5.2.2.4 | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | |
| **CONDITIONING** | | | | | | | | | | | | | |
| **High Humidity/Heat Aging** | 5.2.3.6 | | | | ● | | | | | | | | |
| **Accelerated Heat Aging** | 5.2.3.5 | | | | | ● | | | | | | | |
| **Sequential Environments** | 5.2.3.7 | | | | | | | | | | | | *(sequence)* |
| Thermal Shock (1) | 5.2.3.7.1 | | | | | | ● | ● | ● | | | | |
| Dynamic Shock - Low g (2) | 5.2.3.7.2 | | | | | | ● | ● | | | | | |
| Dynamic Shock - High g (2) | 5.2.3.7.2 | | | | | | | | ● | | | | |
| Vibration - Temperature Cycle (3) | 5.2.3.7.3 | | | | | | ● | ● | ● | | | | |
| Humidity Resistance (4) | 5.2.3.7.4 | | | | | | ● | ● | ● | | | | |
| Salt Spray (5) | 5.2.3.7.5 | | | | | | ● | ● | ● | | | | |
| Drop Test (6) | 5.2.3.7.6 | | | | | | ● | ● | ● | | | | |
| **Pressure Cycle** | 5.2.3.9 | | | | | | | | | | ● | | |
| **POST CONDITIONING CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | | | | ● | ● | ● | ● | ● | | ● | | |
| Weight Inspection | 5.2.2.2 | | | | ● | ● | ● | ● | ● | | | | |
| Visual Inspection | 5.2.2.3.1 | | | | ● | ● | ● | ● | ● | | | | |
| Electrical Checks | 5.2.2.4 | | | | ● | ● | ● | ● | ● | | | | |
| **INFLATOR TESTING** | | | | | | | | | | | | | |
| **Structural Burst** | 5.2.3.1 | | | | | | | | | 22 | | | |
| **Auto-Ignition** | | | | | | | | | | | | | |
| High Temperature Oven Test | 5.2.3.2 | 3 | 3 | 3 | | 3 | | | 3 | | | | |
| Autoignition/Bonfire | 5.2.3.3 | 5 | 5 | 5 | | 6 | | | 6 | | | | |
| Slow Heat/Autoignition | 5.2.3.4 | 5 | 5 | 5 | | 6 | | | 6 | | | | |
| **Flaming** | 5.2.3.8 | | | | | | | | | | | | |
| Open Air +23 °C | | | | | | | | | | | | 6 | |
| Open Air +85 °C | | | | | | | | | | | | 6 | |
| **Live Dissection** | 5.2.2.9 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | | | |
| **Closed Tank** | 5.2.2.8 | | | | | | | | | | | | |
| Full Output -40 °C | | 12 | 12 | 12 | 15 | 15 | 17 | 17 | 15 | | | | |
| Full Output +23 °C | | 14 | 14 | 14 | 15 | 15 | 18 | 18 | 15 | | | | |
| Full Output +85 °C | | 19 | 19 | 19 | 15 | 15 | 18 | 18 | 15 | | | | ***15pc w/ IOP*** |
| 100 ms Delay Output -40 °C | | 10 | 10 | 10 | 5 | 5 | 5 | 5 | 5 | | | | |
| 100 ms Delay Output +23 °C | | 10 | 10 | 10 | 5 | 5 | 5 | 5 | 5 | | | | |
| 100 ms Delay Output +85 °C | | 10 | 10 | 10 | 5 | 5 | 5 | 5 | 5 | | | | |
| Staged Output -40 °C | | 5 | 5 | 5 | | | | | | | | | |
| Staged Output +23 °C | | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | | | | Driver 10 ms, Pass. 20 ms |
| Staged Output +85 °C | | 5 | 5 | 5 | | | | | | | | | |
| **100 ft³ Tank** | 5.2.2.6 | | | | | | | | | | | | |
| Full Output +23 °C | | 2 | 2 | 2 | | | | | | | | | |
| Primary Only Output +23 °C | | 1 | 1 | 1 | | | | | | | | | Do not deploy secondary |
| 100 ms Offset Output +23 °C | | 1 | 1 | 1 | | | | | | | | | |
| **SUPPLEMENTAL EVALUATIONS** | | | | | | | | | | | | | |
| *Sampling Tank Content* | 5.2.2.8.3 | | | | | | | | | | | | |
| Closed Tank Full Output -40 °C | | 2 | 2 | 2 | | | 2 | 2 | | | | | |
| Closed Tank Full Output +23 °C | | 4 | 4 | 4 | | | 3 | 3 | | | | | |
| Closed Tank Full Output +85 °C | | 4 | 4 | 4 | | | 3 | 3 | | | | | |
| *Tank Wash Chemical Speciation* | 5.2.2.8.5 | | | | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 1 | 1 | 1 | | | | | | | | | |
| *Tank Effluents (gas analysis)* | 3.2.3 | 4 | 4 | 4 | | | | | | | | | |
| *Post Deployment Internal Insp.* | 5.2.2.3.2 | | | | | | | | | | | | |
| Full Output +85°C | | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | | | | |
| 100 ms Delay Output +85 °C | | 5 | 5 | 5 | | | | | | | | | |
| Auto-Ignition | | 13 | 13 | 13 | | 15 | | | 15 | | | | |
| Visual Insp./Post Test Doc. | 5.2.3.3.2 | 110 | 110 | 110 | 66 | 81 | 74 | 74 | 81 | 22 | 8 | 6 | |

● Indicates all samples within the group.

DV MATRIX AND POST DEPLOYMENT PLAN - SINGLE STAGE

| Test Sequence | Spec. Section | Qty A | Qty B | Qty C | Qty D | Qty E | Qty F | Qty G | Qty H | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Document Part #, Serial # | | 84 | 48 | 63 | 63 | 63 | 22 | 8 | 12 | 363 Inflators total |
| **INITIAL CHECKS** | | | | | | | | | | |
| Leak Test | 5.2.2.1 | • | • | • | • | • | | • | • | |
| Weight Inspection | 5.2.2.2 | • | • | • | • | • | | • | • | |
| Visual Inspection | 5.2.2.3.1 | • | • | • | • | • | • | • | • | |
| Electrical Checks | 5.2.2.4 | • | • | • | • | • | | • | • | |
| **CONDITIONING** | | | | | | | | | | |
| **High Humidity/Heat Aging** | 5.2.3.6 | | • | | | | | | | |
| **Accelerated Heat Aging** | 5.2.3.5 | | | • | | | | | | |
| **Sequential Environments** | 5.2.3.7 | | | | | | | | | *(sequence)* |
| Thermal Shock (1) | 5.2.3.7.1 | | | | • | • | | | | |
| Dynamic Shock - Low g (2) | 5.2.3.7.2 | | | | • | | | | | |
| Dynamic Shock - High g (2) | 5.2.3.7.2 | | | | | • | | | | |
| Vibration - Temperature Cycle (3) | 5.2.3.7.3 | | | | • | • | | | | |
| Humidity Resistance (4) | 5.2.3.7.4 | | | | • | • | | | | |
| Salt Spray (5) | 5.2.3.7.5 | | | | • | • | | | | |
| Drop Test (6) | 5.2.3.7.6 | | | | • | • | | | | |
| **Pressure Cycle** | 5.2.3.9 | | | | | | | • | | |
| **POST CONDITIONING CHECKS** | | | | | | | | | | |
| Leak Test | 5.2.2.1 | | • | • | • | • | | • | | |
| Weight Inspection | 5.2.2.2 | | • | • | • | • | | | | |
| Visual Inspection | 5.2.2.3.1 | | • | • | • | • | | | | |
| Electrical Checks | 5.2.2.4 | | • | • | • | • | | | | |
| **INFLATOR TESTING** | | | | | | | | | | |
| **Structural Burst** | 5.2.3.1 | | | | | | 22 | | | |
| **Auto-Ignition** | | | | | | | | | | |
| High Temperature Oven Test | 5.2.3.2 | 3 | | 3 | 3 | | | | | |
| Autoignition/Bonfire | 5.2.3.3 | 6 | | 6 | 6 | | | | | |
| Slow Heat/Autoignition | 5.2.3.4 | 6 | | 6 | 6 | | | | | |
| **Flaming** | 5.2.3.8 | | | | | | | | | |
| Open Air +23 °C | | | | | | | | | 6 | |
| Open Air +85 °C | | | | | | | | | 6 | |
| **Live Dissection** | 5.2.2.9 | 3 | 3 | 3 | 3 | 3 | | | | |
| **Closed Tank** | 5.2.2.8 | | | | | | | | | ***w/ IOP Measurement*** |
| Full Output -40 °C | | 15 | 15 | 15 | 15 | 18 | | | | |
| Full Output +23 °C | | 20 | 15 | 15 | 15 | 21 | | | | |
| Full Output +85 °C | | 25 | 15 | 15 | 15 | 21 | | | | |
| **100 ft³ Tank** | 5.2.2.6 | | | | | | | | | |
| Full Output +23 °C | | 6 | | | | | | | | |
| **SUPPLEMENTAL EVALUATIONS** | | | | | | | | | | |
| *Sampling Tank Content* | 5.2.2.8.3 | | | | | | | | | |
| Closed Tank Full Output -40 °C | | 5 | | | | 3 | | | | |
| Closed Tank Full Output +23 °C | | 10 | | | | 6 | | | | |
| Closed Tank Full Output +85 °C | | 10 | | | | 6 | | | | |
| *Tank Wash Chemical Speciation* | 5.2.2.8.5 | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 3 | | | | | | | | |
| *Tank Effluents (gas analysis)* | 3.2.3 | 6 | | | | | | | | |
| *Post Deployment Internal Insp.* | 5.2.2.3.2 | | | | | | | | | |
| Full Output +85 °C | | 10 | 3 | 3 | 3 | 3 | | | | |
| Auto-Ignition | | 15 | | 15 | 15 | | | | | |
| Visual Insp./Post Test Doc. | 5.2.2.3.2 | 84 | 48 | 63 | 63 | 63 | 22 | 8 | 6 | |

• Indicates all samples within the group.

## PV MATRIX AND POST DEPLOYMENT PLAN - SINGLE STAGE

| Test Sequence | Spec. Section | Qty $A_1$ | Qty $A_2$ | Qty $A_3$ | Qty $B_1$ | Qty $C_1$ | Qty $D_1$ | Qty $D_2$ | Qty $E_3$ | Qty $F_1$ | Qty $G_1$ | Qty $H_1$ | Notes ← *(GROUP LOT#)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Document Part #, Serial # | | 63 | 63 | 63 | 48 | 63 | 56 | 56 | 63 | 22 | 8 | 12 | 517 inflators total |
| **INITIAL CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | • | • | • | • | • | • | • | • | | • | • | |
| Weight Inspection | 5.2.2.2 | • | • | • | • | • | • | • | • | | • | • | |
| Visual Inspection | 5.2.2.3.1 | • | • | • | • | • | • | • | • | • | • | • | |
| Electrical Checks | 5.2.2.4 | • | • | • | • | • | • | • | • | | • | • | |
| **CONDITIONING** | | | | | | | | | | | | | |
| **High Humidity/Heat Aging** | 5.2.3.6 | | | | • | | | | | | | | |
| **Accelerated Heat Aging** | 5.2.3.5 | | | | | • | | | | | | | |
| **Sequential Environments** | 5.2.3.7 | | | | | | • | • | • | | | | *(sequence)* |
| Thermal Shock (1) | 5.2.3.7.1 | | | | | | • | • | • | | | | |
| Dynamic Shock - Low g (2) | 5.2.3.7.2 | | | | | | • | • | | | | | |
| Dynamic Shock - High g (2) | 5.2.3.7.2 | | | | | | | | • | | | | |
| Vibration - Temperature Cycle (3) | 5.2.3.7.3 | | | | | | • | • | • | | | | |
| Humidity Resistance (4) | 5.2.3.7.4 | | | | | | • | • | • | | | | |
| Salt Spray (5) | 5.2.3.7.5 | | | | | | • | • | • | | | | |
| Drop Test (6) | 5.2.3.7.6 | | | | | | • | • | • | | | | |
| **Pressure Cycle** | 5.2.3.9 | | | | | | | | | | • | | |
| **POST CONDITIONING CHECKS** | | | | | | | | | | | | | |
| Leak Test | 5.2.2.1 | | | | • | • | • | • | • | | • | | |
| Weight Inspection | 5.2.2.2 | | | | • | • | • | • | • | | | | |
| Visual Inspection | 5.2.2.3.1 | | | | • | • | • | • | • | | | | |
| Electrical Checks | 5.2.2.4 | | | | • | • | • | • | • | | | | |
| **INFLATOR TESTING** | | | | | | | | | | | | | |
| **Structural Burst** | 5.2.3.1 | | | | | | | | | 22 | | | |
| **Auto-Ignition** | | | | | | | | | | | | | |
| High Temperature Oven Test | 5.2.3.2 | 3 | 3 | 3 | | 3 | | | 3 | | | | |
| Autoignition/Bonfire | 5.2.3.3 | 5 | 5 | 5 | | 6 | | | 6 | | | | |
| Slow Heat/Autoignition | 5.2.3.4 | 5 | 5 | 5 | | 6 | | | 6 | | | | |
| **Flaming** | 5.2.3.8 | | | | | | | | | | | | |
| Open Air +23 °C | | | | | | | | | | | | 6 | |
| Open Air +85 °C | | | | | | | | | | | | 6 | |
| **Live Dissection** | 5.2.2.9 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | | | |
| **Closed Tank** | 5.2.2.8 | | | | | | | | | | | | |
| Full Output -40 °C | | 12 | 12 | 12 | 15 | 15 | 17 | 17 | 15 | | | | |
| Full Output +23 °C | | 14 | 14 | 14 | 15 | 15 | 18 | 18 | 15 | | | | |
| Full Output +85 °C | | 19 | 19 | 19 | 15 | 15 | 18 | 18 | 15 | | | | ***15pc w/ IOP*** |
| **100 ft³ Tank** | 5.2.2.6 | | | | | | | | | | | | |
| Full Output +23 °C | | 2 | 2 | 2 | | | | | | | | | |
| **SUPPLEMENTAL EVALUATIONS** | | | | | | | | | | | | | |
| *Sampling Tank Content* | 5.2.2.8.3 | | | | | | | | | | | | |
| Closed Tank Full Output -40 °C | | 2 | 2 | 2 | | | 2 | 2 | | | | | |
| Closed Tank Full Output +23 °C | | 4 | 4 | 4 | | | 3 | 3 | | | | | |
| Closed Tank Full Output +85 °C | | 4 | 4 | 4 | | | 3 | 3 | | | | | |
| *Tank Wash Chemical Speciation* | 5.2.2.8.5 | | | | | | | | | | | | |
| Closed Tank Full Output +23 °C | | 1 | 1 | 1 | | | | | | | | | |
| *Tank Effluents (gas analysis)* | 3.2.3 | 4 | 4 | 4 | | | | | | | | | |
| *Post Deployment Internal Insp.* | 5.2.2.3.2 | | | | | | | | | | | | |
| Full Output +85 °C | | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | | | | |
| Auto-Ignition | | 13 | 13 | 13 | | 15 | | | 15 | | | | |
| Visual Insp./Post Test Doc. | 5.2.2.3.2 | 63 | 63 | 63 | 48 | 63 | 56 | 56 | 63 | 22 | 8 | 6 | |

• Indicates all samples within the group.

# APPENDIX C - STATISTICAL STRUCTURAL MARGIN CALCULATIONS

## *INFLATOR SAFETY FACTOR*

Step 1: Calculate mean ($\bar{x}_B$) and sample standard deviation ($\sigma_B$) of the Structural Burst data set.

Step 2: Calculate the MEOP of IOP values as below. MEOP shall be determined using unfiltered data (use of class 1000 filters so as not to remove short duration peaks is acceptable).

$$MEOP = \bar{x}_I + 3\sigma_I$$

where:

$\bar{x}_I$ = average Internal Operating Pressure data set
$\sigma_I$ = sample standard deviation of Internal Operating Pressure data set

Step 3: Calculate Safety Factor (SF) using the following equation.

$$SF = \frac{\bar{x}_B - 3\sigma_B}{MEOP}$$

Requirement:

$$\boldsymbol{SF > 1.7}$$

*RELIABILITY AND CONFIDENCE INTERVAL OF INFLATOR HOUSING STRENGTH*
*(99.9999% Reliability, 99% Confidence)*

Step 1: Determine the $T_X$ and $C_X$ values for Internal Operating Pressure ($T_I$, $C_I$) and Structural Burst ($T_B$, $C_B$) data sets from the table below, based on sample size N of each data set.

| N | $C_X$ | $T_X$ |
|---|---|---|
| 3 | 397.997 | 8.119 |
| 4 | 66.585 | 3.722 |
| 5 | 27.558 | 2.501 |
| 6 | 16.236 | 1.947 |
| 7 | 11.379 | 1.630 |
| 8 | 8.801 | 1.424 |
| 9 | 7.237 | 1.277 |
| 10 | 6.200 | 1.166 |
| 11 | 5.467 | 1.079 |
| 12 | 4.924 | 1.009 |
| 13 | 4.506 | 0.950 |
| 14 | 4.175 | 0.901 |
| 15 | 3.906 | 0.858 |
| 16 | 3.683 | 0.821 |
| 17 | 3.496 | 0.788 |
| 18 | 3.337 | 0.759 |
| 19 | 3.199 | 0.733 |
| 20 | 3.079 | 0.709 |
| 21 | 2.973 | 0.688 |
| 22 | 2.880 | 0.668 |
| 23 | 2.796 | 0.650 |
| 24 | 2.721 | 0.633 |
| 25 | 2.652 | 0.618 |
| 26 | 2.590 | 0.603 |
| 27 | 2.534 | 0.590 |
| 28 | 2.482 | 0.577 |
| 29 | 2.434 | 0.566 |
| 30 | 2.390 | 0.554 |
| 31 | 2.349 | 0.544 |
| 32 | 2.311 | 0.534 |
| 33 | 2.276 | 0.525 |
| 34 | 2.243 | 0.516 |
| 35 | 2.212 | 0.507 |
| 36 | 2.182 | 0.499 |
| 37 | 2.155 | 0.491 |
| 38 | 2.129 | 0.484 |

| N | $C_X$ | $T_X$ |
|---|---|---|
| 39 | 2.104 | 0.477 |
| 40 | 2.081 | 0.470 |
| 41 | 2.059 | 0.464 |
| 42 | 2.038 | 0.458 |
| 43 | 2.019 | 0.452 |
| 44 | 2.000 | 0.446 |
| 45 | 1.982 | 0.440 |
| 46 | 1.964 | 0.435 |
| 47 | 1.948 | 0.430 |
| 48 | 1.932 | 0.425 |
| 49 | 1.917 | 0.420 |
| 50 | 1.903 | 0.416 |
| 51 | 1.889 | 0.411 |
| 52 | 1.875 | 0.407 |
| 53 | 1.863 | 0.403 |
| 54 | 1.850 | 0.398 |
| 55 | 1.838 | 0.394 |
| 56 | 1.827 | 0.391 |
| 57 | 1.816 | 0.387 |
| 58 | 1.805 | 0.383 |
| 59 | 1.795 | 0.380 |
| 60 | 1.785 | 0.376 |
| 61 | 1.775 | 0.373 |
| 62 | 1.766 | 0.370 |
| 63 | 1.757 | 0.367 |
| 64 | 1.748 | 0.363 |
| 65 | 1.739 | 0.360 |
| 66 | 1.731 | 0.358 |
| 67 | 1.723 | 0.355 |
| 68 | 1.715 | 0.352 |
| 69 | 1.708 | 0.349 |
| 70 | 1.700 | 0.346 |
| 71 | 1.693 | 0.344 |
| 72 | 1.686 | 0.341 |
| 73 | 1.679 | 0.339 |
| 74 | 1.673 | 0.336 |

| N | $C_X$ | $T_X$ |
|---|---|---|
| 75 | 1.666 | 0.334 |
| 76 | 1.660 | 0.332 |
| 77 | 1.654 | 0.329 |
| 78 | 1.648 | 0.327 |
| 79 | 1.642 | 0.325 |
| 80 | 1.636 | 0.323 |
| 81 | 1.631 | 0.321 |
| 82 | 1.625 | 0.319 |
| 83 | 1.620 | 0.317 |
| 84 | 1.615 | 0.315 |
| 85 | 1.610 | 0.313 |
| 86 | 1.605 | 0.311 |
| 87 | 1.600 | 0.309 |
| 88 | 1.595 | 0.307 |
| 89 | 1.591 | 0.305 |
| 90 | 1.586 | 0.303 |
| 91 | 1.582 | 0.302 |
| 92 | 1.577 | 0.300 |
| 93 | 1.573 | 0.298 |
| 94 | 1.569 | 0.296 |
| 95 | 1.565 | 0.295 |
| 96 | 1.561 | 0.293 |
| 97 | 1.557 | 0.292 |
| 98 | 1.553 | 0.290 |
| 99 | 1.549 | 0.289 |
| 100 | 1.545 | 0.287 |
| 200 | 1.349 | 0.201 |
| 300 | 1.273 | 0.163 |
| 400 | 1.230 | 0.141 |
| 500 | 1.203 | 0.126 |
| 600 | 1.183 | 0.115 |
| 700 | 1.168 | 0.106 |
| 800 | 1.156 | 0.099 |
| 900 | 1.146 | 0.094 |
| 1000 | 1.138 | 0.089 |

Step 2: Calculate d value according to the equation below:

$$d = \frac{\bar{x}_B - \bar{x}_I - (T_I\,\sigma_I + T_B\,\sigma_B)}{\sqrt{(C_I\,{\sigma_I}^2 + C_B\,{\sigma_B}^2)}}$$

where:

$\bar{x}_B$ = mean of the Structural Burst data set
$\bar{x}_I$ = mean of the IOP data set
$\sigma_B$ = sample standard deviation of the Structural Burst data set
$\sigma_I$ = sample standard deviation of the IOP data set

Requirement:

$$\boldsymbol{d \geq 4.753}$$

## APPENDIX D - GAS AND PARTICULATE REPORTING TABLES AND ANALYSIS METHODS

Required presentation format of tank wash, speciation and effluent test results obtained from 100 ft$^3$ and 60 L tank testing.

**Tank Wash and Effluent Analysis Preface Information Table**
(to be used on all data submissions)

| | |
|---|---|
| Number of tests performed<br>Dates of deployment<br>Lab analysis | (*see note 9*) |
| Inflator Designation/Supplier<br>Inflator Type (SS/DS)<br>Test Type (stage and/or delay)<br>Inflator Output, kPa | |
| Bag Size<br>Vent Size and Quantity<br>Tank Size | |

**Inflator Gas Composition Table**

| | | | | |
|---|---|---|---|---|
| Gas Type | | | | |
| Gas Percentage | | | | |

**Effluent Analysis Reporting Tables**

| **Effluent Compounds** | **Mean Value** | **Std. Deviation** | **Min Value** | **Max Value** | **Analytical Method** | **Detection Method** | **Apportioned Value** | **Apportioned Value (%)** | **Vehicle Level Max Limit** (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| $NH_3$ Ammonia | | | | | | | | | 50.0 |
| $C_6H_6$ Benzene | | | | | | | | | 22.5 |
| CO Carbon Monoxide | | | | | | | | | 461 |
| $CO_2$ Carbon Dioxide | | | | | | | | | 30000 |
| $Cl_2$ Chlorine | | | | | | | | | 1.0 |
| $CH_2O$ Formaldehyde | | | | | | | | | 2.0 |
| HCl Hydrogen Chloride | | | | | | | | | 5.0 |
| HCN Hydrogen Cyanide | | | | | | | | | 4.7 |
| $H_2S$ Hydrogen Sulfide | | | | | | | | | 15.0 |
| NO Nitric Oxide | | | | | | | | | 75.0 |
| $NO_2$ Nitrogen Dioxide | | | | | | | | | 15.0 |
| $COCl_2$ Phosgene | | | | | | | | | 0.3 |
| $SO_2$ Sulfur Dioxide | | | | | | | | | 5.0 |
| $C_2H_2$ Acetylene<br>*(see note 6)* | | | | | | | | | $25000_{(20\%LEL)}$ |
| $C_2H_4$ Ethylene<br>*(see note 6)* | | | | | | | | | $27000_{(20\% LEL)}$ |
| $CH_4$ Methane<br>*(see note 6)* | | | | | | | | | $50000_{(20 \%LEL)}$ |
| Hydrogen | | | | | | | | | $40000_{(20\% LEL)}$ |