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(R) Airbag Module Deployment Test Procedure			

RATIONALE

This document was revised to reflect numerous changes in measurement technology, airbag module configurations, and industry practices.

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SAE WEB ADDRESS:

1. SCOPE

This SAE Recommended Practice describes a method to be used for the static deployment of airbag module assemblies. The results obtained from the deployment tests will be used to verify compliance with design requirements and/or specifications, and for other engineering purposes such as module performance comparisons, and/or CAE input or validation. The purpose for this procedure is to describe recommended test methods to ensure, to the extent possible, reliable and reproducible test results for driver airbag modules, passenger airbag modules, or other airbag modules (e.g., side airbags, roof rail airbags, knee bolster airbags, etc.). Performance limits or acceptance criteria are not established as they are typically defined based on specific vehicle design requirements and/or manufacturer specifications. It is intended to be a general procedure for repetitive testing and suggests only general guidelines for the safe conduct of tests and reliable data correlation.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

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

SAE J211-1 Instrumentation for Impact Test - Part 1 - Electronic Instrumentation

SAE J211-2 Instrumentation for Impact Test - Part 2 - Photographic Instrumentation

SAE J1538 Glossary of Automotive Inflatable Restraint Systems

3. DEFINITIONS

Refer to SAE J1538 for terms used in this document.

4. GENERAL TEST REQUIREMENTS

Deployment test methods used for acceptance and performance evaluation of airbag module assemblies shall provide accurate, repeatable, and reproducible results, with considerations made to minimize the effects of test-to-test and/or lab-to-lab variability in test equipment, module fixturing, and ambient conditions of the lab and/or specimen storage areas (temperature, humidity, and atmospheric pressure). Toward this end, and with the added incentives of cost and time efficiencies, these tests are generally performed outside the actual vehicle when possible - using only those portions of the actual vehicle that directly influence the applicable performance of the module or the outcome of the test.

4.1 Test Facility

Airbag module assemblies (containing an inflator) are typically Department of Transportation (DOT) classified. Therefore, the facility for conducting tests on pyrotechnic devices must comply with all local and state building codes, including all necessary certifications/permits for receipt, storage, and shipping of these materials.

A suitable floor plan and work area design is important for proper execution of tests. Features shall include a physical safety barrier between test personnel and the device under test. Environmental control is important for both the pre-test conditioning and the deployment. Differences in temperature humidity, and/or atmospheric pressure have been shown to have an effect on certain test results. Ambient laboratory temperature of $22^{\circ}\text{C} \pm 2^{\circ}\text{C}$ shall apply unless otherwise noted for a specific test. The relative humidity (% R.H.) and atmospheric pressure (kPa) for each test shall be clearly stated in the test data and/or test report. An exhaust fan is recommended to vent smoke and particulate from the test bay prior to re-entry by test personnel.

4.2 Safety Requirements

In consideration of safety for test personnel working with experimental devices, appropriate facilities and training must be provided. Examples of the necessary safety equipment include remote airbag triggering systems, shielding for personnel; test warning system (i.e., siren and/or light); and personal safety equipment (PSE) such as eye protection, gloves, hearing protection, respirators, and grounding straps, if required. Proper written safety procedures should be followed in accordance with standard ordinance and pyrotechnic industry practice. All applicable OSHA safety standards must be followed.

4.3 Equipment List

The equipment will typically consist of the following basic components:

- a. Mounting Fixture - The physical structure to which the module is mounted for the deployment test, and those portions of the actual vehicle that directly influence the applicable performance of the module or the outcome of the test
- b. Pressure Transducer - Measures the pressures inside the bag and/or inflator
- c. Data Acquisition System - Records and displays test data, such as the internal bag and/or inflator pressure versus time results, and temperature versus time of the module components during conditioning, when applicable
- d. Temperature Conditioning Chamber - Conditions module to desired deployment temperature (additional equipment, such as heating lamps, may be required for some tests)
- e. High-Speed Video Equipment
- f. Lighting System - Intensity matched to video specifications and desired capture rate
- g. Deployment Source - Provides the proper stimulus to actuate the inflator
- h. Temperature Probe - Measure conditioning chamber and test component temperature during pretest conditioning
- i. Strobe Light - To denote time zero on high-speed video for use during analysis
- j. Labeling equipment

5. EQUIPMENT SPECIFICATION

The equipment used in the module deployment test facility shall meet the following specifications:

5.1 Mounting Fixture

The module test mounting fixture shall allow for the secure attachment of the test airbag module assemblies and all related vehicle components, to the extent necessary for the purpose of the test, needed for the module to deploy naturally (as it would when installed in the intended vehicle). When possible, the actual module attachment hardware used in the vehicle should be used to avoid possible unintended consequences.

The airbag module shall be oriented so that the airbag (cushion) may deploy freely with no unnatural obstructions presented by the fixture or surroundings. The test fixture shall hold the airbag module in an orientation and manner consistent with the intended design of the airbag module assembly and/or the objective of the test.

The specimens being tested (airbag module and related vehicle components) must be identified for traceability purposes. This identification should be visible by the high speed video equipment.

5.1.1 The test fixture shall provide a level of support to the airbag module at least as rigid as the automobile structure to which it will be installed.

5.1.2 Any physical obstructions to bag deployment that are normally present in the vehicle for which the test module is intended should be simulated in the test fixture (e.g., windshield surface, instrument panel surface, etc.).

5.2 Pressure Transducer

A pressure transducer may be utilized to measure pressure inside the airbag. Recommended pressure transducer specifications are provided in Appendix A. All transducers, instrumentation, and data filters (analog and digital) shall be selected per SAE J211.

5.2.1 The pressure transducer and "extension tube," when used, should be mounted in a location clear from the unfolding bag, with the pressure inlet located in an area of reduced gas flow within the module to minimize the "Venturi" effect on the measured pressure. Caution must be observed during interpretation of all module pressure data due to the dynamic variation of pressure during cover opening and bag fill. Guidelines for installing pressure taps in the various airbag module configurations is provided in Appendix B.

5.2.2 Where practicable, pressure transducers used for comparison testing should be standardized. Results from different transducer types or models may vary significantly - especially when measuring short duration pressure pulses such as those produced during airbag deployment door break-out. The break-out pressure reading will also be affected by pick-up tube diameter, length, and material variations. Longer and/or more flexible tubes will have a damping effect on the data similar to filtering.

5.2.3 The dynamic range of the pressure transducer must be compatible with the temperature and pressure expected from the test. A means of calibrating the pressure transducers prior to testing shall be provided. Pressure transducer calibrations shall be conducted regularly and calibration results recorded. Refer to the transducer manufacturer's recommended procedure for calibrations. See Appendix A for recommended performance specifications.

5.3 High-Speed Film and/or Video Camera

The high-speed filming or video taping system should consist of a camera and a recording/monitoring system which can be synchronized for camera start-up during the module deployment test. The filming or taping capability should be at least 1000 pictures per second (pps). A means of verifying film speed should be incorporated into the filming/video operation. Some customer standards may require higher speed capability (i.e., for bag unfolding or cover integrity 3000 pps is recommended). The lighting should be of proper intensity to create a quality film/video image. Multiple cameras may be required to view various module details (i.e., top view, side view, plan view, cover/door/hinge detail, etc.).

5.4 Data Acquisition System

A data acquisition system (per SAE J211) shall be provided to measure and record pressure output versus time for the bag pressure and inflator, if applicable. Filter requirements, data sampling rate of test system, transducer frequency response, and amplifier frequency response should be such that there is minimal effect on data accuracy. Overall accuracy of the data acquisition system should be within 3%. The data acquisition system must have clearly defined capabilities such as sample rate, resolution and digital filtering as supported by SAE J211. Data recorded should include at least 20ms of data prior to T=0, and sufficient duration after T=0 to capture the duration of interest for the test.

5.5 Temperature Conditioning Chambers

Temperature conditioning chambers should be provided to temperature condition modules prior to testing. For the safety of personnel, protective chambers should be considered. Chamber capabilities typically extend from -55 to 120 °C, but as a minimum, should extend from -40 to 90 °C. The temperature conditioning chamber should be capable of providing a uniformity of the temperature extremes with control level variations not to exceed ± 3 °C throughout the chamber. On passenger side systems, sun load temperature differential may be required. This can be accomplished by using heat lamps or other heating means (see 6.1.1).

6. TEST PROCEDURE

Ambient test lab conditions (e.g., temperature, percent relative humidity, and barometric pressure) should be recorded.

6.1 Temperature Conditioning

Test samples may be temperature conditioned prior to testing. The typical lower and upper temperature ranges for conditioning modules are $-30\text{ °C} \pm 3\text{ °C}$ and $+80\text{ °C} \pm 3\text{ °C}$. Ambient test temperature is $22\text{ °C} \pm 3\text{ °C}$. The modules shall be conditioned for a sufficient period of time to ensure that the entire module assembly (including internal temperature) is at the required temperature. Typical conditioning times are 3 to 4 h, but if the module is mounted to a significant thermal mass (such as a vehicle) the time may need to be extended. Modules (installed into the test fixture) are placed in the conditioning chamber in a manner that allows free air movement around assemblies, and no direct contact with chamber walls. To determine the required soak time needed to properly condition a specific module design, an inert sample can be instrumented with thermocouples to monitor internal component temperatures.

6.1.1 When testing passenger modules, actual in-vehicle temperature measurements may be used for deployment pre-conditioning in place of the $+80\text{ °C}$ soak. This practice (referred to as Sun Load Conditioning) is most commonly used when testing top-mount passenger modules to represent a worst-case condition for the airbag cover/skin material without unnecessarily over conditioning the module/inflator. To achieve this kind of conditioning, the entire assembly (module, deployment door, and instrument panel) is conditioned to some temperature (as measured during in-vehicle temperature measurement - typically $65\text{ °C} \pm 3\text{ °C}$). Just prior to deployment, the instrument panel and deployment door surface temperatures are raised and stabilized at the temperature corresponding with maximum vehicle interior component surface temperatures (as measured during in-vehicle temperature measurement - typically $105\text{ °C} \pm 3\text{ °C}$ for top-mount passenger modules) using heat lamps or some other directional heat source. Target temperatures for Sun Load Conditioning are generally obtained while exposing the vehicle to desert sunlight conditions, using thermocouples mounted throughout the instrument panel and airbag module.

6.2 Installation to Mounting Fixture

The air bag module should be securely mounted to the test mounting fixture so that no unnatural movement of the module occurs during testing. See Appendix C for typical test setup for driver and passenger airbag modules. Other airbag modules for deployment tests should be mounted to approximate their in vehicle position.

6.3 Time to Deployment

Typically, the test sample should be deployed in the mounting fixture within 3 min of removing the sample from the temperature conditioning chamber, if conditioned separately from the mounting fixture. If the 3-min period is exceeded, samples should be reconditioned at least 10 min for every minute beyond the 3-min period. However, the acceptable deployment time limit and reconditioning schedule are a function of the module design, which can affect the warm-up or cool-down rate. Thus, consideration should be made to measure the internal and external thermal change rate of a particular module design to determine the proper time limit for deployment after removal from the conditioning chamber. External temperatures may be of particular concern when a function of the test is to determine module cover/door performance or when the conditioning requirements involve sun loading. In such cases a 3-min wait between removal from the chamber and deployment may be inappropriate, as changes in surface/skin temperature occur much more rapidly than the module or inflator core temperatures.

6.4 Deployment Pulse/Stimulus

An appropriate level and duration of deployment pulse or stimulus as specified by the manufacturer or customer should be used to deploy the module, (e.g., all fire current for electric initiators or mechanical shock for mechanical sensors). The deployment pulse or stimulus and equipment specification shall be recorded (including magnitude and duration to establish Time = 0 for the event).

6.5 Typical Test Sequence

The following list is a typical sequence of events for a driver airbag module deployment test and provides an overview of the testing process. Before entering the test area, ensure that all required personal protective equipment (PPE) is being used.

- a. Verify presence and location of all equipment and tools to be used during the test.
- b. Check for proper attachment of transducers.
- c. Perform all system calibrations required including the transducers and system amplifiers.
- d. Verify film speed, camera settings, and lighting.
- e. Log-on to the test computer or data recording device and enter test serial number, etc. Record lab ambient conditions.
- f. Note any time limit to actuate the module after removal from the temperature conditioning chamber.
- g. Mount the module to the test stand ensuring all fastening systems are tightened securely for protection of operating personnel. Verify that test deployment leads are grounded and shorted prior to connection of the inflator/module initiator leads to avoid possible premature deployment of the module due to stray voltage spikes and label test specimen with appropriate test serial number, etc.
- h. Close test bay door and turn on warning light before arming the deployment panel or switch.
- i. Connect cable for supplying inflator deployment current to the deployment circuit.
- j. Review check list to verify completion of all prior listed actions before deploying the module.
- k. Warn personnel in the vicinity that a test is being conducted.
- l. Deploy module and note the response of the data acquisition system to verify successful deployment.
- m. Turn on test bay exhaust fan to remove any fumes and smoke that may exist.
- n. Wearing proper PPE, enter test bay and remove module from test stand. Ensure use of appropriate protective equipment when handling the module since it is likely to be hot.
- o. Perform post-deployment inspection and record condition of module and related components and/or photograph as needed. The inspection should include, but is not limited to:
 - Verify cushion integrity (snags, pin holes, tears on seams, friction marks, burns, combing, etc.).
 - Check the airbag module and attachment fasteners for damage or permanent deformations (belmouthing).
 - Verify airbag cover integrity (fragmentation) and if the cover tear seam opened as design intended.

- Identify if the airbag module/cushion has interacted with other non-related vehicle components that may affect trajectory or deployment. Examples of this are: Trim features such as coat-hooks or grab handles in the case of side impact inflatable curtains, A/C vents in the case of passenger airbags, etc.
- Note the condition of the airbag electrical connector and harness (affects from temperature, snags, etc.)
- Data Reduction

Although only the low-frequency data are of interest, to prevent data aliasing and phase shifting during digitization, the analog data should be digitized at a sample rate at least five times greater than the highest frequency that has any visually significant amplitude. Generally, the trace for airbag pressures will not contain any significant signal content above 1000 Hz; thus a digital sample rate between 5000 and 10 000 samples per second will usually be adequate. An anti-alias analog filter as per SAE J211 is recommended prior to digital sampling. (Note that the highest significant frequency present in the data is also limited by the transducer response time capability and the type of pick-up tube [if used]. However, using a slow transducer to effectively filter the data will produce the same data aliasing and phase shifting as would a slow digital sample rate.)

- 6.6 After acquisition, the digital data trace should be inspected for any anomalies and clarity. If the data have an initial vertical offset, they should be run through an amplitude offset removal routine (e.g., average the last 20 ms of unfiltered data before ignition time zero, and vertically shift the data by this average offset). If the data are noisy, they should be digitally filtered to obtain the underlying smooth pressure curve for data presentation and analysis. For evaluating the cover burst pressure, the recommended filter cutoff frequency is 1650 Hz (Class 1000). For evaluating bag inflation pressure, the recommended filter cutoff frequency is 100 Hz (Class 60). In any case, the filters used should meet the requirements of SAE J211. (If there are any anomalies in the raw data, these must be noted on the filtered data, since filtering will obscure them.)
- 6.7 Accommodation for local atmospheric pressure can be made by adding an offset to the data equal to the difference between recorded atmospheric pressure and standard pressure at sea level (Recorded + $P_{atm} - 101.325$ kPa). This "normalized" data is particularly useful if comparing test results from different regions/altitudes, and when using the data for computer modeling exercises.

7. TEST DATA DOCUMENTATION

7.1 Pressure Versus Time Plot

The pressure versus time history shall be recorded during each test using appropriate and properly calibrated instrumentation. Pressure shall be plotted along the vertical axis, time along the horizontal axis. Maintain appropriate calibration records. Figure 1 for an example of typical plot.

7.1.1 Typical Data Measurements

(Reference: Figure 1) - Typical data measurements for characterizing performance are:

From CFC1000 data:

- a. Time to initial positive pressure (see point "A").
- b. Maximum bag pressure spike typically at cover break point (see point "B").
- c. Time to maximum bag pressure spike (see point "B") from CFC60 Data:
- d. Time to positive pressure after cover/door tear seam break (see point "C").
- e. Maximum bag pressure after positive pressure (see point "D").
- f. Time to maximum bag pressure after positive pressure (see point "D").

- g. "Inflation time: Inflation time is the time from airbag initiation to the time the airbag is fully inflated and can provide protection. The visual indicant used for this determination is somewhat dependant on the type of module being tested. The definitions below for each module type can be used for the majority of modules in production. There are exceptions however, for which alternate methods may need to be established.
- i. Driver module: The driver side airbag is considered "inflated" when, following its expulsion from the module, it moves back to the steering wheel, and the first rebound of the airbag from the steering wheel begins. The evaluation is done on the large diameter of the airbag (equator).
 - ii. Passenger module: The passenger side airbag is considered inflated when, following its expulsion from the module it moves back to the instrument panel, and the first rebound of the airbag from the instrument panel begins.
 - iii. Knee Airbag module: The knee airbag is considered inflated when, following its expulsion from the module it moves back to the instrument panel, and the first rebound of the airbag from the instrument panel begins.
 - iv. Side Airbag module: This measurement is not applicable to the side airbag module. Due to the small gap into which the bag must deploy, loading from the occupant generally begins while the airbag is still deploying.
 - v. Roof Rail Airbag module: The roof rail airbag is considered inflated when, following its deployment downward from the roof rail, it moves back toward the roof rail, and begins again to move downward.

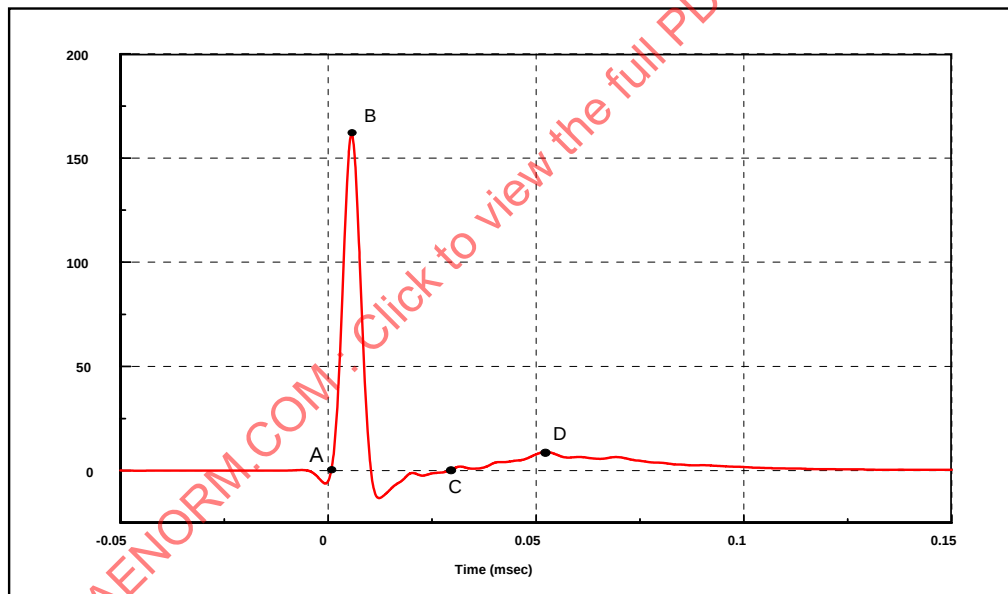


FIGURE 1 - TYPICAL BAG PRESSURE PLOT

7.2 Video Analysis

High-speed photographic sequences from a high-speed camera may be analyzed by various methods to determine bag response from the static deployment test.

8. NOTES

8.1 Marginal Indicia

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APPENDIX A - TRANSDUCER SELECTION

A.1 The following table is provided to highlight some typical requirements of pressure transducers:

TABLE A1 - TYPICAL PRESSURE TRANSDUCER SPECIFICATIONS

Range: Airbag Pressure	0 to 700 kPa
Accuracy	±0.5% F.S.O.
Compensated Temperature Range	−40 to 100 °C
Resonant Frequency	>100 kHz
Response Time	<1/3 ms

A.2 The values for the criteria listed above will depend upon actual test requirements, the transducer type, and manufacturer selected, and are listed only to provide an insight to the typical values used in the airbag industry. Specific transducer selection should be consistent with the guidelines described in SAE J211.

A.3 A definition of the terms used above is provided as follows:

- a. Accuracy - The degree of conformity of an indicated value to a recognized/accepted standard value or ideal value.
- b.. Compensated Temperature Range - The range of temperature within which the transducer will conform to the stated performance specifications.
- d. Resonant Frequency - The mechanical resonant frequency of the pressure sensing assembly; the frequency of pressure application at which the transducer responds with maximum output amplitude.
- e. Response Time - The time required for the output to increase from zero to some specified percentage of its final value, when excited by a step change in pressure.

APPENDIX B - PRESSURE TAP INSTALLATION GUIDELINES

This section describes the configuration of components used in connecting the pressure transducer to the airbag module. The most significant variables in this connection are the "Extension Tube" (diameter, length, and material), position of the pressure port in the airbag module, and the number of 90 degree elbows used.

Extension Tube: The plastic tube used shall meet the following specifications:

- Material: PU or PL
- ID: 4 mm
- Length: 300 mm

NOTE:

1. FESTO PU4, FESTO PL4 and 4 mm RIEGLER PU12 are all currently acceptable options.
2. The use of 90 degree elbows to attach the pressure tube is discouraged as it has been shown to have a small effect on the pressure measurement. If it is necessary to use an elbow due to fixture concerns, limit the number to one if possible.

Connection of the Extension Tube to the module: The general rule here is to terminate the extension tube inside the module at a location away from the inflator nozzles, but within the enclosed volume that first sees pressure (no airbag folds between the inflator and the extension tube). In some modules it is necessary to have an internal tube (usually 3 to 4 mm ID steel tube) that directs the pressure to an Extension Tube attachment outside the module (Figure B1). In other situations the Extension Tube is attached directly to the airbag (Figure B2). In these cases it is advisable to add local reinforcement to the airbag fabric and utilize a flanged attachment (inside and outside bag) to ensure the port stays attached during deployment.



FIGURE B1 - INTERNAL PRESSURE TUBE REQUIRED ON SOME MODULES