

	SURFACE VEHICLE RECOMMENDED PRACTICE	
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Superseding J2238 OCT2001		
Airbag Inflator Ballistic Tank Test Procedure Gas Generating Devices Used In Inflatable Restraint Systems		

RATIONALE

Purposes of this revision to SAE J2238 are to clarify data acquisition system / instrumentation requirements for inflator tank testing, to update some the terminology used to describe inflators including some the newer systems that have been introduced since the revision to this specification.

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1. SCOPE

This SAE Recommended Practice establishes a ballistic tank test procedure for evaluating inflator assemblies used in inflatable restraint systems. It is intended to be a general procedure for repetitive testing and suggests only general guidelines for the safe conduct of tests and data correlation. Uniform test requirements, test procedures, and data recording requirements are specified. The intent of the document is to provide a procedure employing a ballistic tank test method for determining the ability of an inflator to meet requirements for deploying inflatable restraint systems. A ballistic tank test is described which will yield repeatable and comparable results for evaluating a given inflator configuration's pressure output versus time. Use of the ballistic tank test for comparison of various inflator technologies may be of limited value due to differences in gas temperature, gas composition and mass flow effects on airbag performance as it relates to occupant protection.

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 Paper 91080 Use and Selection of Thermocouples

2.1.2 ASME Publication

Available from the American Society of Mechanical Engineers, 22 Law Drive, PO Box 2900, Fairfield, NJ 07007-2900, Tel: 973-882-1170, www.asme.org.

ASME Boiler and Pressure Vessel Code, Section VIII Rule for Construction of Pressure Vessels, Division 11, an American Standard 2007 Edition (please see current amendment)

2.1.3 Other Publication

Lange's Handbook of Chemistry, McGraw Hill, 1985

2.2 Related Publications

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

2.2.1 SAE Publication

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 J1538 Glossary of Automotive Inflatable Restraint Systems

2.2.2 Other Publications

Abernethy, R. B. and Thompson, J. W., "Measurement Uncertainty Handbook," Instrument Society of America, 1980

Stein, P. K., "The Response of Transducers to Their Environment, the Problem of Signal and Noise," Shock and Vibration Bulletin, Vol. 40, No. 7, pp. 115, 1970

Taylor, J. L., "Computer-Based Data Acquisition Systems, Design Techniques," Instrument Society of America, 1986

Megyesy, Eugene F., "Pressure Vessel Handbook," Publishing, Inc., 1989

3. DEFINITIONS:

Per SAE TSB 002 "Preparation of SAE Technical Reports" revised June 1992 developed by the SAE Editorial Advisory Committee.

Section 9.4 of the SAE TSB 002 states:

"Shall" or "Should" -- The use of "shall" or "should" has no bearing on the voluntary nature of SAE technical reports. Inclusion of or reference to an SAE report in a document, standard, or contract by a company or agency is a voluntary act. When a report is so cited, the report becomes a requirement within the limitations set forth by the document, standard, or contract. The following shall apply to the use of "shall" or "should" in SAE reports:

Section 9.4.1 Shall - is to be used wherever the criterion for conformance with the specific recommendations requires that there shall be no deviation. Its use shall not be avoided on the grounds that compliance with the report is considered voluntary.

Section 9.4.2 Should – is to be used wherever noncompliance with a specific recommendation is permissible. "Should" shall not be substituted for "shall" on the grounds that compliance with the report is voluntary.

4. GENERAL TEST REQUIREMENTS

The ballistic tank test equipment for acceptance testing of inflators used in inflatable restraints systems shall provide a reliable, accurate, and repeatable testing system, adaptable for mounting various configurations of inflators. The following sections will describe the general needs for the test facility equipment and safety requirements.

4.1 Test Facility

Airbag inflators are typically classified by the US Department of Transportation (DOT) as a Class 9 miscellaneous hazardous material. Older inflators may have been classified as a 1.4 explosive, Explosive Class C, Flammable Solid or Argon compressed gas nonflammable. Therefore, the facility for conducting tests on pyrotechnic or stored-gas pressure vessel devices must comply with all local and state building codes.

A proper floor plan and work area design is also very important for proper execution of tests. Features include a physical barrier between test personnel and the device under test. In addition, a temperature controlled environment is important for test result accuracy, and a room exhaust fan is recommended to vent smoke and particulates from the test area.

4.2 Safety Requirements

In consideration of safety for test personnel working with experimental devices, appropriate facility and proper personal protective equipment must be provided. Examples of this equipment include remote firing capability, warning system (e.g., siren and/or light) shielding, flame-retardant lab coats, electrostatic ground straps, safety glasses, hearing protection, respirators, and gloves as required.

Proper written safety procedures and check lists should be followed in accordance with industry practice. All applicable OSHA safety standards must be followed.

4.3 Equipment List

The equipment will typically consist of the following basic components:

Item	Equipment	Description
A	Test-Tank	Contains the generated gas
B	Pressure Transducer(s)	Measures pressures inside the tank or inflator
C	Transducer Signal Conditioning	Provides transducer power and amplification as needed by the data acquisition system (may be integral part of data acquisition system)
D	Data Acquisition System	Records and displays pressure, temperature, voltage, current, etc., all versus time from an inflator test
E	Temperature Conditioning Chamber	Conditions inflator to desired deployment temperature
F	Thermocouple(s)	Measures gas temperature inside the tank, tank wall or on the inflator surface (all optional)
G	Firing Source	Provides the proper stimulus to actuate the inflator
H	Current monitor(s)	Measures current applied to an electrical initiator (2 required for dual level inflators)
I	Voltage monitor(s)	Measures voltage applied to an electrical initiator (optional) (2 required for dual level inflators)

Section 4 of this procedure will discuss the equipment specifications typically used.

5. EQUIPMENT SPECIFICATION

The ballistic tank test facility shall consist of equipment meeting the following specifications.

5.1 Test-Tank

A test-tank shall be provided for containing an inflator's pressure output over the anticipated pressure and temperature range. The test-tank construction should conform to the ASME Code for Pressure Vessels Section VIII Division 2. A tank shape with a hemispherical end is preferred to facilitate tank washing. The test-tank shall be secured and of such design that no movement or distortion of the test-tank results upon deployment of the inflator.

5.1.1 Tank Volume

The volume of the test-tank to be used for a particular inflator is determined based on the inflator's design output as follows:

Inflator Application	Typical Test-tank Volumes (Liters)
Driver-Side	28.3 ± 0.3 or 60.0 ± 0.6
Passenger-Side, Pedestrian-Protection, or Occupant-to-Occupant	60.0 ± 0.6
Side-Impact, Roll-Over, Knee, Active Knee Bolster, Active Side Bolsters, or Inflatable Seat Belt	28.3 ± 0.3 or $10. \pm 0.1$

- If different tank volumes exist, a method of correlation of the tank to pressure data is required; i.e., test a statistically significant number of samples in each tank and compare values.
- For other applications such as pretensioners, hypertensioners, headrest, foot, or roof applications, the volume selected should be near the specific application volume or new tank volumes should be developed.
- Tank volume shall be measured. A recommended procedure is outlined in Appendix A.

5.1.2 Inflator Orientation/Sealing

The inflator should be positioned in the test-tank to the extent as possible such that the exhaust-gases from the inflator do not impinge on pressure transducer ports. The test-tank must provide adequate sealing such that pressure is contained within the tank during deployment of the inflator. An exception is for vented tank-tests where vents of a pre-defined size may be present to allow controlled venting during deployment.

5.1.3 Tank Surface Finish

The inside surfaces of the test-tank shall be smooth to facilitate cleaning and tank washing. A finish of equal to or better than $32 \mu\text{m}$ finish is recommended. Coatings may be used to facilitate tank wash; however, caution should be used in coatings that may wear off or otherwise exhibit deterioration.

5.1.4 Tank Configuration

The test-tank shall provide a means to rigidly mount the inflator to the tank without restricting the flow of gas into the tank. Figure 1 depicts one type of test tank used in the airbag industry. Other shapes are acceptable; however, a correlation between different shape tanks may be required.

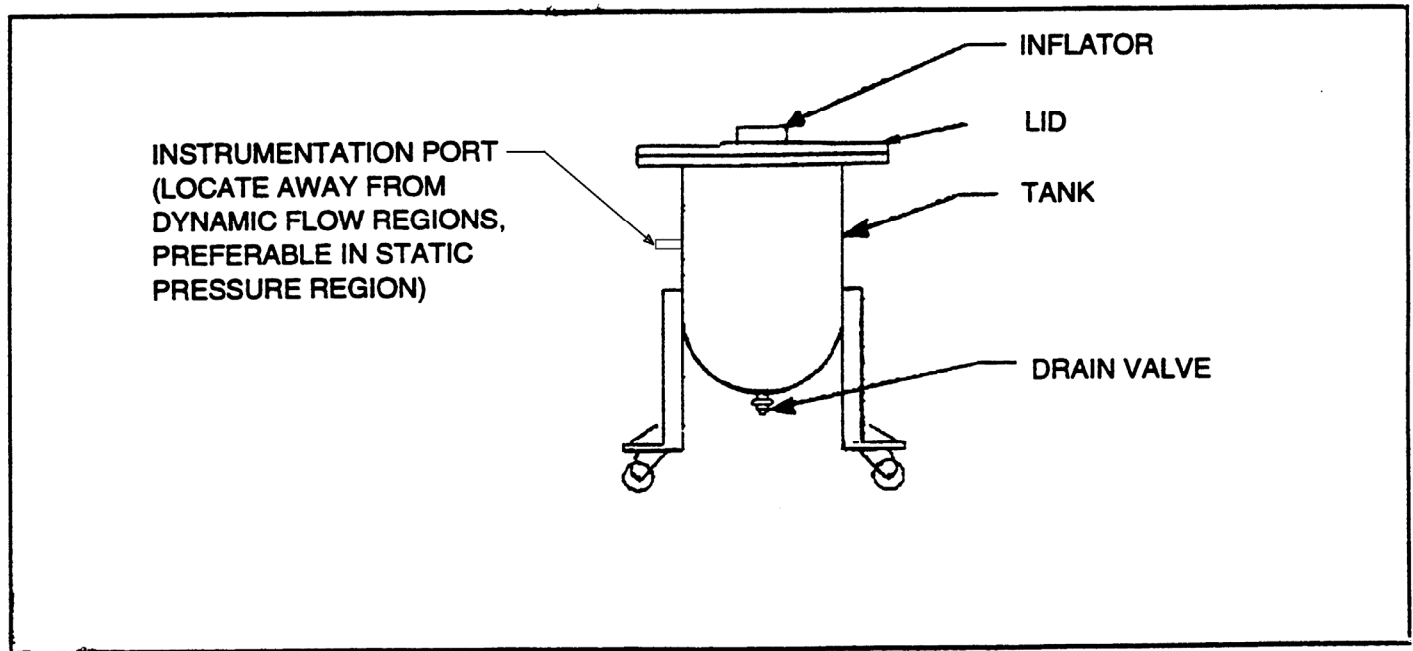


FIGURE 1- CLOSED TEST TANK

5.2 Pressure Transducer

A minimum of one pressure transducer shall be provided and mounted to the test-tank to measure the pressure generated by the inflator. Two pressure transducers may be used for due care to avoid data loss in the event pressure transducer malfunction occurs. The tank-pressure transducer mounting location should be away from dynamic flow regions. Pressure transducers may also be provided to measure the inflator's internal pressure. An additional pressure transducer may also be used as a time-to-first-gas indicator which may be located closer to the inflator exhaust and located within the dynamic flow region.

Strain gage or piezoelectric pressure transducers are both acceptable. Strain gage type pressure transducers may be unamplified or amplified.

Pressure transducers are selected based upon how they are to be used, the speed and range of expected pressures, where they are to be mounted, and the temperature to which they are exposed. 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. All transducers, instrumentation, and data filters (analog and digital) should be selected per SAE J211-1. The following Table shows an example of typical requirements and selection guidelines.

Transducer Selection Criteria

Criteria	Specification	Definition
Minimum Accuracy	0.5% F.S.O. (Full Scale Output)	Percent of full-scale-output
Transducer F.S.O. (Full Scale Output) Selection	Expected Tank Peak Pressure should be within 20% to 80% of the Transducer F.S.O.	
Tank Pressure Gage Resonant Frequency	>4 kHz	The mechanical resonant frequency of the pressure sensing assembly; the frequency of pressure application at which the transducer responds with maximum output amplitude.
Response Time	<0.33 ms	The time required for the output to increase from zero to 97% of its final value when excited by a step change in pressure.
Temperature Range	–55 to 120 °C	The range of temperature within which the transducer will operate without nonreversible changes in the performance specifications.
Compensated Temperature Range	–30 to 80 °C	The range of temperature within which the transducer will conform to the stated performance specification

5.2.1 Transducer Calibration

A means to calibrate 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. If transducers are calibrated separate from the Data Acquisition System, then the transducer amplifier/signal conditioning system must also be calibrated. This ensures that the transducer sensitivity measured on the calibration system will be the same on the data acquisition system.

5.3 Data Acquisition System

A data acquisition system (per SAE J211-1) shall be provided to record pressure, current and/or voltage applied to the initiator(s), and optionally tank-gas temperature or inflator surface temperature, all versus time. Filter requirements, data sampling rate of test system, transducer frequency response, and amplifier frequency response should be such that there is minimal effect on accuracy of the data. The data acquisition system must have clearly defined capabilities such as sample rate, resolution, and filtering as supported by SAE J211-1. Recording of data prior to application of the stimulus (pre-time-zero data) is recommended. Overall accuracy of the data acquisition system should be within 1.5% or better.

Data Acquisition System Minimum Recommended Requirements

Item	Description
Sampling Rate	10,000 points per second per data channel minimum` (20,000 or greater recommended)
Analog-to-Digital-Convertor Resolution	12 bit minimum (16 bit or greater recommended)
Pre-Time-Zero Data Acquisition	0.010 seconds minimum

5.4 Temperature Conditioning Chamber

Temperature conditioning chamber(s) shall be provided to allow conditioning of inflators to a selected temperature prior to deployment. At a minimum, the conditioning temperature capability of a test facility should range from -40°C to $+90^{\circ}\text{C}$. This can be accomplished through individual chambers set to a particular temperature or with a single chamber capable of having multiple set points. Temperature conditioning greater than $+90^{\circ}\text{C}$ and less than -40°C may be needed for special tests. The maximum temperature gradient throughout a conditioning chamber should be less than 3°C .

Because there is a possibility of an inadvertent inflator deployment during conditioning (inflators can generate high pressures when deployed in small closed volumes) appropriate precautions must be taken in the selection of conditioning chambers and their location in the test facility. For safety considerations, explosion-proof chambers are recommended. At a minimum a conditioning chamber should have a pressure relieve mechanism in case of an inadvertent inflator deployment during conditioning. Conditioning chambers should be located in an area with limited personnel access. The position of conditioning chamber pressure relief devices should also be considered to avoid injury to personnel working near a conditioning chamber. Local safety practices at your organization or by local ordinance supersede any safety recommendations made in this document.

5.5 Tank or Inflator Thermocouples

For proper selection and use of thermocouple refer to SAE Paper 910808.

6. TEST PROCEDURE

Ambient test area temperature, % relative humidity, barometric pressure, etc. should be recorded. Test-tank wall temperature may be recorded prior to deployment and should be within the range of $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$. The inflator conditioning temperature and time in conditioning shall be recorded for each test. The tank should normally be cleaned and dried prior to each test. In some circumstances it may be more practical complete a light-clean after each test and to thoroughly clean the tank after a number of tests (see section 5.6 below), e.g., high-volume production lot acceptance testing.

6.1 Temperature Conditioning

Test samples may be temperature conditioned prior to testing. Typical lower and upper temperature ranges for conditioning inflators are $-35^{\circ}\text{C} \pm 3^{\circ}\text{C}$ and $+85^{\circ}\text{C} \pm 3^{\circ}\text{C}$. Ambient test temperature is $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$. The inflator shall be conditioned for a sufficient period of time to ensure the entire inflator assembly is at the required temperature; a minimum of 125% of demonstrated time for the inflator core to reach equilibrium with the conditioning temperature. Inflators shall be placed in the conditioning chamber in a manner that allows free air movement around assemblies and with no direct contact with chamber walls.

6.2 Installation to Tank

The inflator shall be rigidly mounted to the test tank such that no movement of the inflator occurs or gas leaks during deployment. The inflator can be mounted through the test-tank lid with a portion of the inflator exposed outside the tank or mounted completely inside the test tank. When the inflator is mounted inside the test-tank, a sealed electrical pass-through for the firing line(s) and if needed, pressure transducer lines, must be provided.

6.3 Time to Deployment

The normal deployment-time of an inflator is a function of the inflator and test tank designs and can vary from inflator-to-inflator. But for most inflator designs, the test sample should be deployed in the test-tank within a time frame that does not exceed 3 minutes after the inflator has been removed from the temperature conditioning chamber. To minimize test variability it is recommended that for a given inflator design, the time-to-deploy an inflator after it has been removed from the temperature conditioning chamber be within a small time frame (such as +/- 15 seconds) around its normal deployment time. For example; a small side-impact inflator that can be removed from a conditioning chamber, mounted and functioned approximately 1 minute after being removed from the conditioning chamber, should be tested within the time frame from 45 seconds to 1 minute 15 seconds. A large passenger inflator that is mounted inside the test-tank may have a normal deployment time of 2 minutes 45 seconds so its deployment time frame would be from 2 minutes 30 seconds to 3 minutes.

If the time period to deploy the inflator has been exceeded then the inflator must be reconditioned. The inflator should be reconditioned for 10 minutes for every minute that exceeded the normal deployment time. Because the acceptable deployment time limit and reconditioning schedule of an inflator are a function of the inflator design, which can affect the internal warm up or cool down rate, consideration should be made to measure the internal temperature change rate of a particular inflator design to determine the proper time limit to deployment and reconditioning time. In the absence of data, the recommended reconditioning time of the sample of 10 minutes for every minute beyond its normal deployment time, not to exceed the original conditioning time, should be followed.

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 inflator (e.g., all-fire current for electric initiators or mechanical shock for mechanical sensors). The deployment pulse or stimulus shall be recorded (including magnitude and duration to establish time zero for the event). The equipment specification (e.g., hardware, calibration) shall be recorded for each test series.

6.5 Typical Test Sequence

The following list is a typical sequence of events to conduct a tank test and provides an overview of the testing process. See Appendix B for a typical tank test set-up.