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# Standard Test Method for Determining Dynamic Air Permeability of Inflatable Restraint Fabrics[1]

This standard is issued under the fixed designation D6476; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the procedures used to determine under dynamic airflow conditions the high pressure permeability of permeable, uncoated fabrics typically used for inflatable restraints. For the determination of air permeability of inflatable restraint fabrics under low pressure conditions at steady-state air flow, refer to Test Method D737.

1.2 Procedures and apparatus other than those stated in this test method may be used by agreement of purchaser and supplier with the specific deviations from the standard acknowledged in the report.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles

D737 Test Method for Air Permeability of Textile Fabrics

D1776 Practice for Conditioning and Testing Textiles

D2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data (Withdrawn 2008)[3]

D6799 Terminology Relating to Inflatable Restraints

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

## 3. Terminology

3.1 For all terminology relating to D13.20, Inflatable restraints, refer to Terminology D6799.

3.1.1 The following terms are relevant to this standard: average dynamic air permeability (ADAP), dynamic air permeability (DAP), cushion, exponent of dynamic air permeability (EXP, ) inflatable restrain, inflator, module, standard atmosphere for testing textiles

3.2 For all other terms related to textiles, see Terminology D123.

## 4. Summary of Test Method

4.1 A volume of dessicated compressed air at known volume and pressure passes through a fabric specimen into the standard atmosphere for testing textiles. During the portion of the test cycle which simulates airbag inflation, the pressure differential pressure across the specimen rises to a value corresponding to a peak inflation pressure. During the portion of the test cycle which simulates airbag deflation, the pressure differential drops to 0 kPa as the air passes through the specimen. The time to reach the maximum pressure and the subsequent time to correspond to similar times in an airbag deployment.

4.2 Software algorithms integral to the apparatus smooth out the pressure data and determine the values for ADAP and EXP.

## 5. Significance and Use

5.1 For matters relating to lot acceptance of commercial shipments and conformity to specification or other standard, refer to Section 13 of this test method.

5.2 This test method is useful in the selection and design validation of permeable, uncoatable fabrics used in inflatable restraint cushions. The dynamic conditions and higher pressure differentials of this test method may better simulate the inflation and deflation cycle of an airbag module during deployment than do the steady-state conditions of Test Method D737.

5.2.1 Only uncoated, permeable fabrics should be used. Use of coated fabrics may yield invalid results and potentially damage the test apparatus.

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[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.20 on Inflatable Restraints.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

5.3 Within the limits of variance expressed in Section 12, this test method is useful for design validation and may be suitable for incorporation in a material specification or for lot acceptance testing of commercial shipments. Caution is advised on very low permeability fabrics or with the 200 $cm^3$. size test heat because between-laboratory precision as presented in Section 12 may be as high as 21 %.

5.4 This test method may be used for materials other than inflatable restraint fabrics which experience dynamic air permeability in sudden bursts. In such cases, the physical apparatus or its software algorithms may require modification to provide suitability for use.

5.5 Due to the split-second time interval for testing, the pressure versus time data is subject to recording anomalies and electronic noise. The data should be digitally filtered to obtain the underlying smooth pressure curve prior to data analysis. The software in the apparatus includes a reliable algorithm both to smooth the curve and to determine the exponent of air permeability.

5.6 It is inherent in the design and operation of this equipment that major components key to the calibration and measurements are specific to the individual test head. The size or permeability measuring range of the test head is typically chosen to correspond to the fabric specimen to be tested. The precision of this test method is highly dependent on the size of the test head. The precision of the data collected using one test head should be used to estimate the precision of data collected using a different test head, even on the same apparatus.

5.7 It is mandatory that fabric specimens be conditioned and tested in standard atmosphere for testing textiles.

## 6. Apparatus

6.1 *Removable Test Head,* containing a Pressure Vessel of known volume capable of being charged pneumatically from 0 to no less than 400 kPa with a tolerance of ± 3.0 %, of sufficient volume to challenge adequately the fabric being tested, equipped with a solenoid release valve mechanism, a test chamber, and a circular orifice with an area of 50 $cm^2$; and equipped with a means of measuring and adjusting the pressure range in increments of 1 kPa, a minimum range between pressure set points of 5 kPa and rise and fall ranges in ms sufficient to meet the conditions of a material specification for dynamic air permeability testing of inflatable restraint fabrics.

6.2 *Pressure Transducers and Rigid Wall Pickup Tubes,* suitable for measuring the pressure differential of the fabric specimen in a range sufficient to meet the conditions of a material specification for dynamic air permeability testing of inflatable restraint fabrics, with a tolerance of ± 2 %, mounted in a static or low pressure area in the test fixture that does not interfere with airflow.

6.3 *Air Compressor and Air Desiccating Cartridge,* capable of charging the pressure vessel in the test head to the specified pressure up to 400 kPa.

6.4 *Mounting Fixture,* capable of retaining the fabric specimen over the test orifice without stretching the specimen and without air leakage at the periphery of the test area.

6.5 *Electrical Firing Pulse Source,* suitable for actuating the inflation and for communicating with the data acquisition system dependent on an electrical signal.

6.6 *Data Acquisition System,* suitable for recording the output of the pressure transducers versus elapsed time of airflow.

6.7 *Filter Requirements,* data sampling rate, transducer frequency response, and amplifier frequency response shall be such that minimal effect on accuracy of the data occurs. The accuracy of the pressure transducers, amplifiers, and timers within the test apparatus shall be calibrated to within ± 3 %.

## 7. Sampling

7.1 Dynamic air permeability testing is a destructive test and therefore necessitates sampling procedures if used in conjunction with lot acceptance of commercial shipments.

7.2 *Lot Sample:*

7.2.1 For acceptance testing, the lot size is the quantity of fabric finished in one production day or as agreed upon between the purchaser and the supplier.

7.2.2 Unless otherwise agreed upon between the purchaser and the supplier, take as a lot sample all the rolls in a commercial shipment. Consider the rolls to be the primary sampling units.

7.3 *Laboratory Sample*

7.3.1 An entire roll of fabric or a full-width cut from the end of a roll within a lot sample constitutes a laboratory sample.

7.4 *Test Specimens:*

7.4.1 Test specimens are the pieces of fabric that actually undergo testing. Cut or mark specimens from the end of each roll of fabric in the laboratory sample, as indicated in the material specification or equivalent. Cut 165 by 330 mm rectangular specimens from the full-width fabric sample, or mark similarly sized areas across the full-width fabric sample without cutting individual specimens.

7.4.2 If areas of full width fabric are tested without cutting individual specimens, position test areas representing a broad distribution across the length and width, preferably along the diagonal of the laboratory sample, and no nearer the edge than one tenth its width.

## 8. Conditioning

8.1 Precondition test specimens in accordance with Practice D1776 or as agreed upon between the the purchaser and the supplier.

8.2 Prior to testing, bring the test specimens to moisture equilibrium at ambient atmospheric pressure, at 21 ± 1°C, and at 65 ± 2 % relative humidity, unless directed to do otherwise by an agreement by the purchaser and supplier.

8.3 Equilibrium is considered to have been reached when the increase in mass of the specimen in successive weighings made at intervals of not less than 2 h does not exceed 0.1 % of the mass of the specimen.

## 9. Procedure

9.1 Select and condition specimens in accordance with 8.1.

9.2 Mount the fabric specimen on the test fixture, ensuring that the retention mechanism clamps the fabric tightly with minimal tension and without damage or wrinkling.

9.3 Perform all system calibrations.

9.4 Enter the specimen number into recording portions of the data acquisition.

9.5 Ensure the pressure vessel is pressurized with desiccated air to a pressure sufficiently high to test the specimen within the pressure ranges specified.

9.6 In accordance with the applicable material specification or laboratory guideline, select and install the appropriate test head for the fabric type to be measured.

9.7 Preset the start, upper, and lower pressure limits.

9.7.1 Unless otherwise stated in the customer specification, the test head size, and starting pressure should be selected such that an average peak pressure of 100 ± 10 kPa is reached during the test. Also unless otherwise stated in the customer specification, the Lower Limit should be set to 30 kPa and the Upper Limit should be set to 70 kPa.

9.8 Establish data acquisition system response to pressure inputs.

9.9 Initiate the starting sequence and note the response of the data acquisition system to verify successful airflow.

9.10 Record maximum differential pressure in kPa, time to maximum pressure in ms, or whatever data points are required by the material specification.

9.11 Remove the specimen from the test stand and mark it as having been tested.

9.12 On the test report, record the data required by the material specification.

NOTE 1—The unit of permeability commonly used for ADAP measurement is mm/s. A velocity of 1 mm/s is the mathematical equivalent of a permeability of 0.1 $cm^3/(cm^2 \cdot s)$. Permeability and velocity are considered interchangeable terms.

## 10. Equipment Calibration

10.1 For inflatable restraints, all test equipment used in accordance with these test methods shall be certified for calibration annually by an independent agency or equipment manufacturer whose results are traceable to the National Institute of Science and Technology (NIST) or other national standards laboratory. The test parameters of the equipment shall be tested within the operating ranges covered in the material specification or equivalent document.

## 11. Report

11.1 State that the tests were conducted in accordance with this test method for determining the dynamic air permeability of inflatable restraints fabrics.

11.1.1 If deviation from this test method occurred, any reference to this test method shall state: "Testing was performed in accordance with ASTM D6476, with the following changes:"

11.2 The purchaser and supplier shall determine the exact form of the test report. Unless otherwise specified, report the following information:

11.2.1 Fabric designation,
11.2.2 Lot identification,
11.2.3 Date of report,
11.2.4 Name of person certifying report,
11.2.5 Relevant specification,
11.2.6 Number of specimens used in each test,
11.2.7 Tests performed and data obtained,
11.2.8 Laboratory conditions if other than standard, and
11.2.9 Deviations from standard procedures and apparatus.

## 12. Precision and Bias

12.1 *Bias*—For multifilament fabrics such as those used for inflatable restraints, there is no standard reference material available to serve as an accepted standard value for dynamic air permeability testing. In the absence of a known true value, the accuracy of this test method cannot be determined.

12.2 The analysis of precision of test results using this test method is meaningful both within-laboratory and between-laboratory with multiple operators.

12.3 An Interlaboratory Test[4] was planned and conducted on uncoated fabrics covering a range of permeabilities typically used in inflatable restraint cushions in accordance with Practice E691 and Practice D2904. For inflatable restraint fabrics, the typical range of permeabilities is between zero and 10 cfm when measured in accordance with Test Method D737. Two variables, ADAP and EXPONENT were studied. Analysis was done using SAS 6.1, PROC. GLM, and PROC. VARCOMP. Three components of variance - single-operator, within-laboratory, and between-laboratory - were statistically calculated to determine precision of this test method.

12.4 *Precision of ADAP*—For the components of variance listed in Table 1, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 2

12.4.1 Primary source of variance of ADAP is between laboratories.

12.4.2 The critical differences for ADAP values as a percent of the ADAP average at the 95 % probability level for single operator, within laboratory, and between laboratory generally varied inversely with the head size, the air permeability rate, and the number of observations.

12.4.3 The critical differences for ADAP values as a percent of the ADAP average at the 95 % probability level for single-operator, and for within-laboratory values ranged from 3.4 % (for 5 observations using an 800 $cm^3$ head at a permeability of 1814 mm/s) to 17.1 % (for a single observation using a 200 $cm^3$ head at 466 mm/s).

12.4.4 The critical differences for ADAP values as a percent of the ADAP average at the 95 % probability level for

[4] A research report detailing the interlaboratory test is available from ASTM Headquarters. Request RR:D13-1104.

**TABLE 1 Components of Variance as Standard Deviations, Percentage Points**

| ADAP | Single-Operator | Within-Laboratory | Between-Laboratory |
|---|---|---|---|
| Material A:<br>420 d. Nylon<br>200 cc. Head<br>466 mm/s<br>Average ADAP | 6.15 % | 0.00 % | 4.13 % |
| Material B:<br>650 d. Polyester<br>200 cc. Head<br>525 mm/s<br>Average ADAP | 2.78 % | 0.00 % | 3.83 % |
| Material C:<br>420 d. Nylon<br>400 cc. Head<br>799 mm/s<br>Average ADAP | 3.67 % | 0.00 % | 0.00 % |
| Material D:<br>630 d. Nylon<br>400 cc. Head<br>1197 mm/s<br>Average ADAP | 3.53 % | 0.00 % | 4.04 % |
| Material E:<br>630 d. Nylon<br>400 cc. Head<br>1187 mm/s<br>Average ADAP | 3.58 % | 0.00 % | 1.30 % |
| Material F:<br>840 d. Nylon<br>800 cc. Head<br>1814 mm/s<br>Average ADAP | 2.75 % | 0.00 % | 2.46 % |

**TABLE 2 Critical Differences for Conditions Noted 95 % Probability Level, Percentage Points**[A]

| ADAP | Number of Observations in Each Average | Single-Operator Precision | Within-Laboratory Precision | Between-Laboratory Precision |
|---|---|---|---|---|
| Material A: | | | | |
| 420 d. Nylon | 1 | 17.1 % | 17.1 % | 20.5 % |
| 200 cc. Head | 3 | 9.9 % | 9.9 % | 15.1 % |
| 466 mm/s | 5 | 7.6 % | 7.6 % | 13.8 % |
| Average ADAP | | | | |
| Material B: | | | | |
| 650 d. Polyester | 1 | 7.7 % | 7.7 % | 13.1 % |
| 200 cc. Head | 3 | 4.5 % | 4.5 % | 11.5 % |
| 525 mm/s | 5 | 3.5 % | 3.5 % | 11.2 % |
| Average ADAP | | | | |
| Material C: | | | | |
| 420 d. Nylon | 1 | 10.2 % | 10.2 % | 10.2 % |
| 400 cc. Head | 3 | 5.9 % | 5.9 % | 5.9 % |
| 799 mm/s | 5 | 4.5 % | 4.5 % | 4.5 % |
| Average ADAP | | | | |
| Material D: | | | | |
| 630 d. Nylon | 1 | 9.8 % | 9.8 % | 14.9 % |
| 400 cc. Head | 3 | 5.7 % | 5.7 % | 12.6 % |
| 1197 min/s | 5 | 4.4 % | 4.4 % | 12.0 % |
| Average ADAP | | | | |
| Material E: | | | | |
| 630 d. Nylon | 1 | 9.9 % | 9.9 % | 10.6 % |
| 400 cc. Head | 3 | 5.7 % | 5.7 % | 6.8 % |
| 1187 mm/s | 5 | 4.4 % | 4.4 % | 5.7 % |
| Average ADAP | | | | |
| Material F: | | | | |
| 840 d. Nylon | 1 | 7.6 % | 7.6 % | 10.2 % |
| 800 cc. Head | 3 | 4.4 % | 4.4 % | 8.1 % |
| 1814 mm/s | 5 | 3.4 % | 3.4 % | 7.6 % |
| Average ADAP | | | | |

[A]The critical differences were calculated using $z$ = 1.960.

between-laboratory values ranged from 4.5 % (for five readings using an 400 cm$^3$ test head at a permeability of 799 mm/s) to 20.5 % (for a single reading using a 200 cm$^3$ head at 466 mm/s).

12.5 *Precision of EXP*—For the components of variance listed in Table 3, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 4.

12.5.1 Primary source of variance of EXP is between laboratories.

12.5.2 The critical differences for EXP values as a percent of the EXP average at the 95 % probability level for single operator, within laboratory, and between-laboratory generally varied inversely with the test head size, the permeability rate, and the number of observations.

12.5.3 The critical differences for EXP values as a percent of the EXP average at the 95 % probability level for single-operator for single-operator values ranged from 6.0 % (for a single observation using a 200 cm$^3$ test head at 466 mm/s) to 1.7 % (for five observations using an 800 cm$^3$ test head at a permeability of 1814 mm/s).

12.5.4 The critical differences for EXP values as a percent of the EXP average at the 95 % probability level for within-laboratory values ranged from 9.9 % (for a single observation using a 200 cm$^3$ test head at 466 mm/s) to 1.7 % (for five observations using an 800 cm$^3$ test head at a permeability of 1814 mm/s).

12.5.5 The critical differences for EXP values as a percent of the EXP average at the 95 % probability level for between-laboratory values ranged from 9.9 % (for a single observation using a 200 cm$^3$ test head at 466 mm/s) to 2.0 % (for five observations using an 800 cm$^3$ test head at a permeability of 1814 mm/s).

## 13. Conformance

13.1 When lot acceptance applies, the test results of the physical properties of inflatable restraint fabric shall conform to allowable ranges listed in the applicable material specification or other agreement between purchaser and supplier in order to warrant release of the fabric shipment.

13.2 Non-conformity shall be reported by the supplier to the purchaser in writing. A fabric lot that fails to conform to physical testing requirements as specified or as otherwise agreed upon may only be released for shipment upon written consent of the purchaser.

13.3 In case of a dispute arising from differences in reported test results when using these test methods, the purchaser and

**TABLE 3 Components of Variance as Standard Deviations, Percentage Points**

| EXP | Single-Operator | Within-Laboratory | Between-Laboratory |
|---|---|---|---|
| Material A: 420 d. Nylon 200 cc. Head 1.60 EXPONENT Average | 2.16 % | 2.83 % | 0.00 % |
| Material B: 650 d. Polyester 200 cc. Head 1.12 EXPONENT Average | 1.64 % | 1.18 % | 2.32 % |
| Material C: 420 d. Nylon 400 cc. Head 1.27 EXPONENT Average | 1.26 % | 0.00 % | 1.65 % |
| Material D: 630 d. Nylon 400 cc. Head 0.96 EXPONENT Average | 1.38 % | 0.00 % | 3.26 % |
| Material E: 630 d. Nylon 400 cc. Head 0.99 EXPONENT Average | 1.09 % | 0.00 % | 2.94 % |
| Material F: 840 d. Nylon 800 cc. Head 0.84 EXPONENT Average | 1.34 % | 0.00 % | 0.38 % |

the supplier shall conduct comparative tests to determine if there is a statistical bias between their laboratories. As a minimum, the two parties shall take a group of test specimens which are as homogeneous as possible and from the same lot of fabric. The test specimens shall then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories shall be compared using Student's t-test for unpaired data and an acceptable probability level chosen by the two parties before the testing is begun. If a bias is found, either its cause shall be found and corrected or the purchaser and supplier shall agree to interpret future results in light of the known bias.

## 14. Keywords

14.1 airbag; inflatable restraint; permeability

**TABLE 4 Critical Differences for Conditions Noted 95 % Probability Level, Percentage Points[A]**

| EXP | Number of Observations in Each Average | Single-Operator Precision | Within-Laboratory Precision | Between-Laboratory Precision |
|---|---|---|---|---|
| Material A: | | | | |
| 420 d. Nylon | 1 | 6.0 % | 9.9 % | 9.9 % |
| 200 cc. Head | 3 | 3.5 % | 8.6 % | 8.6 % |
| 1.60 EXPONENT Average | 5 | 2.7 % | 8.3 % | 8.3 % |
| Material B: | | | | |
| 650 d. Polyester | 1 | 4.6 % | 5.6 % | 8.5 % |
| 200 cc. Head | 3 | 2.6 % | 4.2 % | 7.7 % |
| 1.12 EXPONENT Average | 5 | 2.0 % | 3.9 % | 7.5 % |
| Material C: | | | | |
| 420 d. Nylon | 1 | 3.5 % | 3.5 % | 5.8 % |
| 400 cc. Head | 3 | 2.0 % | 2.0 % | 5.0 % |
| 1.27 EXPONENT Average | | | | |
| Material D: | | | | |
| 630 d. Nylon | 1 | 3.8 % | 3.8 % | 9.8 % |
| 400 cc. Head | 3 | 2.2 % | 2.2 % | 9.3 % |
| 0.96 EXPONENT Average | 5 | 1.7 % | 1.7 % | 9.2 % |
| Material E: | | | | |
| 630 d. Nylon | 1 | 3.0 % | 3.0 % | 8.7 % |
| 400 cc. Head | 3 | 1.7 % | 1.7 % | 8.3 % |
| 0.99 EXPONENT Average | 5 | 1.4 % | 1.4 % | 8.3 % |
| Material F: | | | | |
| 840 d. Nylon | 1 | 3.7 % | 3.7 % | 3.9 % |
| 800 cc. Head | 3 | 2.2 % | 2.2 % | 2.4 % |
| 0.84 EXPONENT Average | 5 | 1.7 % | 1.7 % | 2.0 % |

[A] The critical differences were calculated using $z = 1.960$.