



Door Trim Structural Integrity Test

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. The door trim structural integrity test is a method to evaluate the crash performance of the front door trim without performing a full vehicle side impact test. In this subsystem test the effects of the vehicle side impact are simulated with respect to its structural integrity. This test can be used earlier in the design process as a development test to uncover failure modes through quick learning cycles.

1.2 Foreword. Not applicable

1.3 Applicability. This door trim structural integrity test is a subsystem level test and applies to all GM passenger cars subjected to ECE R95 regulation.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ECE R95

SAE J211

2.2 GM Standards/Specifications.

None

2.3 Additional References.

CG190 - GM Approved Test Report Form

Drawings - Computer Aided Design (CAD) files (available in GM Information Management and Networking System (IMAN))

3 Resources

3.1 Facilities.

- Structural Test Lab at GME, Russelsheim, Germany that has the drop tower impact tester.
- Safety Lab at GMM, Toluca, Mexico that has the drop tower impact tester.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment. This procedure assumes adequate physical equipment for the drop tower impact test is available and installed. This includes the drop tower impact tester, measurement system, test site controller, impactors, supports and test specimen fixture. The following paragraphs provide a partial list of the equipment required.

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July 2013

Page 1 of 27

3.2.1 Drop Tower Impact Tester. The drop impact tester (see Appendix C, Figure C2) is used to simulate a side impact to the door trim and is adequate to fulfill the physical conditions. The drop impact tester is equipped with a measurement data acquisition system and a bedplate. The required information is given from the Computer Aided Engineering (CAE) simulation for each door trim program. For typical testing conditions, see Table 1.

Table 1: Typical Testing Conditions

Test	Condition
Energy	0.9 kJ to 2.0 kJ
Velocity	4.0 m/s to 5.5 m/s
Drop Weight Short Door	109 kg
Drop Weight Long Door	116 kg

3.2.2 Drop Tower Measurement System. The drop tower impact tester shall be equipped with adequate measurement system for impact acceleration, force, drop weight, drop height and deformation path.

3.2.2.1 Force Transducers. A typical force transducer for drop tower tests in GME is a quartz force sensor, type Kistler Z17835 with charge amplifier type Kistler 5011 B with the specifications in Table 2.

Table 2: GME Force Transducers Specifications Example

Range	0 kN to 50 kN or 0 kN to 100 kN (For the Supports)
Sensitivity	1.99 pC/N
Rigidity	30 kN/ μ m

Note: Supports require 13 force transducers (see drawings in Appendix B, Figure B3 to B8). Alternative adequate transducer and amplifier may also be used.

3.2.2.2 Accelerometer. A typical accelerometer for drop tower tests in GME is a sensor type Kistler 8002 with charge amplifier type Kistler 5011 B with the specifications in Table 3.

Table 3: GME Accelerometer Specifications Example.

Range	$\pm 10\,000$ g
Sensitivity	1.0 pC/g
Frequency	0 Hz to 7000 Hz
Resonant Frequency	40 kHz

Note: Alternative adequate transducer and amplifier may also be used.

3.2.2.3 Deformation Path. For measurement of door trim deformation use a laser sensor with minimum range 400 mm (± 200 mm) and 10 kHz limit frequency.

3.2.2.4 Drop Weight. The drop weight is the calculated sum of the weight of the drop tower crossbeam, impactor, transducer, mounting parts and weights added to the cross beam. The weight is measured by a load cell.

3.2.2.5 Drop Height. The drop height is the calculated difference between impactor height underside in start test position and the door panel specimen height (see Appendix A, Figure A10).

3.2.2.6 Amplifier. The used amplifier is fast and accurate enough to work with the force transducer by an impact.

GM Confidential

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July 2013

Page 2 of 27

3.2.3 Data Acquisition System. The data acquisition system shall be suitable for impact tests with enough channels to manage drop tower measurement systems, supports force transducers and triggers required (for example high speed camera). It is possible to use two systems, one for the drop tower data and one for the support reaction data.

3.2.4 High Speed Camera. Use a high speed camera to document the impact with a minimum 1024 × 1024 at 1000 frames/s. Appropriate lighting shall be used to have high quality video.

3.2.5 Test Specimen Fixture. The test specimen fixture allows mounting the door with door trim in the simulation given position. The door is fixed at the front hinge mounting points and clamped on the lock side (to simulate B-Pillar intrusion by side impact). The clamping allows sliding of rear extension (lowest friction, approximate clamping force $F = 5$ N) with simultaneous fixing in drop direction and opposite direction. A sample for a specimen fixture is shown in Appendix C, Figure C7, Figure C8, and Figure C9.

3.2.6 Impactor. Different, not deformable, and reusable impactors are in use. Which impactor to use depends on the type of door trim.

3.2.6.1 Impactor Long Door. For two (2) or three (3) door passenger cars: The impactor has the following dimensions: Length: 1024 mm; Width: 518 mm; Weight: approximately 42 kg. It is mounted to the cross beam of drop tower. Long door impactor is shown in Appendix B, Figure B1.

3.2.6.2 Impactor Short Door. For four (4) or five (5) door passenger cars: The impactor has following dimensions: Length: 781 mm; Width: 518 mm; Weight: approximately 36 kg. It is mounted to the cross beam of drop tower. Short door impactor is shown in Appendix B, Figure B2.

3.2.7 Support. The supports are reusable and not deformable. The contact forces in drop direction of each support are measured and recorded. The contour of supports is a standardized form for all tests. The position of each support shall be able to be adjusted in x, y and z direction relative to door trim.

3.2.7.1 Support Instrument Panel. The contour is shown in Appendix B, Figure B3.

3.2.7.2 Support Dummy Leg. The contour is shown in Appendix B, Figure B6.

3.2.7.3 Support Dummy Torso. The contour is shown in Appendix B, Figure B7.

3.2.7.4 Support Seat and Seat Track. The contour is shown in Appendix B, Figure B8.

3.2.7.5 Support Seat Back Adjuster. The contour is shown in Appendix B, Figure B5.

3.2.7.6 Support Seat Back. The contour is shown in Appendix B, Figure B4.

3.2.8 Adjust mechanism for supports in direction x, y and z relative to door trim. The mechanism allows adjusting the support in x, y and z direction. It is also possible to use a bedplate for x and y positioning and a mobile column for z positioning. The adjust mechanism or bead plate shall be reusable and not deformable.

3.2.9 Support Transducer. For each support use a force transducer with an adequate amplifier and data acquisition system to measure the contact force in drop direction. A typical contact force in drop direction for a Long Door Impact is up to 45 kN.

3.3 Test Vehicle/Test Piece. This procedure applies only for left hand front door trim. The door trim with all its components and fasteners shall be assembled to the modified door panel inner and the window lifter motor. Below is a brief description of each component.

3.3.1 Modified Door Panel Inner. The modified door panel inner; mount the door trim in the correct impact position. The required information for the position and modifications shall be specified by the CAE simulation. Typical modifications are removing of reinforcements and window frame (see Appendix A, Figure A4).

The rear extension allows a low friction sliding through the rear door fixture during the impact and fixing in drop direction.

3.3.2 Window Lifter Motor. The window lifter motor shall be assembled to the modified door panel inner without glass guides or braces.

3.3.3 Door Trim Assembly. The door trim shall be assembled to the modified door panel inner with all its fasteners (bird beaks, screws, clips, etc.) and shall include switch bezels, screw covers or any other loose part of the assembly.

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July 2013

Page 3 of 27

Documents
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3.4 Test Time.

Calendar time:	4 days
Test hours:	8 hours
Coordination hours:	8 hours

3.5 Test Required Information. To define necessary information for door trim impact test assembly (e.g., position of support parts and impactor, impact energy) numerical simulation for full vehicle and door trim impact test is required as described in 3.5.1 and 3.5.2.

3.5.1 Full Vehicle CAE Simulation. Necessary for the implementation of the following procedures is the availability of a full vehicle side crash model representing ECE R95 test conditions containing all of the components mentioned in the following. Airbags should not be included in the model. From the full vehicle simulation forces acting on the door trim, deflections of the door trim have to be extracted according to the descriptions in 3.5.1.1 to 3.5.1.4.

3.5.1.1 Definition of Typical Contact and Impact Areas. Typical parts interacting with the front door trim during a side crash are:

- Instrument Panel
- Dummy Leg
- Dummy Upper Body
- Backrest
- Hand Wheel
- Seat
- Seat Rail

In any case these components (see Appendix A, Figure A1) should be determined and selected via the full vehicle side crash animation at the time when the door trim impacts the particular area.

3.5.1.2 Contact Definition. The contacts in the full vehicle simulation should be redesigned in a way that an undisturbed evaluation of the contact forces between the parts described in 3.5.1.1 and the door trim is possible. Therefore all concerned parts should be taken out of the general contact and set in separate definitions, tracking the contact forces of these parts and the door trim only for each part individually.

3.5.1.3 Displacement Nodes. The displacement in the main deformation areas should be determined via time-history node definitions. Typical measuring points (see Appendix A, Figure A2) are:

- Fixation Domes Handle (Front/Rear)
- Window Lift Actuator
- Midpoint of Door Beam
- Armrest
- Hand Wheel

The nodes should be selected in a way that typical "first-impact-points" are taken into account.

3.5.1.4 Model Evaluation.

3.5.1.4.1 Displacement. All displacement measures should be evaluated in a standardized relative coordinate system. A simple three-node system spanned between the two hinge-joint mounting points and the shackle opening in the inner door panel (see Appendix A, Figure A3) has proven to be very helpful.

3.5.1.4.2 Contact Forces. The contact forces should be evaluated to provide the best possible match of the full vehicle results to the results obtained from the component model. Each support area should be evaluated separately and each result curve should be provided with an SAE 60 data filter (see SAE J211).

3.5.2 Door Trim Impact Test CAE Simulation Model. The door trim impact test simulation model should be built to enable the reproduction of the loads acting on the door trim as well as the local deformation behavior of the door trim in the full vehicle simulation.

GM Confidential

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July 2013

Page 4 of 27

3.5.2.1 Door Components. Components taken from the full vehicle simulation model typically include:

- Door Panel Inner (frame can be cut off as shown in Appendix A, Figure A4)
- Window Lift Actuator (e.g., fixed to the panel inner)
- Door Trim (including energy absorbers)

Other components might also have to be taken into account if they are found to be important for door trim behavior from the full vehicle simulation.

3.5.2.2 Test Specimen Fixture. The test specimen fixation should be coordinated with the safety lab and has to be modeled accordingly in the easiest possible way. For example the clamps shown in Appendix A, Figure A5 can be modeled as simple chamfered cylinders (see Appendix A, Figure A6).

3.5.2.3 Rear Extension of Door Panel Inner. For the mounting of the door, a rear extension following the outer door flange of the panel inner must be modeled. One way of modeling this part is to drag the innermost node path of the flange in flange direction (+x, i.e., see Appendix A, Figure A7) with the clearance to the flange required by the contact.

The minimum length displayed in Appendix A, Figure A7 should be verified and ensured as sufficient during the first simulation runs.

3.5.2.4 Support Components. All components not belonging to either: door in white, door trim, fixation, impactor or welding are referred as support components. All support components mentioned in 3.5.1.1 are CAD files available in GM Information Management and Networking System (IMAN) as follows (see Appendix B for drawing reference):

- | | |
|----------------------|--|
| • Dummy – Upper Body | Drawing Number: IP47900007 (Figure B7) |
| • Dummy – Leg | Drawing Number: IP47900006 |
| • Instrument Panel | Drawing Number: IP47900001 (Figure B3) |
| • Seat | Drawing Number: IP47900024 (Figure B8) |
| • Seat Rail | Drawing Number: IP47900024 (Figure B8) |
| • Backrest | Drawing Number: IP47900002 (Figure B4) |
| • Hand Wheel | Drawing Number: IP47900003 (Figure B5) |

For the CAE simulation only the outer shells are needed to be modeled (average element length 6 mm) with rigid properties. However a full support assembly is not always needed. Depending on the length of the door and the seat position some parts can be neglected (e.g., the backrest and hand wheel) if from side impact simulation it can be seen that they are not in contact with the door trim during impact.

3.5.2.5 LS-DYNA Software Specific Data. Typical values for the simulation door trim impact test simulation time are 40 ms to 60 ms. The contact forces and the nodal displacements should be written in an output file with at least 100 sampling points to deliver robust data. Analog to the full vehicle model the contacts for the support components shall be designed in such a way as to enable a separate evaluation of the contact forces for each part.

3.5.2.6 Impactors. Due to the different door lengths there is one (1) impactor for three (3) door models and another one (1) for five (5) door model simulation.

3.5.2.6.1 Geometry. The geometry of both impactors was designed resembling the shape of a deformed barrier. They are available in GM IMAN files (see Appendix B, Figures B1 and B2):

- | | |
|-----------------------|----------------------------|
| • Impactor Long Door | Drawing Number: IP47900031 |
| • Impactor Short Door | Drawing Number: IP47900032 |

For the CAE simulation only the outer shells are needed to be modeled with rigid properties as shown in Appendix A, Figure A8.

3.5.2.6.2 Positioning. The positioning of the impactor should prevent impactor from touching the outer walls of the door panel inner as shown in Appendix A, Figure A9.

3.5.2.6.3 Impact Energy. The impact energy value is vehicle dependent and has to be evaluated individually for each vehicle under consideration. A well proven way to determine the necessary impact energy from the full vehicle simulation is as follows:

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First the maximum amount of internal energy in all door trim components that are also integrated into the component model has to be determined from the full vehicle simulation. A fraction of the door panel inner internal energy has to be added on. This fraction can be found by only evaluating the internal energy belonging to the inner part of the door panel inner, excluding the outer walls. The sum of these two energy values gives the impact energy for the door trim impact test. It is appropriate to increase the calculated impact energy by 10% to 15% for taking account energy losses due to test setup and safety margin. From the drop weight, the drop velocity can be calculated with the formula for kinetic energy per 5.1.

3.5.2.7 Planar Adjustment of Support. The support parts shall be adjusted in such a way as to resemble the positioning of the impacted parts (e.g., seat, backrest, etc.) relative to the door trim shortly before contact in the full vehicle simulation. Therefore an approach that has proven purposeful is to export the impact parts at their particular position to the point of time shortly before contacting the door trim from the animation of the full vehicle. By superposing this exported data with the simplified support parts in a preprocessor, the alignment of the component support is easily possible.

3.5.2.8 Vertical Adjustment of Support. The vertical adjustment of the support parts is the most important adjustment since it has the highest influence on the results. Due to the great variety of door trims, door sizes and door structures, there cannot be given an exact procedure for adjustment. The general approach in 3.5.2.8.1 and 3.5.2.8.2 leads to a good starting point with normally only little iterative simulation work left to match the maximum values of contact forces and deflections from the full vehicle simulation.

3.5.2.8.1 Instrument Panel. The instrument panel is usually very close to the door trim. Thus, a setting with an instrument panel support structure near to the door trim should be aspired. Despite the fact that in all hitherto simulations the instrument panel was the most insensitive part regarding the change of reaction forces after vertical adjustments, all other parts should be oriented in relative distances to this component for the first simulation as described in the following:

3.5.2.8.2 Dummy and Seat Components. For the dummy and seat components the following approach to positioning has proven reasonable.

For the Dummy: In the full vehicle animation the “y” distance between instrument panel and the first point of the dummy’s upper body (excluding arms) to impact the door trim needs to be measured at the point of time when the upper body first hits the trim. At the same point of time the “y” distance of the upper body to the leg needs to be measured.

For the Seat: The same procedure can be used.

The required measures are the “y” distance of the point first to impact the door trim to the instrument panel at the time it impacts the trim, as well as the relative distances of the other particular seat components.

3.5.2.9 Model Evaluation.

3.5.2.9.1 Displacement. All displacement measures should be evaluated in a standardized relative coordinate system. A simple three-node system spanned between the two hinge-joint mounting points and the shackle opening in the door panel (see Appendix A, Figure A3) has proven to be very helpful.

3.5.2.9.2 Contact Forces. The contact forces should be evaluated to provide the best possible comparability of the full vehicle results to the results obtained from the component model. Each support area should be evaluated separately and each result curve should be provided with an SAE 60 data filter.

3.5.3 Information Exchange. The data that typically needs to be exchanged between drop impact test laboratory and CAE simulation department is:

3.5.3.1 Simulation to Testing Laboratory. Provide the following data to the door impact test laboratory:

- Geometry data of the positioned support parts, door fixation and impactor position (GM IMAN CAD file compatible) generated from the Finite Element (FE) model of the door trim impact test simulation model relative to the impactor
- Geometry data of rear extension
- Necessary door components (see 3.5.1)
- Type of impactor (Long or Short)
- Total weight to be used on the impact
- Impact energy (see 3.5.2.6.3)
- Drop velocity

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July 2013

Page 6 of 27

h. Expected force level for each of the force transducers in the test model

3.5.3.2 Testing Laboratory to Simulation. Provide the following data to the CAE Simulation department to verify test correlation:

- a. Test report with complete documentation including pictures and movies (if available).
- b. Drop tower measurements such as impactor acceleration, intrusion and impact force. (See Appendix D, Figure D1).
- c. Force measurements for each transducer of the supports used in the testing. (See Appendix D, Figure D2).

3.5.3.3 Test Requester.

3.5.3.3.1 Provide Test Material. The test requester shall provide a door trim, door in white panel modified, screw covers, switches and all necessary attachments to assembly as described in 3.3.

3.5.3.3.2 Approve the Status of Door Trim. The test requester has to check the test parts and approve the parts level and assembly prior to the test.

3.5.3.3.3 Data Exchange. The test requester is responsible for data exchange between simulation department and test laboratory.

3.6 Personnel/Skills. The following individuals are necessary to complete this test procedure:

3.6.1 General Motors Design Release Engineer

3.6.2 Testing Organization's Test Engineer

3.6.3 Testing Organization's Test Technician

3.6.4 Testing Organization's CAE Engineer

4 Procedure

4.1 Preparation.

4.1.1 First check that the expected force level on the supports sensors and energy specified is within the limits of the test equipment.

4.1.2 Create a CAD assembly file for the complete test setup by using the data (impactor, support and positions for support, test specimen fixture and door panel inner with door trim) from the simulation (see Appendix C, Figure C1).

4.1.3 Verify that the door to be tested fits into hinge fixture, in case it does not fit then design a hinge fixture.

4.1.4 Verify that the specified impactor (long or short) is mounted into the crossbeam of the drop tower. If not, then take out the cross beam from the park position to a safe position and install the correct impactor. Additionally check that the specified drop weight is loaded into the drop tower crossbeam.

4.1.5 Position the supports in x, y and z direction per CAD assembly file. (See Appendix C, Figure C3 and Figure C4).

4.1.6 Position the specimen fixtures front and rear in x, y and z position per CAD assembly file and mount the door panel inner with door trim (see Appendix C, Figure C6). After that, check the impact position (see Appendix C, Figure C5). If significant visible deflections of the door due to gravity occur, an appropriate reinforcement of the door panel inner should be added (see Appendix A, Figure A4).

4.1.7 Set up the zero height of the impactor moving down the crossbeam slowly until the impactor barely contacts the specimen. (See Appendix C, Figure C5).

4.1.8 Set up and check the function of the following sensors:

- Laser Sensor Barrier Sensor (see Appendix C, Figure C10).

Note: Adjust height if necessary.

- Laser Sensor for Intrusion Measurement (see Appendix C, Figure C11).

Note: Make sure position is within measurement range.

4.1.9 Set up and check the function of the rebound system, if necessary adjust. (See Appendix C, Figure C12).

4.1.10 Set up and check the function of the measurement and data acquisition system.

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July 2013

Page 7 of 27



Documents
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4.1.11 Position high speed camera and lights to record video of the test.

4.2 Conditions.

4.2.1 Environmental Conditions. Not applicable.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

4.3.1 If all positions are corresponding with the results from the door trim impact test CAE simulation model, then input the impact energy and impactor speed to the drop tower control software to set up impactor drop height. Alternately, drop height can be calculated from impact energy using formulas in 5.1.

4.3.2 Move the impactor to the specified height in 4.3.1.

4.3.3 Make sure camera and lights are turned on and set up triggers on the software to start recording the test.

4.3.4 Run the door trim impact test by dropping the impactor.

4.3.5 Measure the response from the support's force sensors, laser sensor barrier, and intrusion laser sensor and impactor accelerometer. Post process responses and correlate with CAE test set up supports response.

4.3.6 If the response does not match, the CAE simulation engineer shall adjust CAE model to provide new test setup parameters and preparation shall be started again.

4.3.7 If support responses match, then inspect samples and document with pictures of test results. According to 5.3.3 and 5.3.4 of ECE R95, the following requirements shall be met:

No interior device or component shall become detached in such a way as noticeably to increase the risk of injury from sharp projections or jagged edges. Ruptures, resulting from permanent deformation are acceptable, provided these do not increase the risk of injury. Below are typical examples of resulting sharp edges that shall be documented:

4.3.7.1 Door Panel Cracks (see Appendix D, Figure D3).

4.3.7.2 Door Panel Components Separation Due to Joints Failure (see Appendix D, Figure D4).

4.3.7.3 Switch Plate Detachment (see Appendix D, Figure D5).

4.3.7.4 Door panel component formerly hidden by surrounding parts is not cover by surrounding parts after the impact test (see Appendix D, Figure D6 example for armrest cover).

4.3.7.5 Excessive Deformation on door components (see Appendix D, Figure D7 example for armrest deformation).

5 Data

5.1 Calculations.

- Drop Velocity: $v = \sqrt{2 \cdot g \cdot h}$
- Drop Energy: $E = m \cdot g \cdot h = \frac{m}{2} \cdot V^2$

5.2 Interpretation of Results. Not Applicable.

5.3 Test Documentation. The data presentation shall be in accordance with standards. With reference to this test procedure the results shall be presented in a GM approved test report form (CG190 - GM Approved Test Report Form), including the following:

5.3.1 Identification of the door panel components i.e., door trim panel, door in white, window motor regulator, etc., (part number, revision, etc.)

5.3.2 Test conditions (type of impactor, total drop weight, drop energy, drop velocity, drop height, etc.)

5.3.3 CAD files of test setup.

5.3.4 Post processed measurements for impact acceleration, impact force and deformation path (see Appendix D, Figure D1) measurements for each support force transducer (see Appendix D, Figure D2).

5.3.5 Recorded video of the impact.

5.3.6 Pre-test and post-test pictures, as well as photographs to depict any issues.

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July 2013

Page 8 of 27

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems 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.

7 Notes

7.1 Glossary.

SAE 60: Low pass filter which can be digital or analog and has specific processing criteria for impact testing.

LS-DYNA: Advanced general purpose multi-physics simulation software, widely used in automotive crashworthiness and occupant safety.

7.2 Acronyms, Abbreviations, and Symbols.

CAD	Computer Aided Design
CAE	Computer Aided Engineering
FE	Finite Element
IMAN	Information Management and Networking System

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW16943

9 Release and Revisions

This standard was originated in March 2013. It was first approved by the Interior Door Trim GSSLT in June 2013. It was first published in July 2013.

Issue	Publication Date	Description (Organization)
1	JUL 2013	Initial publication.

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July 2013

Page 9 of 27