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Seat Belt Assembly Tensile Test Procedure Development

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16. Abstract

Federal Motor Vehicle Safety Standard (FMVSS) No. 209, Seat Belt Assemblies, specifies requirements, including performance requirements, for seat belt assemblies used in motor vehicles. The standard includes an assembly performance tensile test where seat belt assemblies must withstand a minimum tensile force and not exceed an elongation limit. NHTSA is evaluating potential changes to the test procedures, to better represent in-vehicle restraint angles. To support the tensile test procedure development, NHTSA's Vehicle Research and Test Center collected in-vehicle measurements of seat belt assemblies with different occupant sizes and conducted tensile tests at the resulting representative angles. The seat belts were tested on fabricated fixtures using the original equipment manufacturer seat belt assemblies, including hardware and bolts. Out of 10 seat belt assemblies tested using the in-vehicle seat belt angles, four did not meet the performance criteria when tested using the procedure under evaluation. Additional testing was completed aiming to further develop the test procedure to determine if seat belt assemblies with load limiters can meet the force criterion in one test when using stroke-limited machines. All assemblies tested under the conditions of no webbing on the spool or minimal webbing on the spool reached the force criterion, although more steps were required to test with minimal webbing on the spool and the load limiters were not fully engaged. Overall, the updated test procedure was feasible and converted the in-vehicle geometry of the seat belt assembly into a more representative tensile test. The developed test procedures include a detailed method for collecting the in-vehicle angle measurements, incorporating all in-vehicle hardware, and fabricating unique fixtures to complete tensile tests with representative in-use angles.

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Executive Summary

Federal Motor Vehicle Safety Standard (FMVSS) No. 209, Seat Belt Assemblies, (44 FR 72139, 1979) specifies requirements, including performance requirements, for seat belt assemblies used in motor vehicles. The standard includes an assembly performance tensile test where seat belt assemblies must withstand a minimum tensile force and not exceed an elongation limit. The National Highway Traffic Safety Administration is evaluating potential changes to the test procedures, to better represent in-vehicle restraint angles. To support the tensile test procedure development, NHTSA's Vehicle Research and Test Center (VRTC) collected in-vehicle measurements of seat belt assemblies with different occupant sizes and conducted tensile tests at the representative angles measured. In-vehicle geometry of the seat belt assembly is 3-dimensional (3D) while the tensile test set-up is 2-dimensional (2D). The developed procedures include a method for translating the angles into a 2D set-up using a coordinate measuring machine. To encompass the largest range of representative in-vehicle measurements, the Hybrid III 6-year-old (6YO) and 95th percentile male anthropomorphic test devices (ATDs) were seated in-vehicle and the seat belt assembly angles measured. For front row seating positions, the Hybrid III 5th percentile female was used rather than the 6YO.

The in-vehicle angles were used to fabricate fixtures that held the hardware at the representative angles for tensile testing. Four sets of fixtures (small occupant lap belt, small occupant shoulder belt, large occupant lap belt, large occupant shoulder belt) were created per seat belt assembly. Each seat belt was installed to the appropriate fixtures using the original equipment manufacturer (OEM) seat belt assembly's vehicle attachment hardware and bolts.

Out of 10 seat belt assemblies tested using the in-vehicle seat belt angles, 4 did not meet the FMVSS No. 209 performance criteria when tested using the procedure under evaluation, due to hardware fracture or surpassing the elongation limit. Throughout testing, several additional key observations were noted, including test head rotation, guide loop rotation, buckle stalk movement, multiple guide loops set-up, and updated test procedure comparisons.

Additional testing was completed aiming to further develop the test procedure to determine if seat belt assemblies with load limiters can meet the force criterion in one test when using stroke-limited machines. The assemblies with load limiters were tested in three conditions: no webbing on the spool, minimal webbing on the spool, and retractor pretensioner actuated. All assemblies tested in the conditions of no webbing on the spool or minimal webbing on the spool reached the force criterion, although more steps were required to test with minimal webbing on the spool and the load limiters were not fully engaged. Testing with the retractor pretensioner actuated did not achieve the required load.

Overall, the updated test procedures were feasible and converted the in-vehicle geometry of the seat belt assembly into a more representative tensile test. The developed test procedures include a detailed method for collecting as-used in-vehicle angle measurements, incorporating all vehicle attachment hardware, and fabricating unique fixtures to complete tensile tests at representative in-use angles.

1. Introduction

FMVSS No. 209[1] specifies requirements, including performance requirements, for seat belt assemblies used in motor vehicles. The standard includes an assembly performance tensile test where seat belt assemblies must withstand a minimum tensile force and not exceed an elongation limit. NHTSA's Enforcement Laboratory Test Procedure for FMVSS No. 209[2] details the assembly test procedure and set-up. **Figure 1**, from the Code of Federal Regulations, illustrates the tensile test set-up where the attachment hardware of the seat belt assembly can be secured at discrete angles either parallel, perpendicular, or 45 degrees relative to the seat belt webbing.

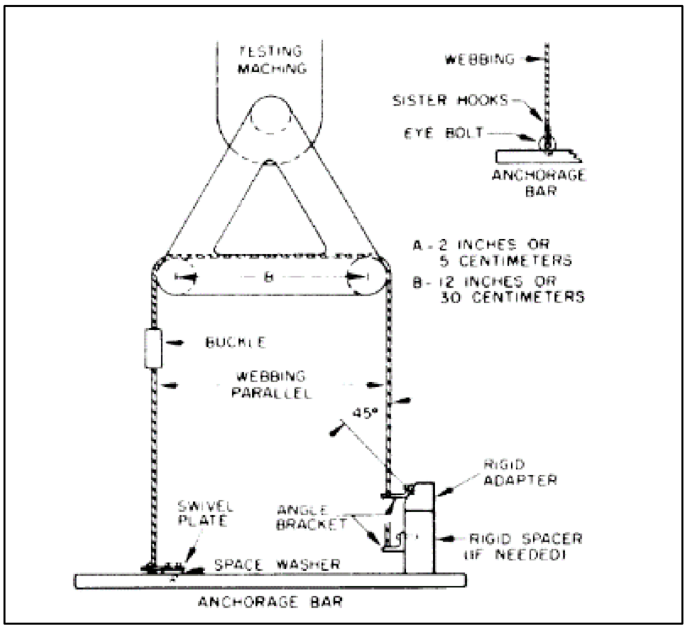

Figure 1. FMVSS No. 209 Tensile Test Set-Up.

NHTSA is evaluating clarifications to the test procedures to better represent in-vehicle restraint angles. To support the tensile test procedure development, the VRTC collected in-vehicle measurements of seat belt assemblies with different occupant sizes and conducted tensile tests for both the pelvis loop (lap belt) and upper torso loop (shoulder belt) at the representative angles with seat belt equipment used in-vehicle. **Figure 2** shows an example of the updated tensile test set-up for the upper torso loop tests.

[1] 44 FR 72139, Dec. 13, 1979; Title 49, Subtitle B, Chapter V, Part 571, mSubpart B, §571.209.
[2] National Highway Traffic Safety Administration. (2007, December 7). *Laboratory test procedure for FMVSS 209, seat belt assemblies* (Report No. TP-209-08). Author. Retrieved from https://one.nhtsa.gov/DOT/NHTSA/Vehicle %20Safety/Test%20Procedures/Associated%20Files/TP-209-08.pdf.

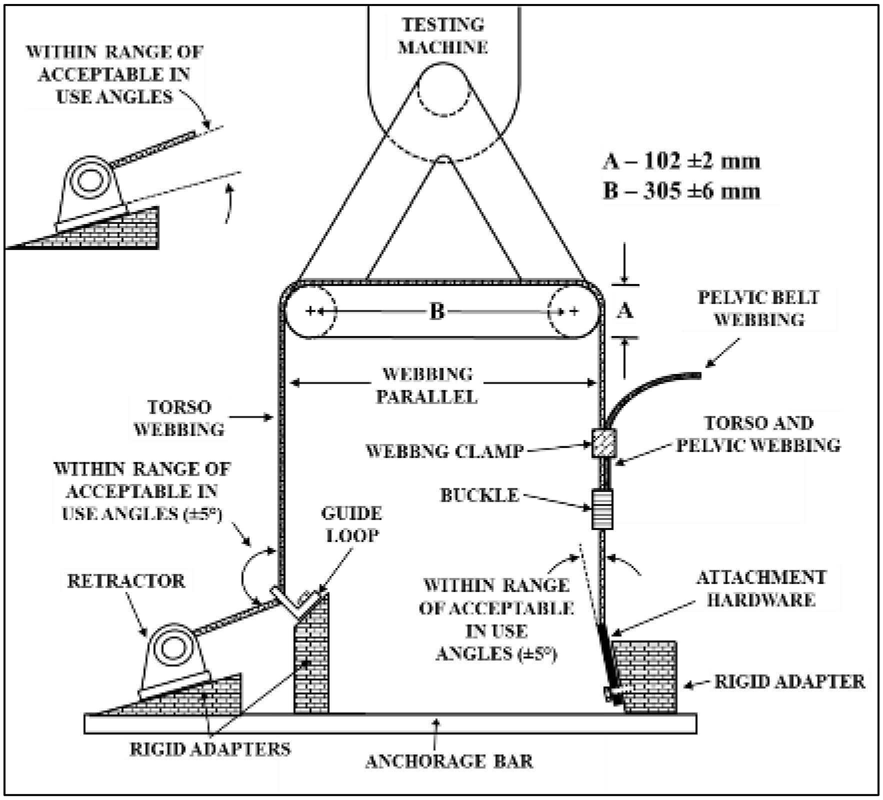

Figure 2. Updated Tensile Test Set-Up—Upper Torso Loop (Shoulder Belt).

2. In-Vehicle Angles Description

In-vehicle geometry of the seat belt assembly is 3D while the tensile test set-up is 2D. The developed procedures include a method for translating measured angles into a 2D set-up using a coordinate measuring machine (a FaroArm[3]). It is anticipated that the angle tolerance would be plus or minus one degree. A detailed procedure for collecting the in-vehicle angles can be found in Appendix A. Four types of in-vehicles angles were identified to be measured for the updated tensile test: retractor, guide loop, outboard hardware, and inboard hardware.

2.1 Outboard and Inboard Hardware Angles

An example of a hardware angle is shown in **Figure 3** as the "webbing angle relative to mounting surface of the attachment hardware." The hardware angles were measured between a line passing through a point on the webbing centerline from the attachment hardware connection to the webbing (yellow dot) to a point on the webbing that was the longest straight segment of the webbing path (yellow dot), and a plane on the mounting surface of the attachment hardware (dashed line).

[3] FARO Technologies, Inc., Lake Mary, FL.

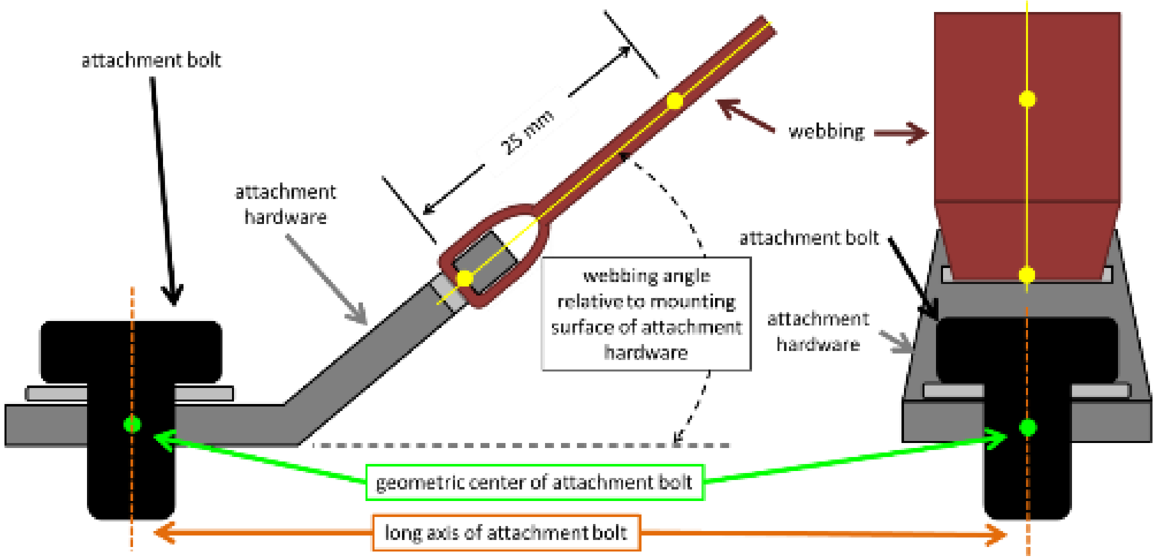

Figure 3. Outboard and Inboard Hardware Angles.

For tensile tests with the pelvis loop (lap belt) portion of the seat belt assembly, the outboard hardware angle is used. However, there are two different inboard hardware angles measured: (1) for the seat belt webbing routed over the ATD lap and (2) for the seat belt webbing routed to the ATD shoulder. The first is used during pelvis loop (lap belt) tensile tests and the second during upper torso loop (shoulder belt) tensile tests.

2.2 Retractor Angle

An example of a retractor angle is shown in **Figure 4** as "webbing angle relative to mounting surface." The retractor angle was measured between a line passing through a point on the webbing centerline where the webbing leaves the retractor to a point on the webbing that was the longest straight segment of the webbing path, and a plane on the mounting surface of the retractor.

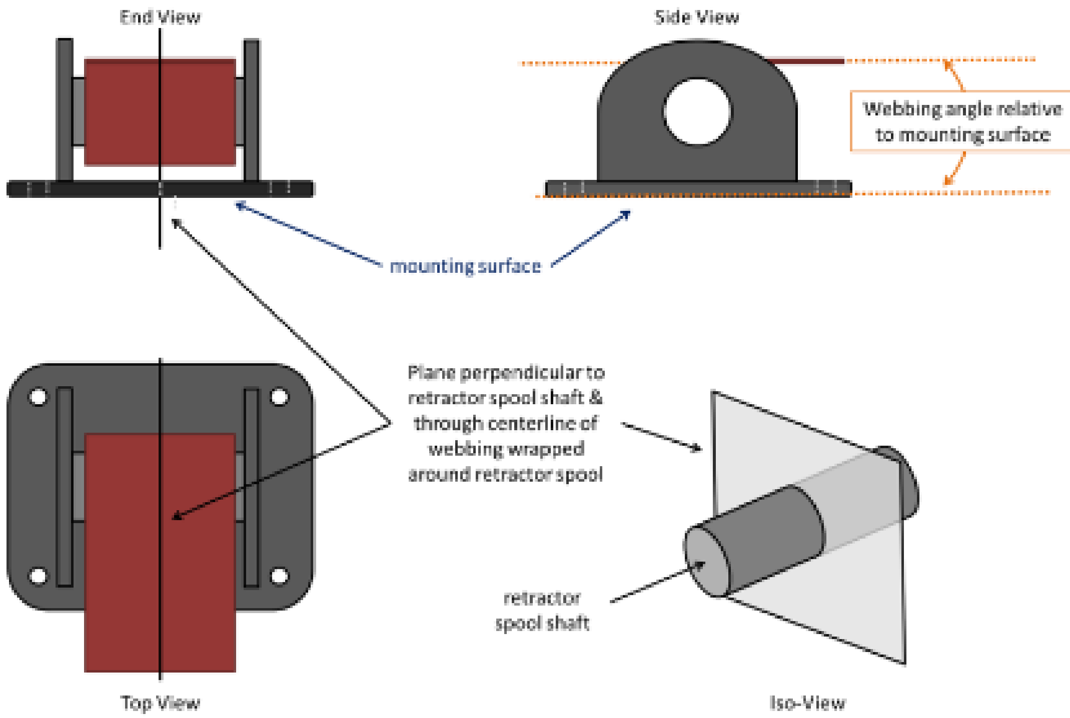

Figure 4. Retractor Angle.

2.3 Guide Loop Angles

An example of a guide loop angle is shown in **Figure 5** as “angles ϴ1 and ϴ2 are webbing angles of interest relative to the mounting surface.” The guide loop, most often a D-ring, has two angles to incorporate into the set-up: one line of webbing extends from the retractor, and the other is generally directed toward the occupant’s shoulder. In some cases, there are seat belt assemblies which have multiple guide loops. In that case, all angles created by the guide loops were measured. The guide loop angles were measured between (1) a line passing through a point on the centerline of the webbing on the bottom side of the guide loop to the centerline of webbing outside of the retractor, or (2) a line passing through a point on the centerline of the webbing on the top portion of the guide loop (yellow dot) and a point at the end of the straightest segment near the occupant’s shoulder, and a plane on the mounting surface of the attachment hardware (dashed line).

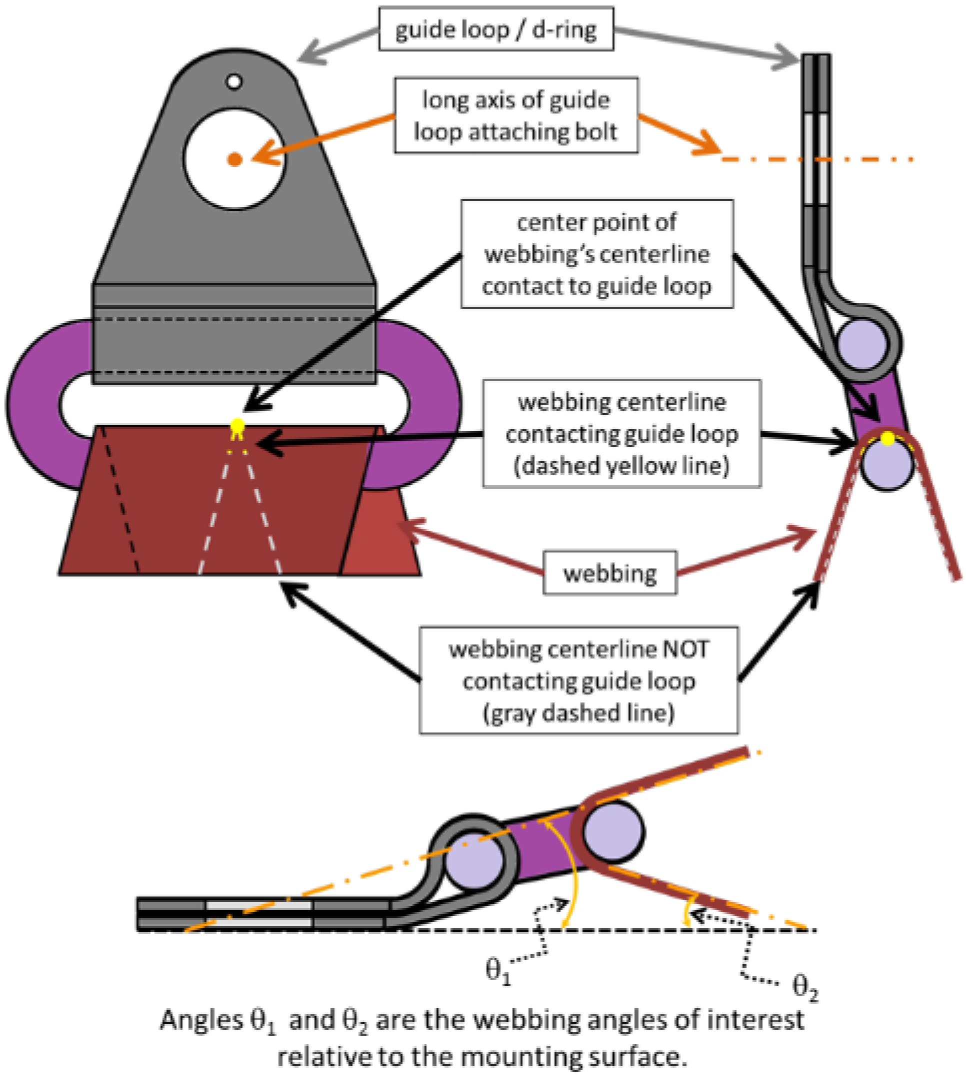

Figure 5. Guide Loop Angles.

3. In-Vehicle Measurements

To encompass the largest range of representative in-vehicle measurements, the Hybrid III 6YO and 95th percentile ATDs were seated in-vehicle and the seat belt assembly angles measured. For front row driver seating positions, the Hybrid III 5th percentile female ATD was used rather than the 6YO. Details regarding the seat configurations and measurement procedure can be found in **Appendix A**.

The representative amount of webbing on the retractor spool for a given ATD was also measured as a part of the measurement procedure. With the belt positioned normally on the given ATD, the webbing was marked where it leaves the retractor spool; then all the webbing was pulled off the spool and a new mark was made where it leaves the retractor. The distance between these two marks was recorded as the representative length of webbing on the retractor spool, with a tolerance of plus or minus 2.5 millimeters.

In-vehicle angles were collected for eight test vehicles, selected to include various seat belt technologies including load limiters, inflatable belts, and multiple guide loops. Table 1 shows the test matrix of vehicles. An example of the resulting in-vehicle angles is shown in Table 2 for the 2014 Hyundai Tucson. All the in-vehicle angle results can be found in **Appendix B**.

Table 1. Vehicle Test Matrix

	Model Year	Make/Model	Seating Position	ATDs	
1	2011	Honda Odyssey	Front Row, Passenger	6YO	95th Male
2	2011	Ford Explorer (inflatable belt option)	2nd Row, Passenger	6YO	95th Male
3	2011	Hyundai Tucson	Front Row, Driver	5th Female	95th Male
4	2011	Chevrolet Traverse	Front Row, Driver	5th Female	95th Male
5	2014	Fiat 500L	2nd Row, Passenger	6YO	95th Male
6	2017	Mercedes E300	2nd Row, Passenger	6YO	95th Male
7	2012	Mercedes S400	2nd Row, Passenger	6YO	95th Male
8	2014	Volkswagen Tiguan	2nd Row, Passenger	6YO	95th Male

Table 2. 2014 Hyundai Tucson In-Vehicle Angles

In-Vehicle Measurements	5th Female	95th Male
Retractor Angle	6°	7°
Inboard Hardware Lap Angle	70°	21°
Inboard Hardware Shoulder Angle	42°	18°
Outboard Hardware Angle	15°	37°
Guide Loop to Shoulder Angle	27°	53°
Guide Loop to Retractor Angle	11°	13°
Webbing on Spool	1,232 mm	1,100 mm

4. Tensile Testing

4.1 Tensile Testing Matrix

Ten seat belt assemblies were a part of the tensile test matrix. Eight were the vehicle-specific belts described previously, and two universal seat belt assemblies were selected because the provided instructions indicated the belts met FMVSS No. 209 standards. Table 3 lists the 10 seat belt assemblies used in tensile testing.

Table 3. Tensile Testing Matrix

	Model Year	Make/Model	Seating Position	ATDs	
1	2011	Honda Odyssey	Front Row, Passenger	6YO	95th Male
2	2011	Ford Explorer (inflatable belt option)	2nd Row, Passenger	6YO	95th Male
3	2011	Hyundai Tucson	Front Row, Driver	5th Female	95th Male
4	2011	Chevrolet Traverse	Front Row, Driver	5th Female	95th Male
5	2014	Fiat 500L	2nd Row, Passenger	6YO	95th Male
6	2012	Mercedes S400	2nd Row, Passenger	6YO	95th Male
7	2017	Mercedes E300	2nd Row, Passenger	6YO	95th Male
8	2014	Volkswagen Tiguan	2nd Row, Passenger	6YO	95th Male
9	Universal	SeatBeltsPlus[4]	N/A	N/A	N/A
10	Universal	Dorman[5]	N/A	N/A	N/A

4.2 Test Set-Up

The in-vehicle angles were used to fabricate fixtures that held the hardware at the representative angles for tensile testing. Four sets of fixtures (small occupant lap belt, small occupant shoulder belt, large occupant lap belt, large occupant shoulder belt) were created per seat belt assembly. In the case of multiple guide loop tests, additional fixtures were required. To simplify fabrication, drawings were created that translated the in-vehicles angles to be relative to horizontal. An example of the 95th male angles for a shoulder belt fixture is shown in **Figure 6** on the following page.

[4] Oceanside, CA.
[5] Dorman Products, Inc., Colmar, PA.

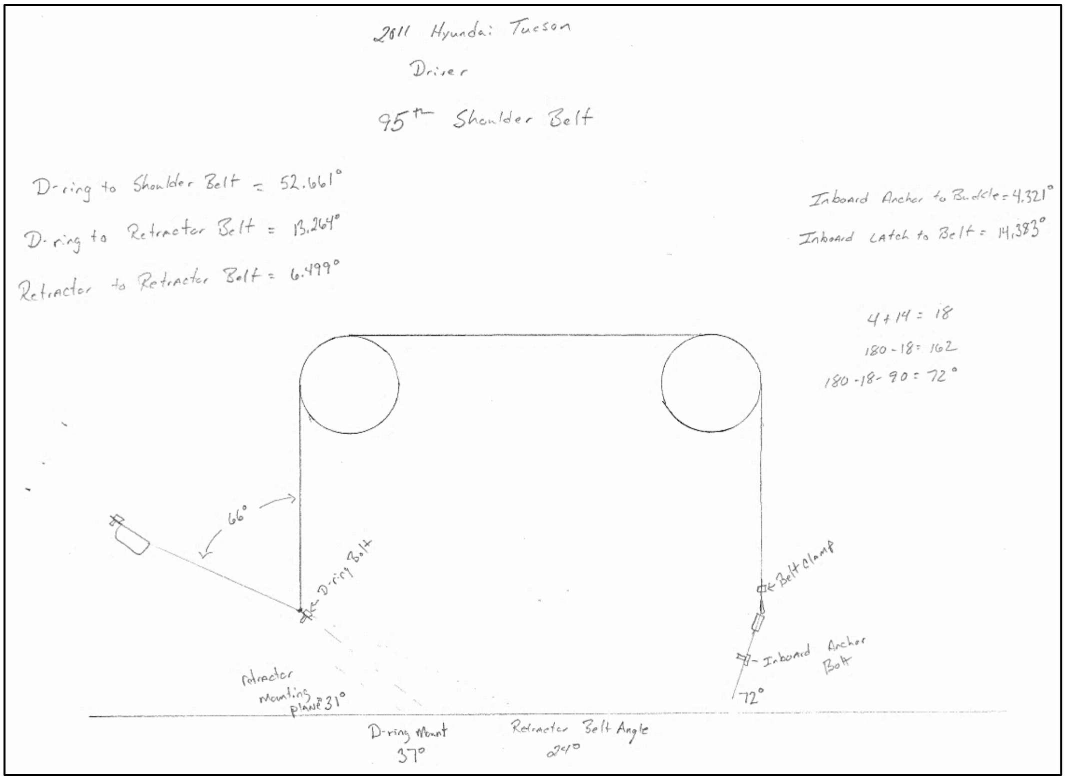

Figure 6. 2014 Hyundai Tucson 95th Male Shoulder Belt Fabrication Drawing.

Care was taken during fabrication to ensure the appropriate loop length required (1,220 to 1,270 millimeters) was achievable during the tensile test. Examples of the shoulder and lap belt test fixtures, for the 2014 Hyundai Tucson, are shown in **Figures 7** and **8**.

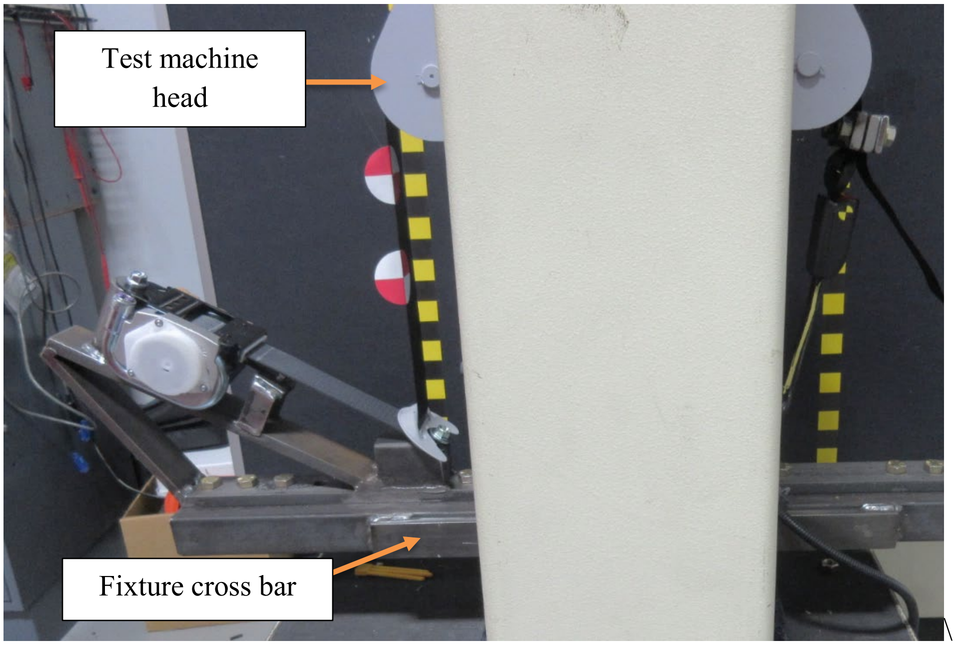

Figure 7. 2014 Hyundai Tucson 95th Shoulder Belt Fixtures.

Figure 8. 2014 Hyundai Tucson 95th Lap Belt Fixtures.

4.3 Tensile Test Procedure

The seat belts were installed on the fixtures using the OEM seat belt assembly's attachment hardware and bolts. The tensile force was applied at a rate of 51 millimeters[6] per minute until the required force was met; the force criterion for the pelvis loop (lap belt) was 22,241 newtons (N), and the criterion for the upper torso loop (shoulder belt) was 13,345 N. Elongation was recorded as movement of the tensile test machine and multiplied by two, representing each segment of seat belt webbing in contact with the test head. The elongation limit criterion for these tests was 508 millimeters (254 mm per segment).[7] The detailed tensile test procedure is included in **Appendix C**.

Along with the representative amount of webbing on the spool, the required loop length was set for each loop test while installed on the fixtures on the tensile test machine. The loop length is defined as the distance between furthest attachment bolts of the seat belt assembly hardware; the required loop length is 1,220 to 1,270 millimeters. As an example, for the upper torso loop, the furthest attachment bolts would be from the retractor bolt to the inboard buckle stalk anchor bolt. When both the loop length and the representative amount of webbing on the spool could not be set in combination, the test was completed with the representative amount on the spool and the resulting loop length was recorded.

4.4 Tensile Test Results

To analyze the results from tensile testing, the maximum force and elongation measurements for each test were tabulated and color coded. Dark red indicates a tensile test where the hardware

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[6] FMVSS No. 209 specifies the heads of the testing machine shall be separated at a rate between 51 and 102 mm per minute. The test equipment used for this test project was capable of only 51 mm per minute.

[7] Elongation limits do not apply to the front seat configurations where seat assemblies include a load limiter because the seating position is covered by FMVSS No. 208 dynamic testing.

fractured, and red indicates the elongation limit was surpassed. Yellow-orange indicates tests where the tensile test machine was not able to complete the test to the required force due to limitation on the stroke of the machine. Results shown in Tables 4 and Table 5 tabulate the force and elongation results for pelvis loop tests and upper torso loop tests, respectively. Data, photos, and videos of each test can be found in NHTSA's Component Data Base (CDB) using the test numbers included (C01376-C01426, C01698-C01714). Cells marked with asterisks indicate front row seating position assemblies with load limiters where the elongation limits do not apply.

Table 4. Pelvis Loop (Lap Belt) Tensile Test Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01377	22,241	146
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01378	22,322	164
2011	Honda	Odyssey	1st Row, Passenger	95th	C01379	22,292	88
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01380	22,309	173
2011	Honda	Odyssey	1st Row, Passenger	95th	C01381	22,293	128
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	95th	C01385	22,276	242
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	95th	C01386	22,287	224
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	6YO	C01387	22,219	379
2011	Hyundai	Tucson	1st Row, Driver	5th	C01388	22,328	179
2011	Hyundai	Tucson	1st Row, Driver	95th	C01389	22,359	81
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01390	22,314	156
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01391	22,310	130
2014	Fiat	500L	2nd Row, Passenger	95th	C01392	22,324	136
2014	Fiat	500L	2nd Row, Passenger	6YO	C01393	22,300	146
2017	Mercedes	E300	2nd Row, Passenger	95th	C01394	22,285	194
2017	Mercedes	E300	2nd Row, Passenger	6YO	C01395	22,296	261
2012	Mercedes	S400	2nd Row, Passenger	95th	C01396	22,293	88
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01397	13,523	162
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01398	17,456	114
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01399	22,303	186
Universal	Seat Belts Plus	N/A	N/A	N/A	C01382	22,276	159
Universal	Seat Belts Plus	N/A	N/A	N/A	C01383	22,280	142
Universal	Dorman	tensilN/A	N/A	N/A	C01384	22,273	203

Table 5. Upper Torso Loop (Shoulder Belt) Tensile Test Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01400	11,431	580*
2011	Honda	Odyssey	1st Row, Passenger	95th	C01376	13,382	524*
2011	Honda	Odyssey	1st Row, Passenger	95th	C01401	13,369	534*
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01402	13,380	532*
2011	Honda	Odyssey	1st Row, Passenger	95th	C01403	13,380	536*
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	95th	C01406	13,400	500
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	6YO	C01407	13,356	688
2011	Hyundai	Tucson	1st Row, Driver	5th	C01408	7,477	768*
2011	Hyundai	Tucson	1st Row, Driver	5th	C01409	5,411	546*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01410	7,230	492*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01411	5,903	592*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01412	6,941	498*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01413	6,298	480*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01414	6,924	514*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01415	6,473	508*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01416	5,951	456*
2014	Fiat	500L	2nd Row, Passenger	95th	C01417	13,397	208
2014	Fiat	500L	2nd Row, Passenger	6YO	C01418	13,371	444
2017	Mercedes	E300	2nd Row, Passenger	95th	C01419	13,360	324
2017	Mercedes	E300	2nd Row, Passenger	6YO	C01420	13,398	514
2012	Mercedes	S400	2nd Row, Passenger	95th	C01421	10,431	227
2012	Mercedes	S400	2nd Row, Passenger	95th	C01422	10,012	172

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2012	Mercedes	S400	2nd Row, Passenger	95th	C01423	13,372	164
2012	Mercedes	S400	2nd Row, Passenger	95th	C01424	13,377	186
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01425	9,036	380
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01426	12,384	366
Universal	Seat Belts Plus	N/A	N/A	N/A	C01404	13,402	275
Universal	Seat Belts Plus	N/A	N/A	N/A	C01405	13,385	343
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01698	13,379	136
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01699	13,378	122
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01704	13,373	310
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01705	13,413	308
2011	Hyundai	Tucson	1st Row, Driver	5th	C01700	13,483	89*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01701	13,474	76*
2011	Hyundai	Tucson	1st Row, Driver	5th	C01706	13,390	739*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01707	13,386	605*
2011	Hyundai	Tucson	1st Row, Driver	5th	C01711	7,098	740*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01712	7,210	710*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01702	13,371	131*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01703	13,382	118*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01708	13,373	675*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01709	11,056	737*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01710	13,372	711*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01713	9,924	737*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01714	9,801	704*

4.5 Tensile Test Discussion

Additional analysis was completed on tensile tests that did not meet the FMVSS No. 209 performance criteria. Out of 10 seat belt assemblies tensile tested, 4 did not meet the performance criteria via hardware fracture or surpassing the elongation limit.

4.5.1 2014 Volkswagen Tiguan

The 2014 Volkswagen Tiguan had a complete fracture on the pelvic loop during tensile testing at the 6YO representative in-vehicle angles (C01397). The Tiguan buckle consisted of a steel cable welded to a steel loop around the attachment bolt. The fracture occurred due to a broken weld before the required force was met. **Figure 9** shows the pre-test set-up of the 2014 Volkswagen Tiguan buckle; **Figure 10** is post-test, highlighting the fracture. The test was repeated with a new seat belt assembly and the fracture occurred in the repeat test (C01398).

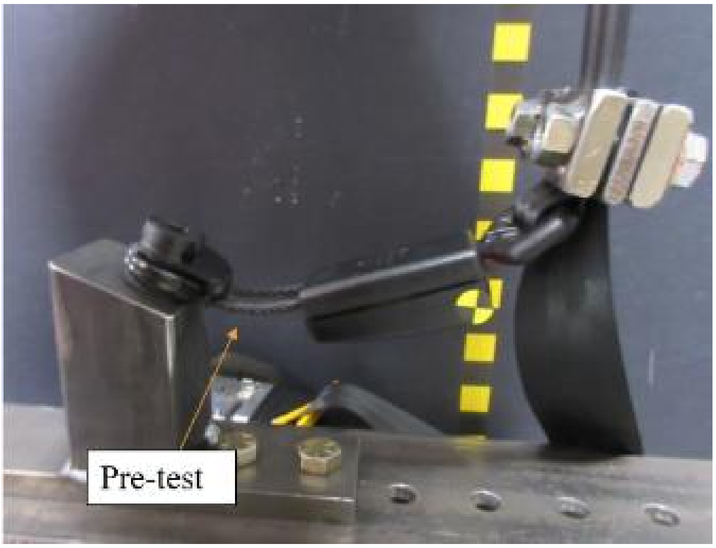

Figure 9. 2014 Volkswagen Tiguan Buckle Pre-Test.

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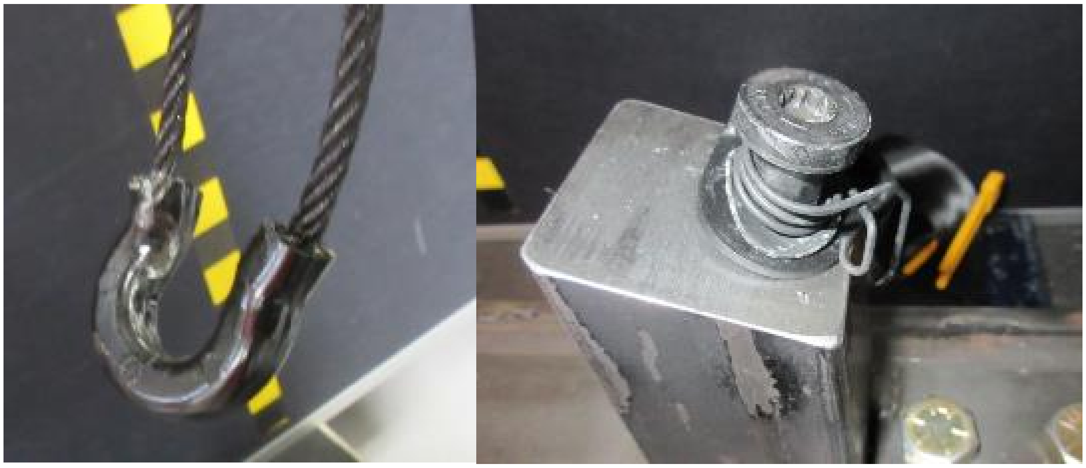

Figure 10. 2014 Volkswagen Tiguan Buckle Fracture.

4.5.2 2011 Ford Explorer Inflatable Belt

The 2011 Ford Explorer inflatable belt included a retractor in the pelvic loop assembly due to an inflator attached to the buckle. The lap belt retractor was measured in-vehicle and installed at the representative angles. **Figure 11** shows the pre-test set-up of the 2011 Ford Explorer pelvis loop test at the 6YO angles (C01387). During the tensile test, the retractor bracket tore resulting in the fracture shown in **Figure 12**. Additionally, the 2011 Ford Explorer upper torso loop test at the 6YO representative angles exceeded the elongation limit at 688 millimeters with the representative amount of webbing on the retractor spool.

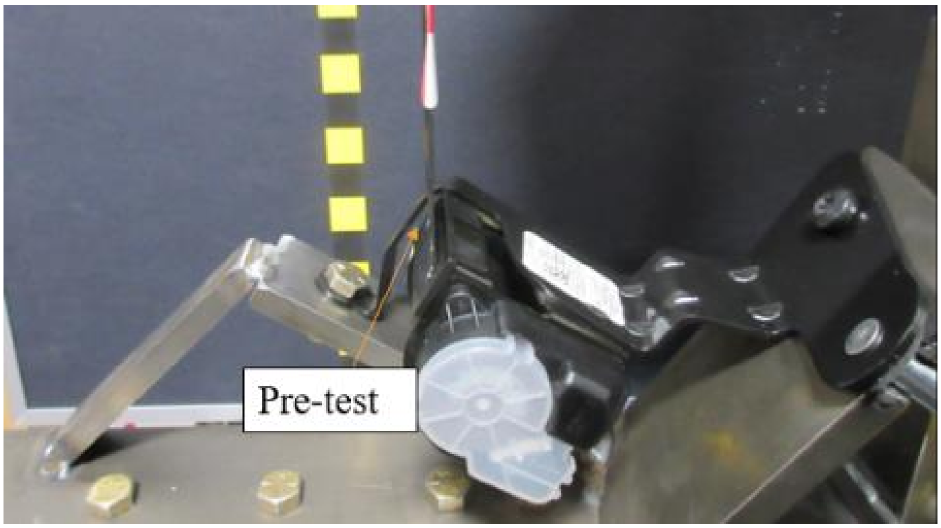

Figure 11. 2011 Ford Explorer Inflatable Belt Lap Belt Retractor Pre-Test.

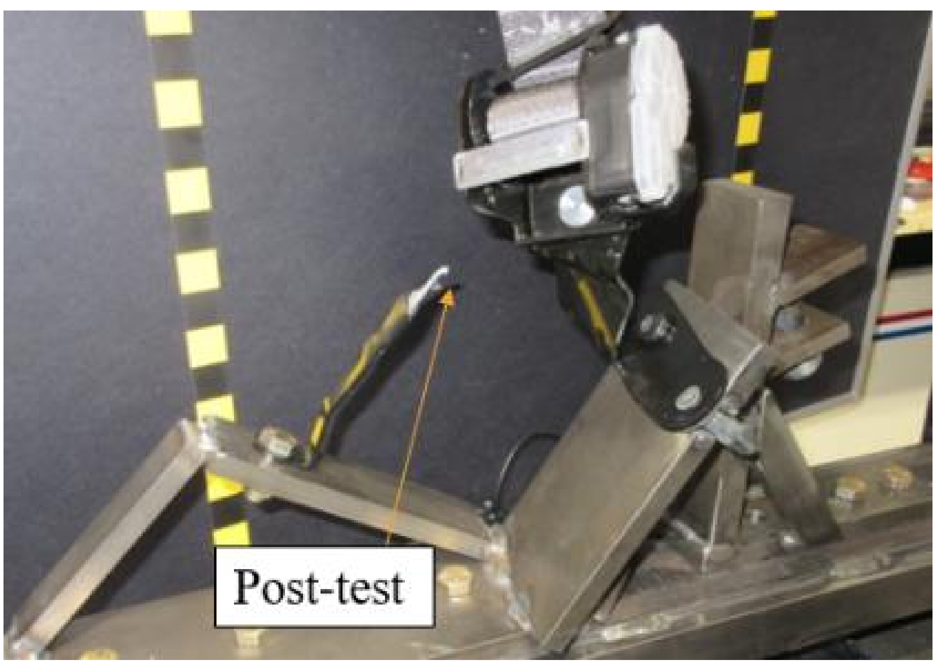

Figure 12. 2011 Ford Explorer Inflatable Belt Lap Belt Retractor Fracture.

4.5.3 2012 Mercedes S400

The 2012 Mercedes S400 was selected for this study because it had multiple guide loops (described as a guide bar and D-ring) in the shoulder belt assembly. Tests were completed to compare the effect of multiple guide loops (see 4.6.4 for more discussion of these tests). Tests at the 95th percentile in-vehicles angles used 1) both the D-ring and guide bar assembly, 2) guide bar only, and 3) D-ring only. **Figure 13** shows the guide bar only test set-up (C01422). A guide bar bolt sheared off before the required force was met as shown in **Figure 14**. Guide bar fracture occurred on the test with the guide bar only (C01422) and the test with both the D-ring and guide bar (C01421).

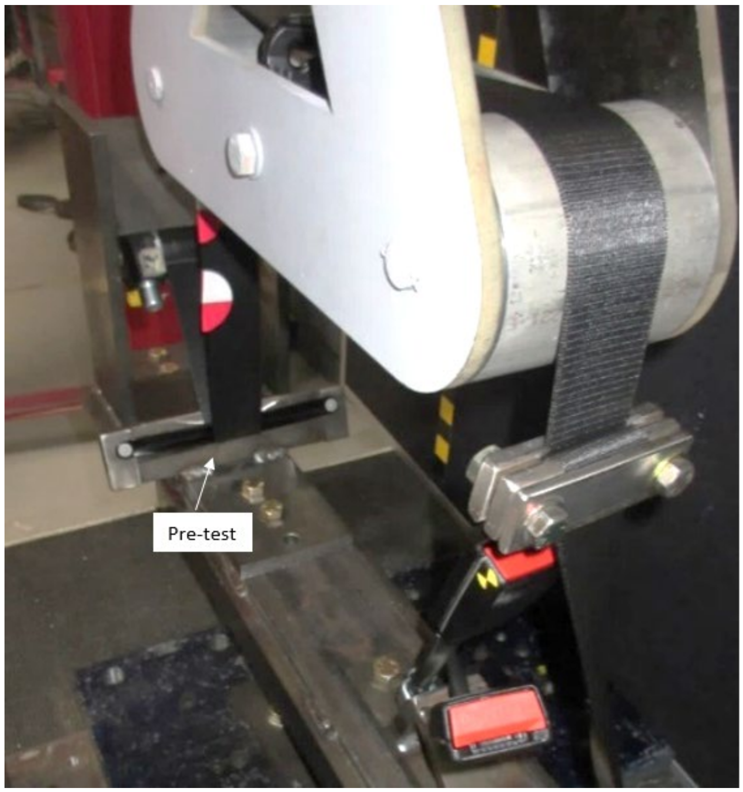

Figure 13. 2012 Mercedes S400 (Guide Bar Only) Pre-Test.

Figure 14. 2012 Mercedes S400 Guide Bar Fracture.

4.5.4 2017 Mercedes E300

The 2017 Mercedes E300 upper torso loop (shoulder belt) test (C01420) at the 6YO representative angles exceeded the elongation limit at 514 millimeters with the representative amount of webbing on the retractor spool.

4.5.5 Seat Belt Assemblies With Load Limiters

As previously described, the representative amount of webbing on the spool for each ATD was measured during in-vehicle measurements. This length was then implemented in tensile testing with the seat belt assembly. The front row 2011 Hyundai Tucson and 2011 Chevrolet Traverse, and second row 2014 Volkswagen Tiguan seat belt assemblies had load limiters. During tensile testing with these seat belt assemblies, the test machine at VRTC reached its maximum stroke before the force criterion was met because the webbing slowly released from the retractor spool. Per the compliance testing laboratory's test procedure, the webbing that has been pulled off the spool would be pulled tight from the loop, the test machine reset, and then the tensile test continued. Section 5 details a study aiming to further develop the test procedure to determine if seat belt assemblies with load limiters can meet the force criterion in one test when using stroke-limited machines.

4.6 Tensile Test Comparisons

Throughout testing, several additional comparisons were made based on observations during testing including test head rotation, guide loop rotation, buckle stalk movement, multiple guide loops set-up, and updated test procedure comparisons.

4.6.1 Test Head Rotation

Initially, the fabricated test machine head (triangle shaped fixture) could rotate during the testing. This caused the webbing and hardware to be loaded unevenly and changed the angles at which the fixture was pulling on the hardware. The 2011 Honda Odyssey seat belt assembly was initially tested with the rotating test head (marked in grey). However, the seat belt assembly was re-tested, with new belts, with the test head fixed. **Figure 15** shows the differences between when the test head could rotate (top) and when the test head was fixed (the following page).

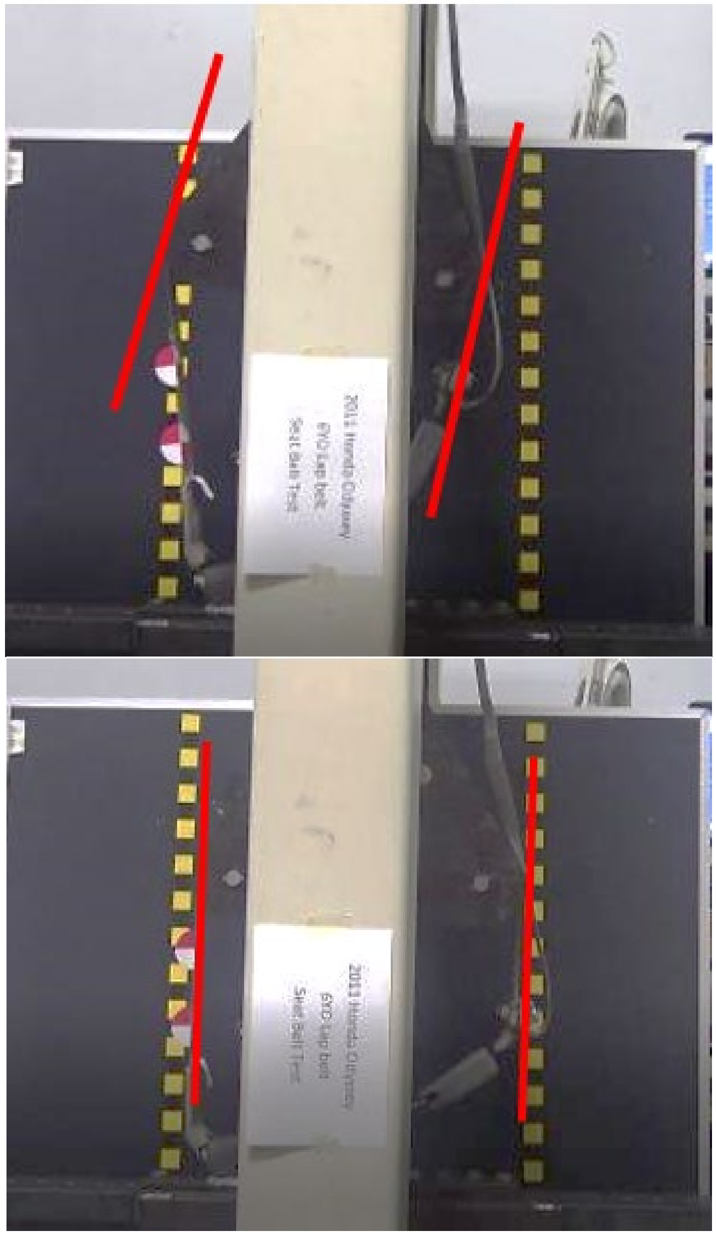

Figure 15. Test Head Rotation (top) and Test Head Fixed (bottom).

Elongation results showed some variation between the rotating and fixed test head conditions, while the force results did not show any significant differences. Direct comparisons are found in Table 6 and 7 below, for the pelvic loop and upper torso loop respectively, with the rotating test head tests shown in grey. The cell marked in yellow-orange did not reach the required force due to a software error but was included for comparison purposes.

Table 6. Pelvis Loop Test Head Rotation Comparison

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01378	22,322	164
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01380	22,309	173
2011	Honda	Odyssey	1st Row, Passenger	95th	C01379	22,292	88
2011	Honda	Odyssey	1st Row, Passenger	95th	C01381	22,293	128

Table 7. Upper Torso Loop Test Head Rotation Comparison

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01400	11,431	580*
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01402	13,380	532*
2011	Honda	Odyssey	1st Row, Passenger	95th	C01376	13,382	524*
2011	Honda	Odyssey	1st Row, Passenger	95th	C01403	13,380	536*

4.6.2 Guide Loop Rotation

During tensile testing, it was observed that the guide loop (D-ring) tended to rotate in certain seat belt assemblies during upper torso loop tests. For two vehicle specific assemblies, the 2011 Hyundai Tucson and 2011 Honda Odyssey, the guide loop slowly rotated during the entirety of the test until the rotation caused the webbing to bunch up in the guide loop. A photo of the bunched webbing in the guide loop is shown in **Figure 16**. The bunched-up webbing caused an increase in force results for most tests. Repeat tests were completed with the guide loops fixed by fabricating additional wings on the fixtures (**Figure 17**). A direct comparison of results can be found in Table 8 and Table 9. The comparisons for the 2011 Honda Odyssey were inconclusive. The 2011 Hyundai Tucson saw decreased force results when the guide loop was fixed, while the elongation results were inconclusive due to high variability when the guide loop rotated.

Figure 16. Guide Loop Rotation.

Figure 17. Fixed Guide Loop.

Table 8. 2011 Honda Odyssey Guide Loop Rotation Comparison

	Model Year	Make	Model	Seating Position	ATD	CDB Number	Upper Torso Loop Test	
							Force (N)	Elongation (mm)
Guide Loop Rotation	2011	Honda	Odyssey	1st Row, Passenger	6YO	C01400	11,431	580*
	2011	Honda	Odyssey	1st Row, Passenger	95th	C01376	13,382	524*
Fixed Guide Loop	2011	Honda	Odyssey	1st Row, Passenger	6YO	C01402	13,380	532*
	2011	Honda	Odyssey	1st Row, Passenger	95th	C01403	13,380	536*

Table 9. 2011 Hyundai Tucson Guide Loop Rotation Comparison

	Model Year	Make	Model	Seating Position	ATD	CDB Number	Upper Torso Loop Test	
							Force (N)	Elongation (mm)
Guide Loop Rotation	2011	Hyundai	Tucson	1st Row, Driver	5th	C01408	7,477	768*
	2011	Hyundai	Tucson	1st Row, Driver	95th	C01410	7,230	492*
Fixed Guide Loop	2011	Hyundai	Tucson	1st Row, Driver	5th	C01409	5,411	546*
	2011	Hyundai	Tucson	1st Row, Driver	95th	C01411	5,903	592*

4.6.3 Buckle Stalk Movement

When incorporating the representative in-vehicles angles into the tensile test set-up, the initial orientation of the buckle and connected buckle stalk was observed to start in a location that allowed the stalk to move during the test. A target was placed on the top edge of the buckle for better visibility. As shown in **Figure 18**, the buckle stalk started at a shallow angle behind the tensile test machine uprights, then as the tensile test occurs, the buckle and connected buckle stalk move upward, rotating about the attachment bolt. This motion occurred for every test, and the magnitude of movement varied depending on in-vehicle angle measurements and buckle stalk design. Per the test procedure, the elongation is zeroed at the 98 newtons pre-load, so in some cases the approximate buckle stalk movement value is greater than the elongation value because of this difference in reporting. Because the buckle stalk movement is included in the maximum elongation value, the approximate buckle stalk movement was quantified using desktop caliper software (Iconico Screen Calipers) for every test. All tensile test force and elongation results, along with the approximate buckle stalk movement in the Z-direction (component of elongation) can be found in **Appendix D**. The buckle stalk movement values ranged from a minimum of 7 millimeters to a maximum of 133 millimeters. The 2017 Mercedes E300 buckle stalk moved approximately 133 millimeters which is 51 percent of the total elongation recorded. Overall, many seat belt assemblies had more than 100 millimeters in buckle stalk movement, accounting for 10 to 20 percent of their total elongation results. Although the buckle stalk movement adds to the total elongation of the system in this procedure, because the test, including the buckle stalk, replicates the in-vehicle angles, the elongation measurement is more representative of in-use conditions than the current FMVSS No. 209 procedure.

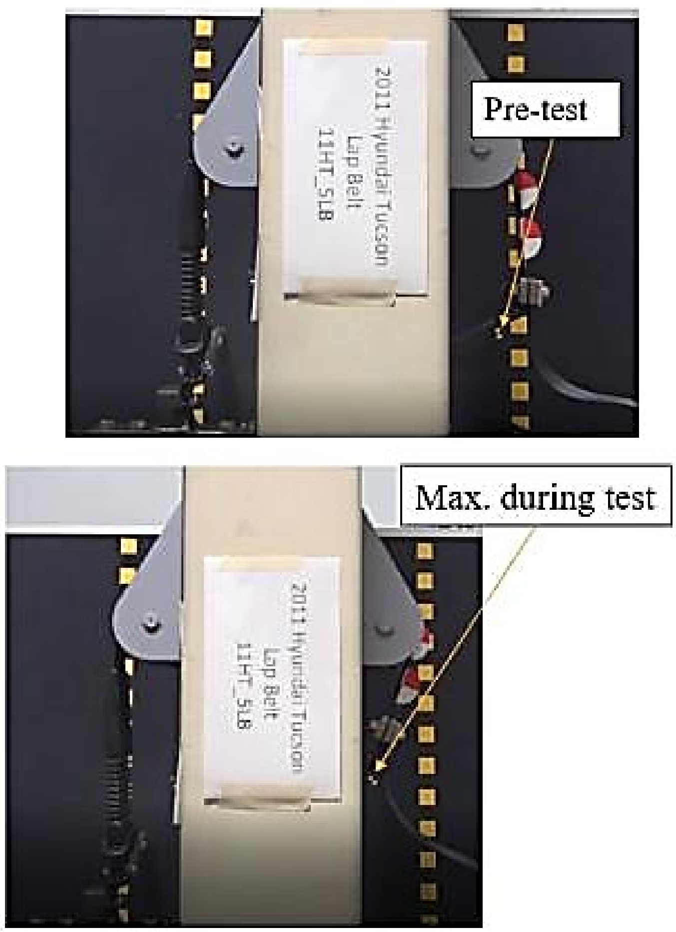

Figure 18. Buckle Stalk Movement Example.

4.6.4 Multiple Guide Loops

At least one seat belt assembly with multiple guide loops was selected to be a part of the test matrix as described previously. In the end, two vehicles (2012 Mercedes S400 and 2011 Chevrolet Traverse) were tested that had multiple guide loops. The 2012 Mercedes S400 had a guide bar in the seat belt assembly, as shown in **Figure 19**. The guide bar was a curved metal bar that was attached by two bolts on either end.

Figure 19. 2012 Mercedes S400 Guide Bar.

The 2011 Chevrolet Traverse seat belt assembly included a second guide loop. The guide loop was held in by a plastic pin in the B-pillar of the vehicle, as shown in **Figure 20**. Another angle was created because of this guide loop, so it was measured and included in the tensile tests.

Figure 20. 2011 Chevrolet Traverse Second Guide Loop.

These assemblies were tested in multiple configurations: both D-ring and guide bar/loop, guide bar/loop only, and D-ring only. Additional angles were measured in these vehicles to orient the hardware at representative in-vehicle angles. The different guide bar/loop set-ups for the 2012 Mercedes S400 and 2011 Chevrolet Traverse are shown in **Figures 21** and **22**, respectively.

Comparisons of results can be found in Tables 10 and 11, for the Mercedes S400 and Chevrolet Traverse, respectively.

Results of testing with multiple guide loop configurations for the 2012 Mercedes S400 showed that the use of a guide bar produced failure at a lower force level because the guide bar fractured during the multiple guide loop and guide bar only tests, yet also produced higher elongation results. Results from the 2011 Chevrolet Traverse were inconclusive because the tensile test machine reached is maximum movement before the required force was met. However, because the Chevrolet Traverse is a front row seat belt assembly and has a load limiter, elongation is not a criterion, indicated by the asterisks.

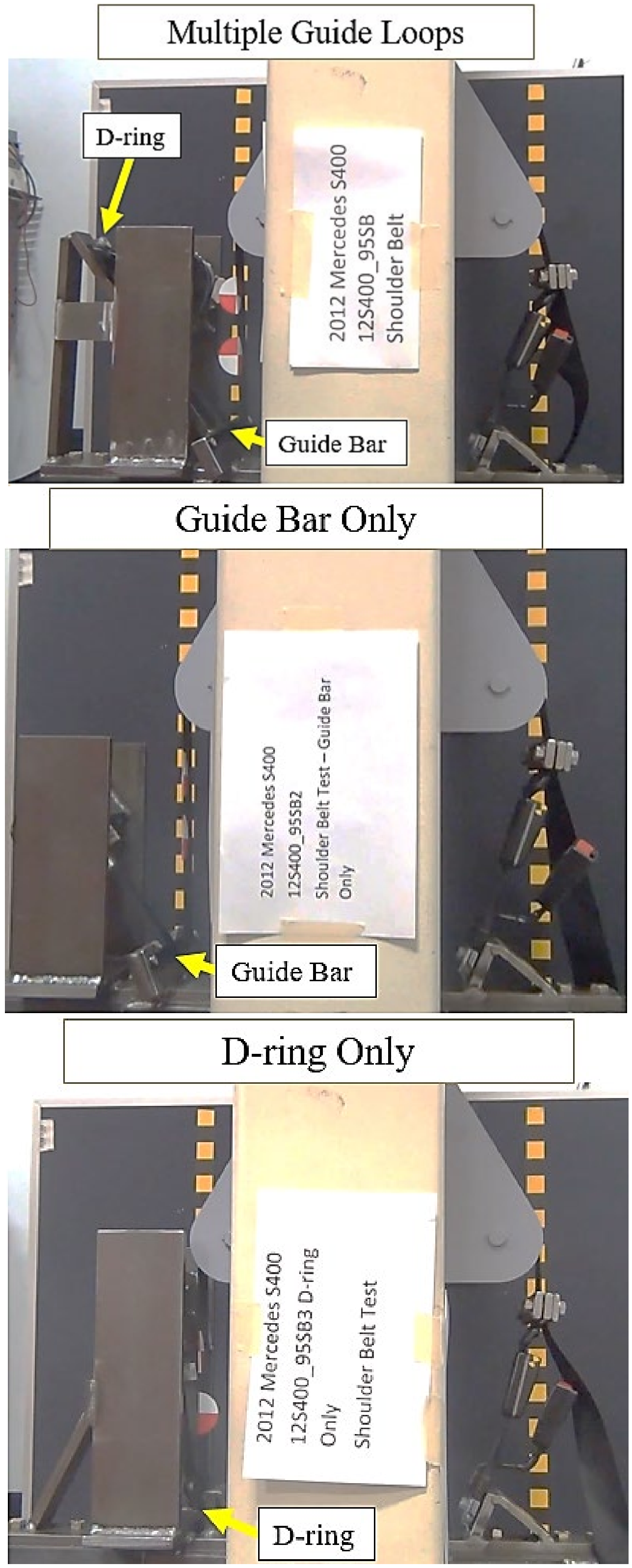

Figure 21. 2012 Mercedes S400 Multiple Guide Loops Comparison.

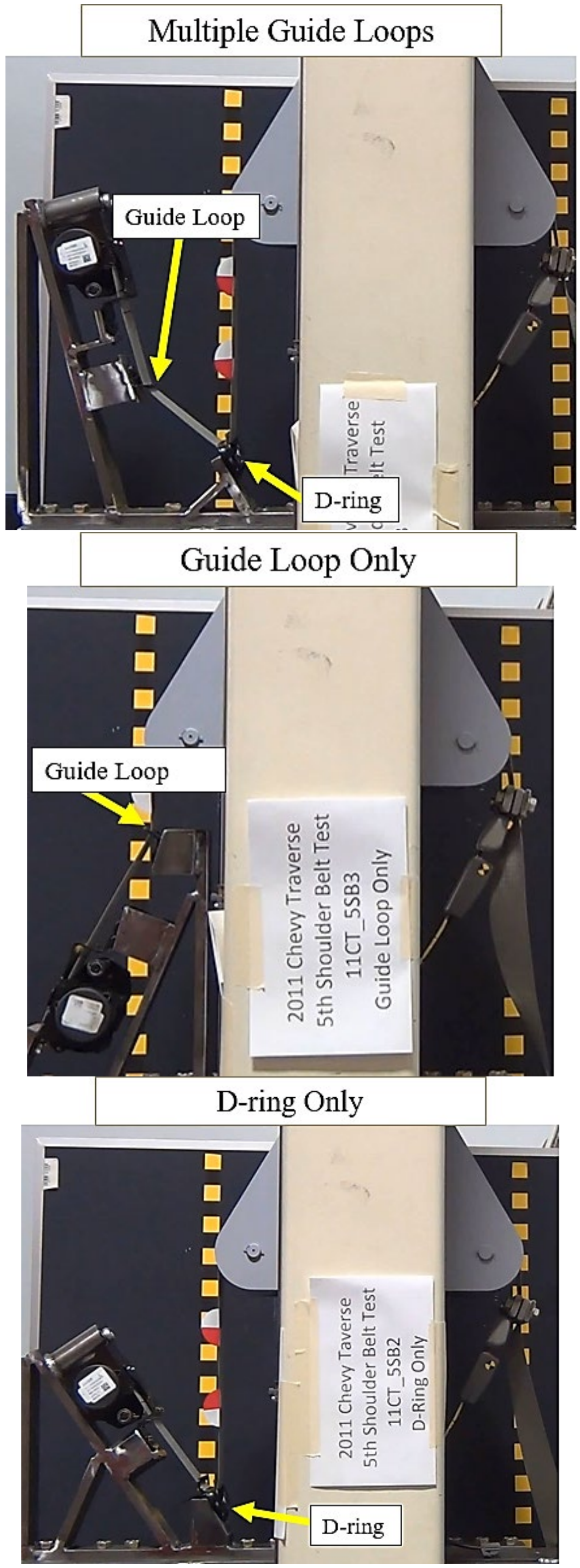

Figure 22. 2011 Chevrolet Traverse Multiple Guide Loops Comparison.

Table 10. 2012 Mercedes S400 Multiple Guide Loops Results

Model Year	Make	Model	Seating Position	ATD	Test Description	CDB Number	Upper Torso Loop Test	
							Force (N)	Elongation (mm)
2012	Mercedes	S400	2nd Row, Passenger	95th	Multiple Guide Loops	C01421	10,431	227
2012	Mercedes	S400	2nd Row, Passenger	95th	D-ring Only	C01423	13,372	164
2012	Mercedes	S400	2nd Row, Passenger	95th	D-ring Only	C01424	13,377	186
2012	Mercedes	S400	2nd Row, Passenger	95th	Guide Bar Only	C01422	10,012	172

Table 11. 2011 Chevrolet Traverse Multiple Guide Loops Results

Model Year	Make	Model	Seating Position	ATD	Test Description	CDB Number	Upper Torso Loop Test	
							Force (N)	Elongation (mm)
2011	Chevrolet	Traverse	1st Row, Driver	5th	Multiple Guide Loops	C01412	6,941	498*
2011	Chevrolet	Traverse	1st Row, Driver	5th	D-ring Only	C01413	6,298	480*
2011	Chevrolet	Traverse	1st Row, Driver	5th	Guide Loop Only	C01414	6,924	514*

4.6.5 Updated and FMVSS No. 209 Test Procedure Comparisons

Two of the seat belt assemblies (2014 Fiat 500L and 2014 Volkswagen Tiguan) tested with the updated test procedure incorporating representative angles had been previously tested by NHTSA's Office of Rulemaking. Therefore, comparisons could be made between the current FMVSS No. 209 test procedure and the updated test procedure. Examples of the differences in test set-up are shown in **Figures 23** and **24** for the Fiat 500L and **Figures 25** and **26** for the Volkswagen Tiguan seat belt assemblies.

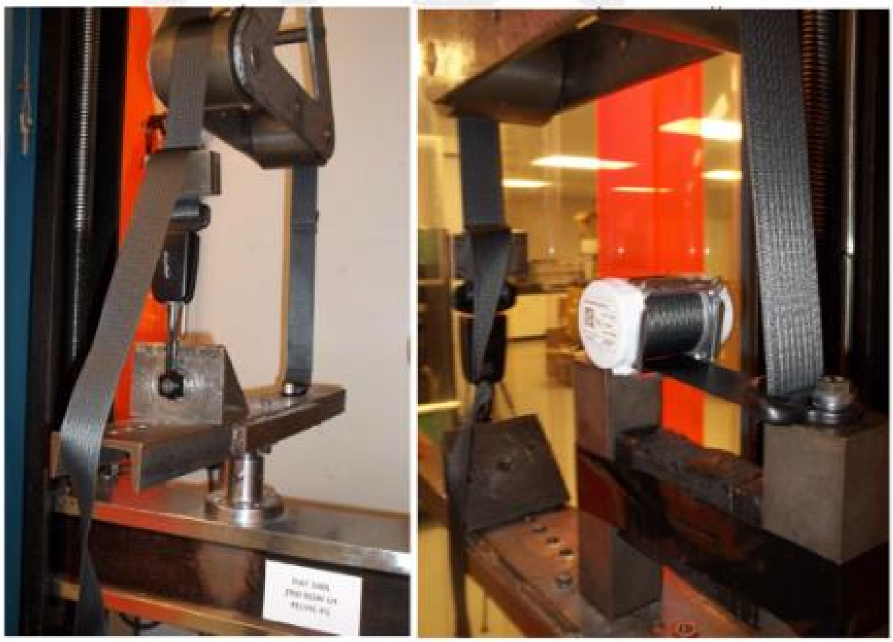

Figure 23. FMVSS No. 209 Test Set-Up for Pelvis Loop (left) and Upper Torso Loop (right) of 2014 Fiat 500L Seat Belt Assembly.

Figure 24. Updated Test Set-Up for Pelvis Loop (left) and Upper Torso Loop (right) of 2014 Fiat 500L Seat Belt Assembly.

Figure 25. FMVSS No. 209 Test Set-Up for Pelvis Loop (left) and Upper Torso Loop (right) of 2014 Volkswagen Tiguan Seat Belt Assembly.

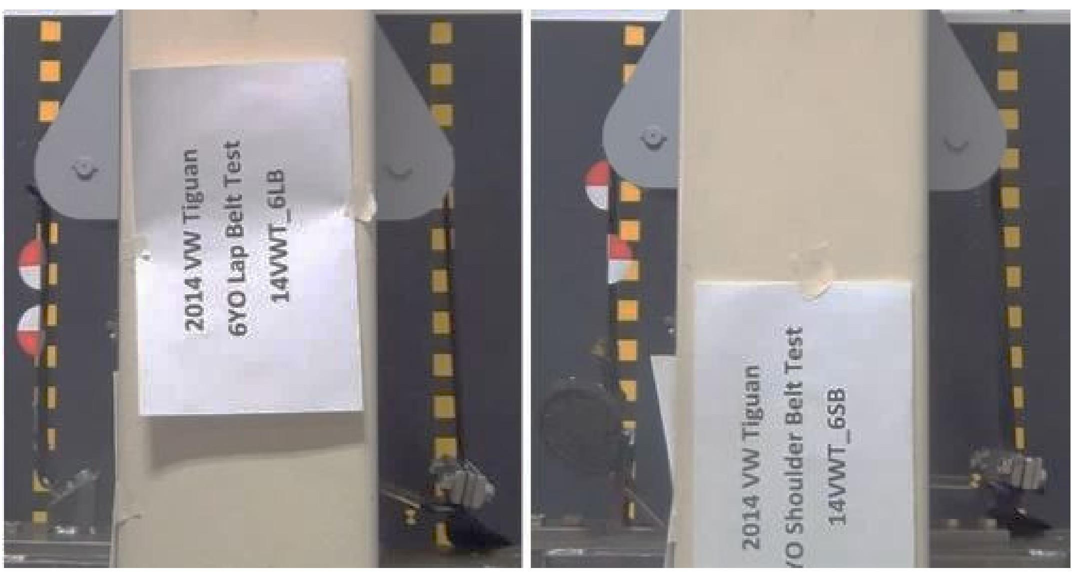

Figure 26. Updated Test Set-Up for Pelvis Loop (left) and Upper Torso Loop (right) of 2014 Volkswagen Tiguan Seat Belt Assembly.

A direct comparison of results can be found in Tables 12 and 13, for the 2014 Fiat 500L and 2014 Volkswagen Tiguan seat belt assemblies, respectively. Results from the current FMVSS No. 209 test procedure are shown in grey. For the Fiat 500L, the current and upgraded test procedures produced similar results for the pelvic loop tests. For the upper torso loop tests, the current procedure produced results similar to those for the updated procedure when the 6YO angles were used, while the use of the 95th angles resulted in less than half the elongation. The cell marked in red indicates that the anchor plate fractured during NRM testing. For the Volkswagen Tiguan, the FMVSS No. 209 test procedure generally produced less elongation than the upgraded procedure in the pelvis loop tests, and those tests with the 6YO angles had hardware fractures that were not seen in the NRM testing. The rear seat belt assembly with load limiter did not meet the elongation limit during one of the NRM upper torso loop tests. However, with the updated procedure, the seat belt assembly was not tested to the required force due to the spool out of the shoulder belt webbing during the test because of the stroke limitation of the tensile test machine.

Table 12. 2014 Fiat 500L Procedure Results Comparison

Model Year	Make	Model	Seating Position	ATD	Pelvic Loop Tests		Upper Torso Loop Tests	
					Force (N)	Elongation (mm)	Force (N)	Elongation (mm)
2014	Fiat	500L	2nd Row, Passenger	N/A	22,241	142	13,345	457
2014	Fiat	500L	2nd Row, Passenger	N/A	20,020	N/A	13,345	432
2014	Fiat	500L	2nd Row, Passenger	N/A	22,241	135	13,345	442
2014	Fiat	500L	2nd Row, Passenger	95th	22,324	136	13,397	208
2014	Fiat	500L	2nd Row, Passenger	6YO	22,300	146	13,371	444

Table 13. 2014 Volkswagen Tiguan Procedure Results Comparison

Model Year	Make	Model	Seating Position	ATD	Pelvic Loop Tests		Upper Torso Loop Tests	
					Force (N)	Elongation (mm)	Force (N)	Elongation (mm)
2014	Volkswagen	Tiguan	2nd Row, Passenger	N/A	22,241	130	13,345	472
2014	Volkswagen	Tiguan	2nd Row, Passenger	N/A	22,241	130	13,345	> 853 mm
2014	Volkswagen	Tiguan	2nd Row, Passenger	N/A	22,241	148	Not Tested	Not Tested
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	22,303	186	12,384	366
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	13,523	162	9,036	380

Model Year	Make	Model	Seating Position	ATD	Pelvic Loop Tests		Upper Torso Loop Tests	
					Force (N)	Elongation (mm)	Force (N)	Elongation (mm)
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	17,456	114	Not Tested	Not Tested

5. Load Limiter Evaluation

Four of the 10 seat belt assemblies in the tensile test matrix included load limiters. Three assemblies (2011 Chevrolet Traverse, 2011 Hyundai Tucson, and 2014 Volkswagen Tiguan) were selected for continued testing, and each included a torsion bar load limiter design. As described in Section 4, the tensile test machine reached its maximum stroke before the force criterion was met for these seat belt assemblies. Further testing was conducted aiming to develop a test procedure to determine if seat belt assemblies with load limiters can meet the force criterion in one test when using stroke-limited machines.

For the load limiter evaluation test matrix, the same loop length and in-vehicle angles were used as in Section 4 tensile testing, per respective vehicle. In the initial tensile test matrix, the 2011 Chevrolet Traverse was tested in three different configurations due to the multiple guide loops included in the shoulder belt assembly. In the load limiter evaluation test matrix, the Chevrolet Traverse was tested using the D-ring and guide loop configuration for the 95th percentile male and the guide loop only configuration for the 5th percentile female in-vehicle angles because they recorded the highest elongation.

Three test conditions were developed which were anticipated to allow the shoulder belt assemblies with load limiters to reach the required force in one test:

- The first test condition was to remove all the webbing from the spool before testing.
- The second test condition was to determine and use the minimal amount of webbing possible on the spool which allowed webbing to be fully off the spool before the tensile test machine reached its maximum stroke. A procedure was developed to determine the minimal amount of webbing required for each shoulder belt assembly and is detailed in **Appendix E**.
- The third test condition was to actuate the seat belt retractor pretensioners before tensile testing. Only the Chevrolet Traverse and Hyundai Tucson seat belt assemblies included retractor pretensioners, so only they were tested in this condition.

The test matrix for the load limiter evaluation testing is shown in Table 14.

Table 14. Load Limiter Evaluation Test Matrix

	Model Year	Make/Model	Seating Position	ATDs		Webbing Condition	Retractor Pretensioner
1	2014	Volkswagen Tiguan	2nd Row, Passenger	6YO	95th Male	No Webbing on Spool	Not Actuated
2	2011	Hyundai Tucson	Front Row, Driver	5th Female	95th Male	No Webbing on Spool	Not Actuated
3	2011	Chevrolet Traverse	Front Row, Driver	5th Female	95th Male	No Webbing on Spool	Not Actuated
4	2014	Volkswagen Tiguan	2nd Row, Passenger	6YO	95th Male	Minimal Webbing on Spool	Not Actuated
5	2011	Hyundai Tucson	Front Row, Driver	5th Female	95th Male	Minimal Webbing on Spool	Not Actuated
6	2011	Chevrolet Traverse	Front Row, Driver	5th Female	95th Male	Minimal Webbing on Spool	Not Actuated
7	2011	Hyundai Tucson	Front Row, Driver	5th Female	95th Male	Measured Amount	Actuated
8	2011	Chevrolet Traverse	Front Row, Driver	5th Female	95th Male	Measured Amount	Actuated

Yellow-orange in the subsequent tables indicates tests where the tensile test machine was not able to complete the test to the required force due to limitation on the stroke of the machine. Cells marked with an asterisk indicate front row seating position assemblies with load limiters where the elongation limits do not apply.

5.1 No Webbing on the Spool

All three shoulder belt assemblies with load limiters were tested with no webbing on the spool. Before testing, all the webbing was removed from the spool and the shoulder belt assembly was set-up with the same loop length and representative in-vehicle angles as the Section 4 tensile test series. The load limiters do not engage in this configuration. The results from the no webbing condition tests are reported in Table 15, and all tests reached the required force.

Table 15. Load Limiter Evaluation—No Webbing Condition Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01698	13,379	136
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01699	13,378	122
2011	Hyundai	Tucson	1st Row, Driver	5th	C01700	13,483	89*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01701	13,474	76*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01702	13,371	131*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01703	13,382	118*

5.2 Minimal Webbing on the Spool

All three shoulder belt assemblies were tested with a minimal amount of webbing on the spool which allowed webbing to be fully off the spool before the tensile test machine reached its maximum stroke. This allowed the load limiter to engage at least partially during testing and ensured the force criterion could be met during the tensile test.

Due to the different loop lengths, each shoulder belt assembly required a different amount of webbing on the spool to ensure that the webbing would run out before the tensile test machine reached its maximum stroke. A procedure to determine the required amount of webbing was developed and is detailed in **Appendix E**. Table 16 reports the amount of webbing on the spool for each belt assembly tested with the minimal webbing.

Table 16. Minimal Amount of Webbing

In-Vehicle Measurements	5th Female or 6YO	95th Male
Volkswagen Tiguan	390 mm	440 mm
Hyundai Tucson	625 mm	530 mm
Chevrolet Traverse	540 mm	585 mm

The results from the minimal webbing condition tests are shown in Table 17. The force criterion was met for all shoulder belt assemblies tested with the determined minimal amount of webbing on the spool. However, this condition does not necessarily fully engage the load limiter. Test C01709 did not reach the force criterion because 50 millimeters was originally used for the initial clearance between the crosshead and the top of the tensile test machine stroke (see steps 2 and 3 in **Appendix E**). Subsequently, it was determined that 100 millimeters was needed to provide adequate clearance, so the procedure was modified. When re-tested (C01710), that shoulder belt assembly met the required force. So, the remaining tests (C01704-01708) were tested with 100-millimeter clearance.

Table 17. Load Limiter Evaluation—Minimal Webbing Condition Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01704	13,373	310
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01705	13,413	308
2011	Hyundai	Tucson	1st Row, Driver	5th	C01706	13,390	739*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01707	13,386	605*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01708	13,373	675*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01709	11,056	737*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01710	13,372	711*

5.3 Actuated Retractor Pretensioner

Two shoulder belt assemblies were tested with the retractor pretensioner actuated before testing. The loop lengths and representative amounts of webbing used in the Section 4 tensile test series were matched. For each test, the shoulder belt assembly was set-up and then the retractor pretensioner was actuated with the belt in this position on the tensile test machine. The actuation of the pretensioner resulted in the removal of all extra slack in the webbing and a resulting average force of approximately 1,000 newtons was observed for both pretensioners. After actuating the pretensioner, the force was zeroed on the tensile test machine to measure the change in force, and the shoulder belt assembly was tested using the tensile test procedure outlined in **Appendix C**. Despite actuating the pretensioner, the maximum stroke of the tensile test machine was reached before the required force for both seat belt assemblies. The results of the actuated retractor pretension test series are shown in Table 18.

Table 18. Load Limiter Evaluation—Actuated Retractor Pretensioner Condition Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)
2011	Hyundai	Tucson	1st Row, Driver	5th	C01711	7,098	740*
2011	Hyundai	Tucson	1st Row, Driver	95th	C01712	7,210	710*
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01713	9,924	737*
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01714	9,801	704*

5.4 Load Limiter Evaluation Testing Observations

During the load limiter evaluation test series, it was observed that both the Chevrolet Traverse guide loop and Hyundai Tucson D-ring reacted differently than in the Section 4 test series. During the initial testing, the guide loop did not bend, likely a difference because the force criterion was not met in the initial series.

For each condition tested on the 2011 Chevrolet Traverse shoulder belt in the load limiter evaluation test series, the guide loop bent outwards towards the retractor but did not fracture for any test. **Figure 27** illustrates the bending of the guide loop in each condition.

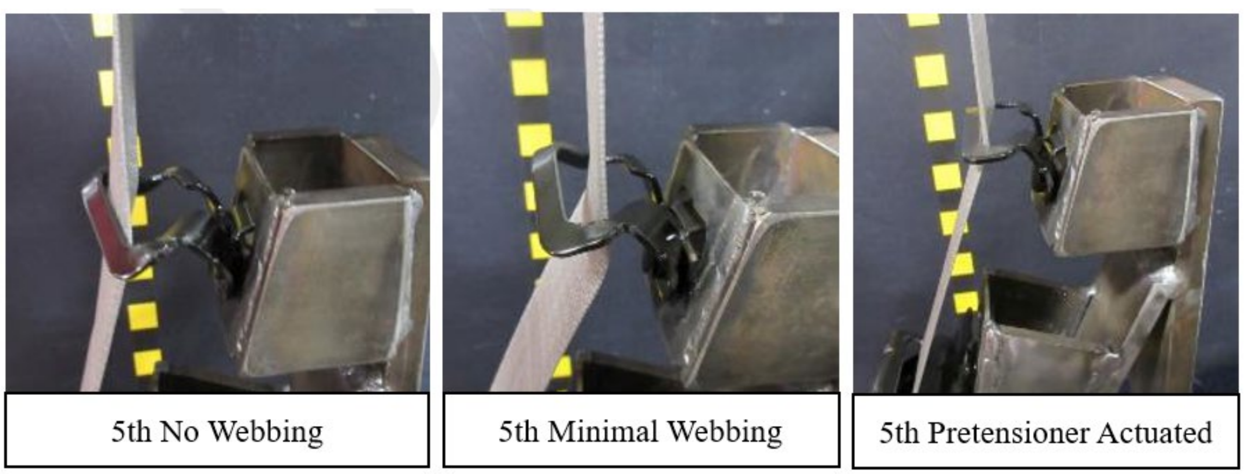

Figure 27. Chevrolet Traverse Guide Loop Bending.

The D-ring of the Hyundai Tucson shoulder belt assembly rotated during the load limiter evaluation test series. The Hyundai Tucson was in the fixed D-ring orientation, but during testing, the D-ring was pushed slightly past the fixed D-ring fixture, allowing slight rotational movement. The maximum D-ring rotation was observed in the actuated retractor pretensioner condition. Minor rotation was observed in the minimal webbing condition, and no rotation was observed in the no webbing condition. **Figure 28** shows post-test photos of the slightly rotated D-ring in the actuated retractor pretensioner condition.

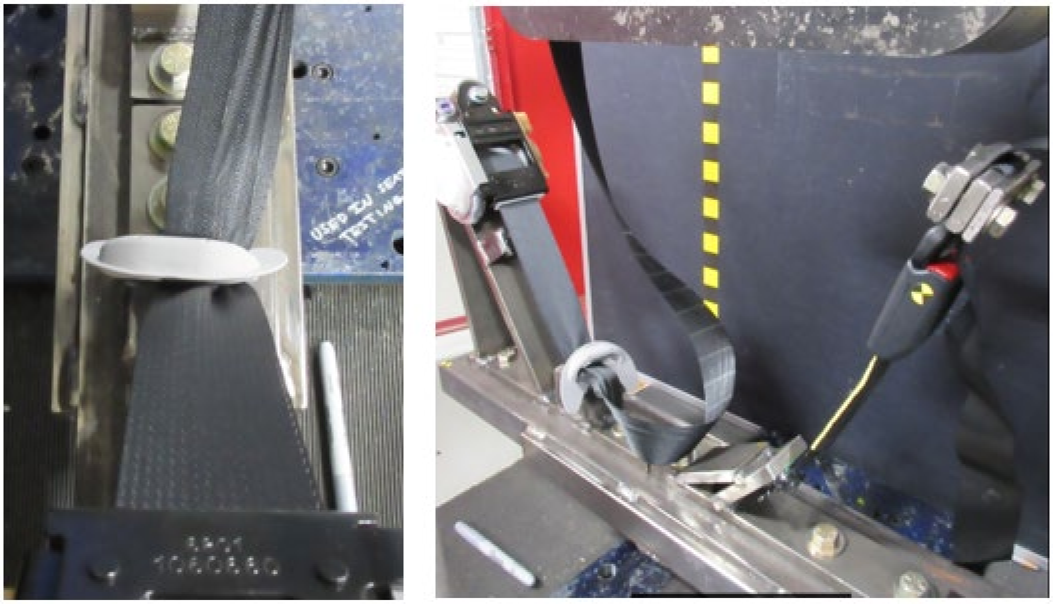

Figure 28. Hyundai Tucson D-ring Rotation.

6. Summary

FMVSS No. 209 specifies performance requirements for seat belt assemblies used in motor vehicles. The standard includes an assembly performance tensile test where seat belt assemblies must withstand a minimum tensile force and not exceed an elongation limit. NHTSA is evaluating potential changes to the test procedures, to better represent in-vehicle restraint angles. To support the tensile test procedure development, VRTC collected in-vehicle measurements of seat belt assemblies with different occupant sizes and conducted tensile tests at the resulting representative angles. Out of 10 seat belt assemblies tested using the in-vehicle seat belt angles, four did not meet the performance criteria when tested using the procedure under evaluation. Throughout testing, several additional comparisons were made based on observations including test head rotation, guide loop rotation, buckle stalk movement, multiple guide loops set-up, and updated test procedure comparisons. Additional testing was completed aiming to further develop the test procedure to determine if seat belt assemblies with load limiters can meet the force criterion in one test when using stroke-limited machines. All assemblies tested under the conditions of no webbing on the spool or minimal webbing on the spool reached the required force, although more steps were required to test with minimal webbing on the spool and the load limiters were not fully engaged. Overall, the updated test procedure was feasible and converted the in-vehicle geometry of the seat belt assembly into a more representative tensile test. The developed test procedures include a detailed method for collecting the in-vehicle angle measurements, incorporating all in-vehicle hardware, and fabricating unique fixtures to complete tensile tests at representative in-use angles.

APPENDIX A: In-Vehicle Measurement Procedure

1) Remove any trim pieces to gain access to all seat belt mounting bolts and hardware.
2) Seat the ATD following the below seating procedure:
    a. Hybrid III 6-year-old child ATD.
        i. The 6YO should be seated with the head restraint in the full down position, the seat track full forward, the guide loop at its lowest achievable height, and the seat back at 25 degrees per SAE J826.
    b. Hybrid III 5th percentile female per FMVSS No. 208 (TP208-13 G1) seating procedure.
        i. The 5th percentile female should be seated with the head restraint in the full down position, the seat track full forward, the guide loop at mid-height, and the seat back fully upright.
    c. Hybrid III 95th male ATD.
        i. The 95th percentile male should be seated with the head restraint in the full up position, the seat track full rearward, the guide loop at its highest achievable height, and the seat back at 25 degrees per SAE J826.
3) Retractor Angle (**Figure A1**).
    a. * All angles measured will be the most acute angle found between the intersection of the respective line and plane.
    b. Mark and collect the following points:
        i. P1: Center of the belt at retractor (this point should be as close as possible to the center of the belt where the webbing leaves the retractor).
        ii. P2: Center of the belt at the back of the guide loop (or longest straight line from P1).
    c. Create the retractor mounting plane (PL1).
        i. PL1: The plane created around the mounting bolt on the retractor surface. Three points must be collected by going around the retractor bolt, creating a plane from those points.
    d. Create a centerline connecting points P1 and P2 (L1).
    e. Record the "Retractor Angle" by finding the angle at which PL1 and L1 intersect.

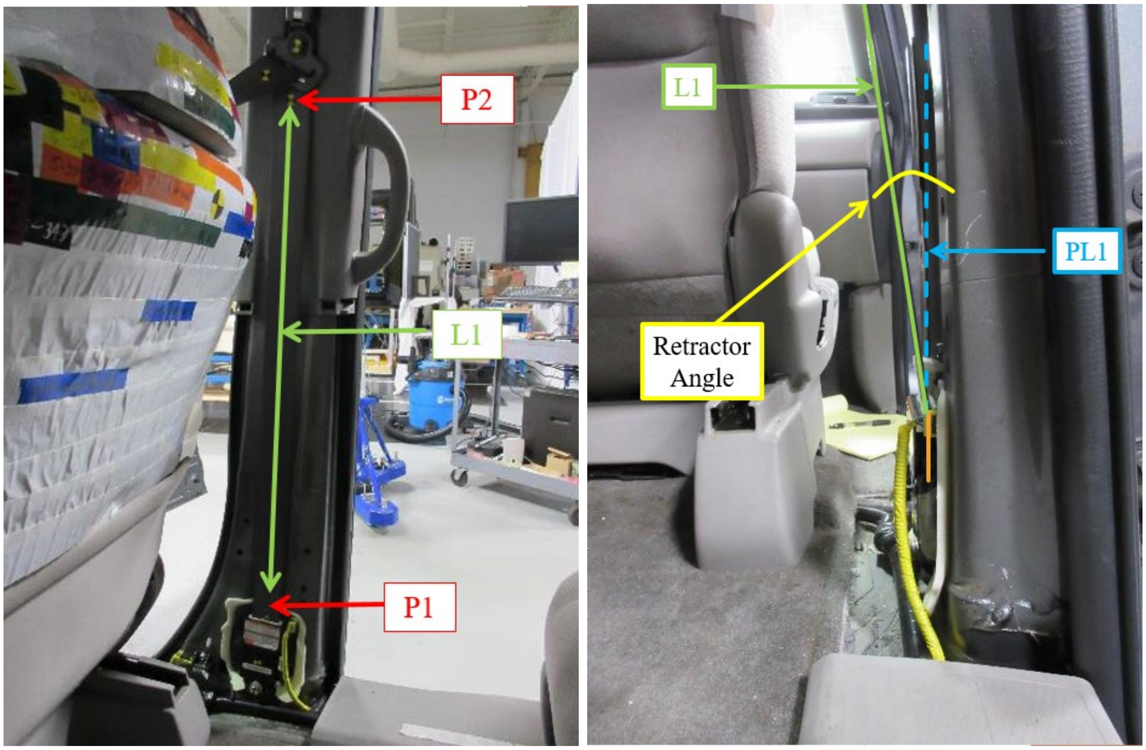

Figure A1. All Points, Lines, and Planes Created to Find Retractor Angle (left). Retractor Angle Defined by Using the Intersection of PL1 and L1 (right).

4) Guide Loop Angles (**Figure A2**).
   a. * All angles measured will be the most acute angle found between the intersection of the respective line and plane.
   b. Mark and collect the following points:
      i. P3: Center of the belt at the front of the guide loop.
      ii. P4: Center of the belt at the longest straight section from the guide loop to the ATD shoulder at the center of the belt.
      iii. P5 (if multiple guide loops are included): Center of the belt at the longest straight section from the guide loop to the retractor at the center of the belt.
         1. In cases with only one guide loop, P5 and P1 will be at the same location.
   c. Create the guide loop mounting plane (PL2).
      i. PL2: The plane created around the mounting bolt on the guide loop. Three points must be collected by going around the mounting bolt, creating a plane from those points.
   d. Create a centerline connecting points P3 and P4 (L2).
   e. Create a centerline connecting points P2 and P5 (L3).
      i. L3 only necessary in assemblies with additional belt guides.
   f. Measure the "Guide Loop to Retractor Angle" by finding the angle at which L3 intersects with PL2.
   g. Measure the "Guide Loop to Shoulder Angle" by finding the angle at which L2 intersects with PL2.

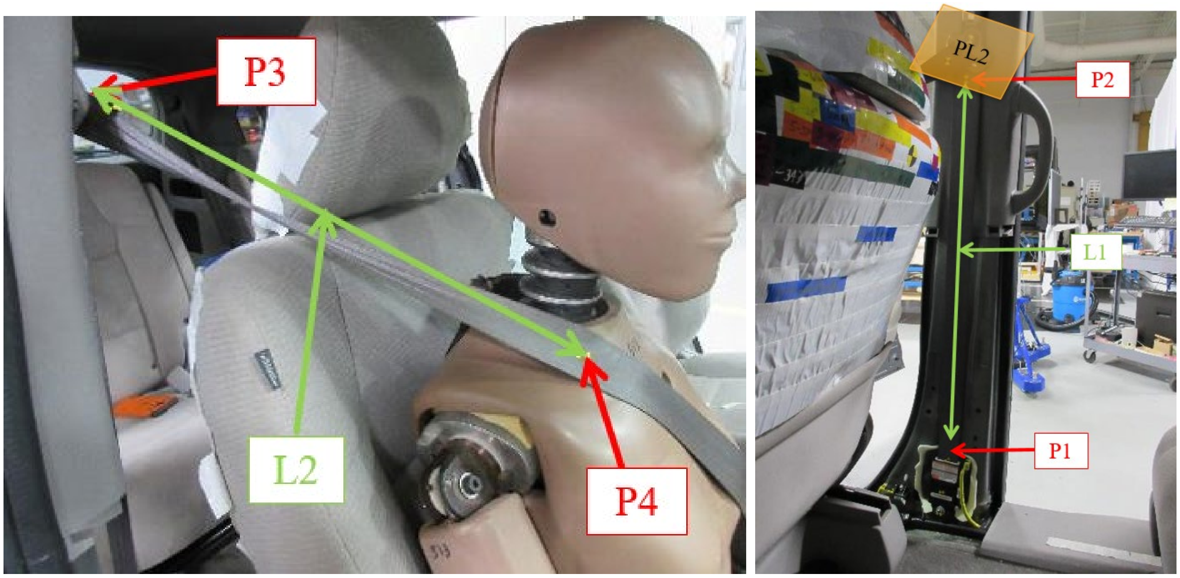

Figure A2. All Points, Lines, and Planes Created to Find Guide Loop Angle (left). Guide Loop Angles Defined by Using the Intersection of PL2 and L2 (right).

5) Inboard Hardware Angle (**Figure A3**).
   a. * All angles measured will be the most acute angle found between the intersection of the respective line and plane.
   b. Mark and collect the following points:
      i. P6: Inboard top center of buckle.
      ii. P7: Inboard anchor buckle attachment.
      iii. P8: Center of shoulder belt, 76 mm (3 inches) from tongue belt loop.
      iv. P9: Center of shoulder belt at tongue belt loop.
      v. P10: Center of lap belt at tongue belt loop.
      vi. P11: Center of lap belt, 76 mm (3 inches) from tongue belt loop.
   c. Create the mounting planes and center lines.
      i. PL3: The plane created around the anchor attachment of the inboard hardware. Three points must be collected by going around the mounting bolt, creating a plane from those points.
      ii. PL4: The plane created on the tongue latch plate. Three points must be collected by going around the latch plate, creating a plane from those points.
      iii. Use P6 and P7 to create a centerline of the inboard buckle (L4).
      iv. Use P8 and P9 to create a centerline for tongue shoulder belt (L5).
      v. Use P10 and P11 to create a centerline for tongue lap belt (L6).
   d. Measure the "Inboard Buckle Angle" by finding the angle at which L4 intersects with PL3.
   e. Measure the 'Latch Shoulder Belt Angle' by finding the angle at which L5 intersects with PL4.
   f. Measure the 'Latch Lap Belt Angle' by finding the angle at which L6 intersects with PL4.
   g. Determine the Inboard Hardware Angles by adding the "Latch Lap Belt Angle" and "Inboard Buckle Angle" for the Inboard Hardware Lap Angle and adding the

“Latch Shoulder Belt Angle” and “Inboard Buckle Angle” for the Inboard Hardware Shoulder Angle.

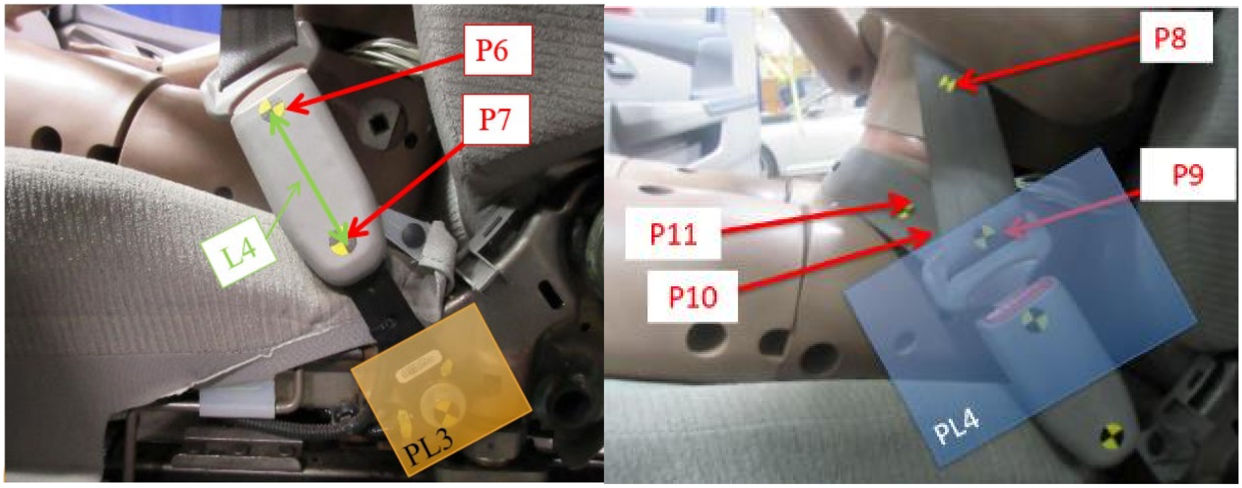

Figure A3. All Points, Lines, and Planes Created to Find Inboard Angles (left and right).

6) Outboard Hardware Angle (**Figure A4**).
    a. * All angles measured will be the most acute angle found between the intersection of the respective line and plane.
    b. Mark and collect the following points:
        i. P12: Outboard seat belt anchor attachment.
            1. Remove plastic covering if necessary.
        ii. P13: Outboard anchor center of the seat belt, past cover or longest straight segment.
    c. Create the mounting plane.
        i. PL5: The plane created around the anchor attachment of the outboard hardware. Three points must be defined by going around the mounting bolt, creating a plane from those points.
    d. Create a centerline of the outboard seat belt using P12 and P13 to (L7).
    e. Measure the “Outboard Hardware Angle” by finding the angle at which L7 and PL5 intersect.

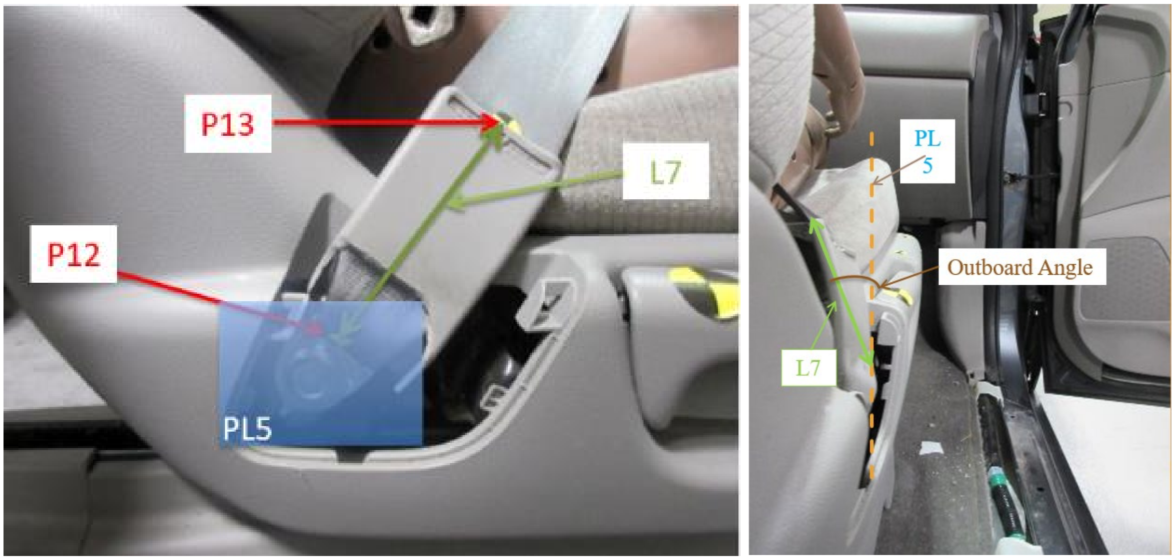

Figure A4. All Points, Lines, and Planes Created to Find Outboard Hardware Angle (left). Outboard Hardware Angle Defined by Using the Intersection of PL5 and L7 (right).

7) With the ATD is seated and the seat belt buckled, mark the webbing where it leaves the retractor spool.
8) After completing all the measurements with the ATD seated, pull all the webbing off the spool and mark where it leaves the retractor.
    a. Record the distance between the two marks on the webbing as the representative length of webbing on the retractor spool.

APPENDIX B: In-Vehicle Measurements

Table B1. 2011 Honda Odyssey In-Vehicle Angles

In-Vehicle Measurements	6YO	95th Male
Retractor Angle	5°	7°
Inboard Hardware Lap Angle	78°	15°
Inboard Hardware Shoulder Angle	39°	18°
Outboard Hardware Angle	29°	23°
Guide Loop to Shoulder Angle	6°	3°
Guide Loop to Retractor Angle	47°	57°
Webbing on Spool	1,283 mm	989 mm

Table B2. 2011 Ford Explorer In-Vehicle Angles

In-Vehicle Measurements	6YO	95th Male
Retractor Angle	16°	15°
Inboard Hardware Lap Angle	76°	16°
Inboard Hardware Shoulder Angle	41°	25°
Outboard Hardware Angle	31°	47°
Guide Loop to Shoulder Angle	40°	33°
Guide Loop to Retractor Angle	3°	3°
Webbing on Spool	1,240 mm	535 mm

Table B3. 2014 Hyundai Tucson In-Vehicle Angles

In-Vehicle Measurements	5th Female	95th Male
Retractor Angle	6°	7°
Inboard Hardware Lap Angle	70°	21°
Inboard Hardware Shoulder Angle	42°	18°
Outboard Hardware Angle	15°	37°
Guide Loop to Shoulder Angle	27°	53°
Guide Loop to Retractor Angle	11°	13°
Webbing on Spool	1,232 mm	1,100 mm

Table B4. 2011 Chevrolet Traverse In-Vehicle Angles

In-Vehicle Measurements	5th Female	95th Male
Retractor Angle	3°	0°
Inboard Hardware Lap Angle	51°	20°
Inboard Hardware Shoulder Angle	36°	20°
Outboard Hardware Angle	55°	32°
Guide Loop to Shoulder Angle	31°	61°
Guide Loop to Second Guide Loop	7°	8°
Guide Loop to Retractor Angle	28°	28°
Webbing on Spool	595 mm	570 mm

Table B5. 2014 Fiat 500L In-Vehicle Angles

In-Vehicle Measurements	6YO	95th Male
Retractor Angle	2°	3°
Inboard Hardware Lap Angle	35°	32°
Inboard Hardware Shoulder Angle	28°	35°
Outboard Hardware Angle	36°	30°
Guide Loop to Shoulder Angle	40°	35°
Guide Loop to Retractor Angle	2°	2°
Webbing on Spool	1,250 mm	652 mm

Table B6. 2017 Mercedes E300 In-Vehicle Angles

In-Vehicle Measurements	6YO	95th Male
Retractor Angle	31°	8°
Inboard Hardware Lap Angle	104°	63°
Inboard Hardware Shoulder Angle	85°	71°
Outboard Hardware Angle	77°	77°
Guide Loop to Shoulder Angle	N/A	N/A
Guide Loop to Retractor Angle	N/A	N/A
Webbing on Spool	1,035 mm	790 mm

Table B7. 2012 Mercedes S400 In-Vehicle Angles

In-Vehicle Measurements	6YO	95th Male
Retractor Angle	10°	9°
Inboard Hardware Lap Angle	59°	18°
Inboard Hardware Shoulder Angle	36°	23°
Outboard Hardware Angle	84°	76°
Guide Loop to Shoulder Angle	47°	39°
Guide Loop to Guide Bar	0°	2°
Guide Loop to Retractor Angle	1°	1°
Webbing on Spool	NA	795 mm

Table B8. 2014 Volkswagen Tiguan In-Vehicle Angles

In-Vehicle Measurements	6YO	95th Male
Retractor Angle	4°	2°
Inboard Hardware Lap Angle	112°	28°
Inboard Hardware Shoulder Angle	92°	32°
Outboard Hardware Angle	58°	61°
Guide Loop to Shoulder Angle	N/A	N/A
Guide Loop to Retractor Angle	N/A	N/A
Webbing on Spool	1,530 mm	785 mm

APPENDIX C: Tensile Test Procedure

- If testing a belt with a retractor, mark one-inch increments across the webbing starting from the mark which represents the representative length of webbing on the retractor spool.
- Set-up the seat belt on the double roller block assembly on the tensile test machine.
  - Use the webbing length on the spool for the representative ATD.
  - Record webbing length on spool.
- Position the attachments on the adapter fixtures at the representative ATD angles targeting a 1,245 mm loop length.
  - Measure loop length from furthest attachment bolts (record loop length).
  - Verify the belt is aligned:
    - Make sure webbing is in the middle of the guide loop slot.
    - Measure offset of belt on the rollers (record offset).
  - Mark webbing clamp to make sure there's no slippage.
  - Measure vertical webbing angles.
- Add signboard and targets for video (i.e. Model Year/Make/Model, Test Description, Test Number).
- Add a target on edge of buckle for video analysis and paint/marker on buckle stalk.
- Be sure the force pre-test is zeroed.
- Run Preload tensile test machine program:
  - Apply 245 N load.
  - Reduce the load to 0 N.
- Verify the loop length between attaching bolts is between 1,220 and 1,270 mm (record webbing length).
- Take pre-test photos:
  - Whole set up (from all angles).
  - Each hardware/fixture.
  - Webbing and hardware.
  - The triangle apparatus.
  - Each hardware with inclinometer.
  - Each vertical webbing with inclinometer.
  - Marked line at clamp.
- Start video recording (set video recorder back so the rotation of the test head can be observed, and as much of the tensile test machine uprights as possible can be seen).
- Verify the ALR/ELR is locked.
- Run shoulder belt or lap belt tensile test machine program:
  - Preload to 98 N.
    - Do not zero this preload.
    - Zero position at 98 N.
  - Pull at a minimum rate of 51 mm/min until 22,241 or 13,345 N, measured at the test machine head, is reached.
- Release load from test equipment.
- Report displacement at 22,241 N or 13,345 N (record max. force and max. displacement).
  - Criteria: Withstand force of 22,241 N for lap belt (11,120 N per segment). or 13,345 N (6,672 N per segment) for shoulder belt without fracture.
  - Elongation: No more than 254 mm movement of machine head.

    - Not required for front outboard designated seating position seat belts with load limiters.
- Stop video recording.
- Take post-test photos:
  - Whole set up (from all angles).
  - Each hardware set up.
  - Webbing and hardware.
  - The triangle apparatus.
  - Marked line at clamp.
  - Any fractured metal or visibly broken components.
- Record test details in notebook.
- Write test number on seat belt assembly parts.

APPENDIX D: Tensile Test Results

Table D1. Pelvic Tensile Test Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)	Buckle Stalk Movement (mm)
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01377	22,241	146	120
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01378	22,322	164	102
2011	Honda	Odyssey	1st Row, Passenger	95th	C01379	22,292	88	19
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01380	22,309	173	76
2011	Honda	Odyssey	1st Row, Passenger	95th	C01381	22,293	128	16
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	95th	C01385	22,276	242	9
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	95th	C01386	22,287	224	7
2011	Ford	Explorer (inflatable)	2nd Row, Passenger	6YO	C01387	22,219	379	81
2011	Hyundai	Tucson	1st Row, Driver	5th	C01388	22,328	179	114
2011	Hyundai	Tucson	1st Row, Driver	95th	C01389	22,359	81	14
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01390	22,314	156	69
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01391	22,310	130	22
2014	Fiat	500L	2nd Row, Passenger	95th	C01392	22,324	136	15
2014	Fiat	500L	2nd Row, Passenger	6YO	C01393	22,300	146	34
2017	Mercedes	E300	2nd Row, Passenger	95th	C01394	22,285	194	55
2017	Mercedes	E300	2nd Row, Passenger	6YO	C01395	22,296	261	133
2012	Mercedes	S400	2nd Row, Passenger	95th	C01396	22,293	88	29
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01397	13,523	162	184
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01398	17,456	114	186
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01399	22,303	186	44
Universal	Seatbelt Plus	N/A	N/A	N/A	C01382	22,276	159	95
Universal	Seatbelt Plus	N/A	N/A	N/A	C01383	22,280	142	48
Universal	Dorman	N/A	N/A	N/A	C01384	22,273	203	69

Table D2. Upper Torso Tensile Test Results

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)	Buckle Stalk Movement (mm)
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01400	11,431	580*	33
2011	Honda	Odyssey	1st Row, Passenger	95th	C01376	13,382	524*	37
2011	Honda	Odyssey	1st Row, Passenger	95th	C01401	13,369	534*	14
2011	Honda	Odyssey	1st Row, Passenger	6YO	C01402	13,380	532*	25
2011	Honda	Odyssey	1st Row, Passenger	95th	C01403	13,380	536*	13
2011	Ford	Explorer	2nd Row, Passenger	95th	C01406	13,400	500	10
2011	Ford	Explorer	2nd Row, Passenger	6YO	C01407	13,356	688	60
2011	Hyundai	Tucson	1st Row, Driver	5th	C01408	7,477	768*	60
2011	Hyundai	Tucson	1st Row, Driver	5th	C01409	5,411	546*	47
2011	Hyundai	Tucson	1st Row, Driver	95th	C01410	7,230	492*	12
2011	Hyundai	Tucson	1st Row, Driver	95th	C01411	5,903	592*	10
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01412	6,941	498*	41
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01413	6,298	480*	31
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01414	6,924	514*	40
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01415	6,473	508*	15
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01416	5,951	456*	14
2014	Fiat	500L	2nd Row, Passenger	95th	C01417	13,397	208	38
2014	Fiat	500L	2nd Row, Passenger	6YO	C01418	13,371	444	26
2017	Mercedes	E300	2nd Row, Passenger	95th	C01419	13,360	324	41
2017	Mercedes	E300	2nd Row, Passenger	6YO	C01420	13,398	514	24
2012	Mercedes	S400	2nd Row, Passenger	95th	C01421	10,431	227	30
2012	Mercedes	S400	2nd Row, Passenger	95th	C01422	10,012	172	22
2012	Mercedes	S400	2nd Row, Passenger	95th	C01423	13,372	164	14
2012	Mercedes	S400	2nd Row, Passenger	95th	C01424	13,377	186	2
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01425	9,036	380	115

Model Year	Make	Model	Seating Position	ATD	CDB Number	Force (N)	Elongation (mm)	Buckle Stalk Movement (mm)
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01426	12,384	366	36
Universal	Seatbelt Plus	N/A	N/A	N/A	C01404	13,402	275	NA
Universal	Seatbelt Plus	N/A	N/A	N/A	C01405	13,385	343	NA
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01698	13,379	136	53
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01699	13,378	122	13
2014	Volkswagen	Tiguan	2nd Row, Passenger	6YO	C01704	13,373	310	77
2014	Volkswagen	Tiguan	2nd Row, Passenger	95th	C01705	13,413	308	29
2011	Hyundai	Tucson	1st Row, Driver	5th	C01700	13,483	89*	44
2011	Hyundai	Tucson	1st Row, Driver	95th	C01701	13,474	76*	9
2011	Hyundai	Tucson	1st Row, Driver	5th	C01706	13,390	739*	13
2011	Hyundai	Tucson	1st Row, Driver	95th	C01707	13,386	605*	62
2011	Hyundai	Tucson	1st Row, Driver	5th	C01711	7,098	740*	51
2011	Hyundai	Tucson	1st Row, Driver	95th	C01712	7,210	710*	7
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01702	13,371	131*	36
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01703	13,382	118*	16
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01708	13,373	675*	42
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01709	11,056	737*	23
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01710	13,372	711*	22
2011	Chevrolet	Traverse	1st Row, Driver	5th	C01713	9,924	737*	27
2011	Chevrolet	Traverse	1st Row, Driver	95th	C01714	9,801	704*	17

APPENDIX E: Minimal Webbing on the Spool Procedure

1) Install the respective hardware and fixtures on the tensile test machine.
2) Move the double roller block assembly/crosshead of the tensile test machine to the top of the machine's stroke and zero the position (**Figure E1**).

Figure E1. Crosshead of the Tensile Test Machine at Starting Position (left) Compared to Top of Stroke (right).

3) Move the crosshead down 100 mm and then zero the position.
4) Remove all webbing from the retractor spool and secure a locking clip to ensure no webbing retracts back on the spool (**Figure E2**).

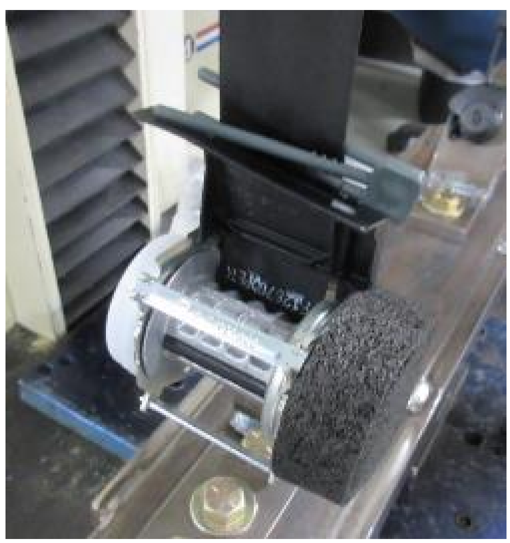

Figure E2. All Webbing Removed With Locking Clip.

5) Insert buckle and pull through any additional slack. Lock 3-bar locking clip above buckle to ensure no slipping of the webbing (**Figure E3**).

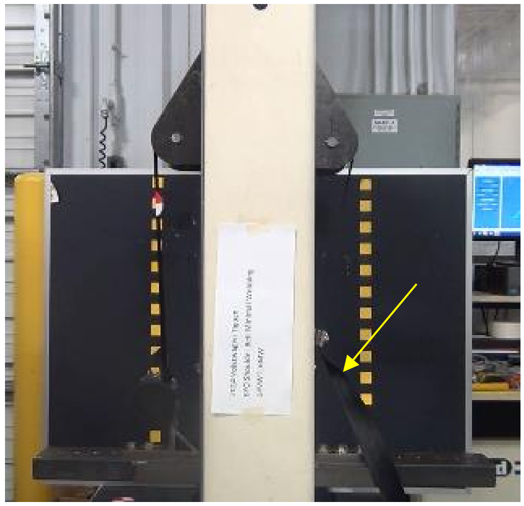

Figure E3. All Excess Webbing Pulled Through to the Buckle Side of the Assembly.

6) Jog the crosshead down and remove the locking clip to allow the webbing to spool back onto the retractor until the loop length matches the measured amount of webbing on the spool in the vehicle (**Figure E4**).

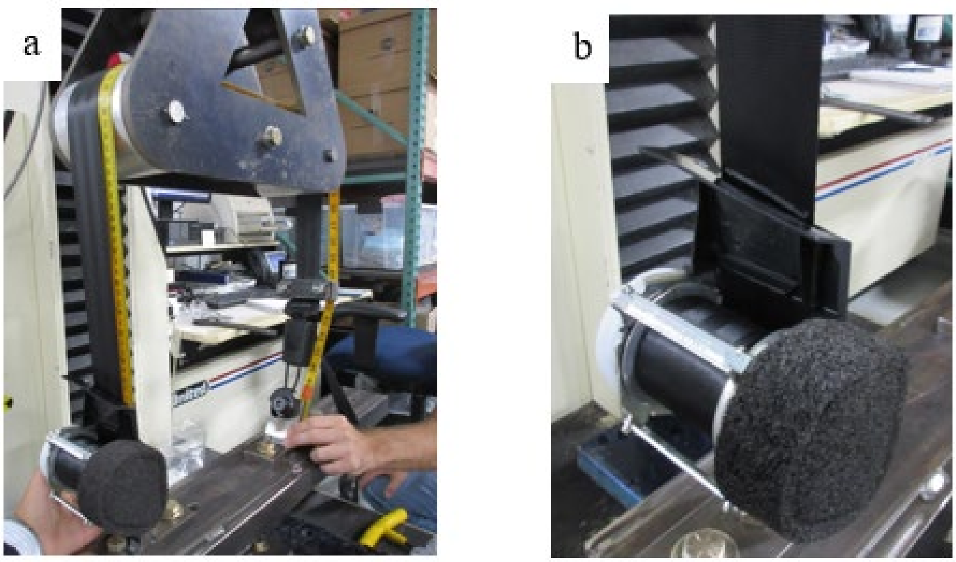

Figure E4. (a) Measured Loop Length That Matches Previous Testing; (b) Bebbing Spooled Back on the Retractor.

7) Verify the webbing is locked in the retractor.
8) Holding onto the retractor webbing to keep any webbing from spooling back onto retractor, unbuckle the buckle. Next, zero the force and elongation.
9) Load in the program and re-insert the buckle.
10) Run the test and record data per the Appendix C procedures.

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