
# JRS Dynamic Rollover Test

## 2007 Toyota Camry

### Hybrid Version

***Sponsored By:***

**Automotive Safety Research Institute**
**Charlottesville, VA.**

## Introduction

Center for Injury Research conducted a JRS dynamic rollover test consisting of two rolls of a 2007 Toyota Camry Hybrid on November 5th and 17th, 2009. This test report is organized in sections containing test information, data tables and photographs as follows:

Section 1 – Test Procedures and Summaries

Section 2 – Test Results, Data Tables and Selected Comparison Photographs for Roll 1.

Section 3 – Test Results, Data Tables and Selected Comparison Photographs for Roll 2.

Section 4 – Header Reinforcement Procedure

Section 5 – Data Graphs

Section 6 – All Test Photographs

Enclosed with this report is a DVD of the video of both rolls.

**2007 Toyota Camry Hybrid**


## Executive Summary

The test was a two roll event. The planned difference between the rolls was the pitch of the vehicle; 4.8 degrees in Roll 1 and 10.2 degrees in Roll 2 and the position of the Hybrid III dummy. For Roll 1, the dummy was located “out of position;" leaning towards the passenger side approximately 30°. For Roll 2, the dummy was placed in the position it was located at the end of Roll 1. Table 1 below describes the impact conditions of each test.

**Table 1** Summary of Test Conditions

| Roll | Pitch | Road Speed | Contact Angle | Roll Rate |
|---|---|---|---|---|
| **1** | 4.8 deg | 14.9 mph | 143 deg | 180 deg/sec |
| **2** | 10.2 deg | 14.9 mph | 136 deg | 185 deg/sec |

In Roll 1, the peak lower neck compressive load was 887 N and the peak lower neck moment was 22 Nm in flexion and 86 Nm in extension. The peak intrusion speed at the top of the A-Pillar was 5.2 mph with a peak crush of 5 inches.

In Roll 2, the peak lower neck compressive load was 273 N and the peak lower neck moment was 1 Nm in flexion and 37 Nm in extension. The peak intrusion speed at the top of the A-Pillar was 5.5 mph with a peak crush of 2.9 inches.

## 1. Test Procedure and Summaries

For each roll of the test, the following steps are performed:

1. Inspect the test vehicle for prior damage, rust or other factors that might influence the outcome of the test
2. Prepare the test equipment
3. Install and prepare the instrumentation and video cameras
4. Install the test vehicle in test fixture
5. Perform pre-test measurements
6. Photograph the vehicle
7. Conduct the test
8. Perform post test measurements
9. Photograph the vehicle following the test

The set up of the test vehicle in the fixture and the instrumentation in the vehicle was the same for Rolls 1 and 2 with the exception of the pitch angle; Roll 1 = 4.8° and Roll 2 = 10.2°.

The test weight of the vehicle was 3,545 pounds. The initial weight of the vehicle was 3,470 pounds. The test roll moment of inertia was approximately 480 lb*ft*sec$^2$ for a referenced value of 505 lb*ft*sec$^2$.

The header of the vehicle was reinforced with approximately 2.5 lbs of steel sheet metal. For a more detailed description refer to the header reinforcement procedure in section 5 of this report.

The vehicle was suspended on mounts at the rear and at the front in a manner that permits it to roll freely and be dropped, passenger side (the near side) leading.

Four string potentiometers were placed between the approximate longitudinal roll axis of the vehicle and the roof structure at the top of the driver's side A-pillar and B-pillar, at the header inboard of the A-pillar and at the top of the passenger's side A-pillar. An instrumented, restrained Hybrid III 50th percentile male test dummy was placed in the driver's seat. The dummy was instrumented with upper and lower neck load cells as well as a triaxial head accelerometer. In addition, seat belt load cells were utilized.

Each roll was conducted with a Hybrid III dummy equipped with a more biofidelic neck and lumbar joint, located in the driver's seat which was positioned 1.5" rearward of the mid seat position. The dummy was restrained using the vehicle's standard 3 point harness with a non-deployed pre-tensioner. For Roll 2, the shoulder belt was placed at the location it was found at the end of Roll 1; which was across the upper arm of the dummy. The dummy's head was chalked before each

roll to locate impact marks during the tests. To make the Hybrid III dummy more biofidelic, a 0.5 inch rubber insert was placed at the bottom of the lower spine. The two cables in the lower spine of the dummy were removed. The upper neck mounting block was replaced with a different block which increased the neck angle forward 30 degrees from the nominal position.

Six vertical and two lateral load cells were placed in the moving roadway to record the impact characteristics of the test.

Two string potentiometers were placed on the fixture support towers to record vehicle vertical motion characteristics during the test. One string potentiometer was located in the front drop tower and the other was located in the rear drop tower.

A roll encoder was placed on the cable pulley which pulls the moving roadway to record the roadway velocity throughout the test. In addition, a roll rate sensor was placed inside the vehicle.

The equipment used in the conduct of this test is listed in Table 2 and the test vehicle identification data is shown in Table 3 below.

**Table 2** Equipment and Instrumentation

| Item | MFR./Model |
|---|---|
| String Potentiometer – Driver's Side A-Pillar | Space Age Control – 301432 |
| String Potentiometer – Driver's Side B-Pillar | Space Age Control – 301432 |
| String Potentiometer – Roof Header | Space Age Control – 301432 |
| String Potentiometer – Passenger's Side A-Pillar | Space Age Control – 301432 |
| String Potentiometer – Front Fixture Support Tower | Space Age Control – 4332-01 |
| String Potentiometer – Rear Fixture Support Tower | Space Age Control – 4332-01 |
| Upper Neck Load Cell | RA Denton 1716A |
| Lower Neck Load Cell | RA Denton 1794A |
| Triaxial Head Accelerometer | Endevco, 7264C-2KTZ-2-240 |
| Belt Load Cell - Lap | RADenton 3255 |
| Belt Load Cell - Torso | RADenton 3255 |
| Roll Rate Sensor | DTS ARS |
| Hybrid III, 50$^{th}$ Percentile Male | Denton 50th Male |
| Vertical Load Cell 1 | Transducer Techniques, SWP-20k – 173372 |
| Vertical Load Cell 2 | Transducer Techniques, SWP-20k – 176138 |
| Vertical Load Cell 3 | Transducer Techniques, SWP-20k – 176139 |
| Vertical Load Cell 4 | Transducer Techniques, SWP-20k – 176140 |
| Vertical Load Cell 5 | Transducer Techniques, SWP-20k – 176141 |
| Vertical Load Cell 6 | Transducer Techniques, SWP-20k – 176142 |
| Lateral Load Cell 1 | Transducer Techniques, DSM-8k – 149806 |
| Lateral Load Cell 2 | Transducer Techniques, DSM-8k – 149807 |
| Roadway Velocity Roll Encoder | Contelec – RSC 2201 236 111 106 |
| Vehicle Roll Angle Roll Encoder | Contelec – RSC 2201 236 111 106 |
| Vehicle Data Acquisition System | Diversified Technical Systems, TDAS PRO SIM |
| Roadway Data Acquisition System | Diversified Technical Systems, TDAS PRO SIM |
| JRS Fixture Acquisition System | Measurement Computing, USB – 1608FS |

**Table 3** General Test Vehicle Data Test Vehicle: 2007 Toyota Camry Hybrid

| **Test Vehicle Information:** | |
|---|---|
| Manufacturer: Toyota | VIN: 4T1BB46K07U012585 |
| Gross Weight: 4,655 lbs | Curb Weight: 3,637 lbs |
| Sunroof: No | 2WD/4WD: 2WD |
| Equivalent Years: 2007- Present | Body Type: 4 Door Sedan |

## 2. Test Results, Data Tables and Selected Comparison Photographs for Roll 1.

The results of the first roll of the JRS Dynamic Rollover Test are presented in this section. In the roll, the vehicle dropped as planned and contacted the vehicle's roof structure.

**Roll 1 – 11/05/2009**

Summary of Results

| Instrument | Peak Value | Residual Intrusion (inches) | Peak Velocity (mph) |
|---|---|---|---|
| Sum of Vertical Load Cells (near side)* | 10,439 lbs | | |
| Sum of Vertical Load Cells (far side)* | 20,024 lbs | | |
| Sum of Lateral Load Cells (near side) | 1,045 lbs | | |
| Sum of Lateral Load Cells (far side) | 2,230 lbs | | |
| Driver's Side A-Pillar String Potentiometer | 5.0 in | 2.7 | 5.2 |
| Driver's Side B-Pillar String Potentiometer | 4.2 in | 1.7 | 5.1 |
| Roof Header String Potentiometer | 2.9 in | 1.5 | 4.5 |
| Passenger's Side A-Pillar String Potentiometer | 0.5 in | -0.5 | 1.3 |

* Vertical load cell number 2 did not function properly and its data was excluded.

| Instrument | Maximum Value | Minimum Value |
|---|---|---|
| Dummy Head Accelerometer, Ax | 53 g | -28 g |
| Dummy Head Accelerometer, Ay | 52 g | -33 g |
| Dummy Head Accelerometer, Az | 35 g | -68 g |
| Head Injury Criteria (HIC) | 108 | |
| Lower Neck Load, Fx | 1,688 N | -163 N |
| Lower Neck Load, Fy | 530 N | -195 N |
| Lower Neck Load, Fz | 887 N | -229 N |
| Lower Neck Load, Mx | 18 N-m | -9 N-m |
| Lower Neck Load, My | 22 N-m | -86 N-m |
| Upper Neck Load, Fz | 239 N | -2,683 N |
| Lap Belt Load | 177 lbs | -5 lbs |
| Torso Belt Load | 136 lbs | -4 lbs |

The vertical load cells mounted on the roadway platform show the near and far side impacts. The vehicle struck the roadway on the near side at approximately 1.59 seconds. The entire roll sequence was completed by approximately 1.94 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 3.8 inches and the rear dropped 4.7 inches prior to initial touch down. The vehicle was pitched at 4.8 degrees at contact.

The roll encoder located on the cable pulley shows the roadway velocity throughout the roll. The roadway was traveling at 14.9 mph at contact. A roll rate sensor in the vehicle was used to determine the roll angle and rate at impact. The roll angle of the vehicle was 143 degrees and the roll rate was 180 degrees per second at the roadway impact.

During the first roll the windshield fractured and the rear window shattered. There was deformation of the far side C-pillar. There was no indication of fluid leakage from the Hybrid system.

Roadway vertical load cell number 2 recorded very large amounts of noise during the impact phase of the test. The data from number 2 was excluded from all charts and values concerning vertical roadway impact loads. The roadway load charts and values only contain the sum of the vertical load recorded by 5 of the 6 load cells. For reference, from an almost identical previous test with a non-hybrid 2007 Toyota Camry weighing about 10% less, we estimate that the peak value measured by load cell number 2 would have been approximately 3,300 lbs.

**Roll 1 Comparison Photographs**


Figure 1: Vehicle Pre Roll 1 (roof view)


Figure 2: Vehicle Post Roll 1

## 3. Test Results, Data Tables and Selected Comparison Photographs for Roll 2.

The results of the second roll of the JRS Dynamic Rollover Test are presented in this section. In the roll, the vehicle dropped as planned and contacted the vehicle's roof structure.

**Roll 2 – 11/17/2009**

Summary of Results

| Instrument | Peak Value | Residual Intrusion (inches) | Peak Velocity (mph) |
|---|---|---|---|
| Sum of Vertical Load Cells (near side) | 9,850 lbs | | |
| Sum of Vertical Load Cells (far side) | 28,919 lbs | | |
| Sum of Lateral Load Cells (near side) | 829 lbs | | |
| Sum of Lateral Load Cells (far side) | 1,769 lbs | | |
| Driver's Side A-Pillar String Potentiometer | 2.9 in | 1.0 | 5.5 |
| Driver's Side B-Pillar String Potentiometer | 1.4 in | 0.0 | 3.1 |
| Roof Header String Potentiometer | 2.5 in | 1.0 | 4.0 |
| Passenger's Side A-Pillar String Potentiometer | 1.9 in | 0.6 | 2.3 |

| Instrument | Maximum Value | Minimum Value |
|---|---|---|
| Dummy Head Accelerometer, Ax | 11 g | -11g |
| Dummy Head Accelerometer, Ay | 25g | -4 g |
| Dummy Head Accelerometer, Az | 6 g | -11 g |
| Head Injury Criteria (HIC) | 12 | |
| Lower Neck Load, Fx | 1,129 N | -18 N |
| Lower Neck Load, Fy | 557 N | -93 N |
| Lower Neck Load, Fz | 243 N | -134 N |
| Lower Neck Load, Mx | 7 Nm | -15 Nm |
| Lower Neck Load, My | 1 Nm | -37 Nm |
| Upper Neck Load, Fz | 172 N | -1,048 N |
| Lap Belt Load | 154 lbs | -8 lbs |
| Torso Belt Load | 123 lbs | -2 lbs |

The vertical load cells mounted on the roadway platform show the near and far side impacts. The vehicle struck the roadway on the near side at approximately 1.75 seconds. The entire roll sequence was completed by approximately 2.07 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 4.9 inches and the rear dropped 4.3 inches prior to initial touch down. The vehicle was pitched at 10.2 degrees at contact.

The roll encoder located on the cable pulley shows the roadway velocity throughout the roll. The roadway was traveling at 14.9 mph at contact. A roll rate sensor in the vehicle was used to determine the roll angle and roll rate at impact. The roll angle of the vehicle was 136 degrees and the roll rate was 185 degrees per second at the roadway impact.

During the second roll the windshield fractured further. There was minor additional deformation of the far side C-Pillar. There was no indication of fluid leakage from the Hybrid system. The front tower mount contacted the front stop during the roll at approximately 200 degrees. There was minimal deformation of the deformable stop indicating that the vehicle would not have dropped much more (if at all) if the stop was not there. The roof therefore would have had a minimal amount of additional roof crush on the far side.

**Roll 2 Comparison Photographs**


Figure 3: Vehicle Pre Roll 2


Figure 4: Vehicle Post Roll 2

## 4. Header Reinforcement Procedure

The following reinforcement procedure was performed on the 2007 Toyota Camry Hybrid prior to testing. Figure 5 describes the fabrication of the steel component that was attached to the header of the vehicle.

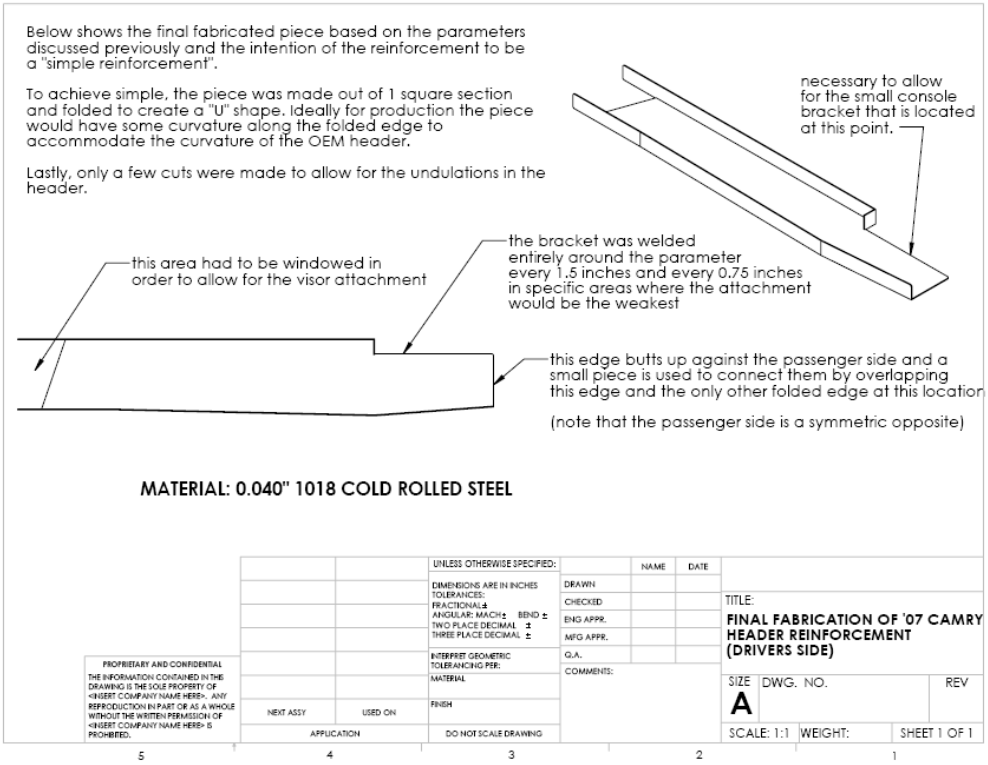



Figure 5. Drawing of reinforcement component

The header was welded along the inboard edge every 2-2.5 inches. 20 rivets, with backup washers on the blind side, were also used along the 45 inch span of the header. See figure 6.


Figure 6. Driver side of header

The driver's side component was connected to the passenger's side component via a welded junction . See figure 7. The small triangular center piece wraps around towards the windshield.

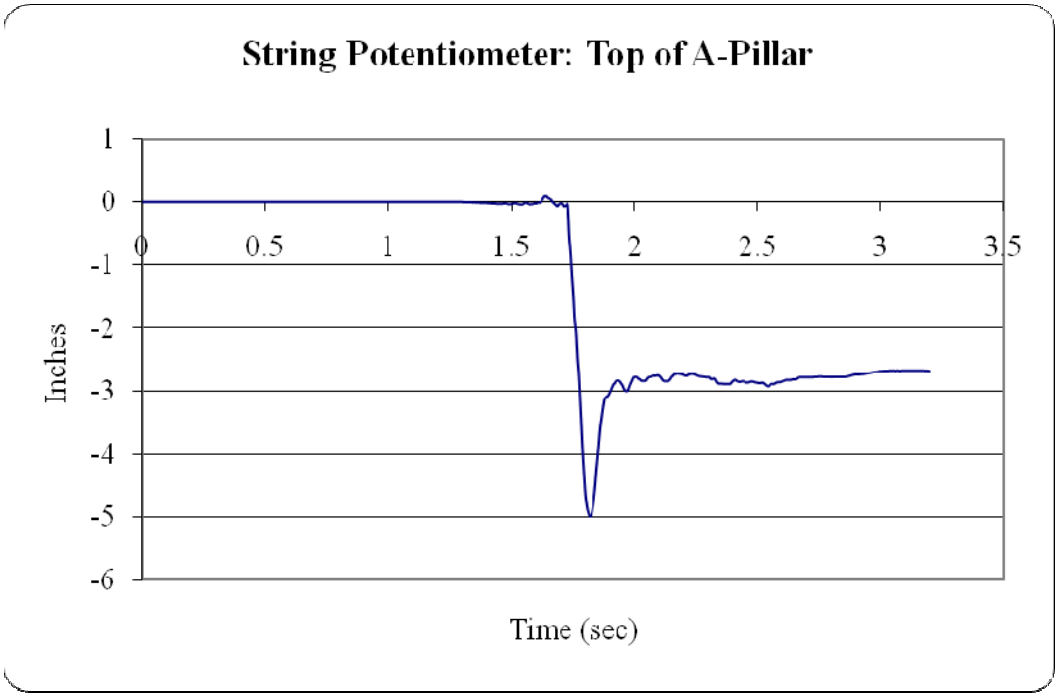

Figure 7. Junction at the center

Each end of the component was fabricated to allow for access to the visor attachment and to ease the transition from the stiffer reinforced section to the weaker corner without creating a connection prone to high stresses. See figure 8.


Figure 8. Driver side outboard attachment

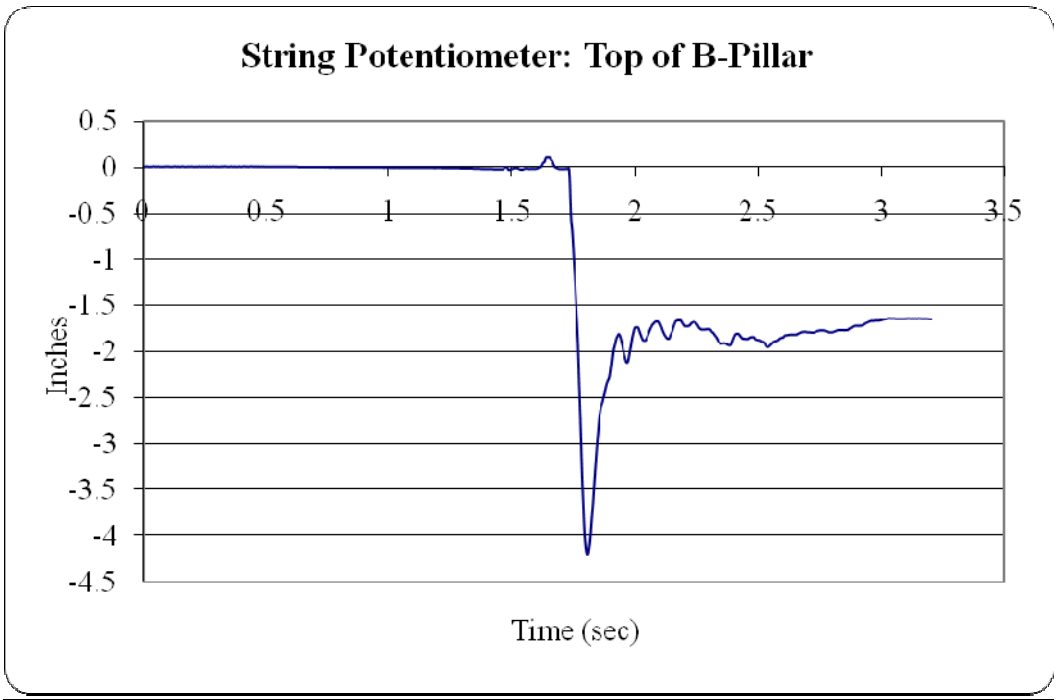
## 5. Data Graphs

**Roll 1 Data Plots – 11/05/2009**




Plot 1: String Potentiometer Driver's Side A-Pillar Displacement v. Time

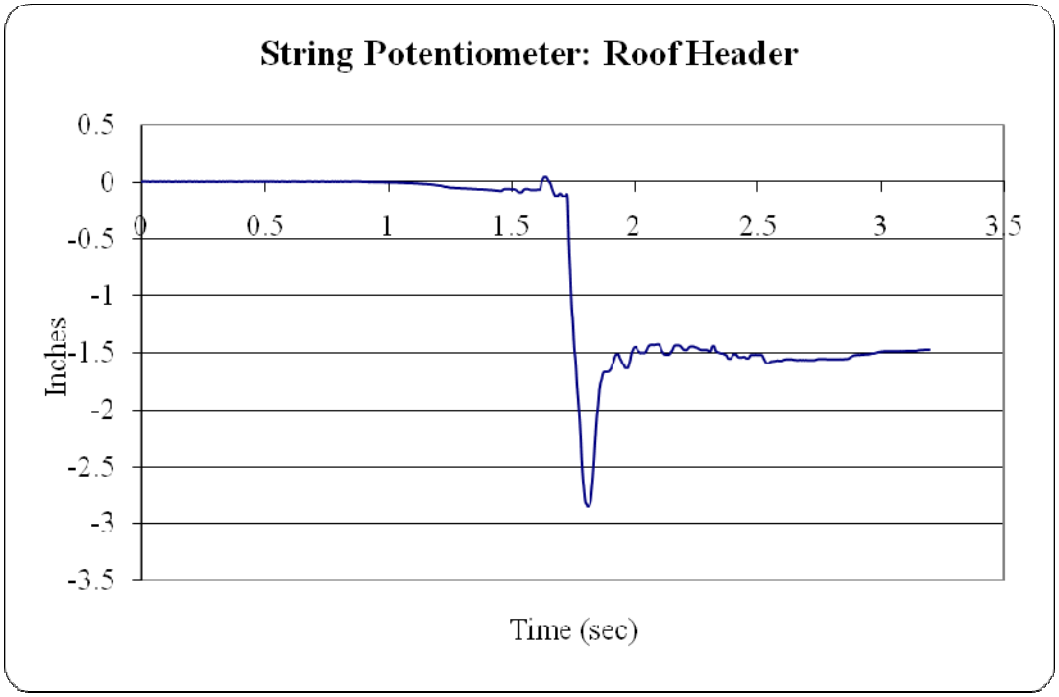
Data Sampling Rate: 10 kHz




Plot 2: String Potentiometer Driver's Side B-Pillar Displacement v. Time

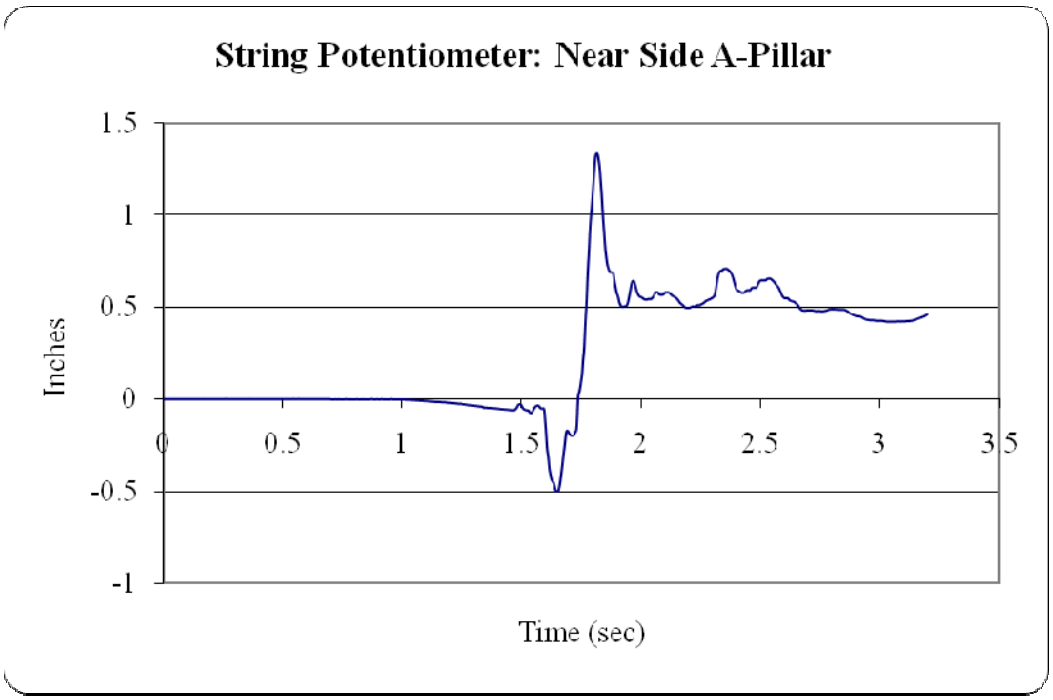
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 3: String Potentiometer Driver's Side Roof Header Displacement v. Time

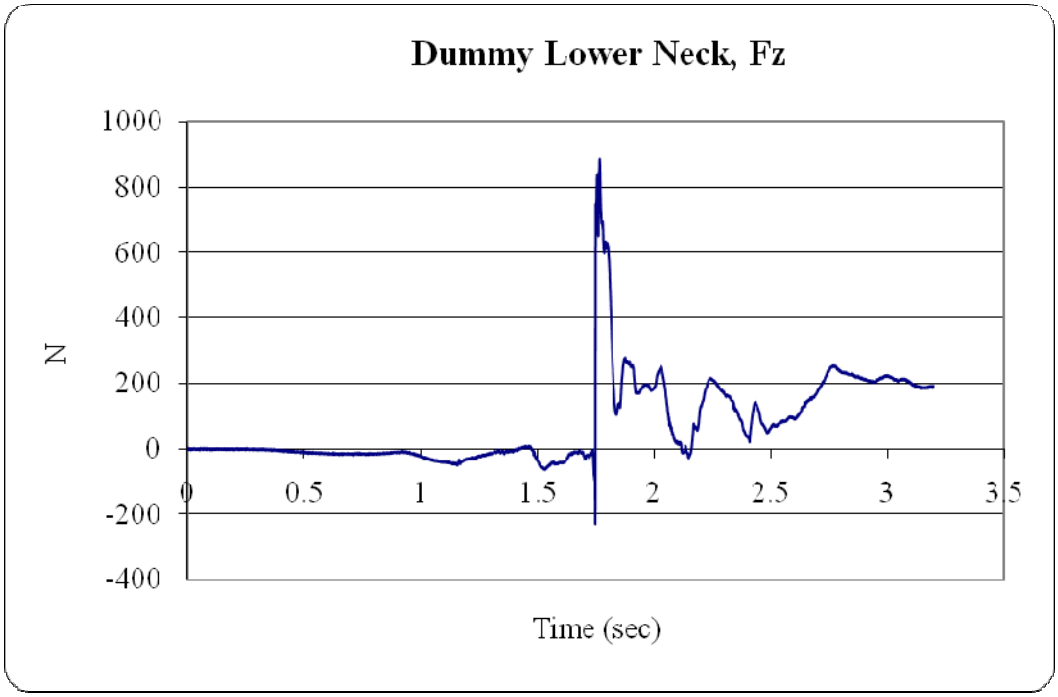
Data Sampling Rate: 10 kHz




Plot 4: String Potentiometer Passenger's Side A-Pillar Displacement v. Time

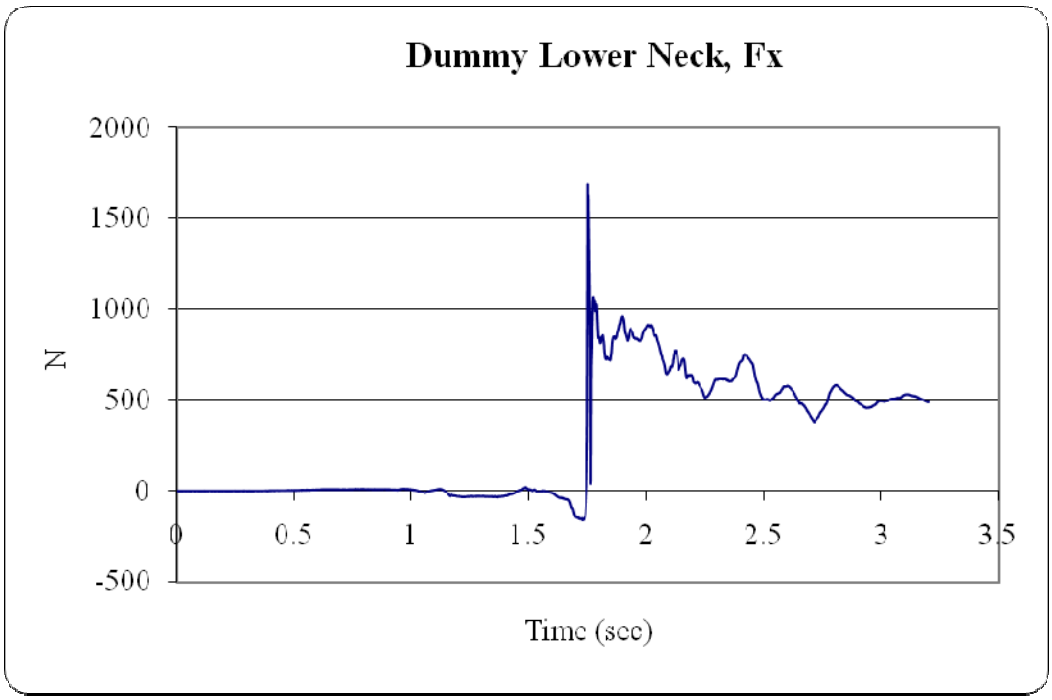
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 5: Lower Neck Load, Fz, v. Time

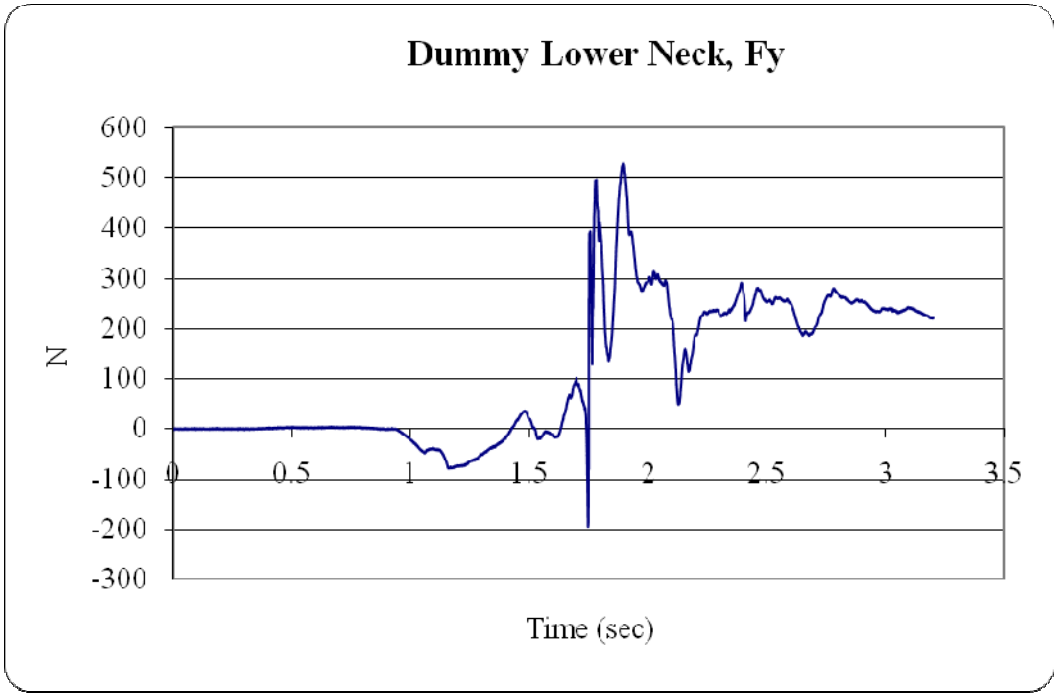
Data Sampling Rate: 10 kHz




Plot 6: Lower Neck Load, Fx, v. Time

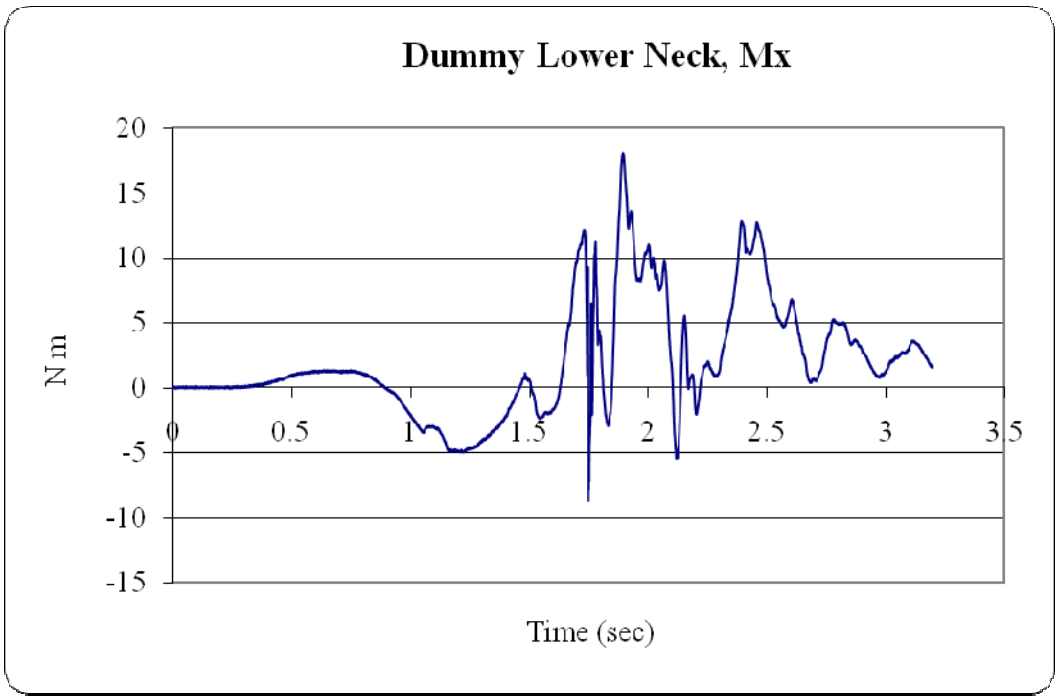
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 7: Lower Neck Load, Fy, v. Time

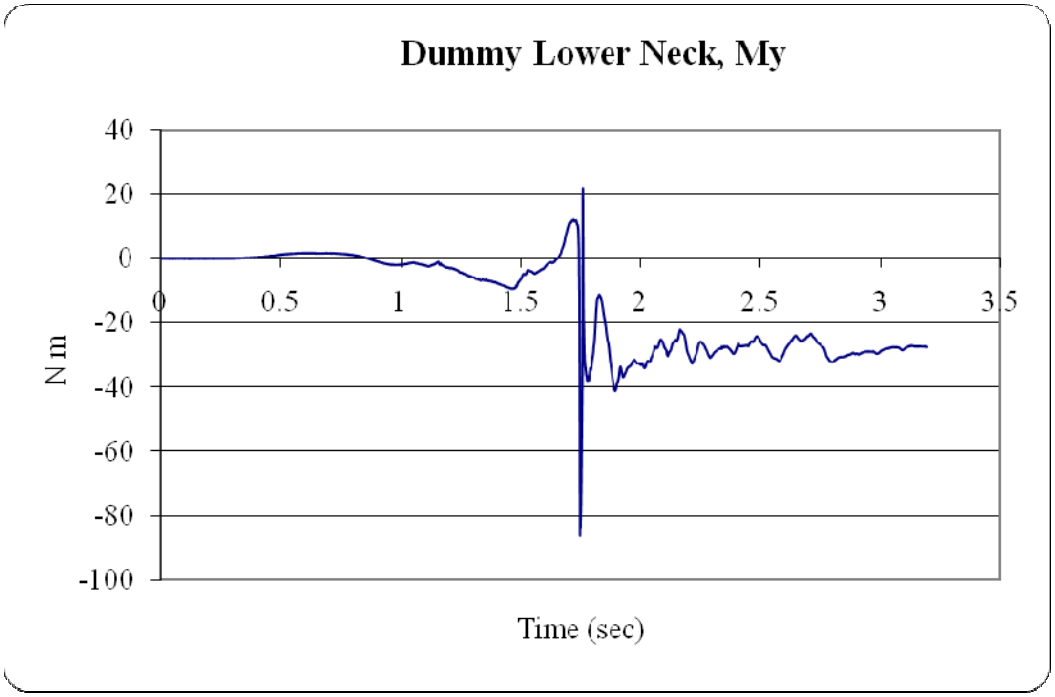
Data Sampling Rate: 10 kHz




Plot 8: Lower Neck Load, Mx, v. Time

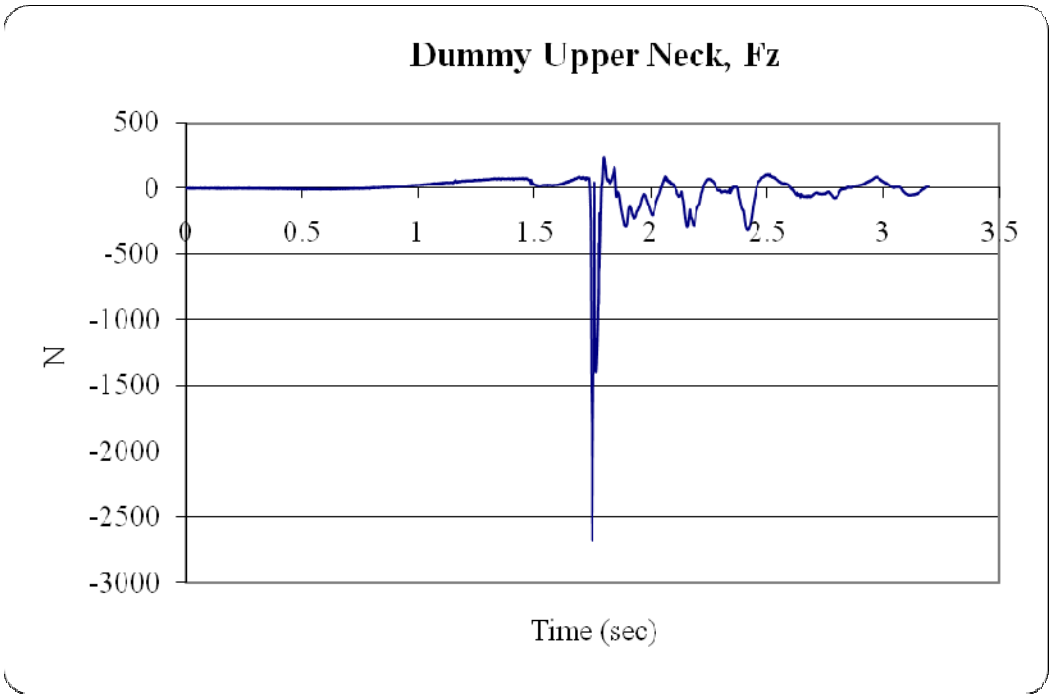
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 9: Lower Neck Load, My, v. Time

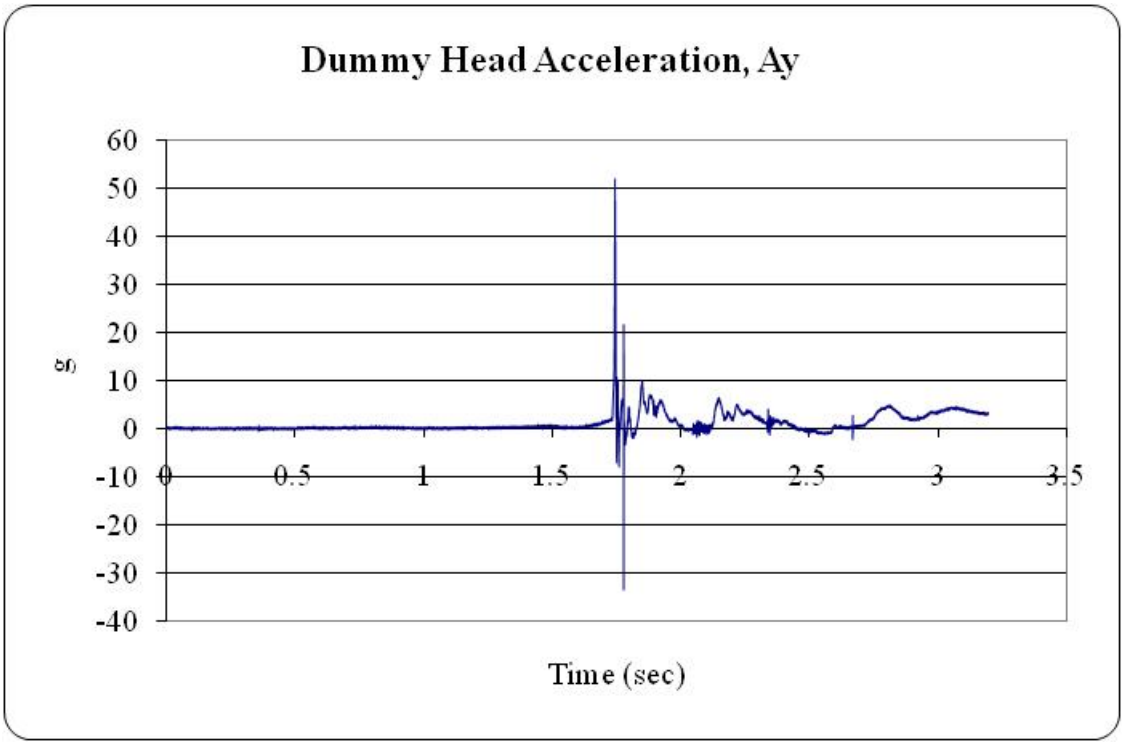
Data Sampling Rate: 10 kHz




Plot 10: Upper Neck Load, Fz, v. Time

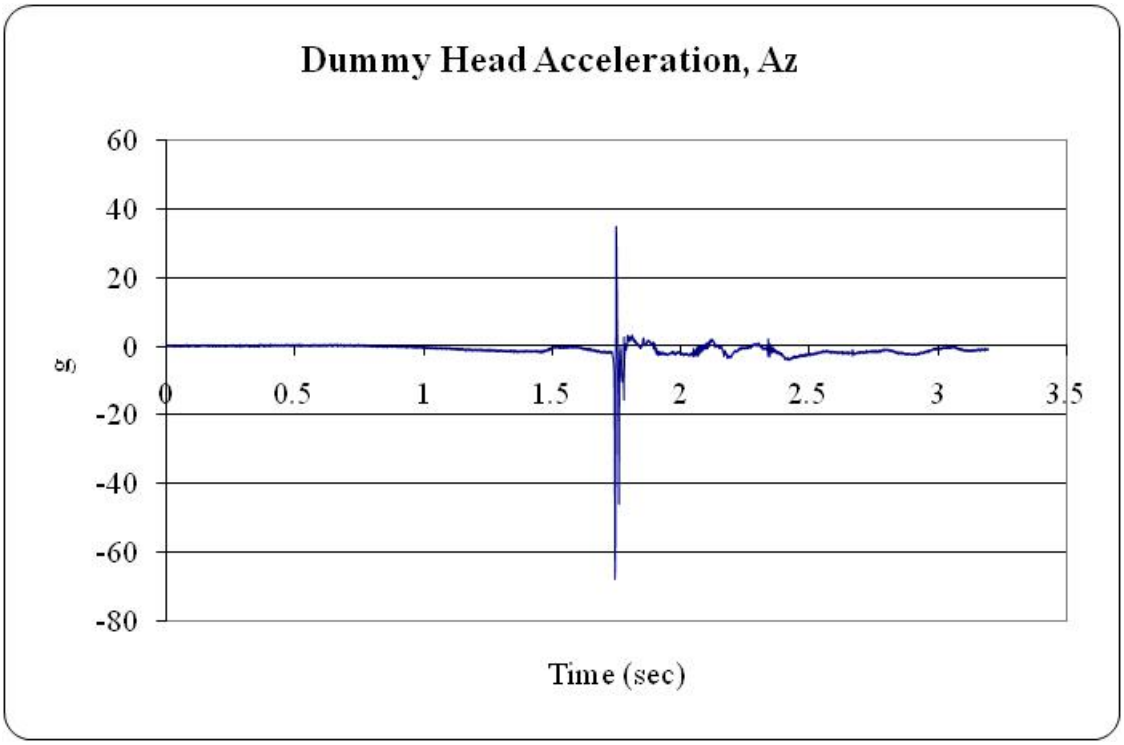
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 11: Head Acceleration, Ay, vs. Time

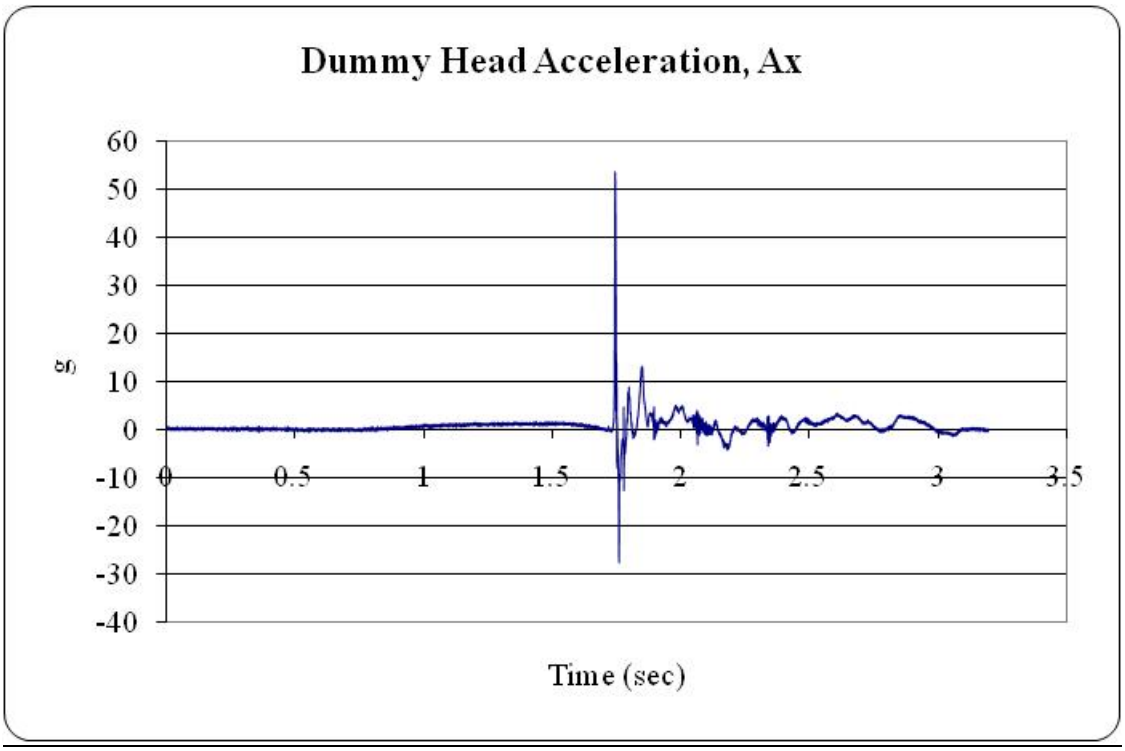
Data Sampling Rate: 10 kHz




Plot 12: Head Acceleration, Az, vs. Time

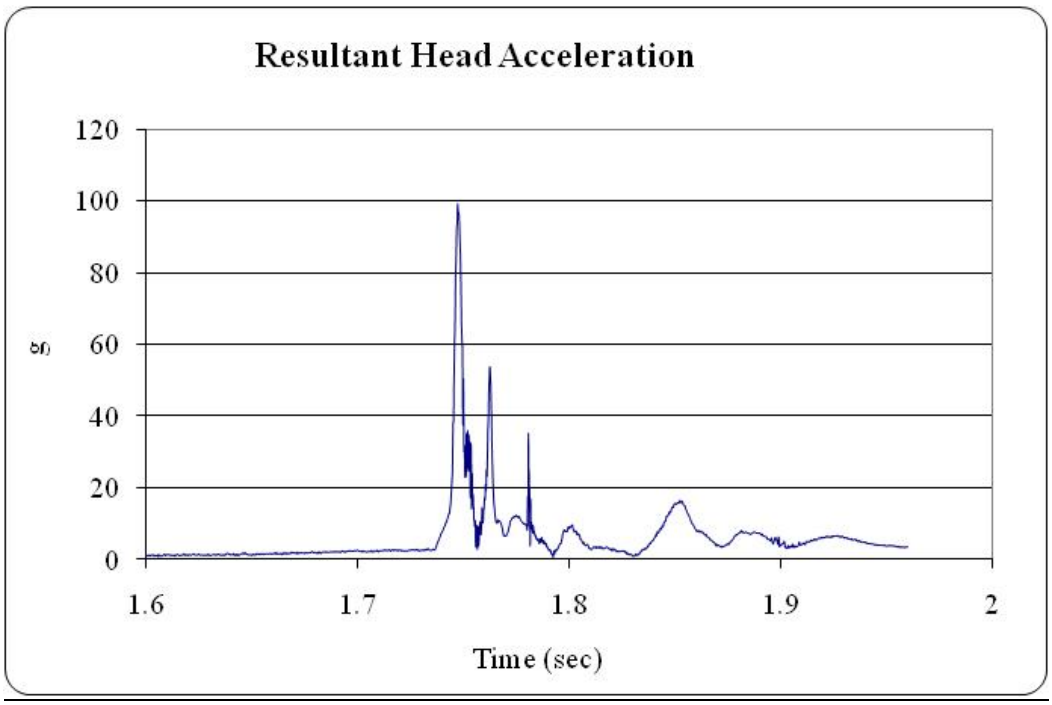
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 13: Head Acceleration, Ax, vs. Time

Data Sampling Rate: 10 kHz

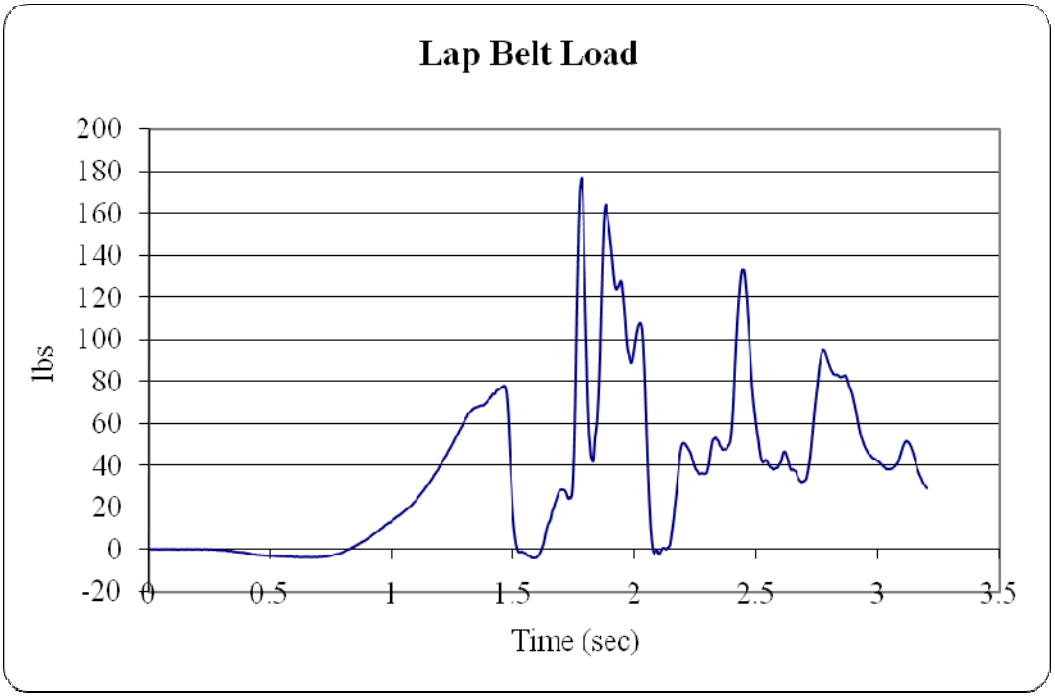



Plot 14: Resultant Head Acceleration vs. Time

**HIC = 108**

Data Sampling Rate: 10 kHz

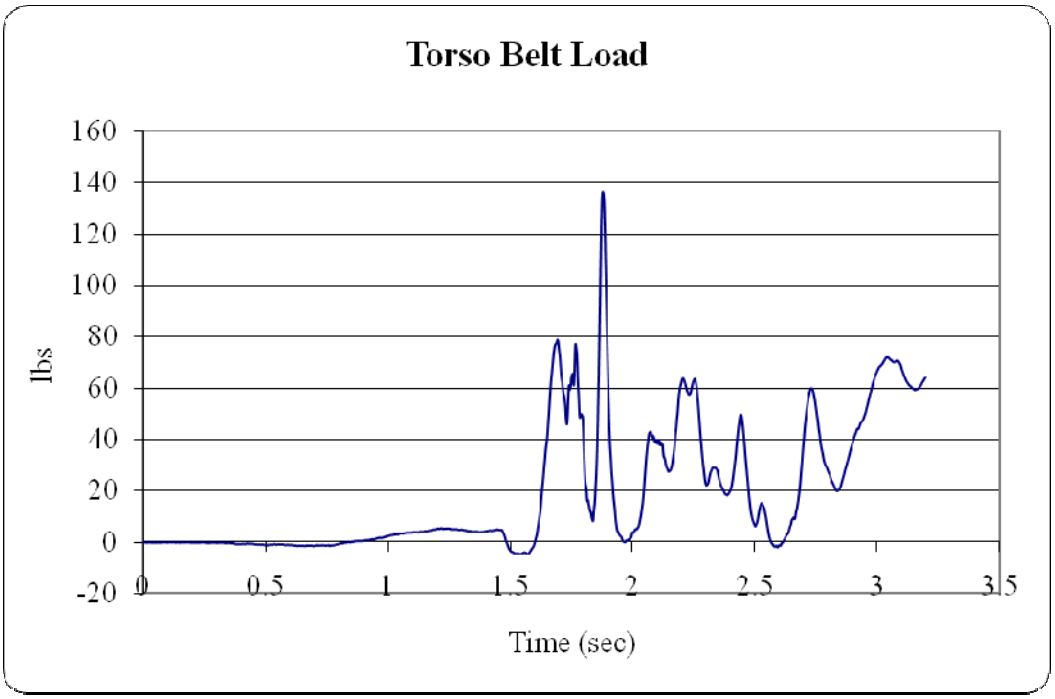
**Roll 1**




Plot 15: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

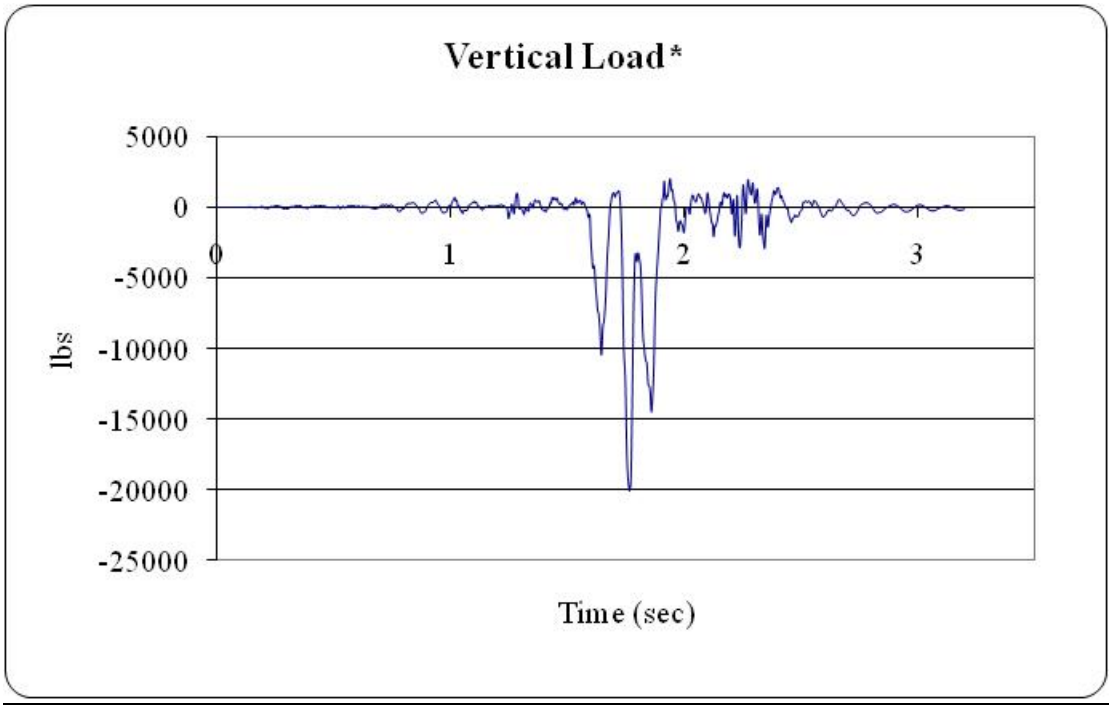



Plot 16: Torso Belt Load* vs. Time

*Measured on one side of the belt

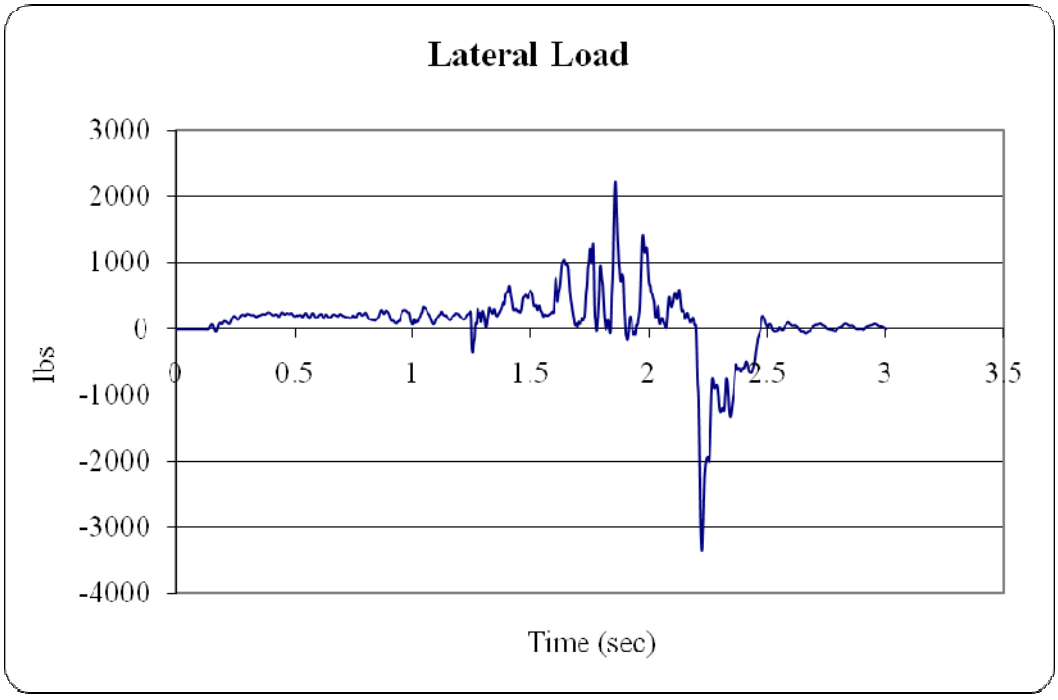
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 17: Total Vertical Load* v. Time

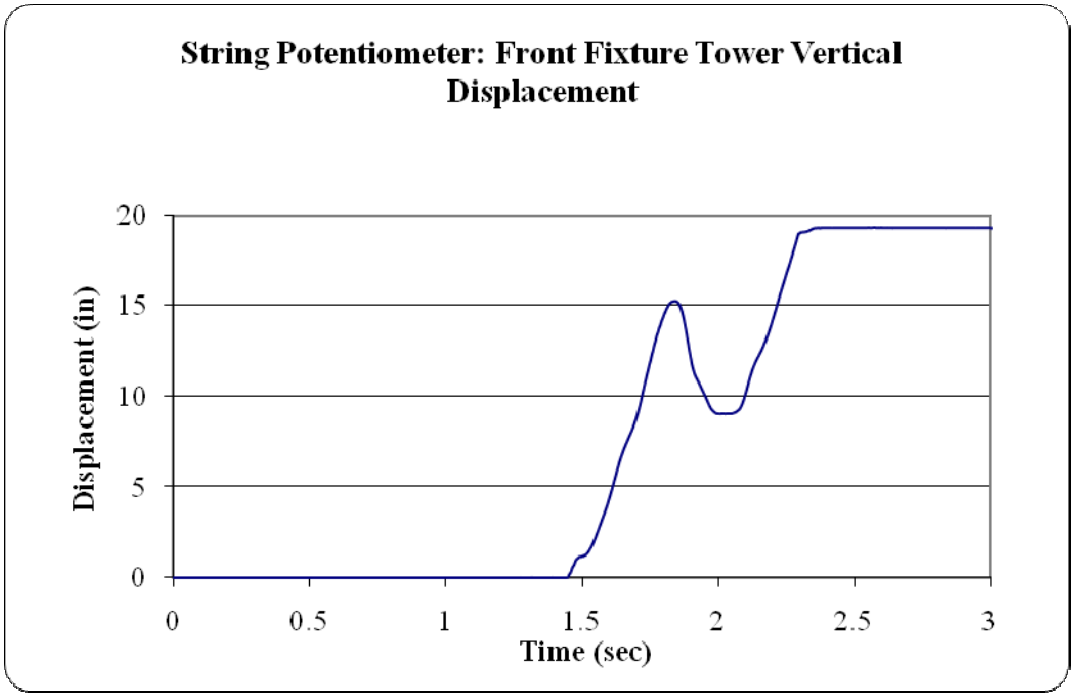
*Vertical load cell number 2 (out of 6) did not function properly and its data was excluded.
Data Sampling Rate: 10 kHz




Plot 18: Total Lateral Load v. Time

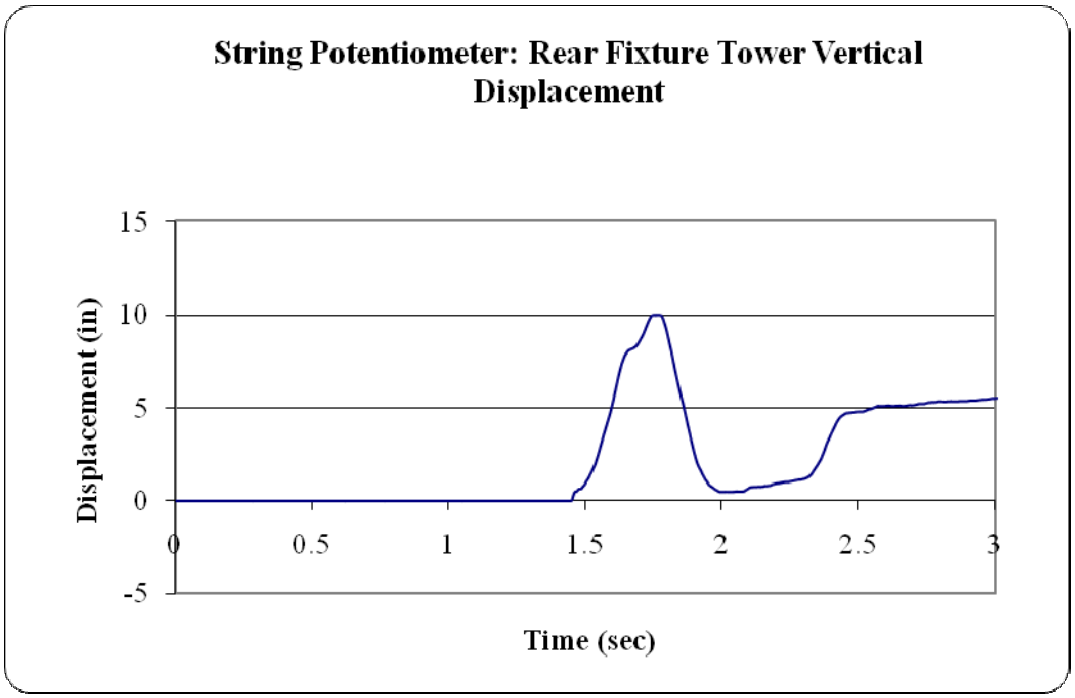
Data Sampling Rate: 10 kHz

**Roll 1**




Plot 19: String Potentiometer Front Fixture Support Tower Displacement vs. Time

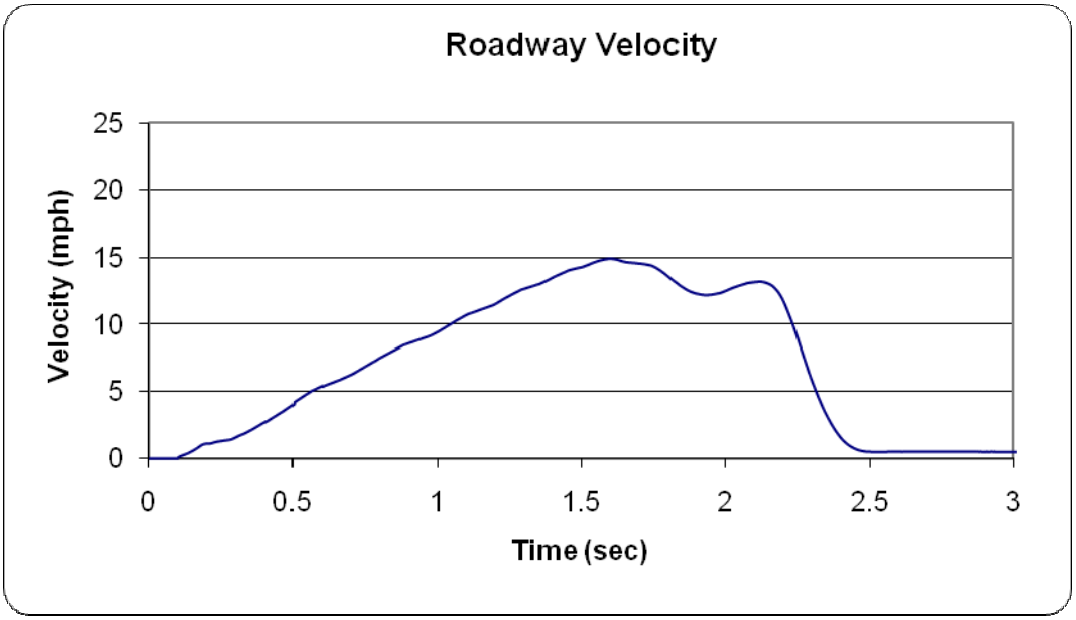
Data Sampling Rate: 1 kHz




Plot 20: String Potentiometer Rear Fixture Support Tower Displacement vs. Time

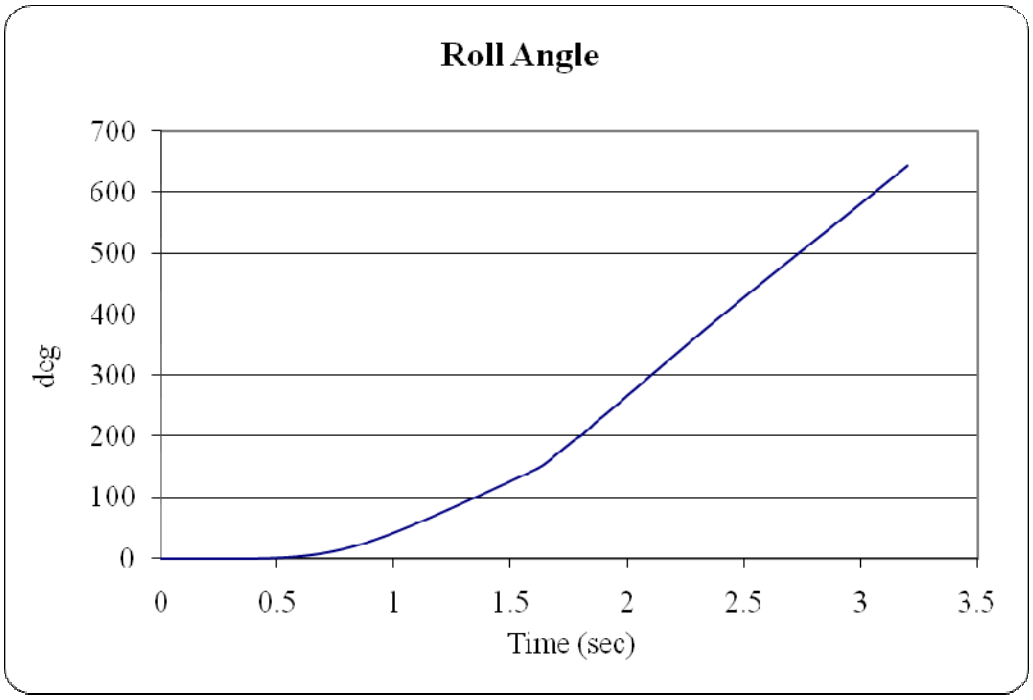
Data Sampling Rate: 1 kHz

**Roll 1**




Plot 21: Roll Encoder on Roadway Velocity vs. Time

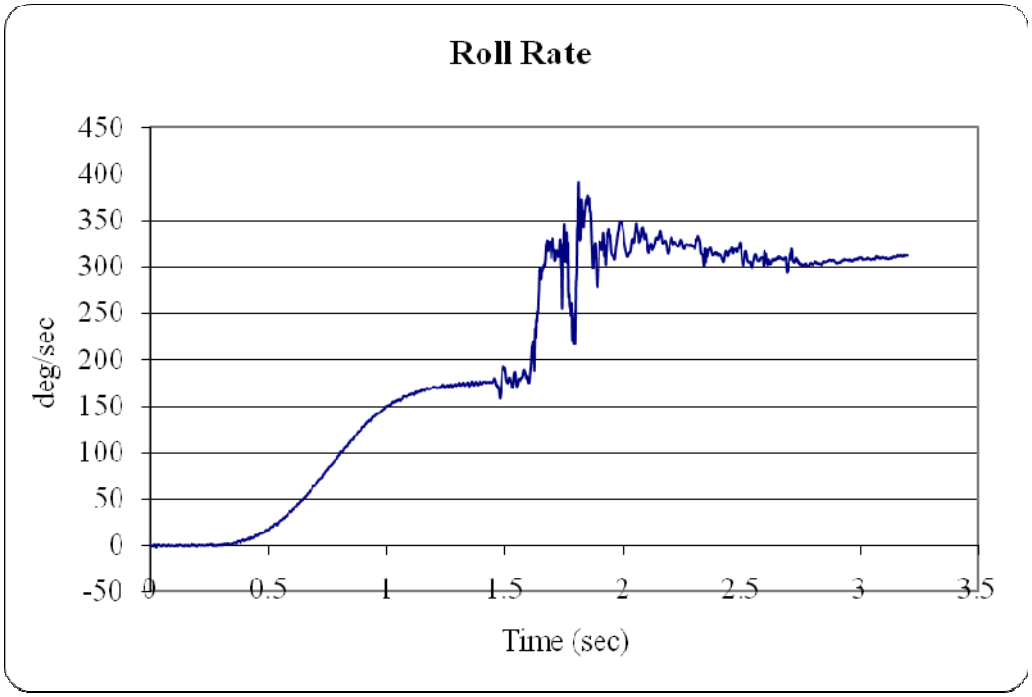
Data Sampling Rate: 1 kHz




Plot 22: Roll Angle vs. Time

Data Sampling Rate: 10 kHz

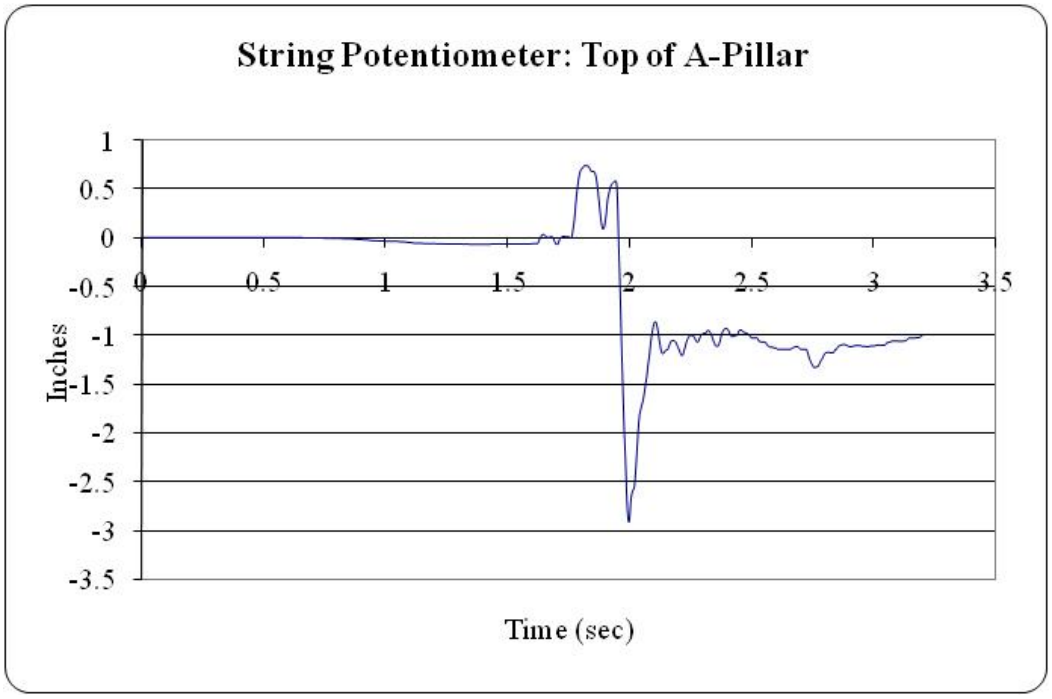
**Roll 1**




Plot 23: Roll Rate vs. Time

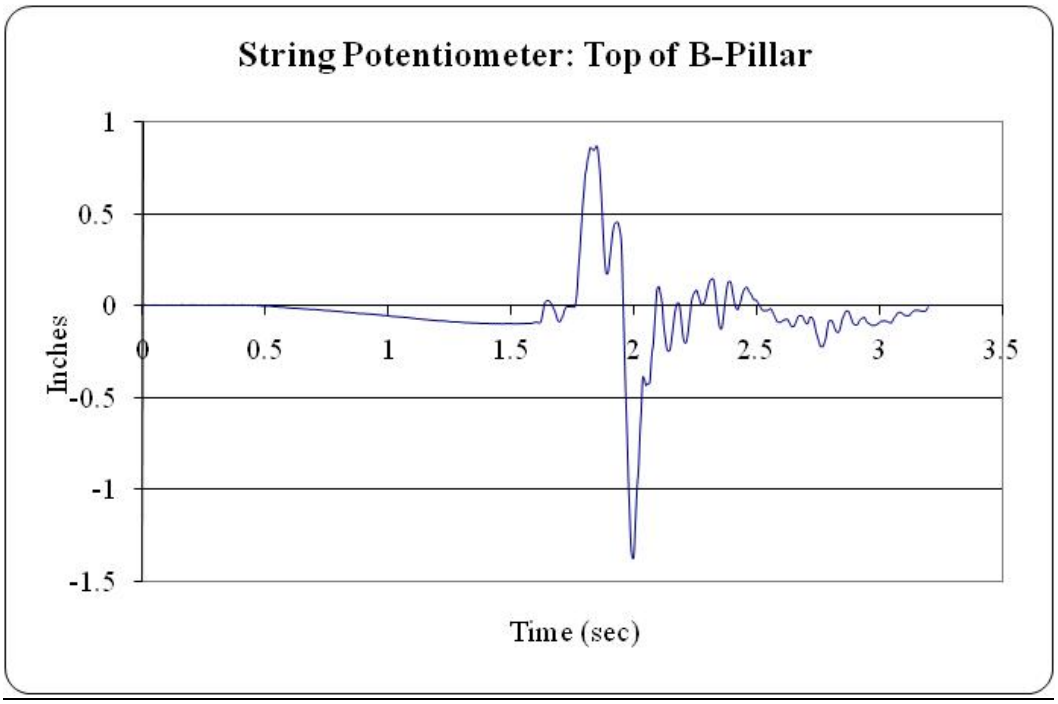
Data Sampling Rate: 10 kHz

**Roll 2 Data Plots – 11/17/2009**




Plot 24: String Potentiometer Driver's Side A-Pillar Displacement v. Time

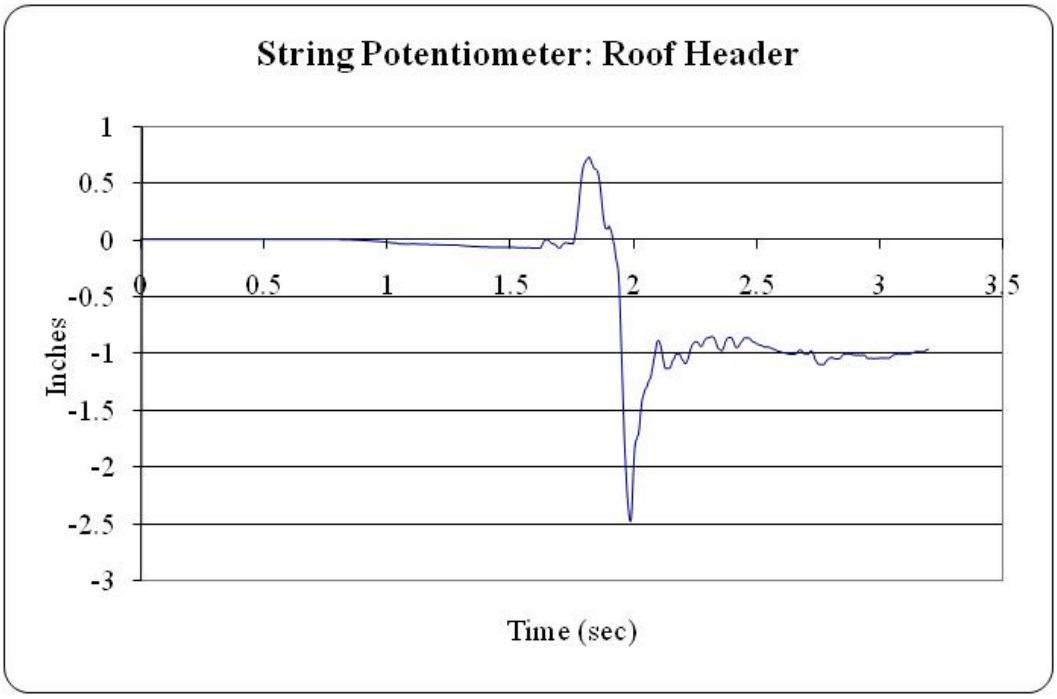
Data Sampling Rate: 10 kHz




Plot 25: String Potentiometer Driver's Side B-Pillar Displacement v. Time

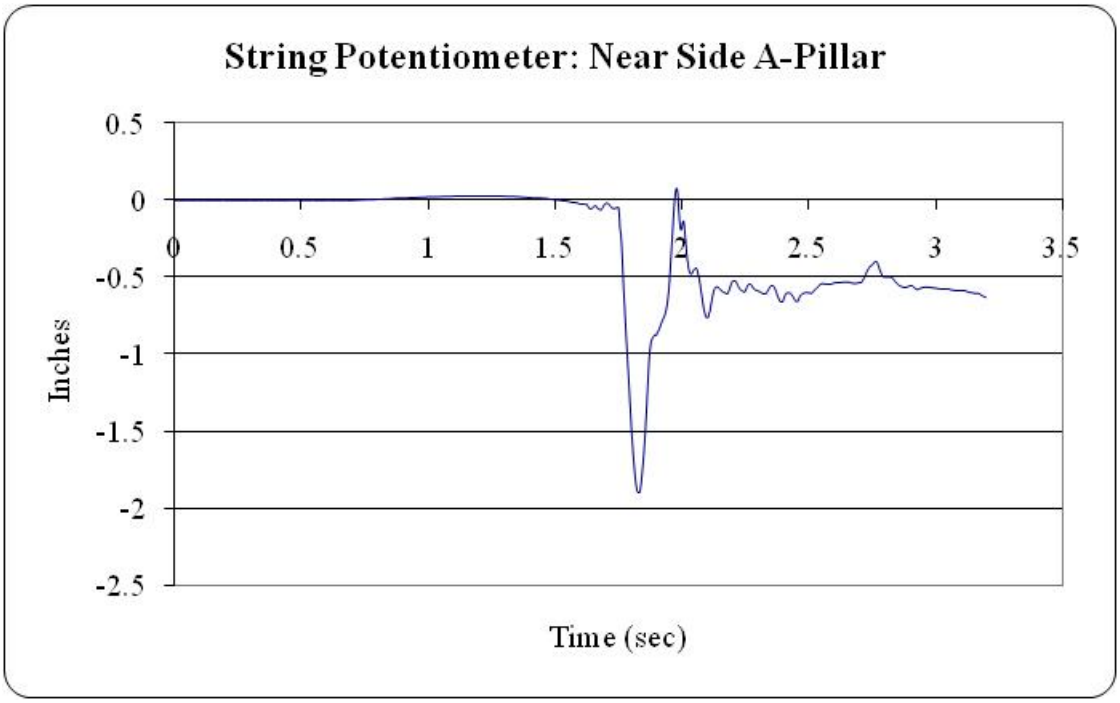
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 26: String Potentiometer Driver's Side Roof Header Displacement v. Time

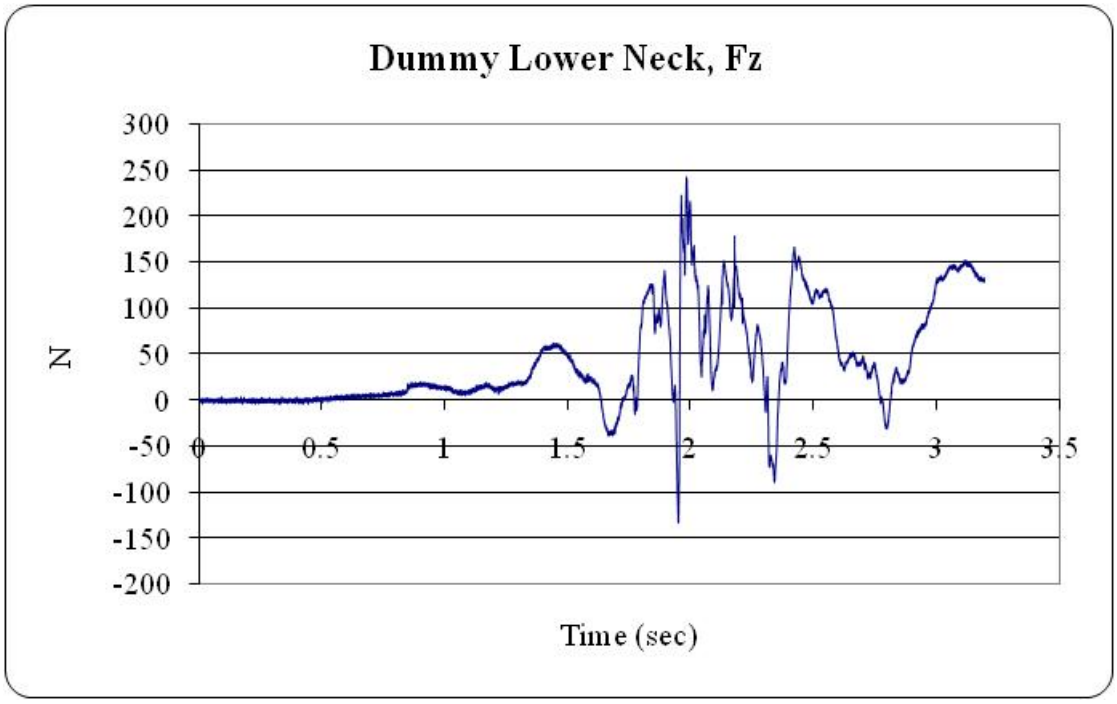
Data Sampling Rate: 10 kHz




Plot 27: String Potentiometer Passenger's Side A-Pillar Displacement v. Time

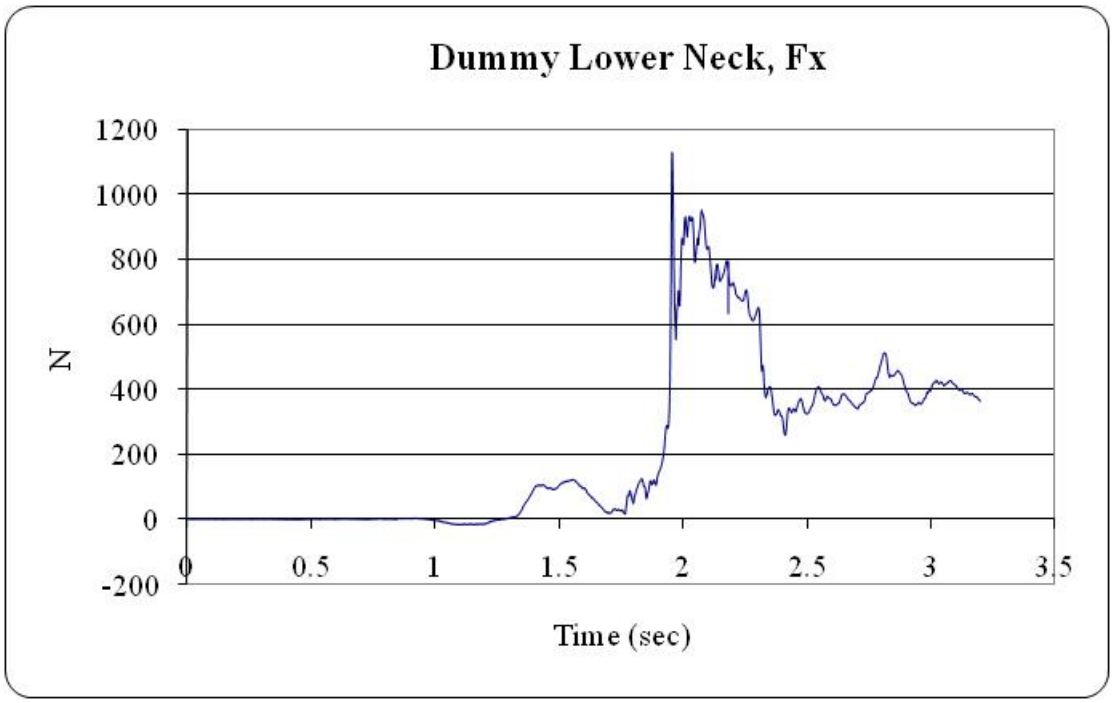
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 28: Lower Neck Load, Fz, v. Time

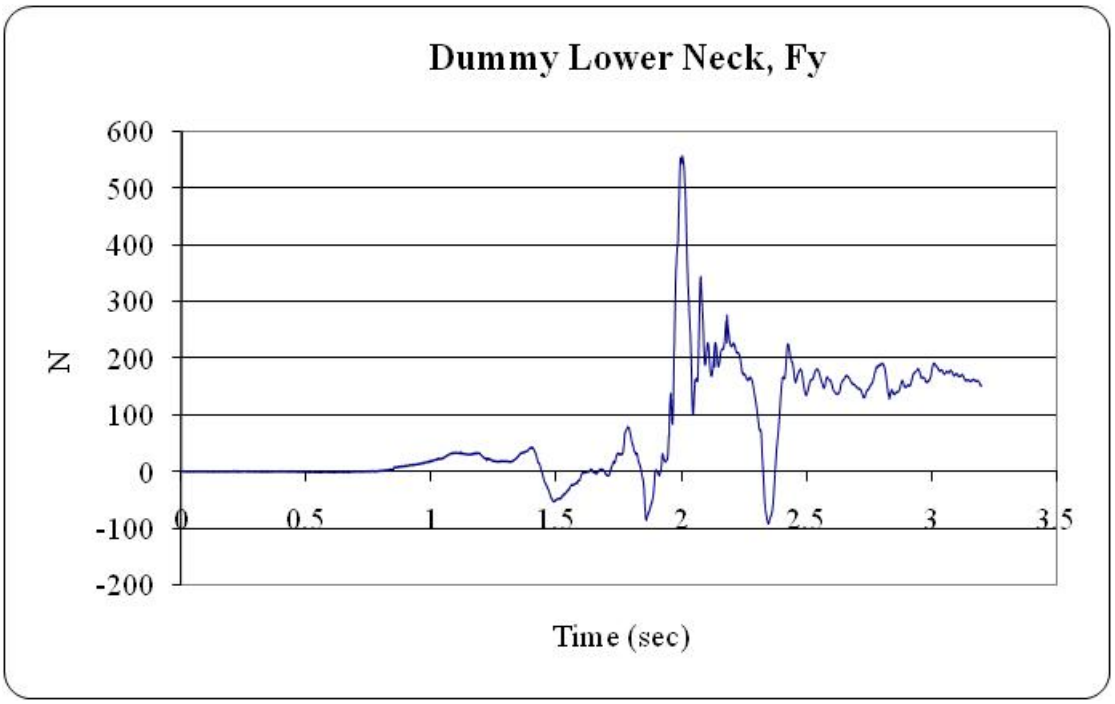
Data Sampling Rate: 10 kHz




Plot 29: Lower Neck Load, Fx, v. Time

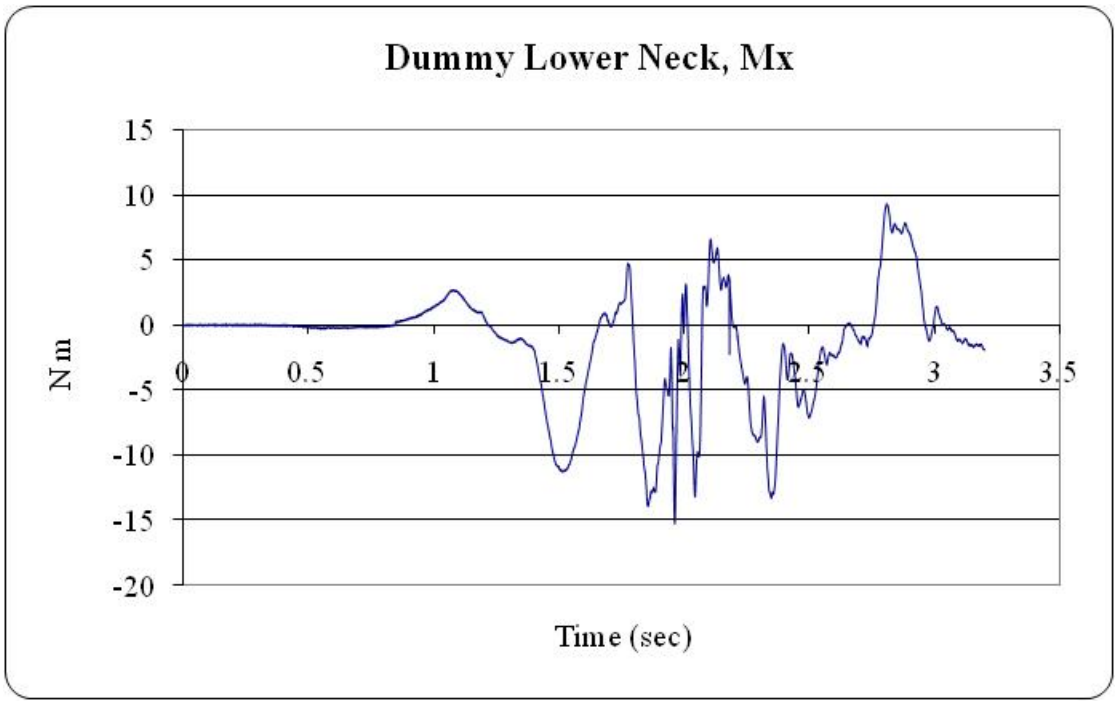
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 30: Lower Neck Load, Fy, v. Time

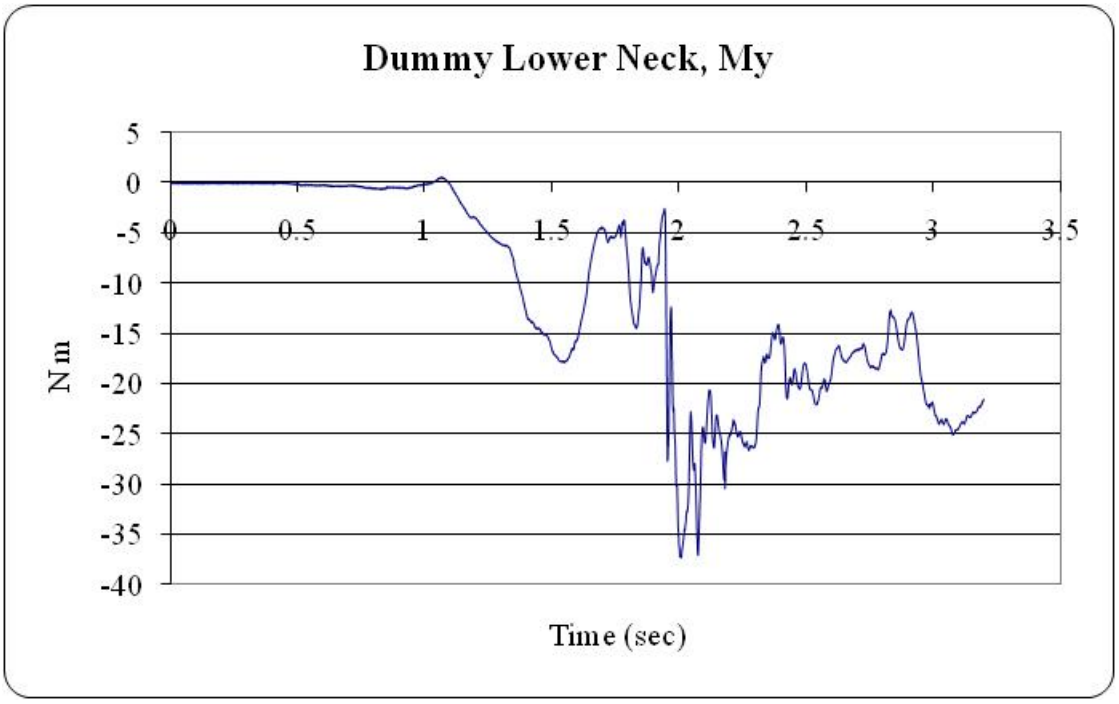
Data Sampling Rate: 10 kHz




Plot 31: Lower Neck Load, Mx, v. Time

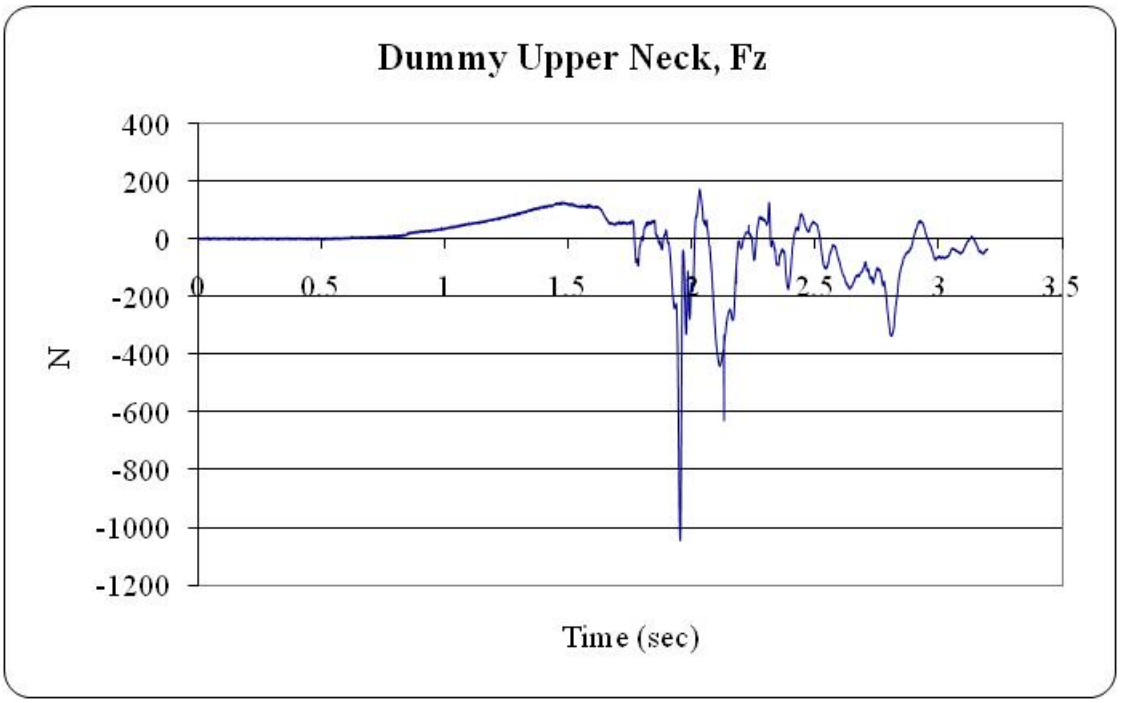
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 32: Lower Neck Load, My, v. Time

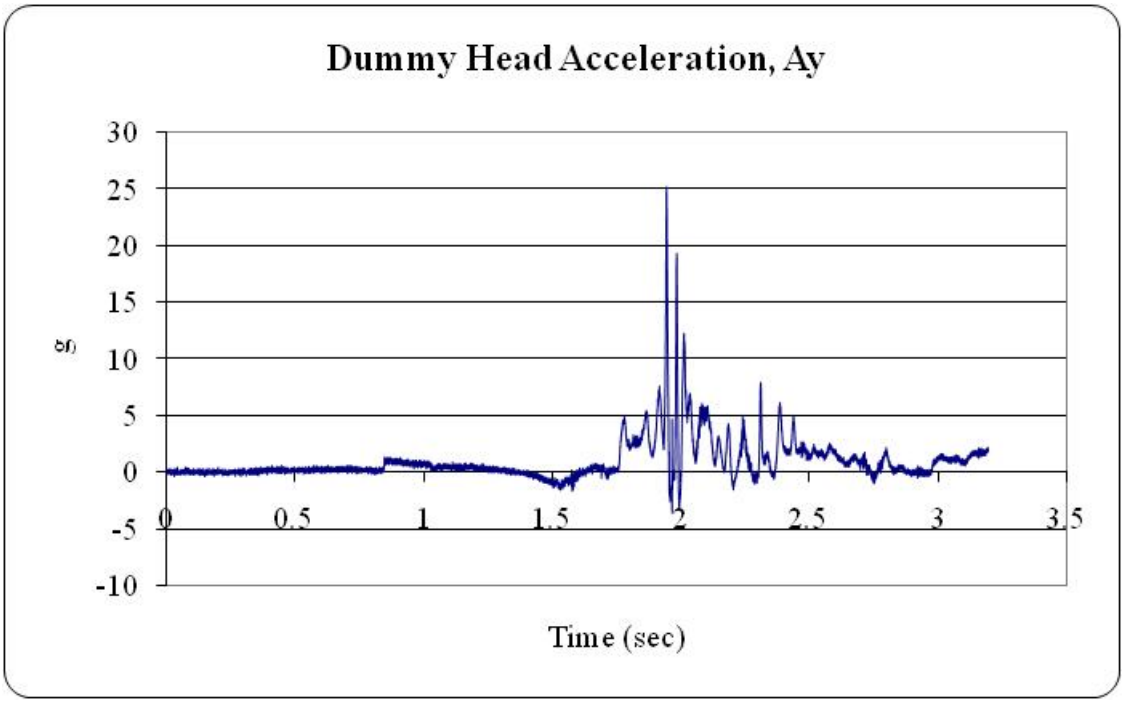
Data Sampling Rate: 10 kHz




Plot 33: Upper Neck Load, Fz, v. Time

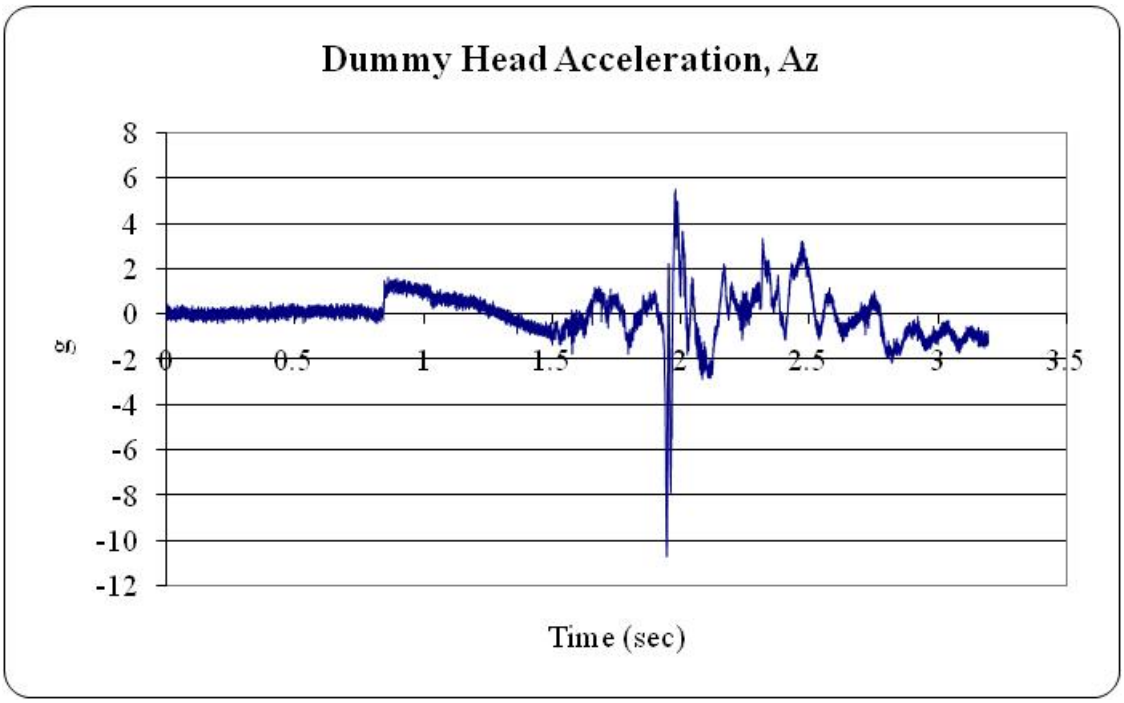
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 34: Head Acceleration, Ay, vs. Time

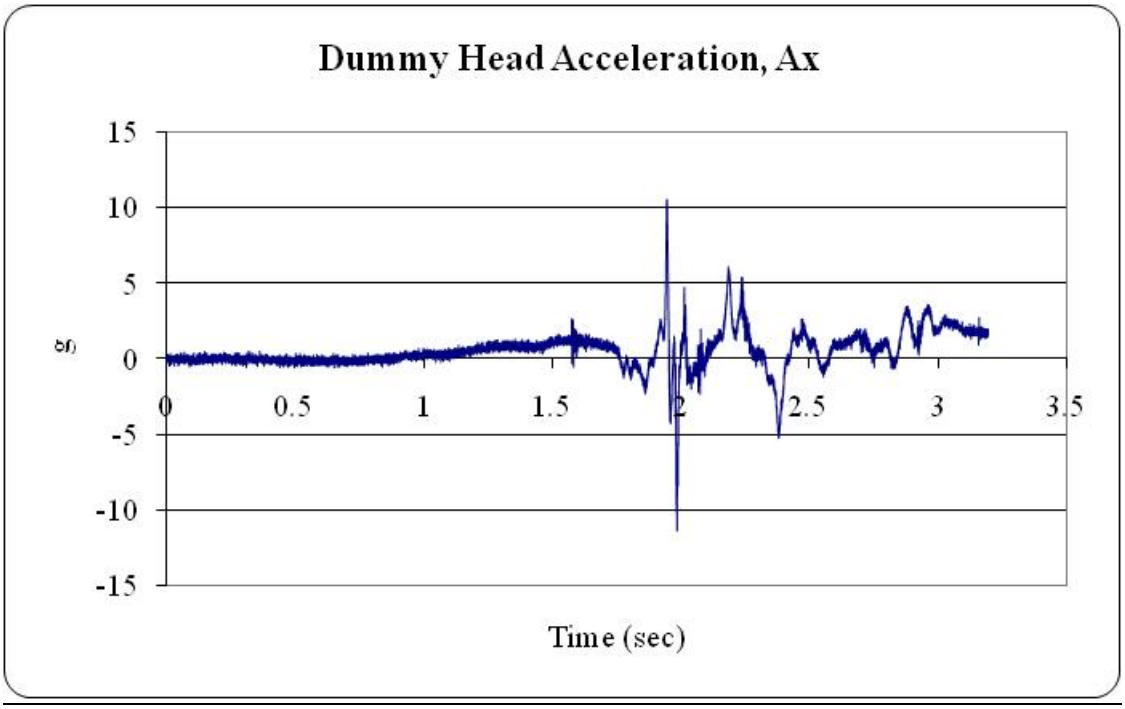
Data Sampling Rate: 10 kHz




Plot 35: Head Acceleration, Az, vs. Time

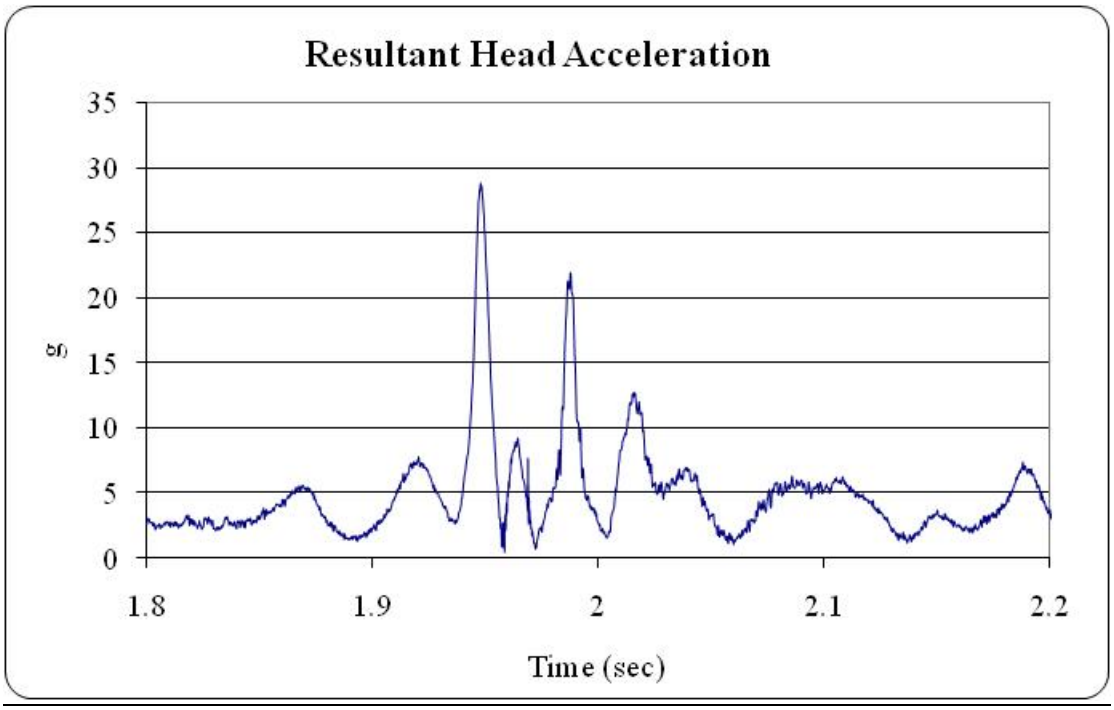
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 36: Head Acceleration, Ax, vs. Time

Data Sampling Rate: 10 kHz

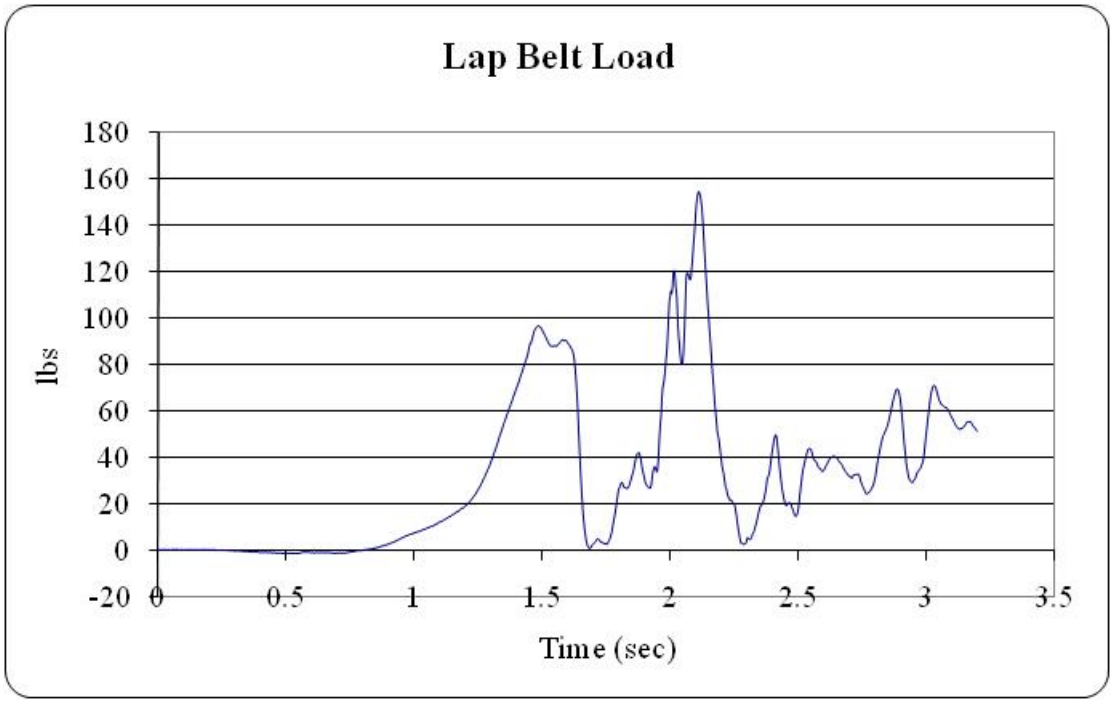



Plot 37: Resultant Head Acceleration vs. Time

**HIC = 12**

Data Sampling Rate: 10 kHz

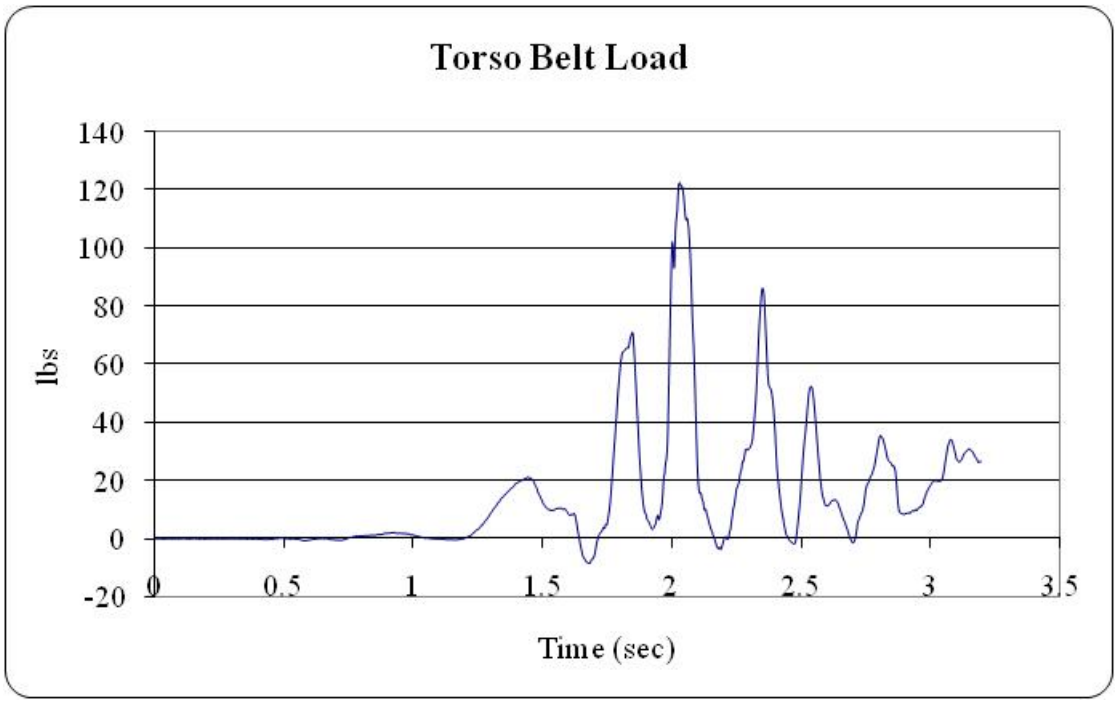
**Roll 2**




Plot 38: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

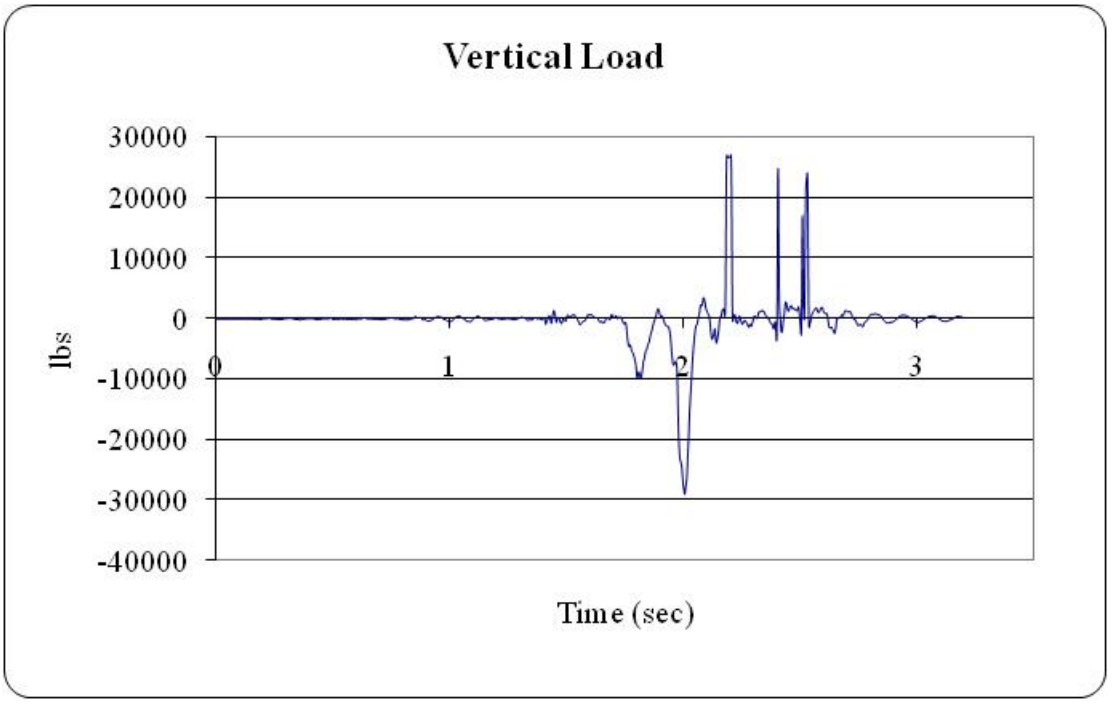



Plot 39: Torso Belt Load* vs. Time

*Measured on one side of the belt

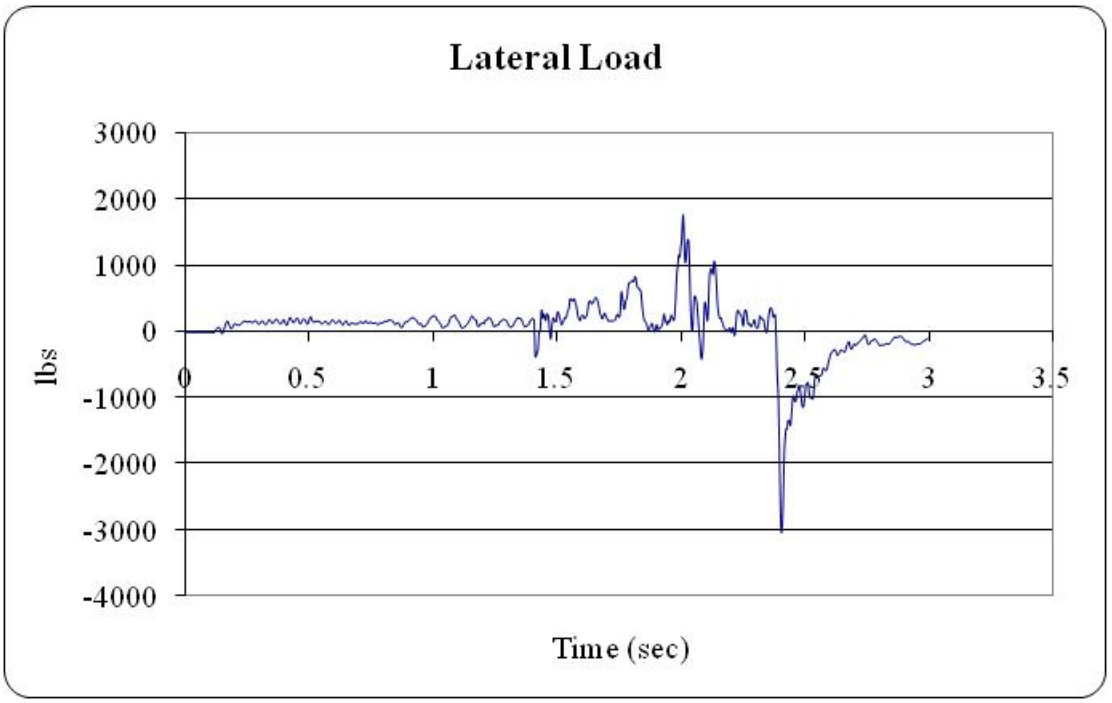
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 40: Total Vertical Load v. Time

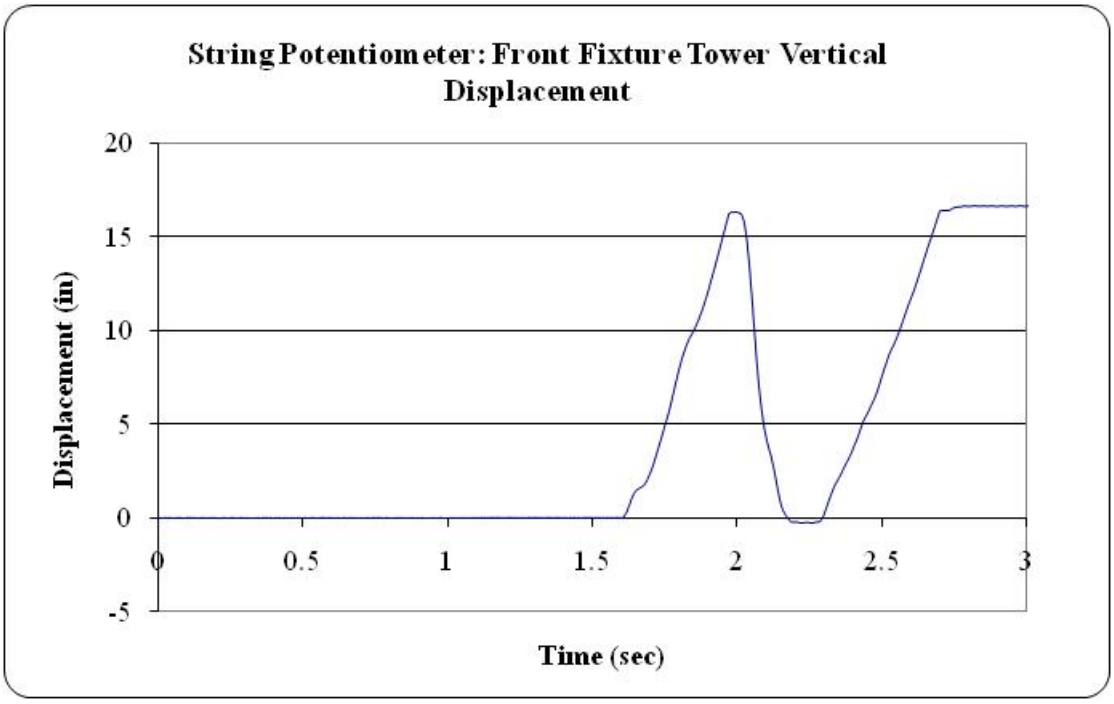
Data Sampling Rate: 10 kHz




Plot 41: Total Lateral Load v. Time

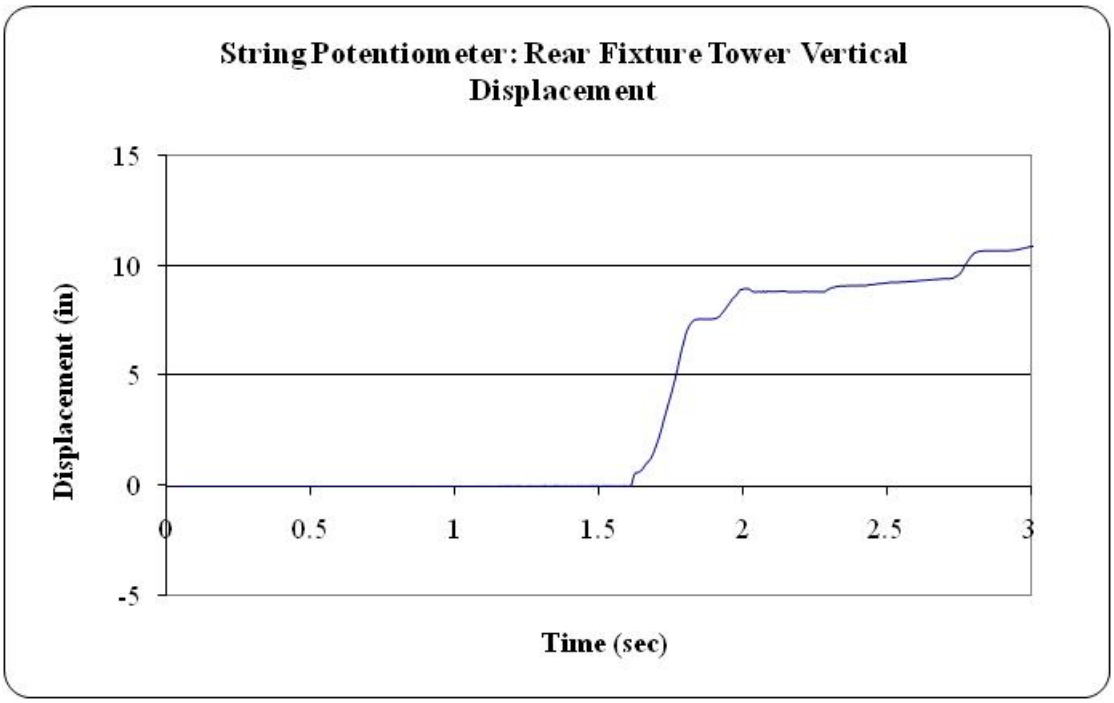
Data Sampling Rate: 10 kHz

**Roll 2**




Plot 42: String Potentiometer Front Fixture Support Tower Displacement vs. Time

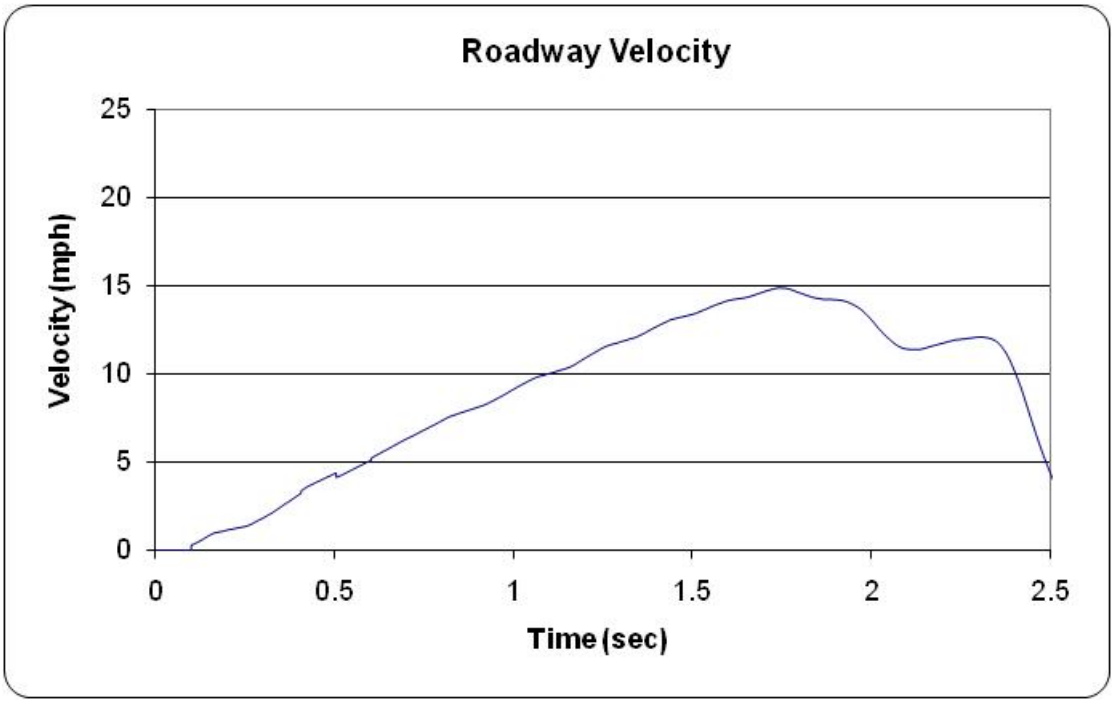
Data Sampling Rate: 1 kHz




Plot 43: String Potentiometer Rear Fixture Support Tower Displacement vs. Time

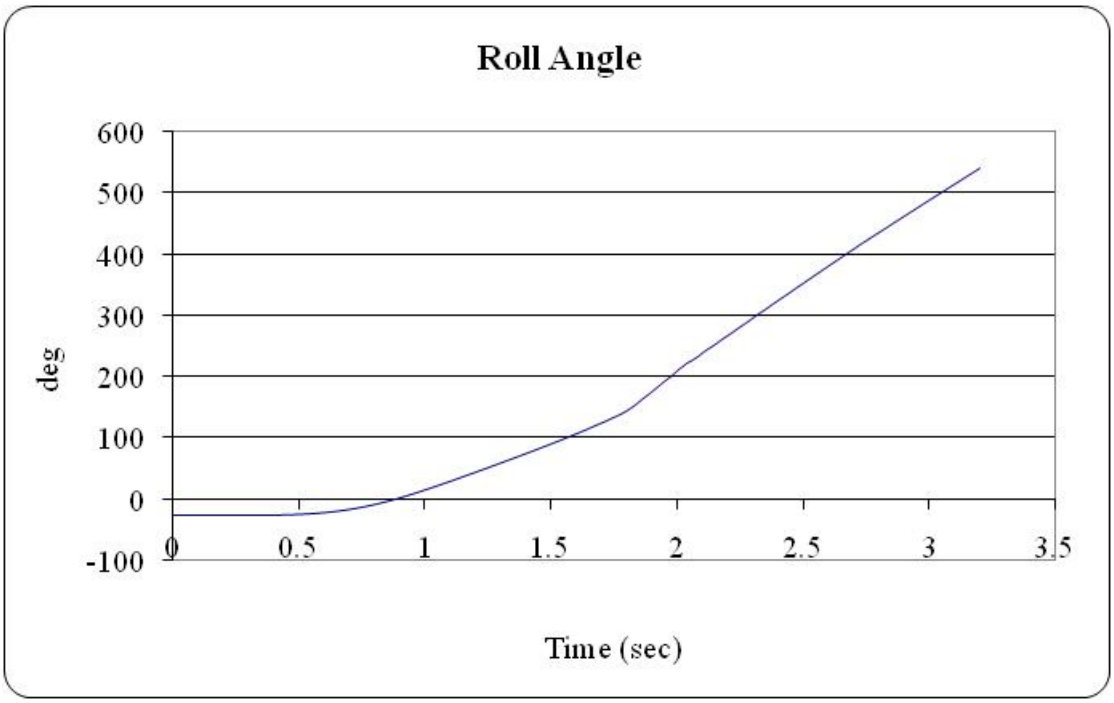
Data Sampling Rate: 1 kHz

**Roll 2**




Plot 44: Roll Encoder on Roadway Velocity vs. Time

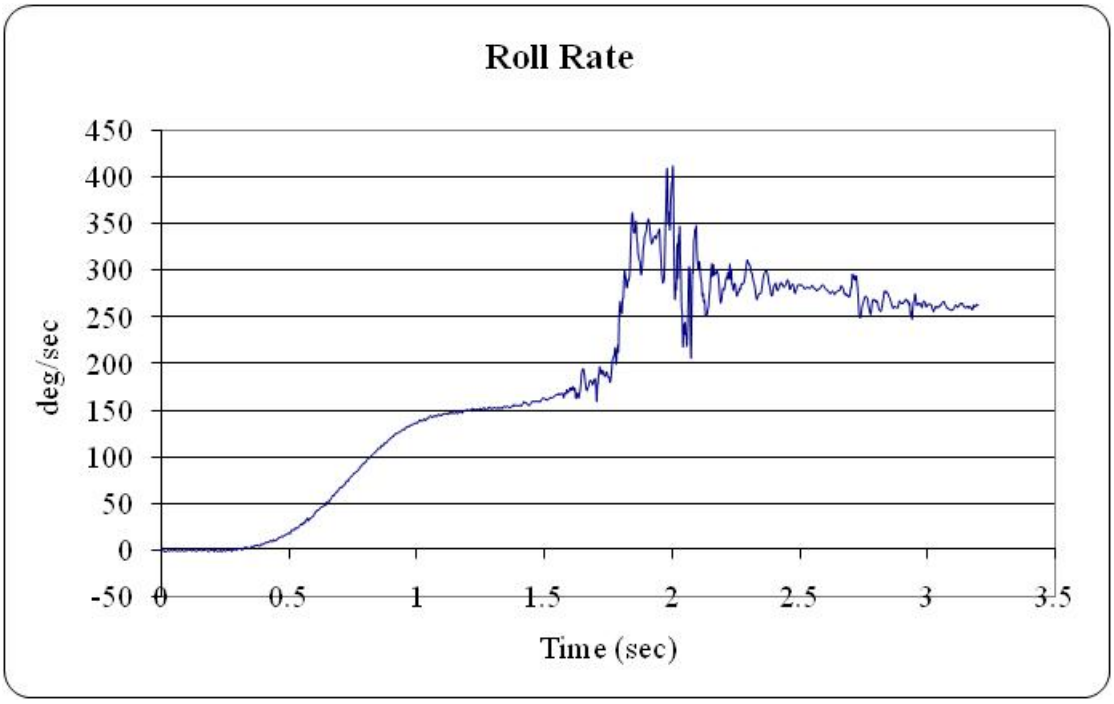
Data Sampling Rate: 1 kHz




Plot 45: Roll Angle vs. Time

Data Sampling Rate: 10 kHz

**Roll 2**

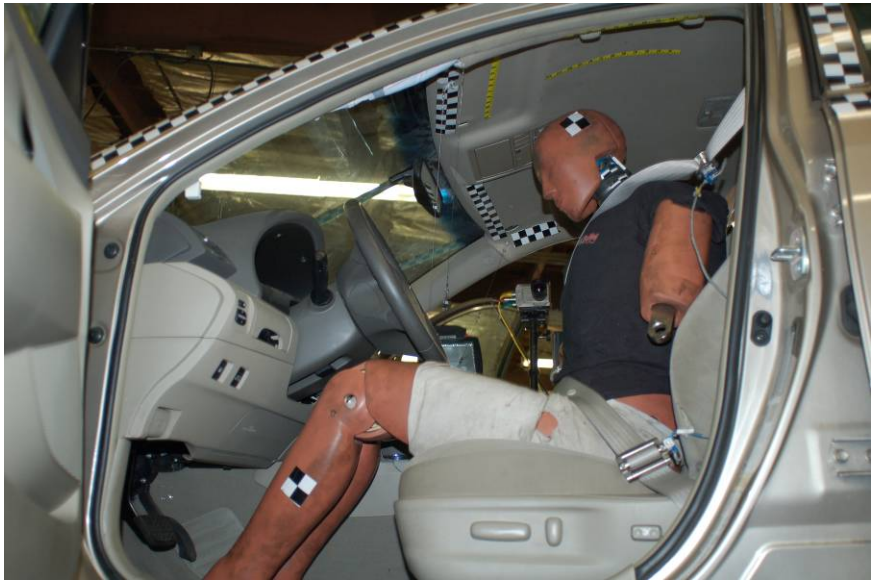



Plot 46: Roll Rate vs. Time

Data Sampling Rate: 10 kHz

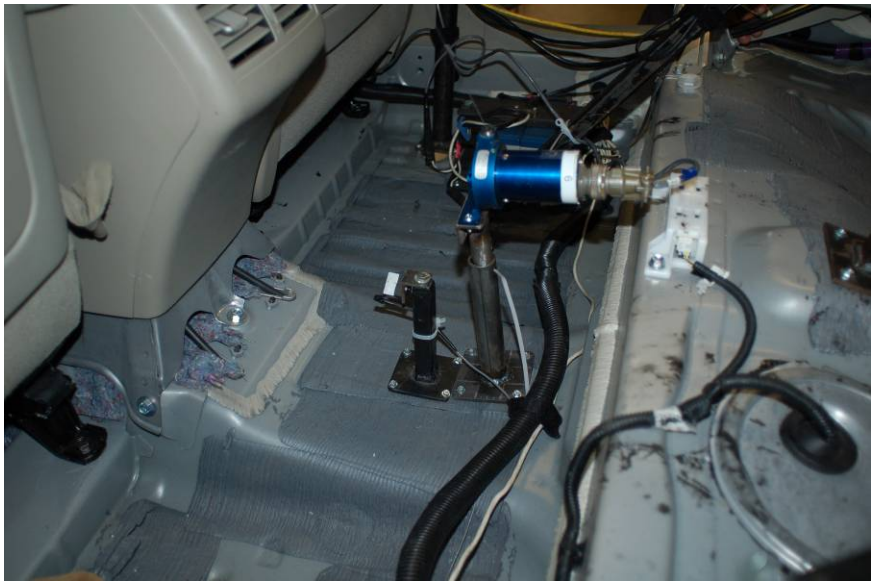
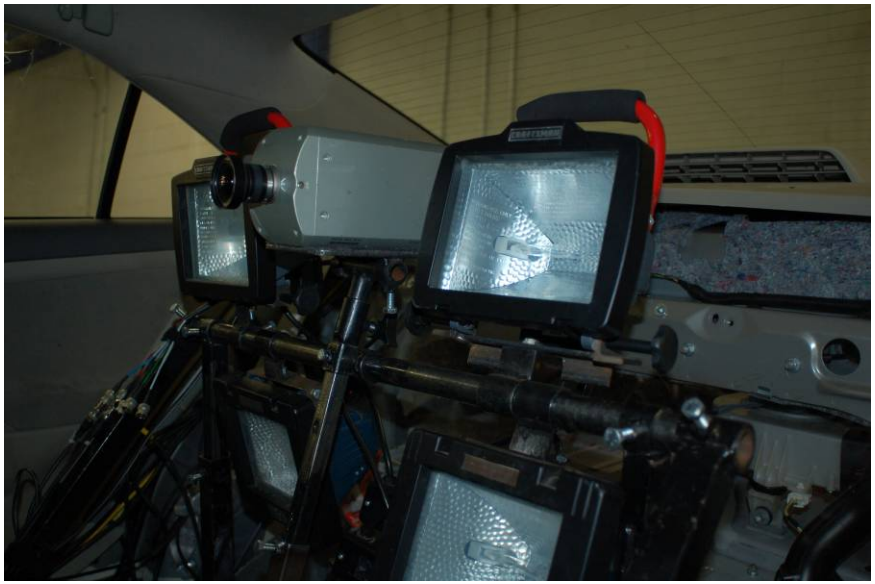
## 6. All Test Photographs – Vehicle Instrumentation


**Vehicle Instrumentation**

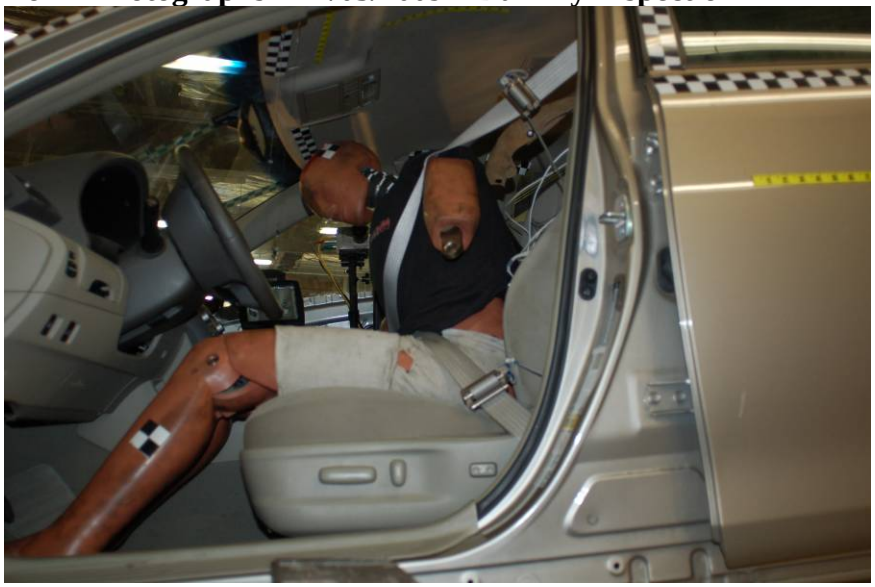


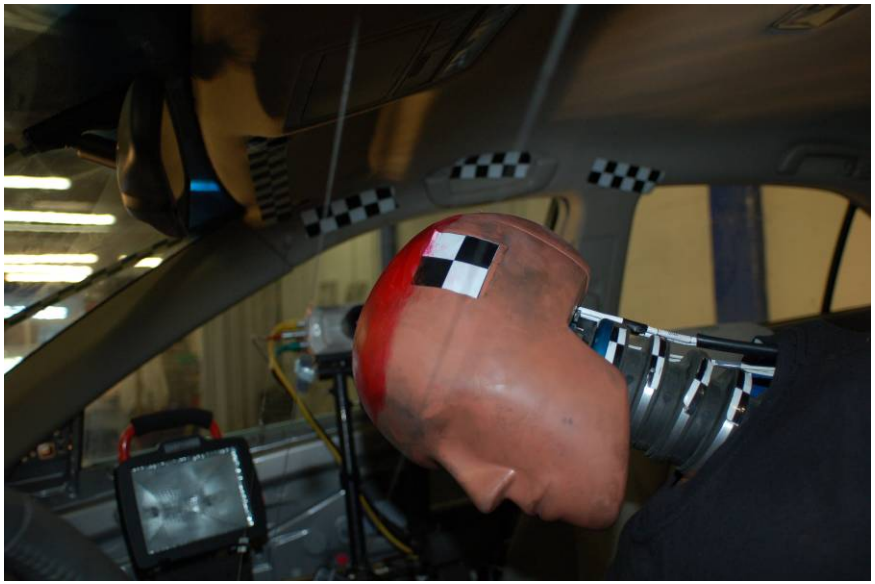
**Vehicle Instrumentation**



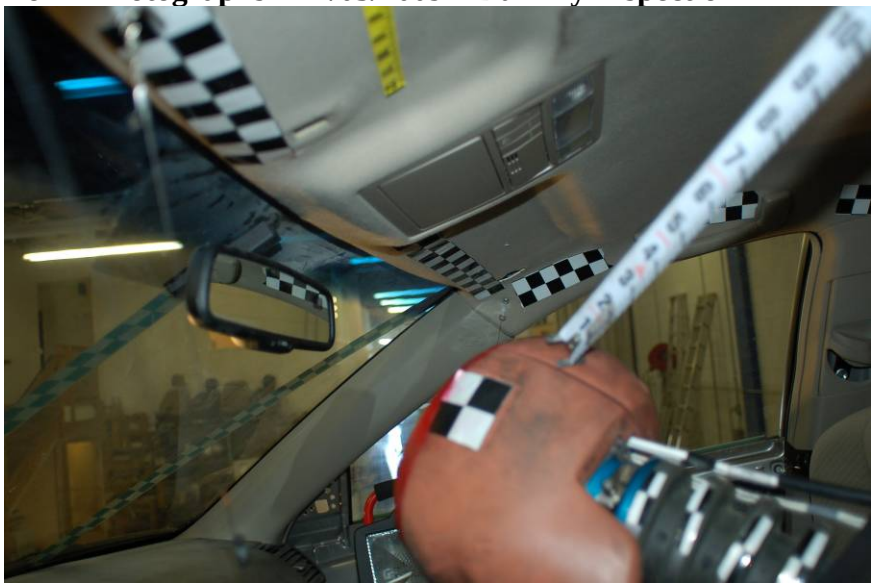
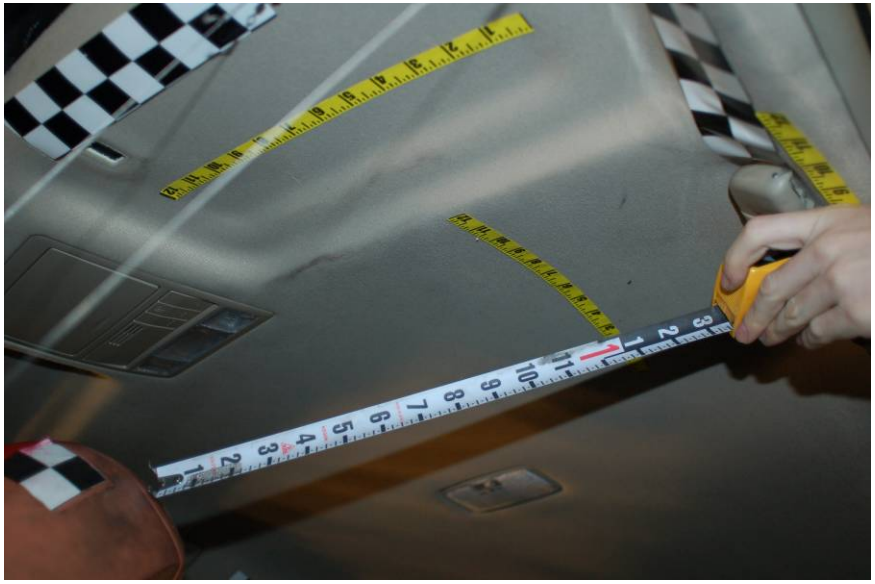



**Roll 1 Photographs – 11/05/2009 – Dummy Inspection**

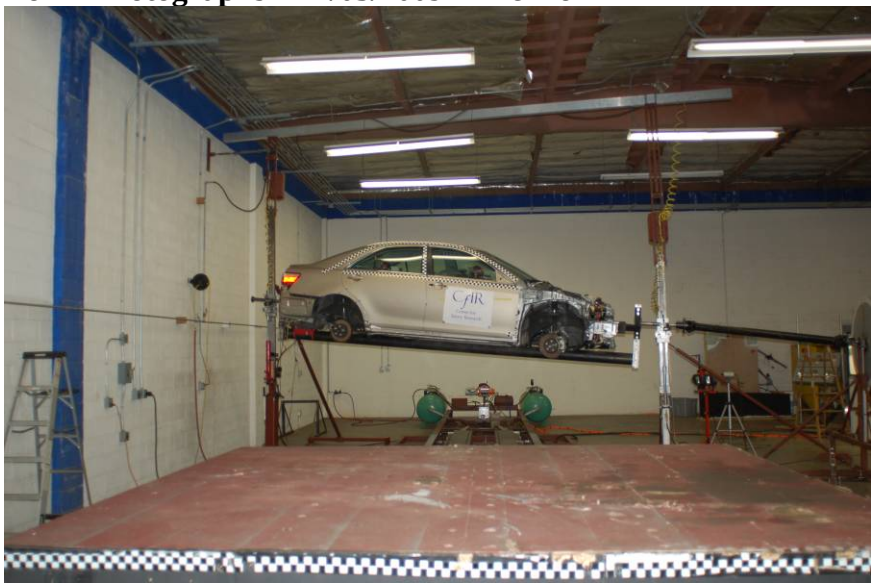


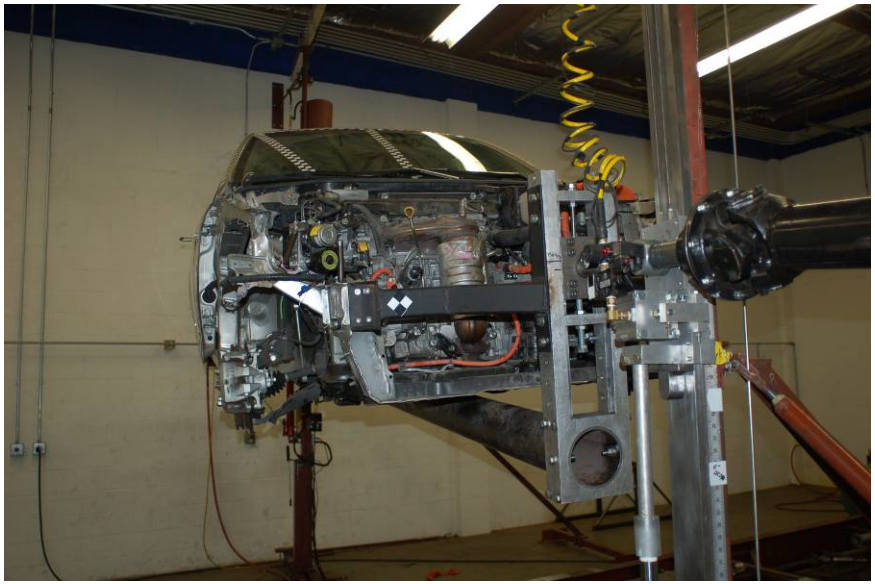



**Roll 1 Photographs – 11/05/2009 – Dummy Inspection**

**Roll 1 Photographs – 11/05/2009 – Pre-Roll**

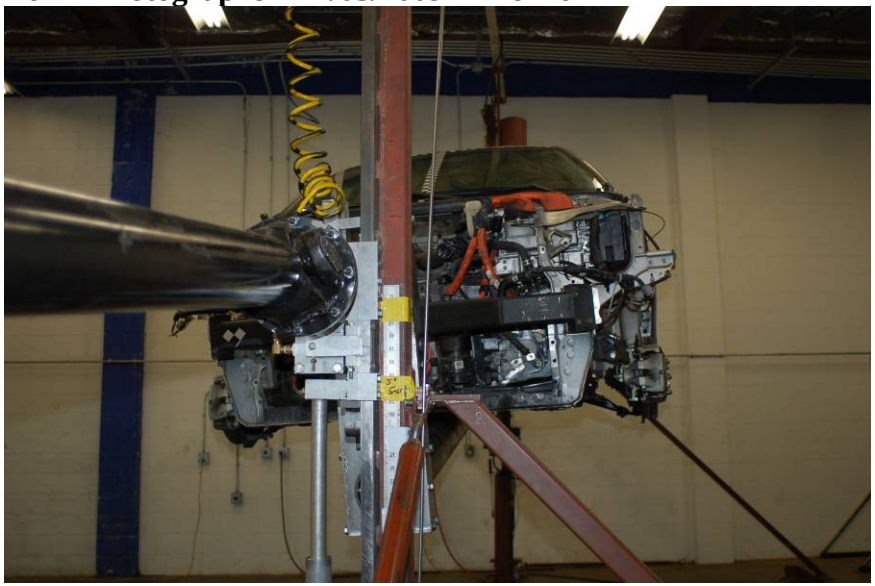


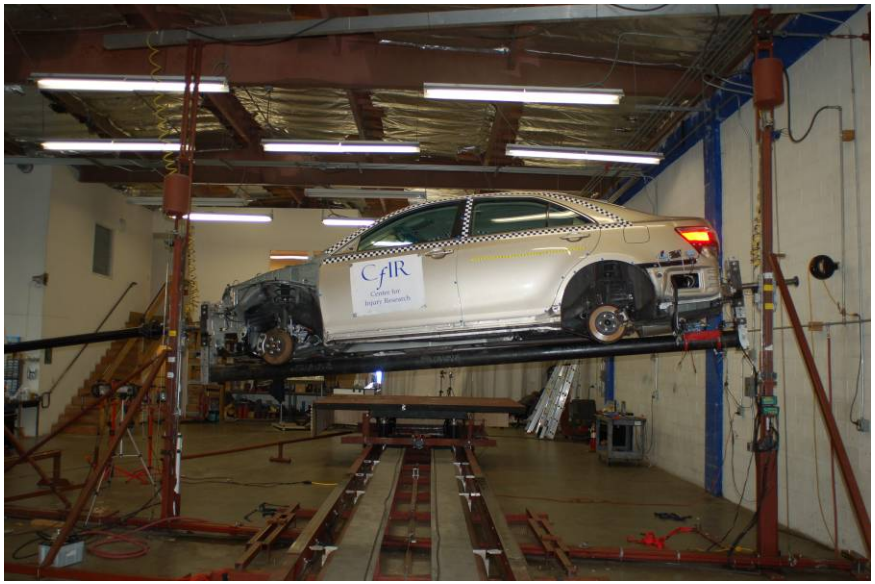
**Roll 1 Photographs – 11/05/2009 – Pre-Roll**



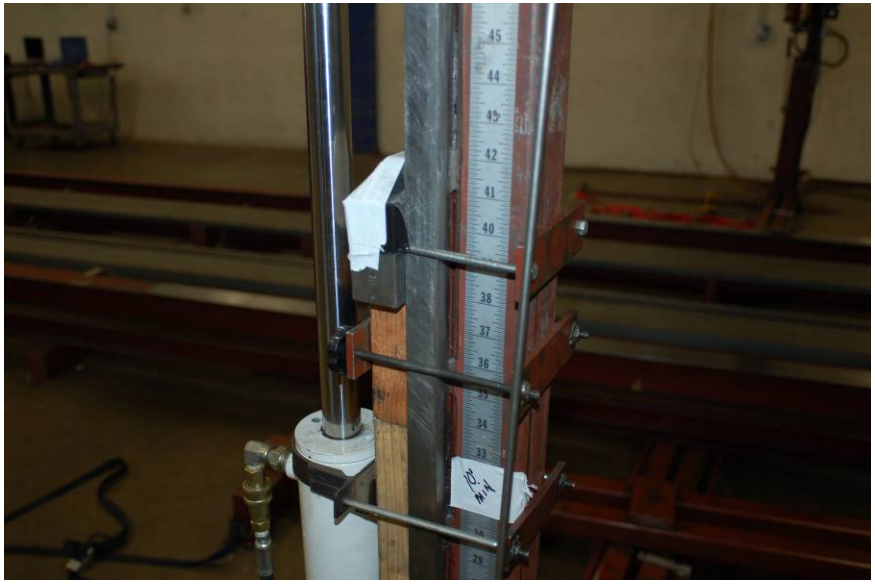

**Roll 1 Photographs – 11/05/2009 – Pre-Roll**

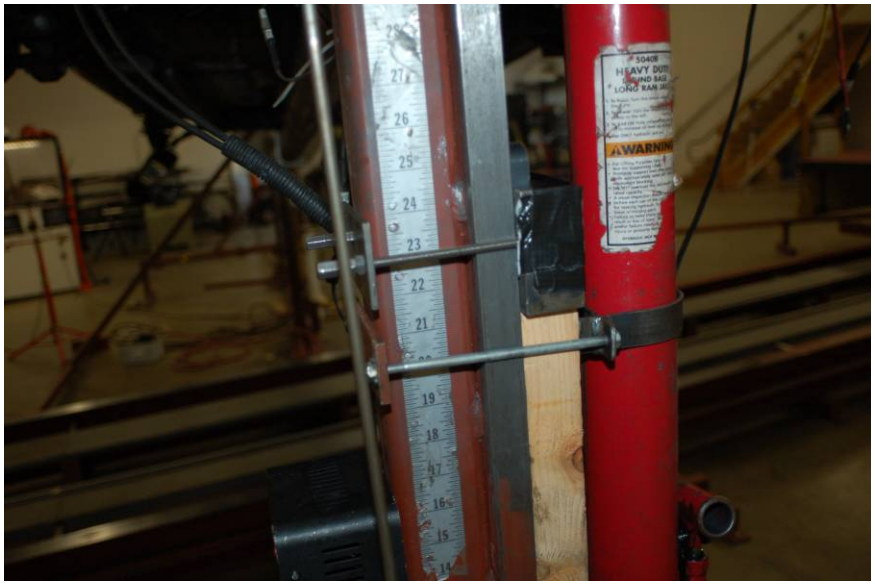






**Roll 1 Photographs – 11/05/2009 – Pre-Roll**

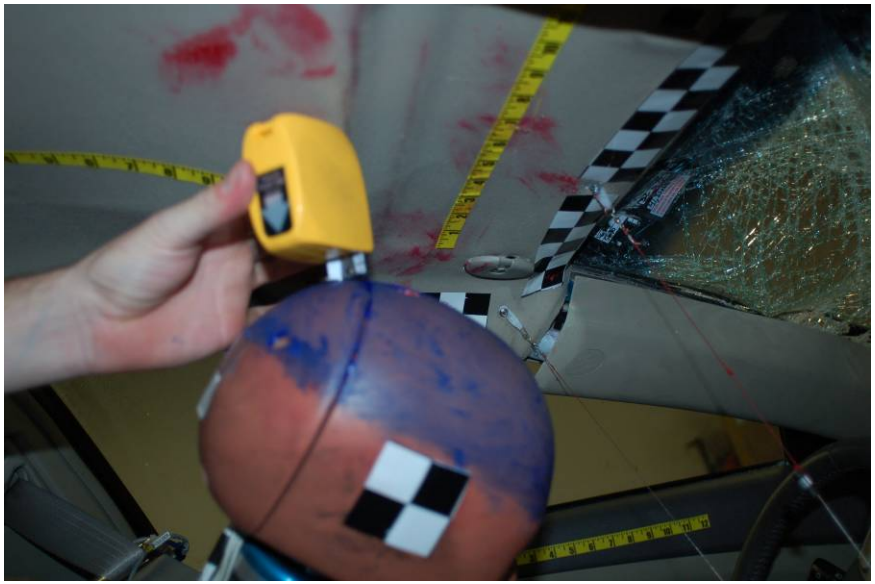
**Roll 1 Photographs – 11/05/2009 – Post-Roll**


**Roll 1 Photographs – 11/05/2009 – Post-Roll**



**Roll 2 Photographs – 11/17/2009 – Dummy Inspection**

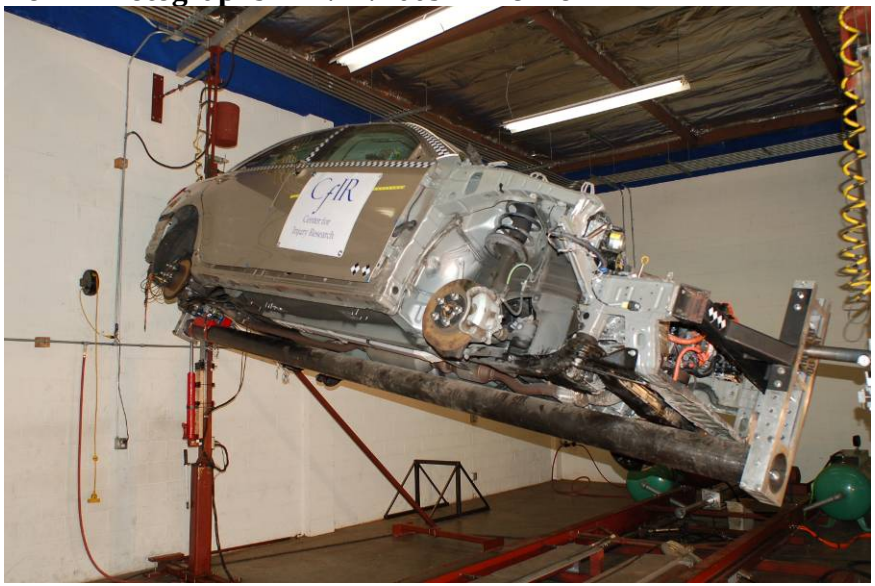


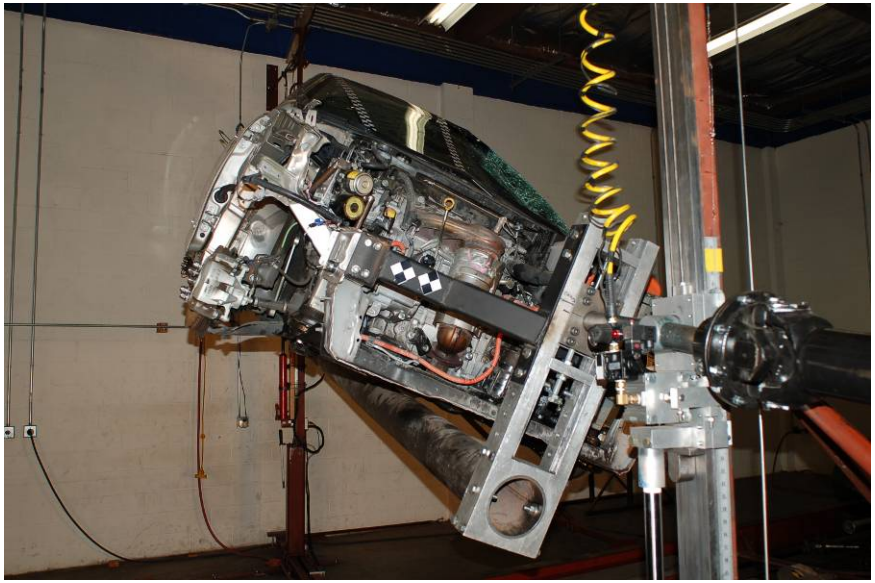



**Roll 2 Photographs – 11/17/2009 – Dummy Inspection**

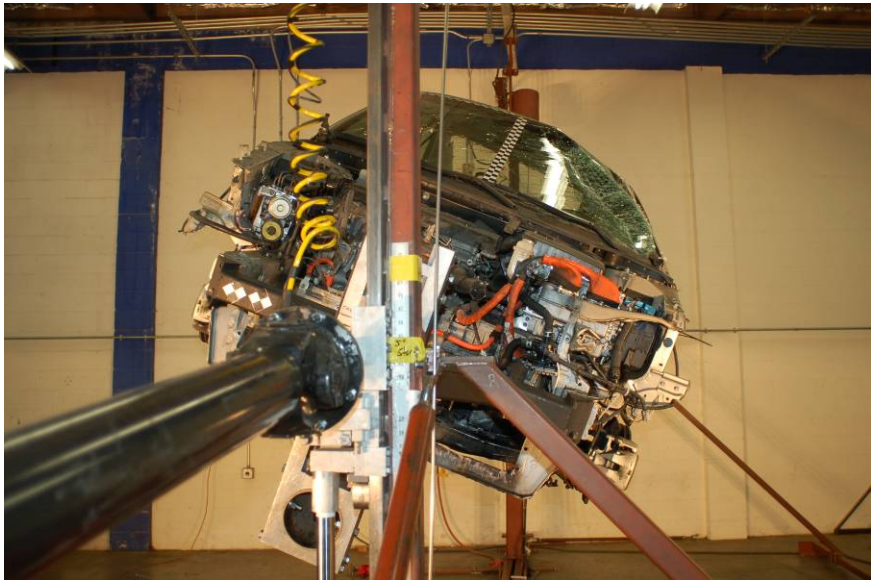
**Roll 2 Photographs – 11/17/2009 – Pre-Roll**

**Roll 2 Photographs – 11/17/2009 – Pre-Roll**



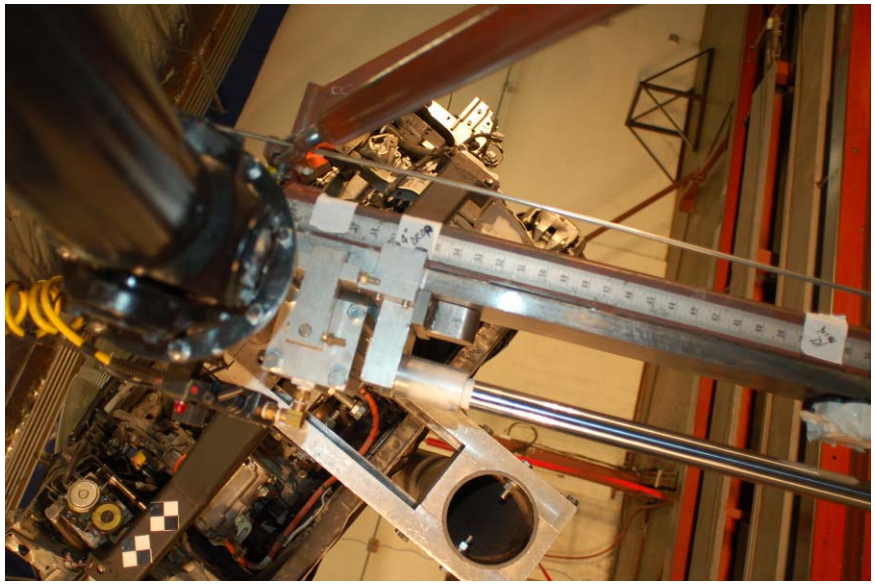



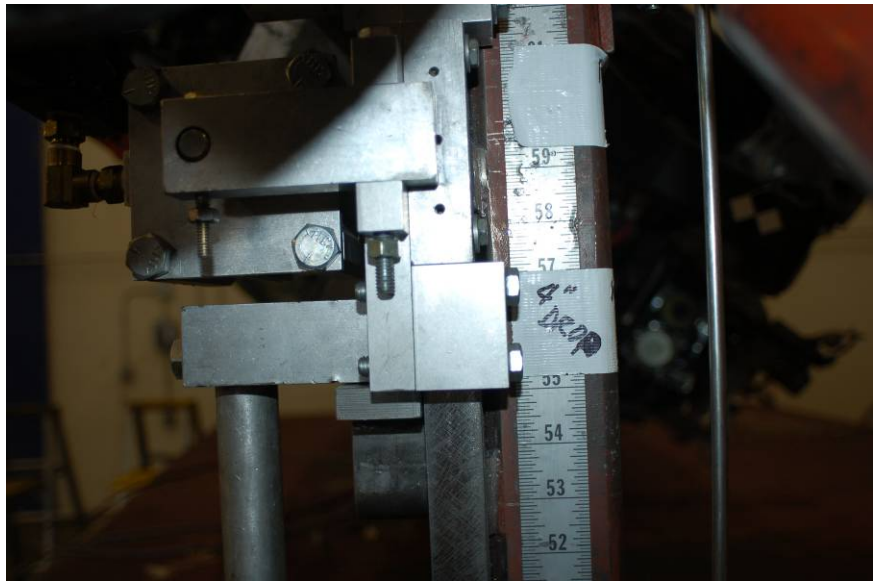
**Roll 2 Photographs – 11/17/2009– Pre-Roll**



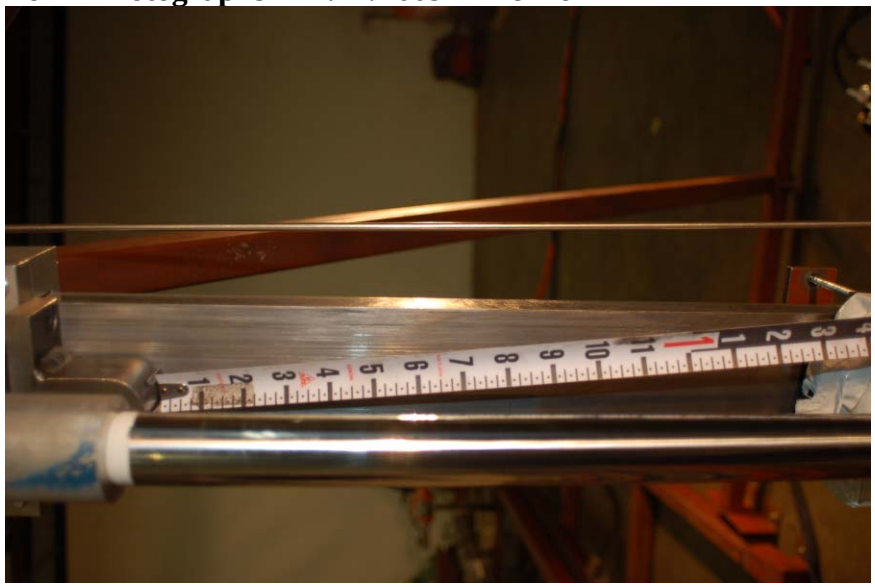
**Roll 2 Photographs – 11/17/2009 – Pre-Roll**

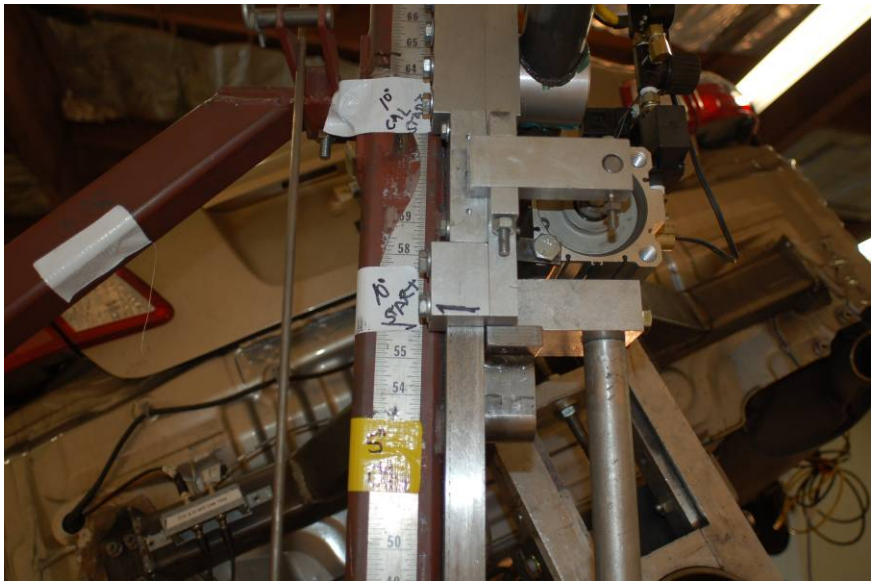


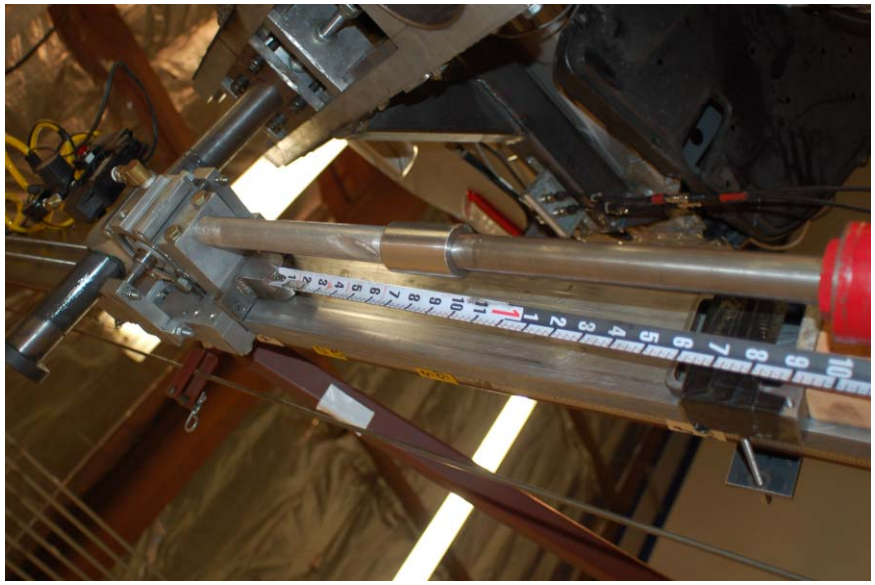




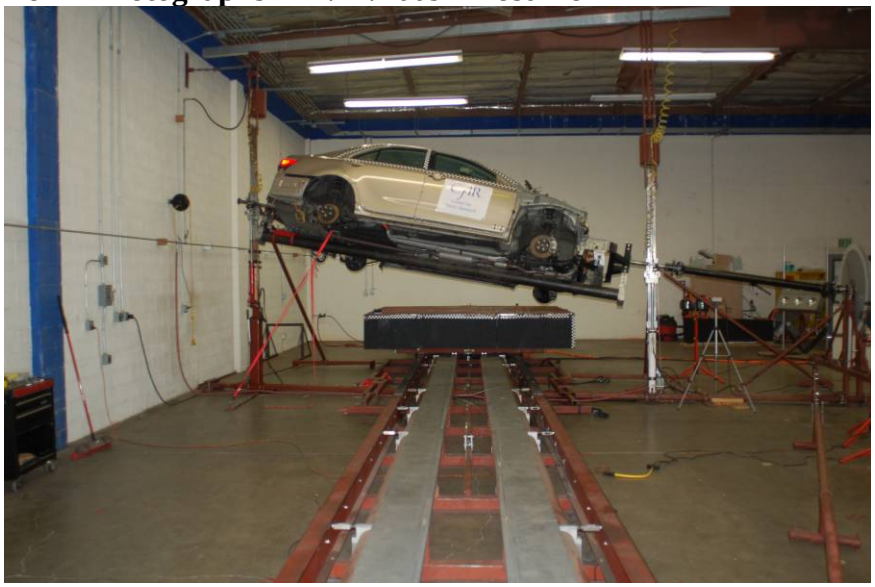
**Roll 2 Photographs – 11/17/2009 – Pre-Roll**



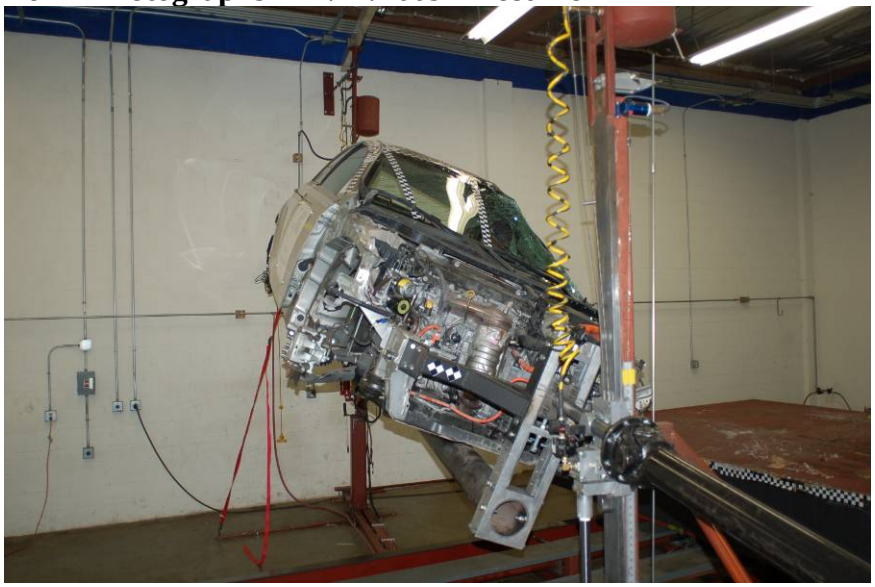
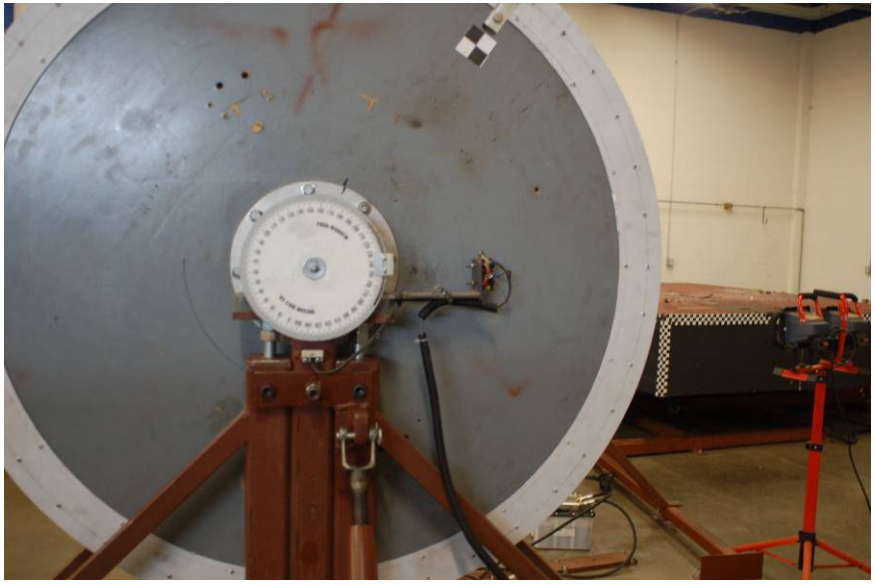




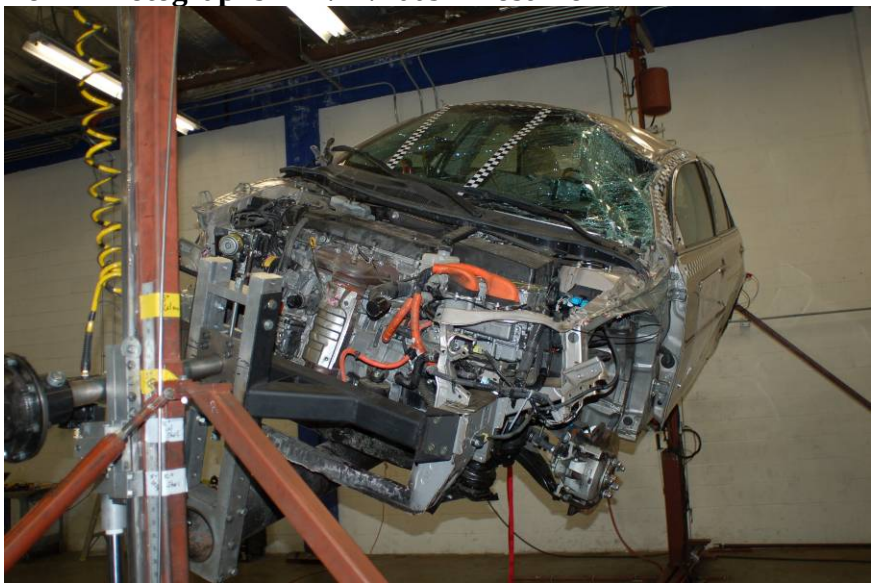
**Roll 2 Photographs – 11/17/2009 – Post-Roll**

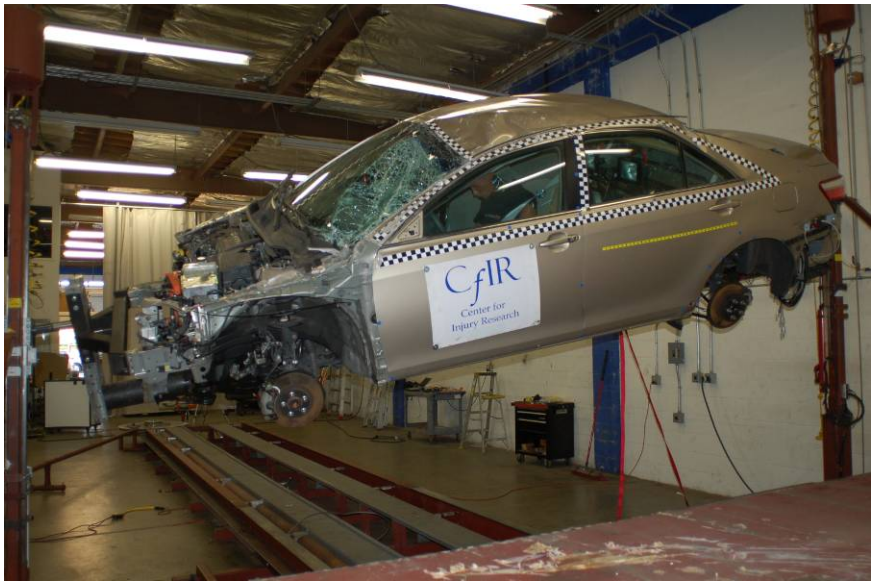


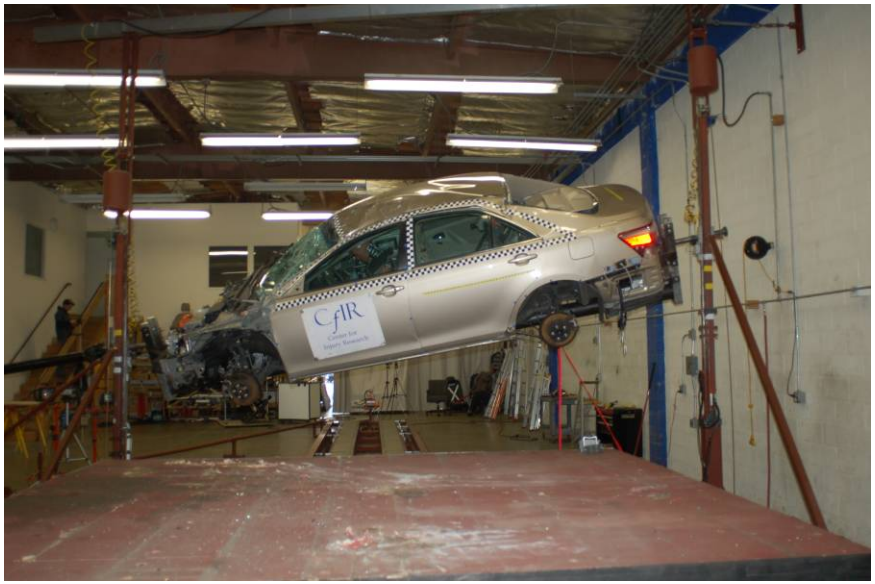

**Roll 2 Photographs – 11/17/2009 – Post-Roll**

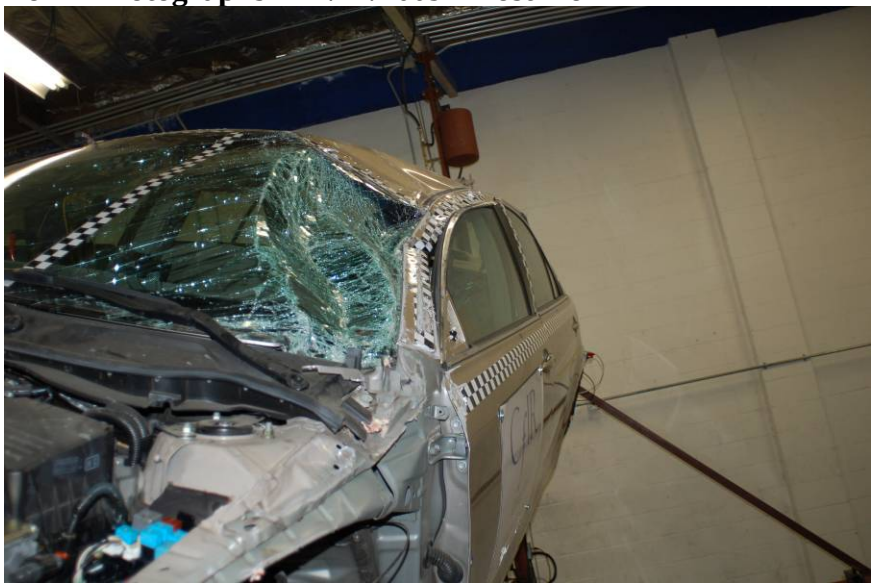
**Roll 2 Photographs – 11/17/2009 – Post-Roll**

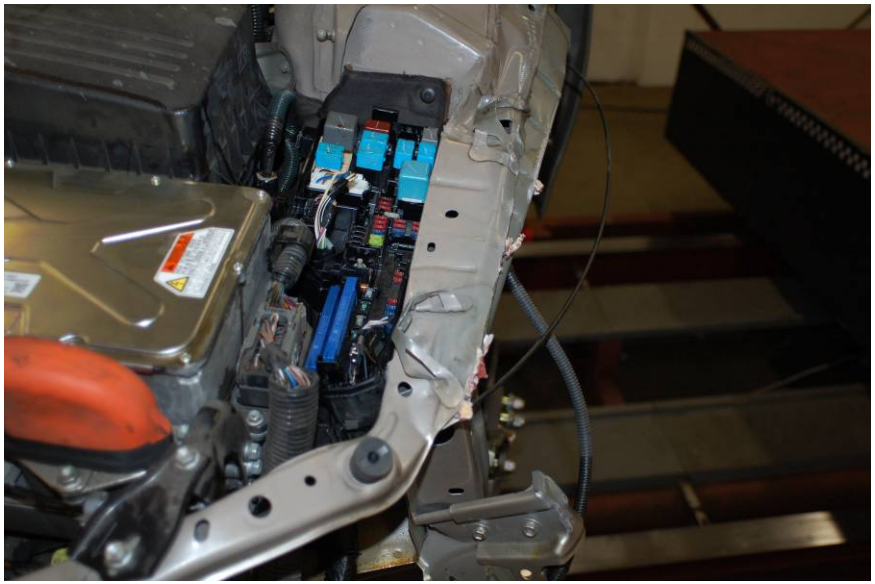


**Roll 2 Photographs – 11/17/2009 – Post-Roll**






**Roll 2 Photographs – 11/17/2009 – Post-Roll**