JRS Dynamic Rollover Test

2010 Toyota Prius

Sponsored By:

Automotive Safety Research Institute
Charlottesville, VA.

Vehicle Donated by:
State Farm Insurance Company
Chicago, IL.

Introduction

Center for Injury Research conducted a JRS dynamic rollover test consisting of two rolls of a 2010 Toyota Prius on August 11 and 12, 2010. 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 – Data Graphs

Section 5 – All Test Photographs

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

2010 Toyota Prius

Executive Summary

The test was a two roll event. The planned difference between the rolls was the pitch of the vehicle; 5 degrees in Roll 1 and 10 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 45°. For Roll 2, the dummy was placed in the nominal seating position. Table 1 describes the impact conditions of each test. Table 2 shows the injury assessment reference values for the low durometer neck that was used.

Table 1 Summary of Test Conditions

Roll	Pitch	Road Speed	Contact Angle	Roll Rate
1	5 deg	15 mph	147 deg	187 deg/sec
2	10 deg	14.9 mph	142 deg	187 deg/sec

Table 2 Lower Neck IARV's for 10% Probability of an AIS ≥ 3 Injury

Neck Type	My (Nm) Flexion	My (Nm) Extension	Mx (Nm)	Axial Fz (N)
Production	380	−156	268	4000
Low Durometer	90-110	−38-−46	59-90	1640-2000
Human/Cadaver	58			1500

In Roll 1, the peak lower neck compressive load was 315 N and the peak lower neck moment was 19 Nm in flexion and 40 Nm in extension. The peak intrusion speed at the top of the A-Pillar was 4.3 mph with a peak crush of 4.4 inches.

In Roll 2, the lower neck mount failed during the test. Data from the neck was recorded, but the peak values cannot be validated. The peak lower neck compressive load was 451 N and the peak lower neck moment was 14 Nm in flexion and 95 Nm in extension The peak intrusion speed at the top of the A-Pillar was 8.2 mph with a peak crush of 6.6 inches.

1. Test Procedure and Summaries

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

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 = 5.0° and Roll 2 = 10.0°.

The test weight of the vehicle was 3,233 pounds. The initial weight of the vehicle was 3,070 pounds. The test roll moment of inertia was approximately 389 lb*ft*sec^2 for a referenced value of 398 lb*ft*sec^2.

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

Due to the shape and location of the center console the four string potentiometer mounts were placed approximately 7 inches lateral of the longitudinal roll axis of the vehicle. The sensors measured the roof dynamics 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. The mounting positions of the string potentiometers resulted in less than 1% error in their measurements as compared to normal mounting locations, which place the string pots on the longitudinal axis. 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 (low durometer) neck and lumbar joint, located in the driver's seat which was positioned in the mid seat position. The dummy was restrained using the vehicle's standard 3 point harness with a non-deployed pre-tensioner. The dummy's head was chalked before each roll to locate impact marks during the tests. To make the Hybrid III dummy more biofidelic, the two cables in the lower

spine of the dummy were removed. The lower neck mounting block was replaced with a block that increased the neck angle forward 30 degrees from the nominal position.

For the first roll the dummy was tethered "out of position" with a light wire that electronically disconnected at approximately 90° of roll. The "out of position" location of the dummy was found by rotating the vehicle by 90° toward the passenger side. This orientation simulated the dummy accelerating toward the passenger side door at 1 g. For the second roll the dummy was placed in the nominal seating 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 3 and the test vehicle identification data is shown in Table 4 below.

Table 3 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, 50th 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 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 4 General Test Vehicle Data Test Vehicle: 2010 Toyota Prius

Test Vehicle Information:	
Manufacturer: Toyota	VIN: JTDKN3DU1A0085103
Gross Weight: 3,980 lb	Curb Weight: 3,042 lb
Sunroof: Yes	2WD/4WD: 2WD
Equivalent Years: 2010- Present	Body Type: 4 Door Hatchback

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 – 8/11/2010

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)	Peak Velocity (mph)
Sum of Vertical Load Cells (near side contact)	11,828 lb		
Sum of Vertical Load Cells (far side contact)	16,853 lb		
Sum of Lateral Load Cells (near side contact)	1,241 lb		
Sum of Lateral Load Cells (far side contact)	1,269 lb		
Driver's Side A-Pillar String Potentiometer	-4.4 in	-1.8	-4.3
Driver's Side B-Pillar String Potentiometer	-2.3 in	-0.9	-3.6
Roof Header String Potentiometer	-2.5 in	-0.7	-3.8
Passenger's Side A-Pillar String Potentiometer	-1.4 in	0.0	-2.0

Instrument	Maximum Value	Minimum Value
Lap Belt Load	207 lb	-4 lb
Shoulder Belt Load	401 lb	-3 lb
Dummy Head Acceleration Ax	10 g	-1 g
Dummy Head Acceleration Ay	8 g	-2 g
Dummy Head Acceleration Az	1 g	-8 g
Lower Neck Load Cell Fx	1,258 N	-98 N
Lower Neck Load Cell Fy	352 N	-127 N
Lower Neck Load Cell Fz	526 N	-315 N
Lower Neck Load Cell Mx	21 Nm	-8 Nm
Lower Neck Load Cell My	19 Nm	-40 Nm
Upper Neck Load Cell Fz	187 N	-1,397 N
HIC	40	N/A

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 1.72 seconds. The entire roll sequence was completed by approximately 2.1 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 4.4 inches and the rear dropped 4.3 inches prior to initial touch down. The vehicle was pitched at 5.0 degrees at contact.

The roll encoder located on the cable pulley shows the roadway velocity throughout the roll. The roadway was traveling at 15 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 147 degrees and the roll rate was 187 degrees per second at the roadway impact.

During the first roll the windshield fractured and peeled away from the driver side A-pillar. A small buckle type deformation occurred in the far side C-pillar. The Hybrid battery in the rear of the vehicle was undamaged.

Pull tests were conducted on both the driver side doors of the vehicle after the first roll. Each door required less than 15 lb-f to open.

Roll 1 Comparison Photographs

Figure 1: Vehicle Pre Roll 1

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 – 8/12/2010

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)	Peak Velocity (mph)
Sum of Vertical Load Cells (near side contact)	6,906 lb		
Sum of Vertical Load Cells (far side contact)	22,314 lb		
Sum of Lateral Load Cells (near side contact)	452 lb		
Sum of Lateral Load Cells (far side contact)	1,380 lb		
Driver's Side A-Pillar String Potentiometer	-6.6 in	-2.0	-8.2
Driver's Side B-Pillar String Potentiometer	-3.0 in	-0.8	-5.4
Roof Header String Potentiometer	-5.3 in	-1.5	-6.8
Passenger's Side A-Pillar String Potentiometer	-1.7 in	0.0	-3.9

Instrument	Maximum Value	Minimum Value
Lap Belt Load	310 lb	-5 lb
Shoulder Belt Load	210 lb	-4 lb
Dummy Head Acceleration Ax	10 g	-1 g
Dummy Head Acceleration Ay	8 g	-2 g
Dummy Head Acceleration Az	1 g	-8 g
Lower Neck Load Cell Fx*	2,331 N	-290 N
Lower Neck Load Cell Fy*	474 N	-173 N
Lower Neck Load Cell Fz*	298 N	-451 N
Lower Neck Load Cell Mx*	13 Nm	-17 Nm
Lower Neck Load Cell My*	14 Nm	-95 Nm
Upper Neck Load Cell Fz	204 N	-2,103 N
HIC	89	N/A

*The lower neck mount failed during the test, which resulted in peak values that cannot be validated.

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 1.73 seconds. The entire roll sequence was completed by approximately 2.05 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 4.0 inches and the rear dropped 4.1 inches prior to initial touch down. The vehicle was pitched at 10 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 142 degrees and the roll rate was 187 degrees per second at the roadway impact.

During the second roll the windshield fractured further. The small quarter windows in front and rear of the driver side broke.

Pull tests were conducted on both the driver side doors of the vehicle after the second roll. Each door required less than 15 lb-f to open.

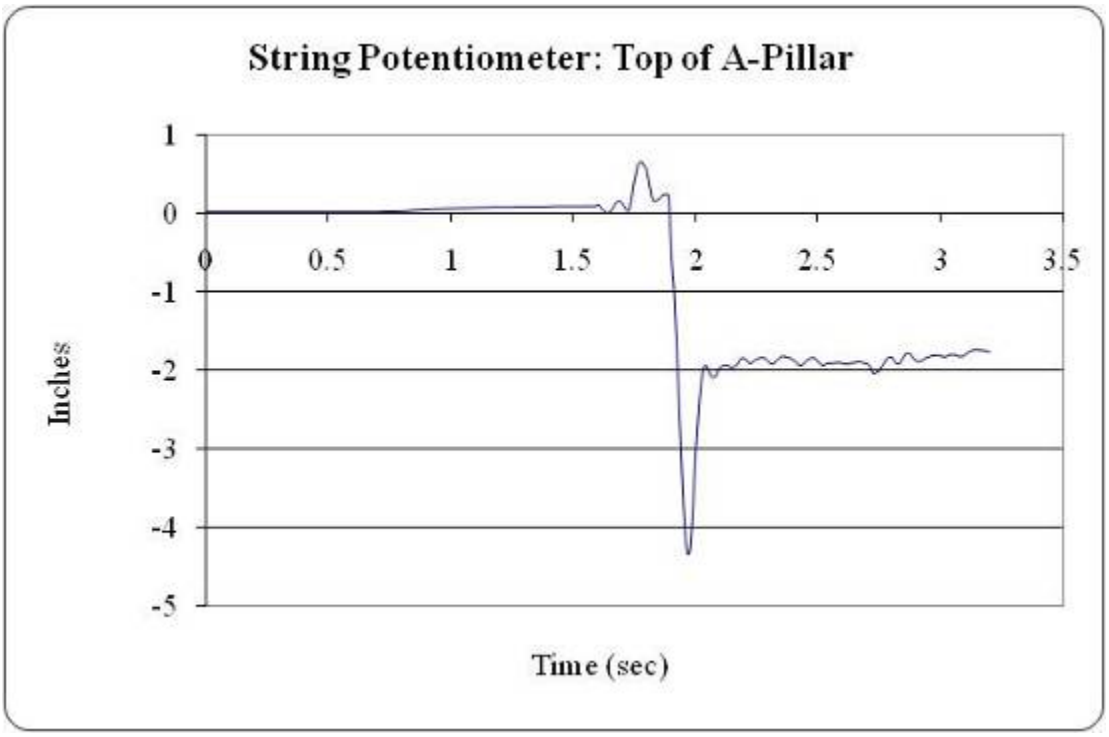
Roll 2 Comparison Photographs

Figure 3: Vehicle Pre Roll 2

Figure 4: Vehicle Post Roll 2

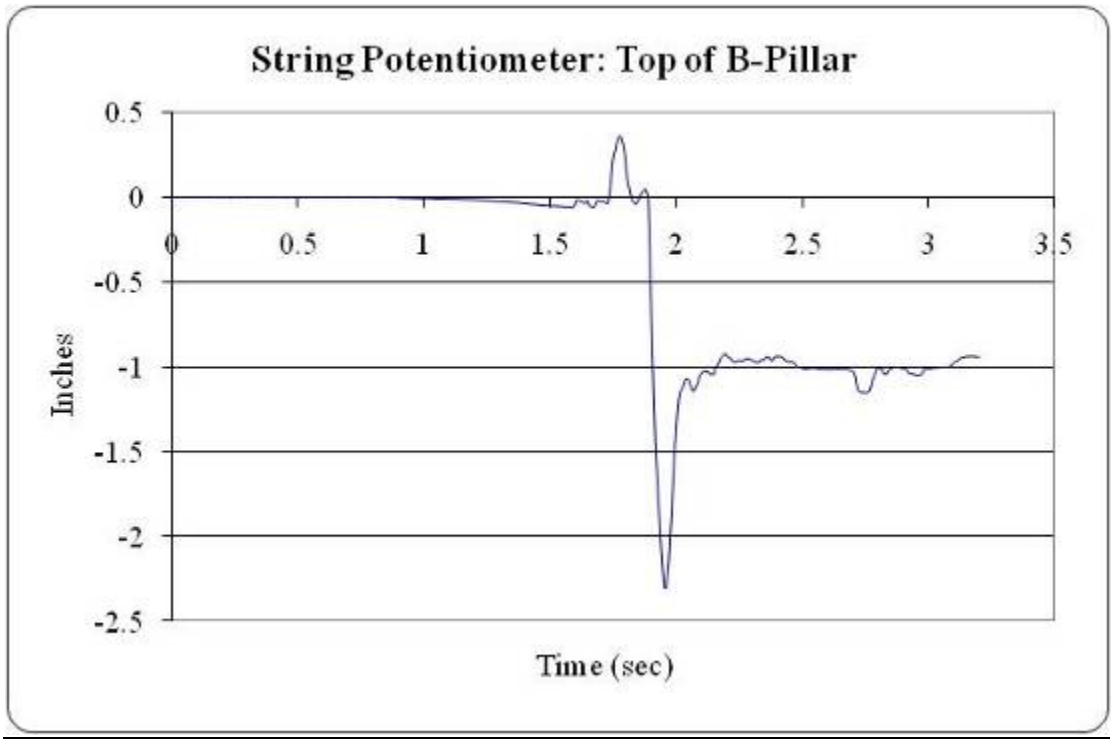
4. Data Graphs

Roll 1 Data Plots – 8/11/2010



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

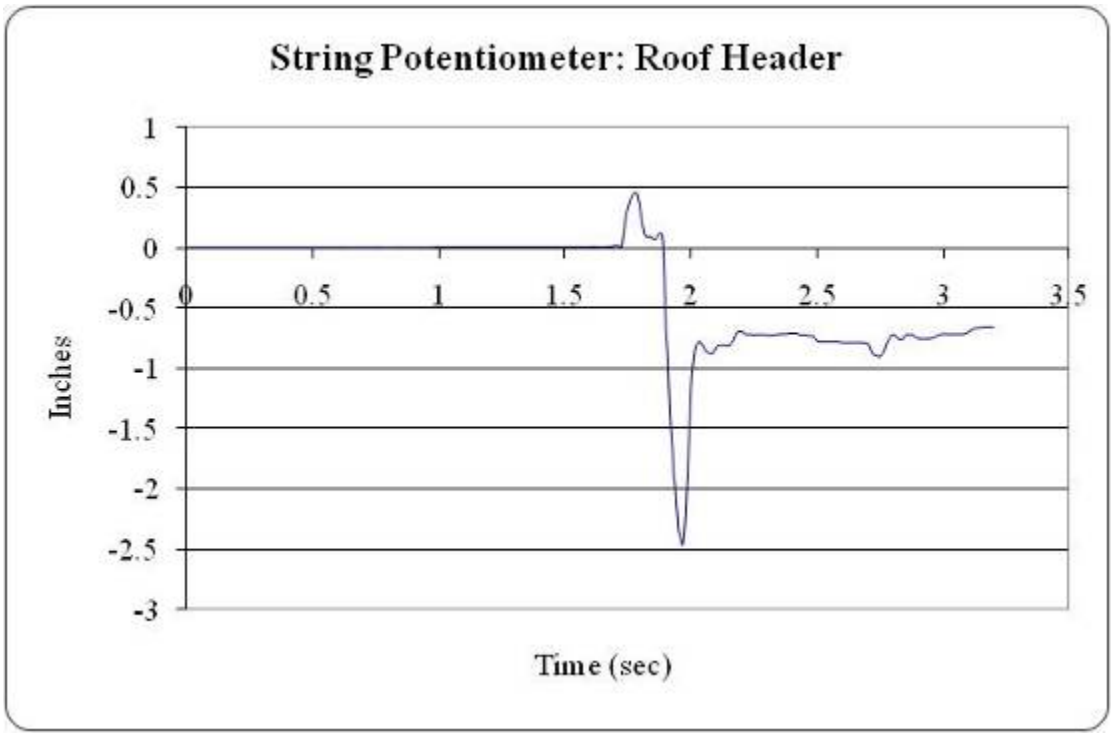
Data Sampling Rate: 10 kHz



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

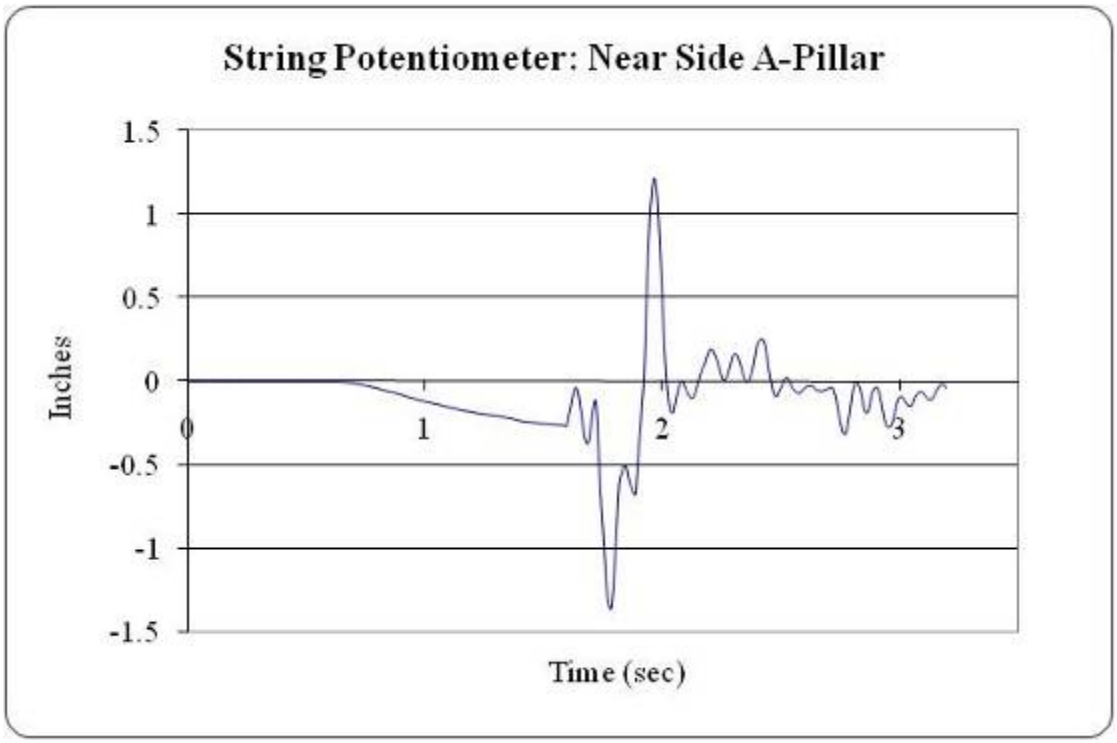
Data Sampling Rate: 10 kHz

Roll 1



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

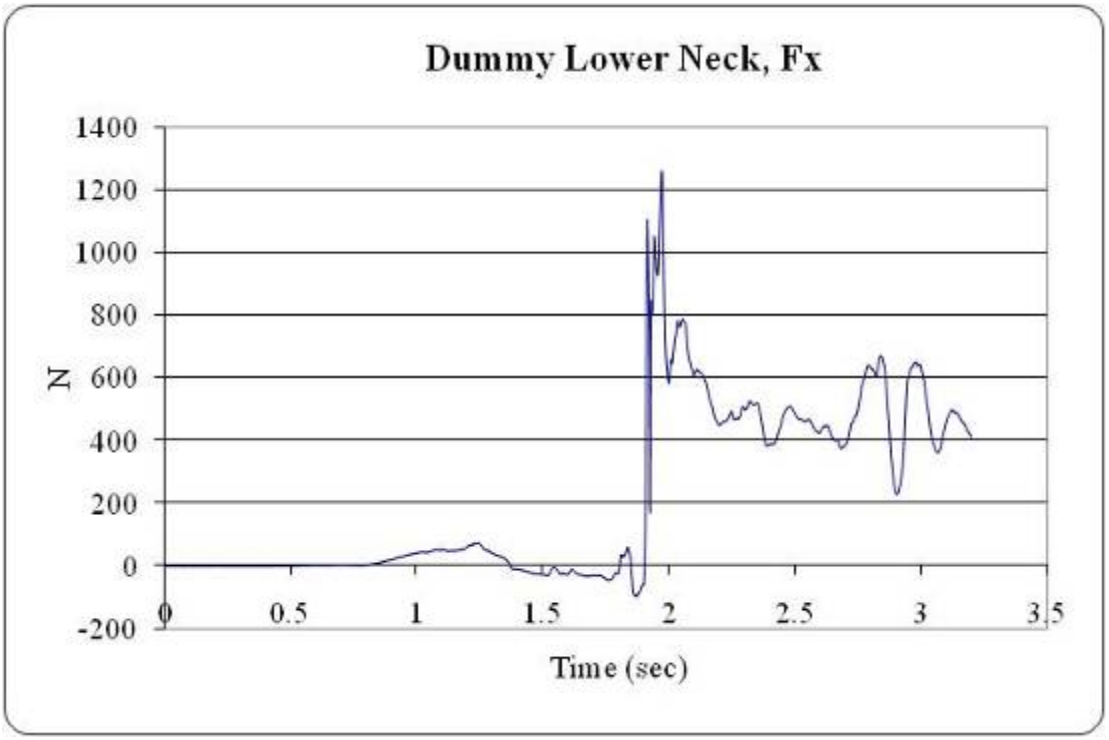
Data Sampling Rate: 10 kHz



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

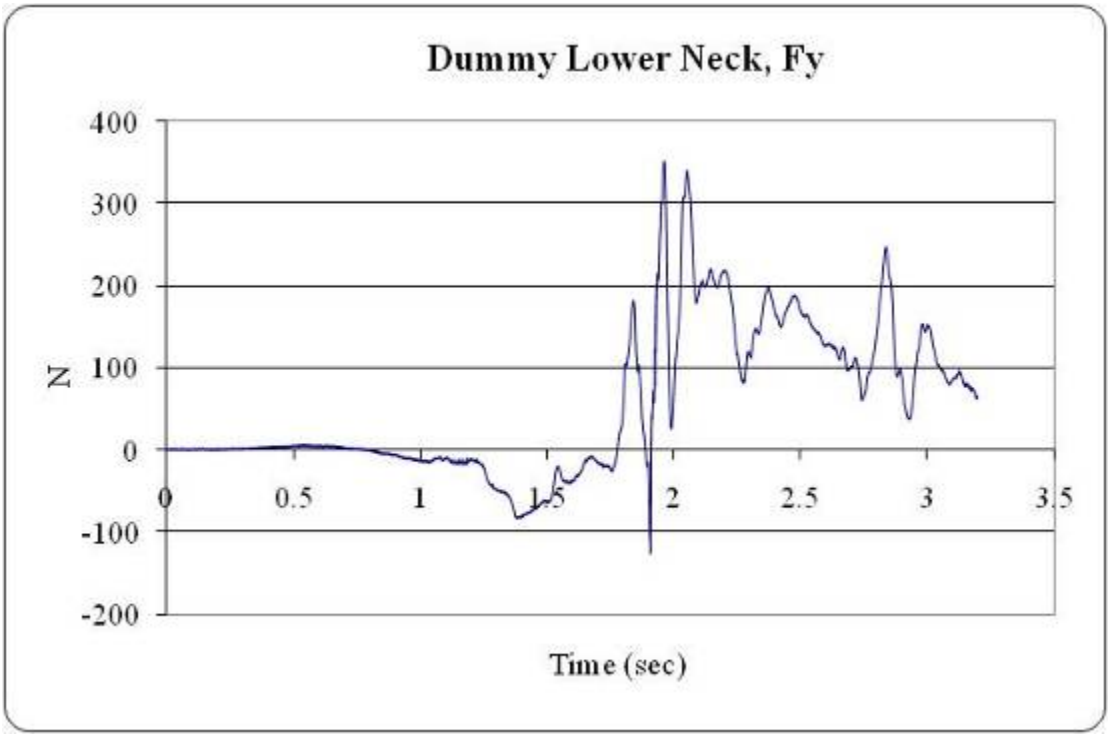
Data Sampling Rate: 10 kHz

Roll 1



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

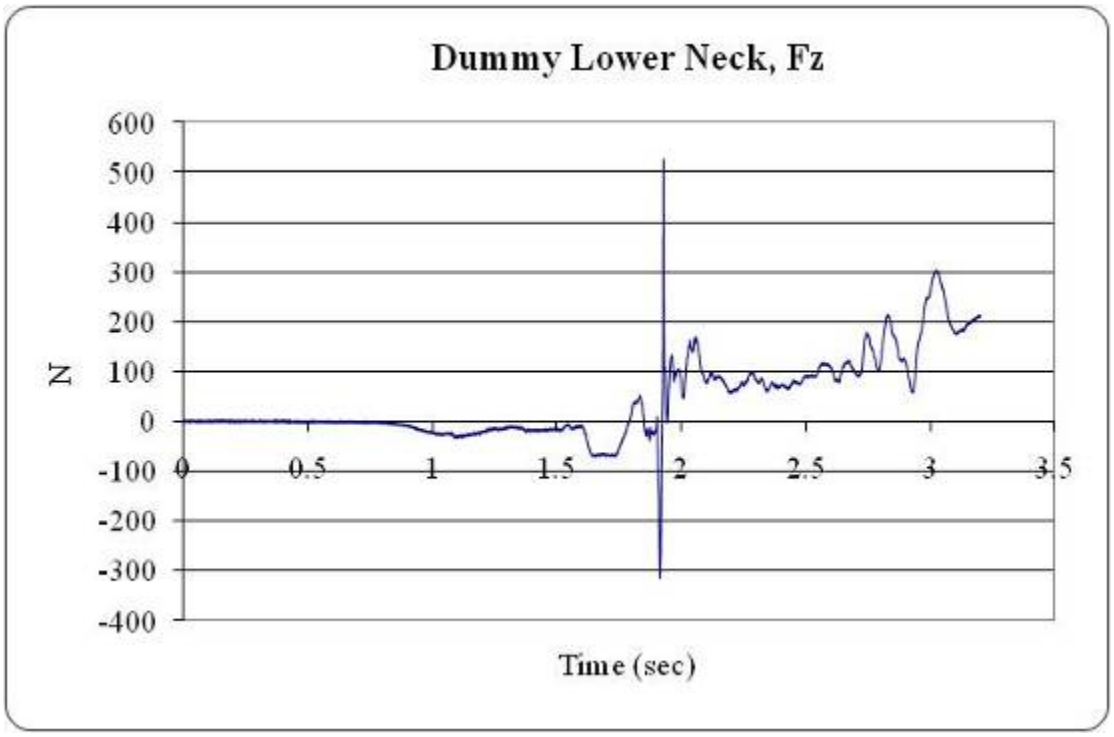
Data Sampling Rate: 10 kHz



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

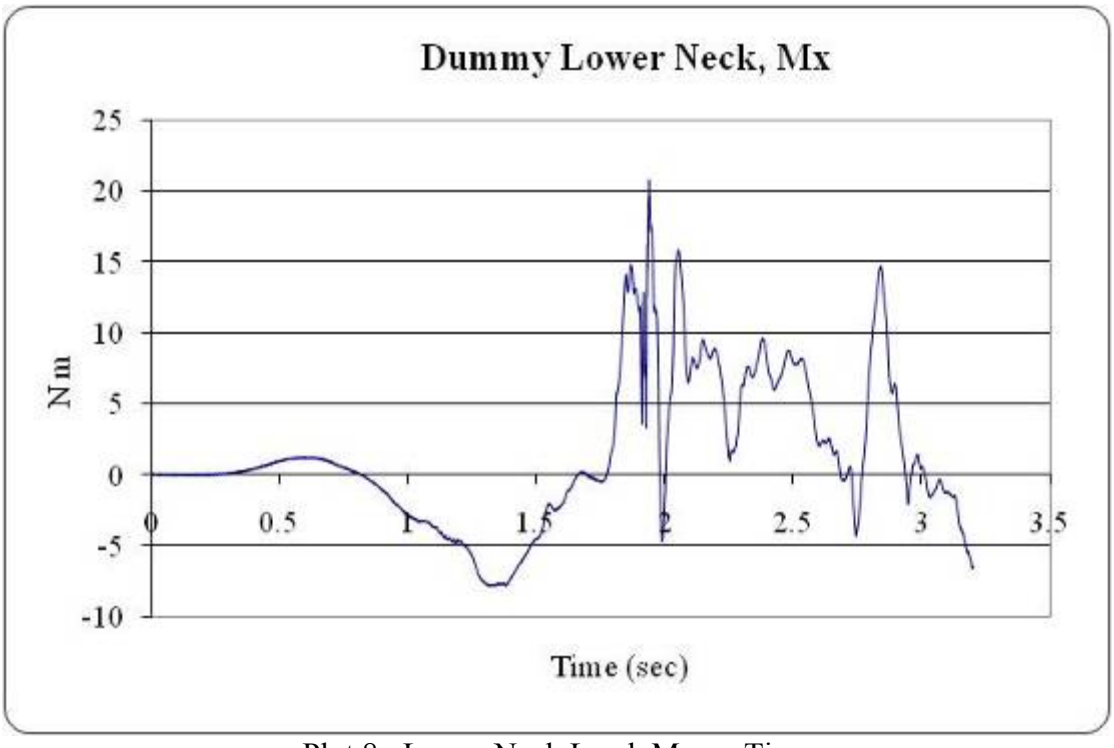
Data Sampling Rate: 10 kHz

Roll 1



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

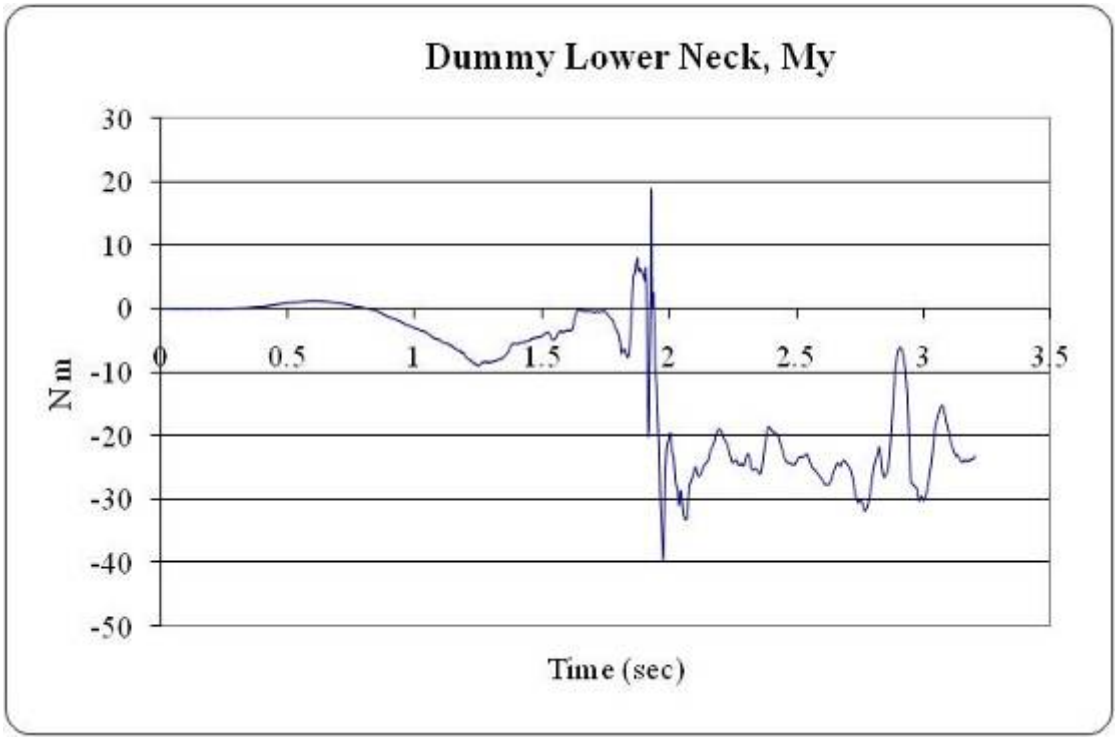
Data Sampling Rate: 10 kHz



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

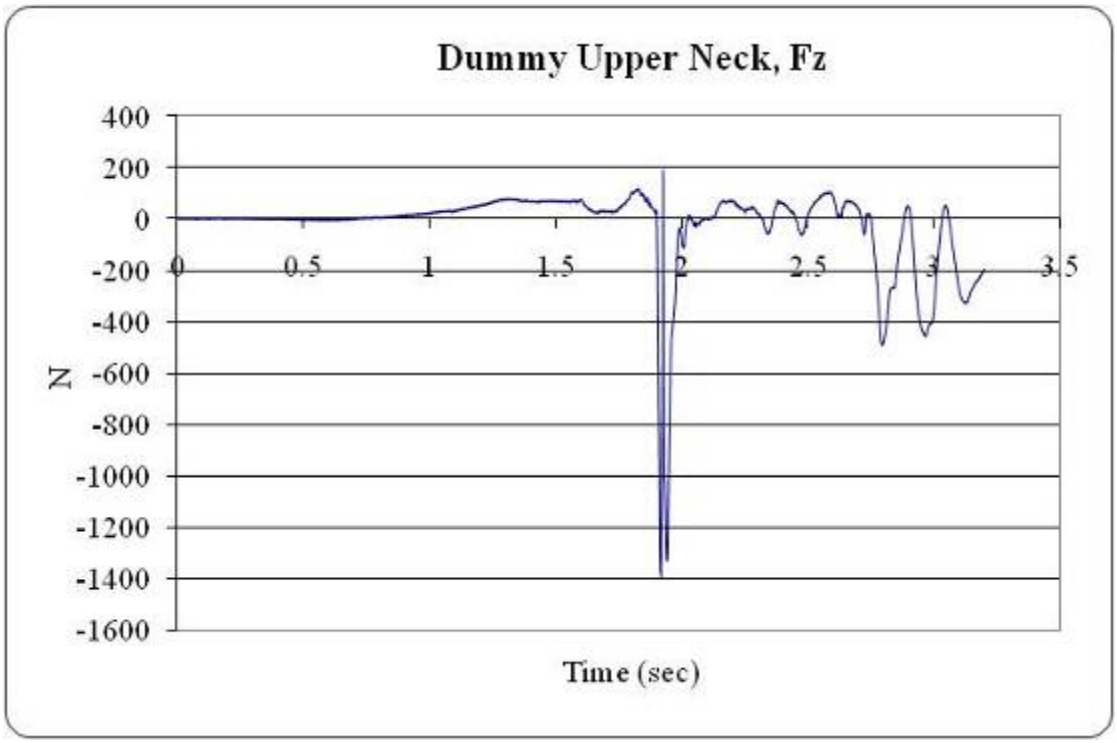
Data Sampling Rate: 10 kHz

Roll 1



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

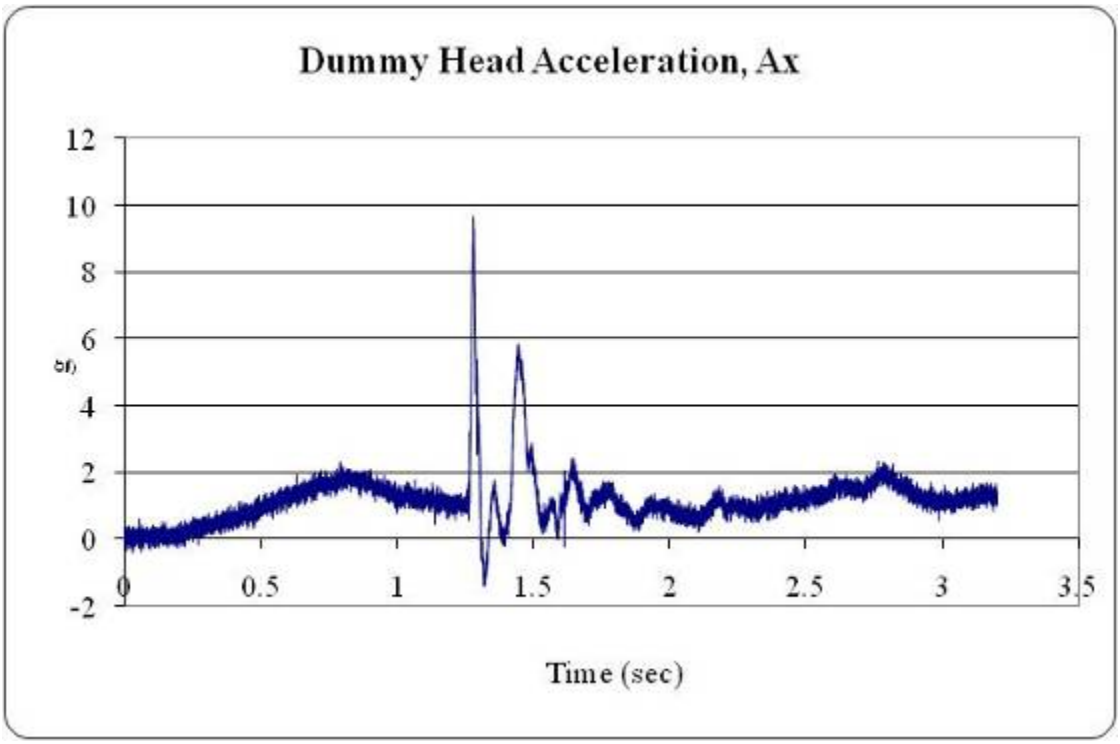
Data Sampling Rate: 10 kHz



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

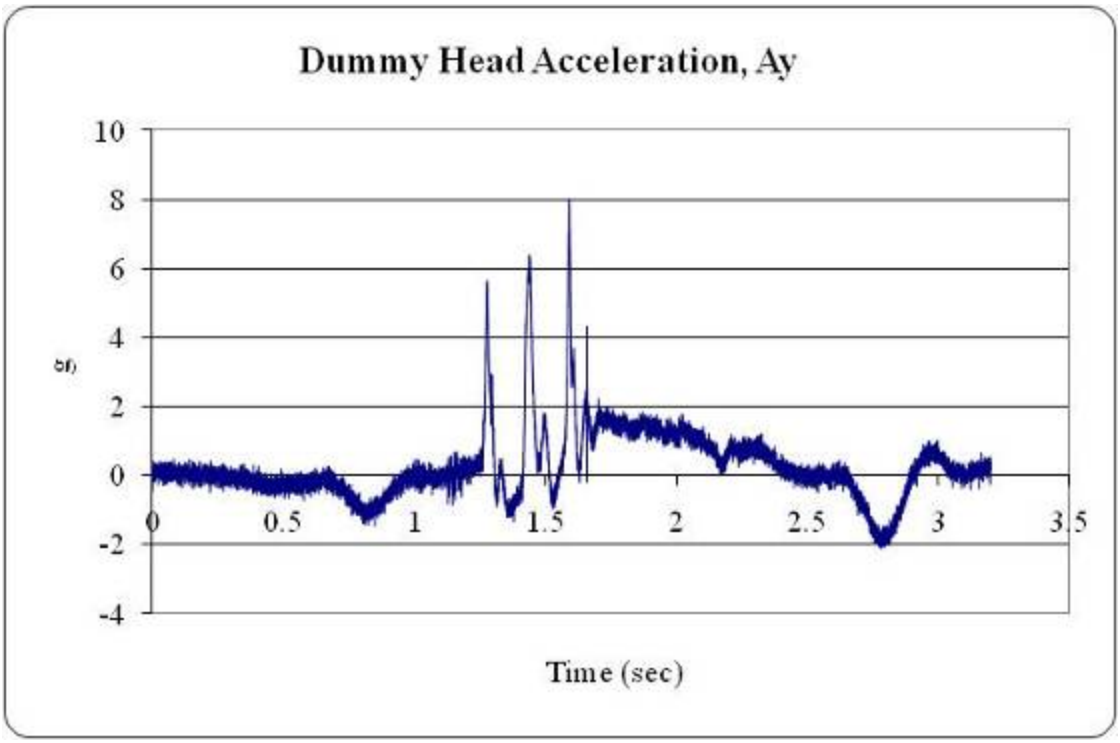
Data Sampling Rate: 10 kHz

Roll 1



Plot 11: Head Acceleration, Ax, vs. Time

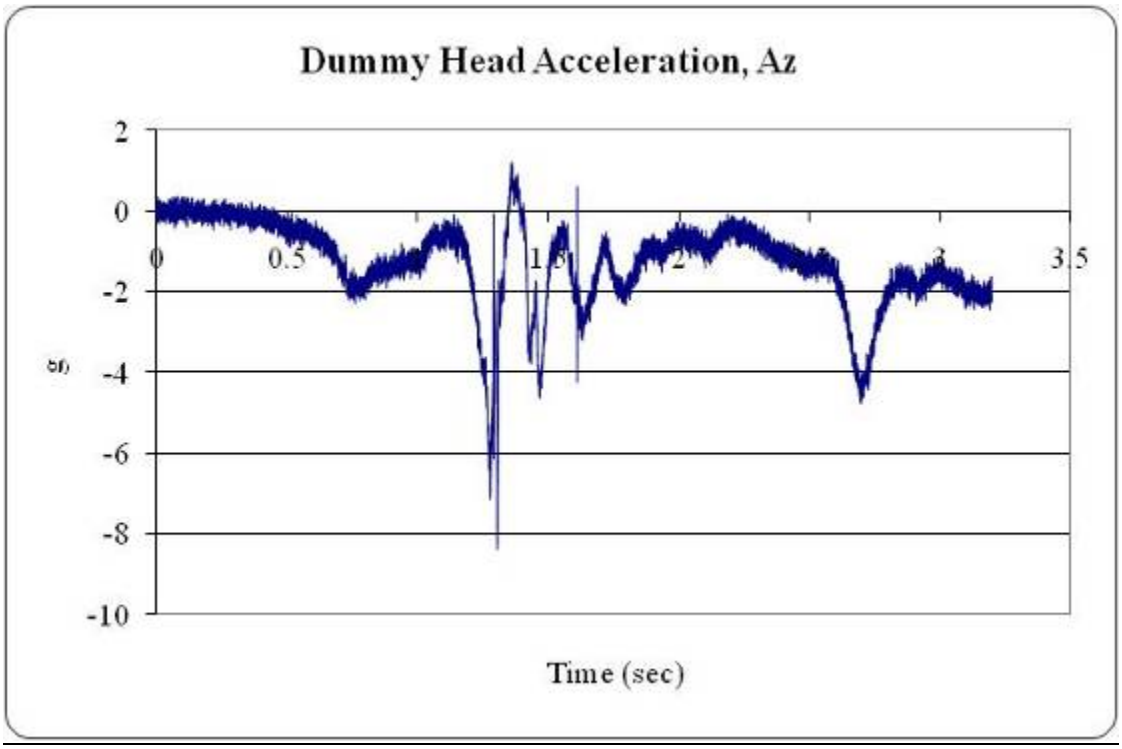
Data Sampling Rate: 10 kHz



Plot 12: Head Acceleration, Ay, vs. Time

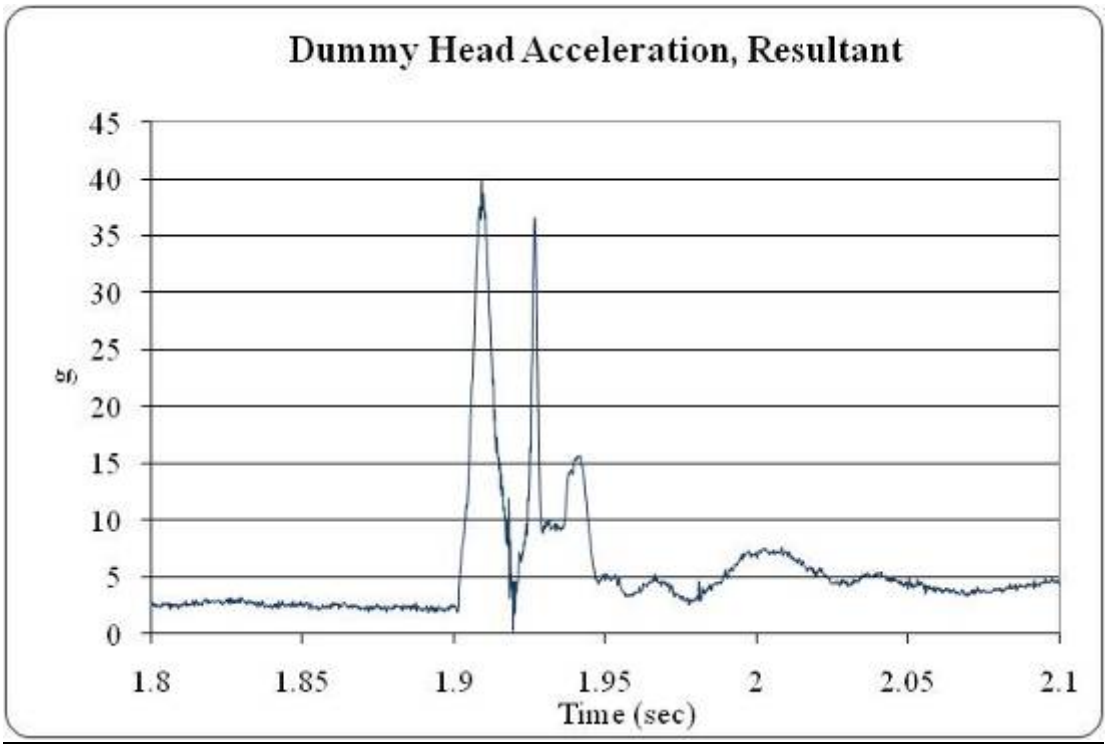
Data Sampling Rate: 10 kHz

Roll 1



Plot 13: Head Acceleration, Az, vs. Time

Data Sampling Rate: 10 kHz

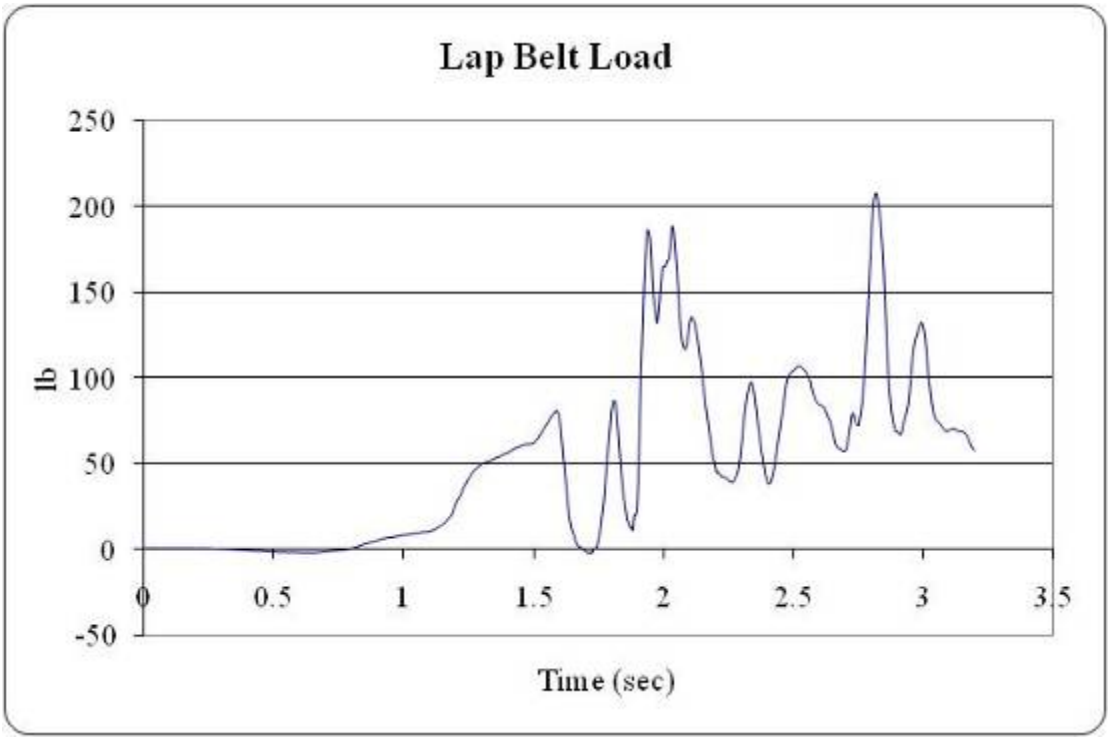


Plot 14: Resultant Head Acceleration vs. Time

HIC = 40

Data Sampling Rate: 10 kHz

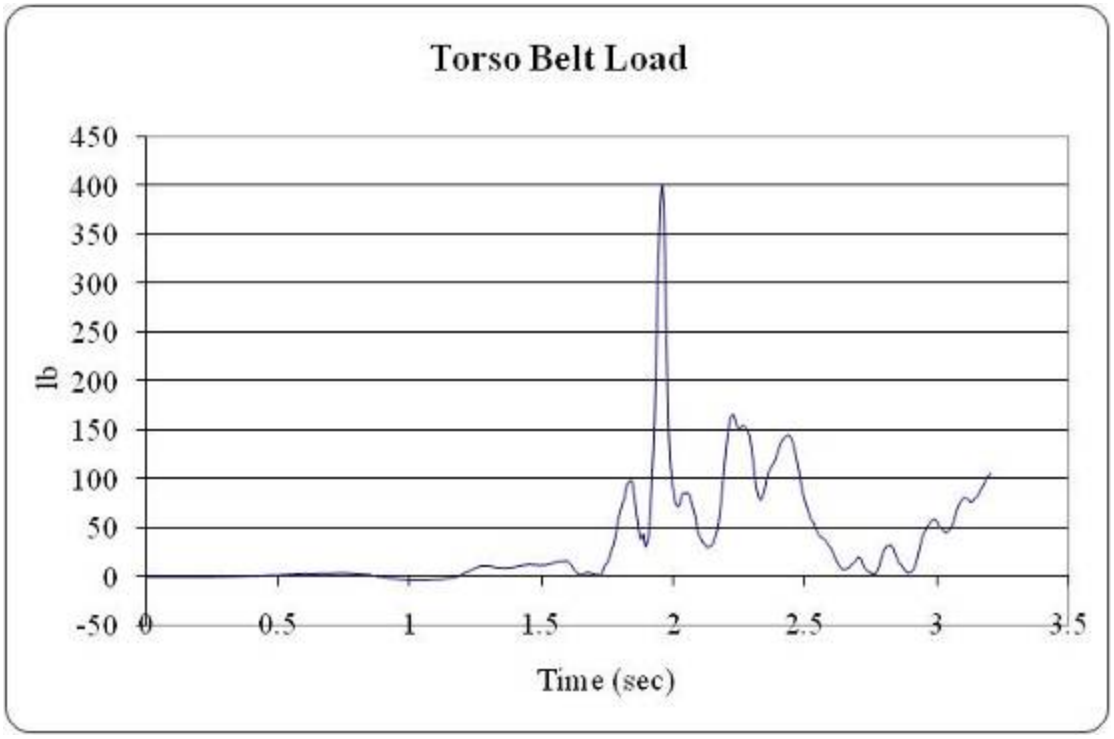
Roll 1



Plot 15: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

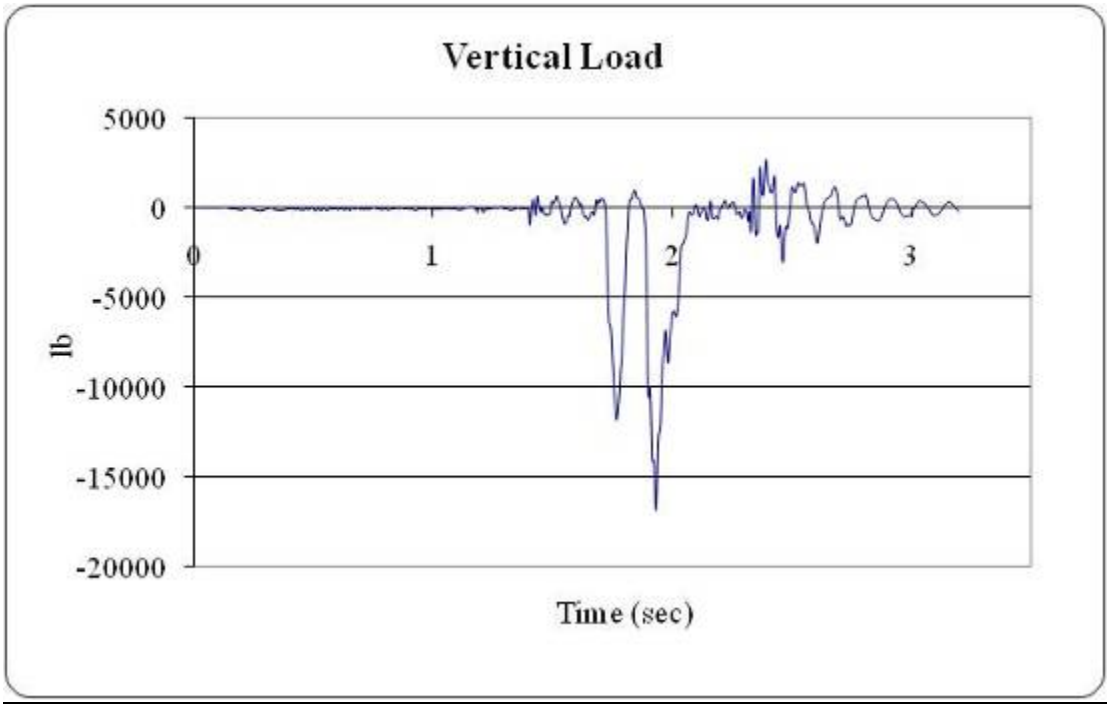


Plot 16: Torso Belt Load* vs. Time

*Measured on one side of the belt

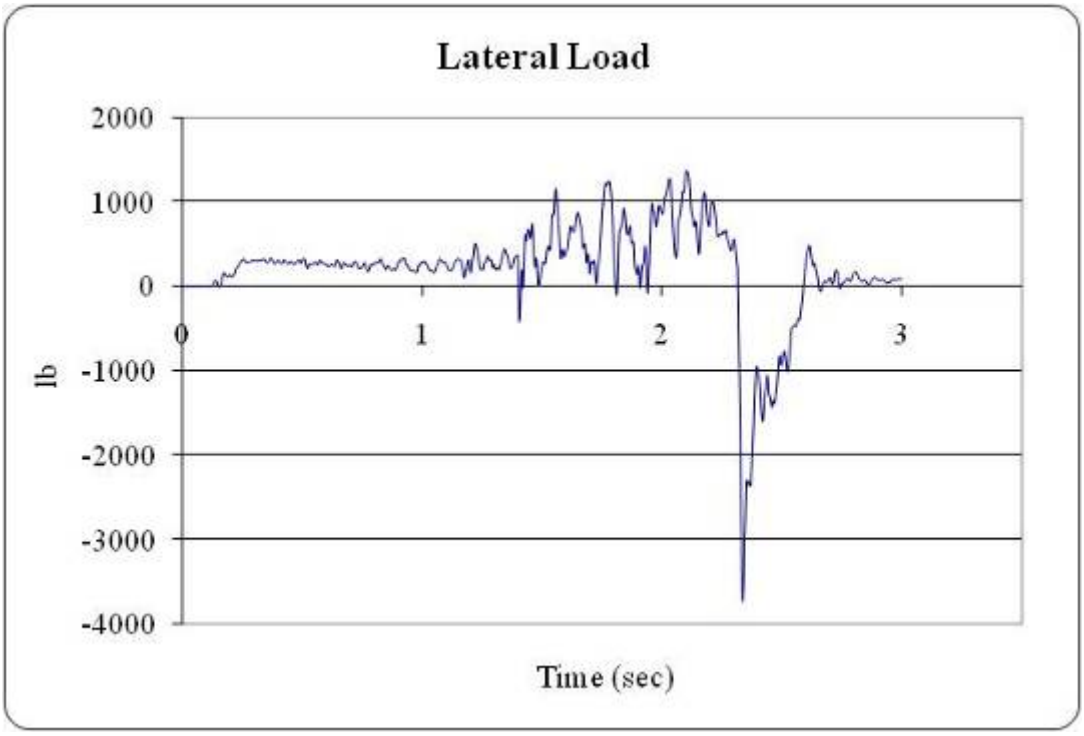
Data Sampling Rate: 10 kHz

Roll 1



Plot 17: Total Vertical Load v. Time

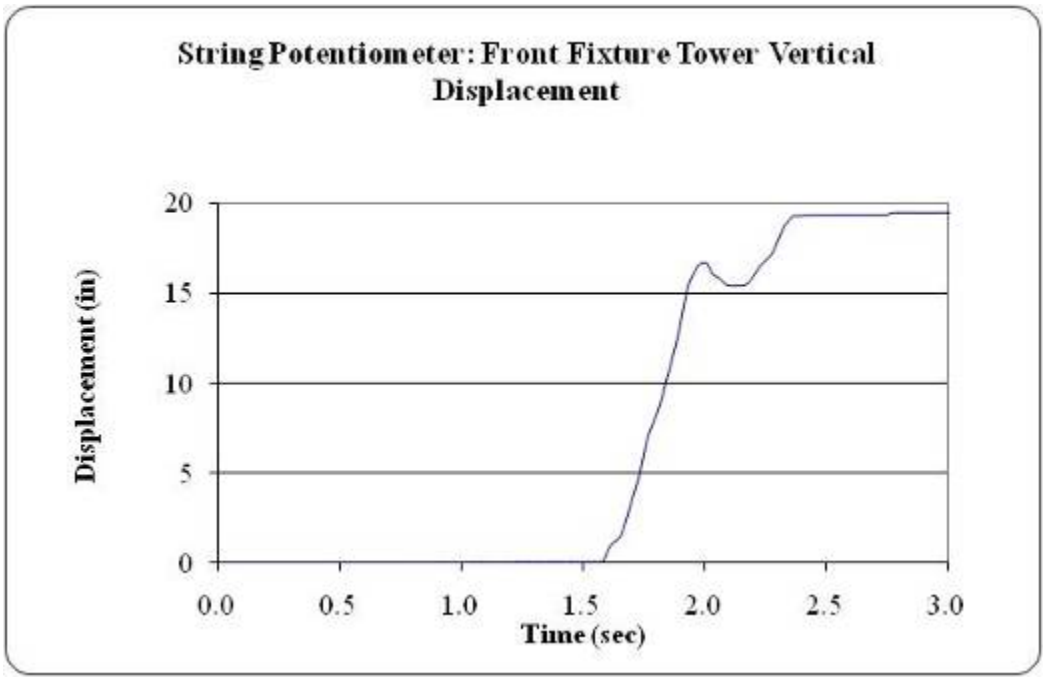
Data Sampling Rate: 10 kHz



Plot 18: Total Lateral Load v. Time

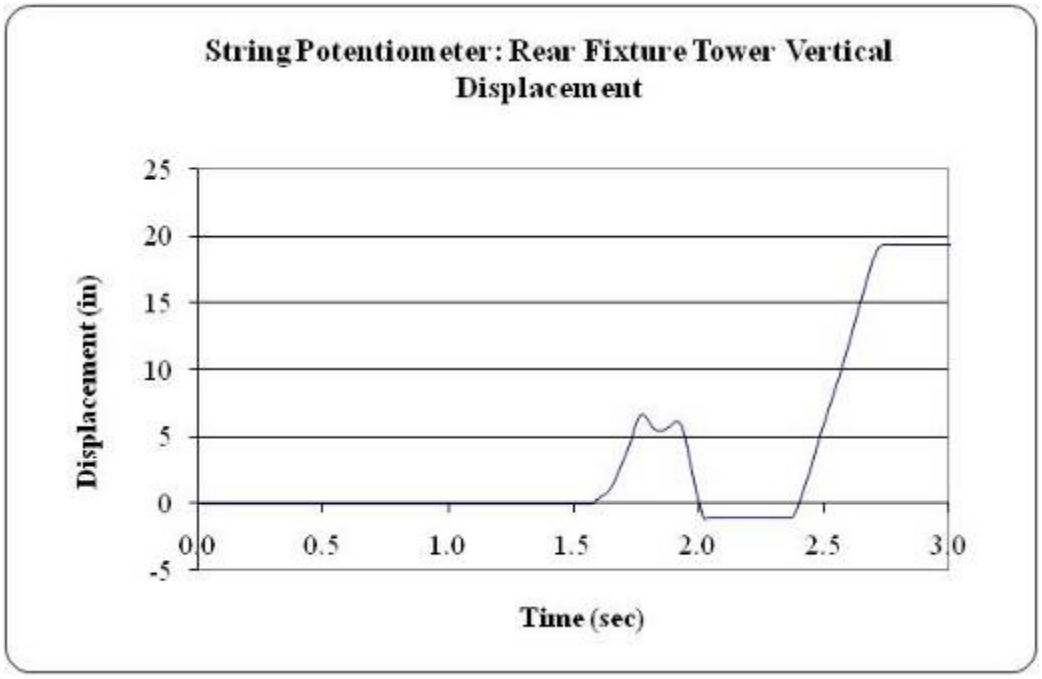
Data Sampling Rate: 10 kHz

Roll 1



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

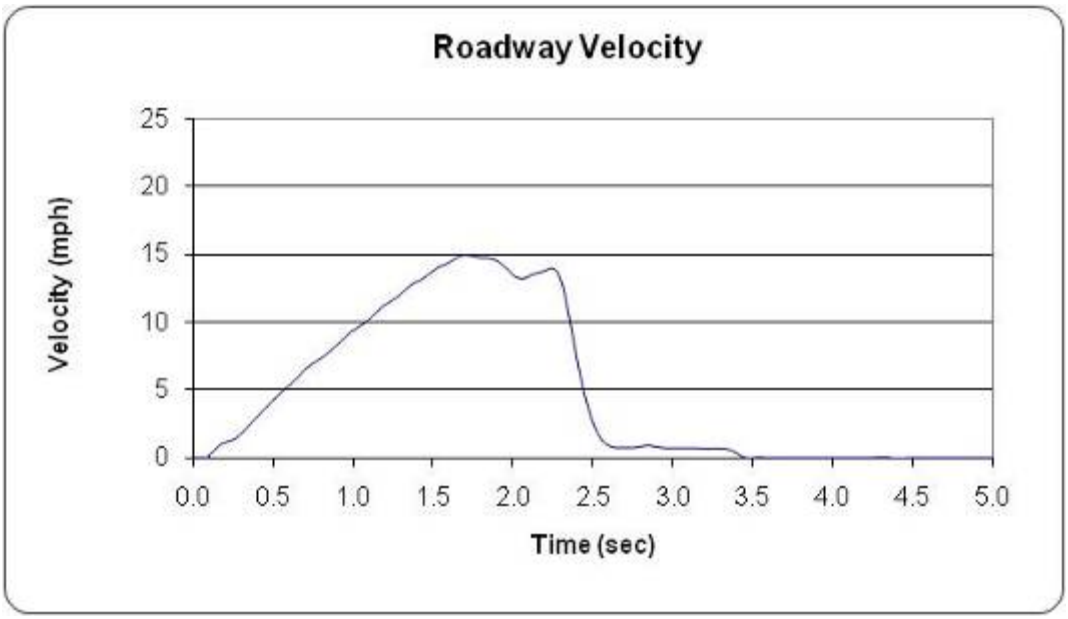
Data Sampling Rate: 1 kHz



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

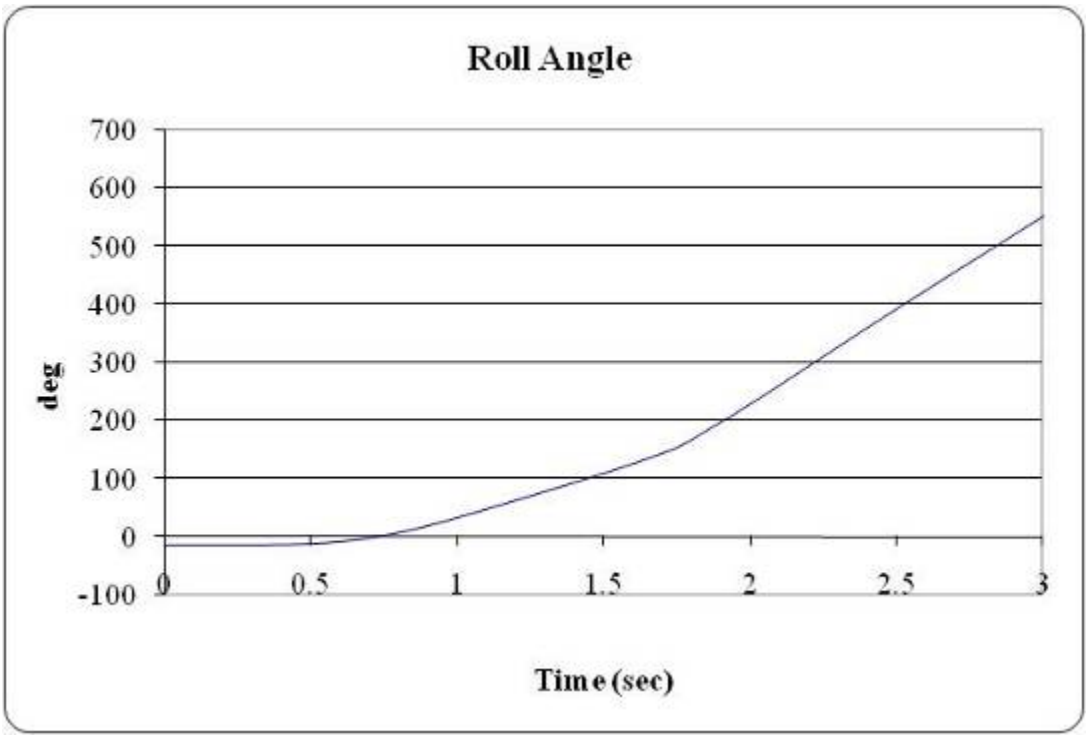
Data Sampling Rate: 1 kHz

Roll 1



Plot 21: Roll Encoder on Roadway Velocity vs. Time

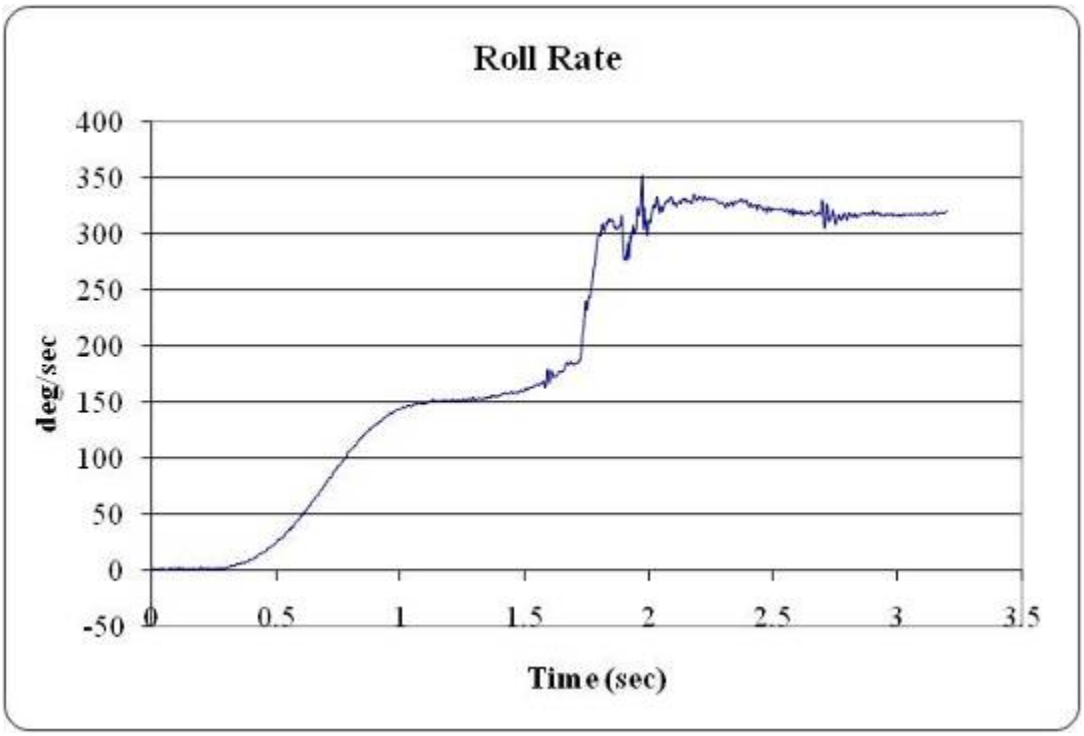
Data Sampling Rate: 1 kHz



Plot 22: Roll Angle vs. Time

Data Sampling Rate: 10 kHz

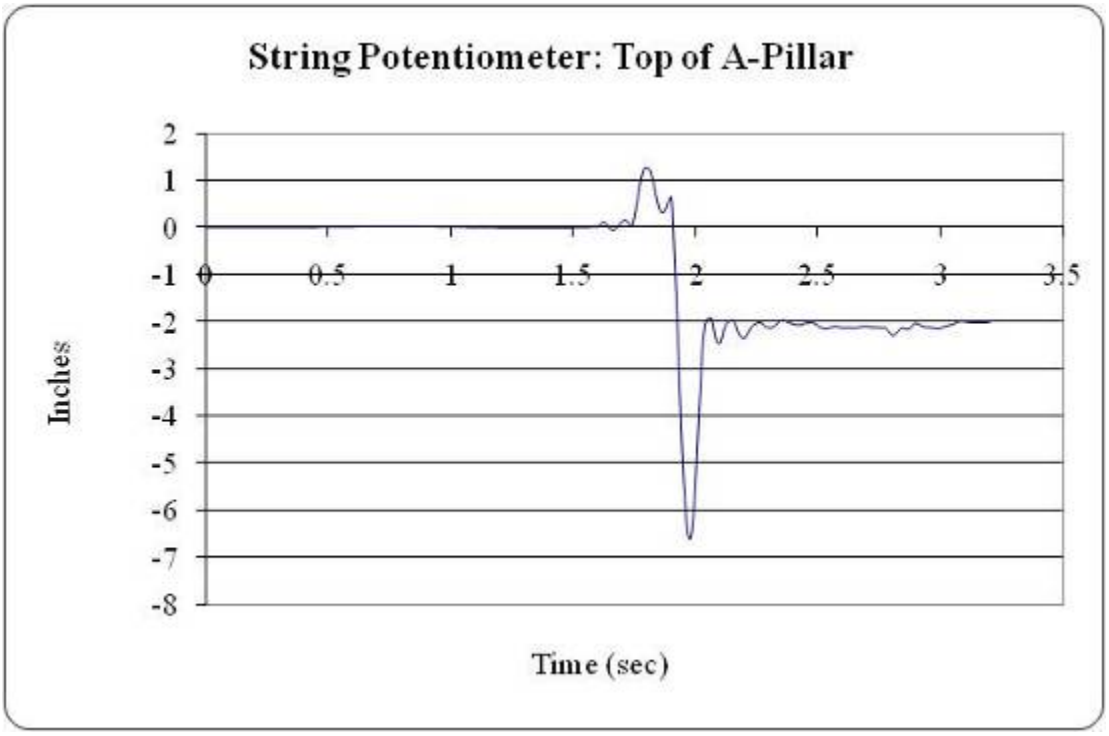
Roll 1



Plot 23: Roll Rate vs. Time

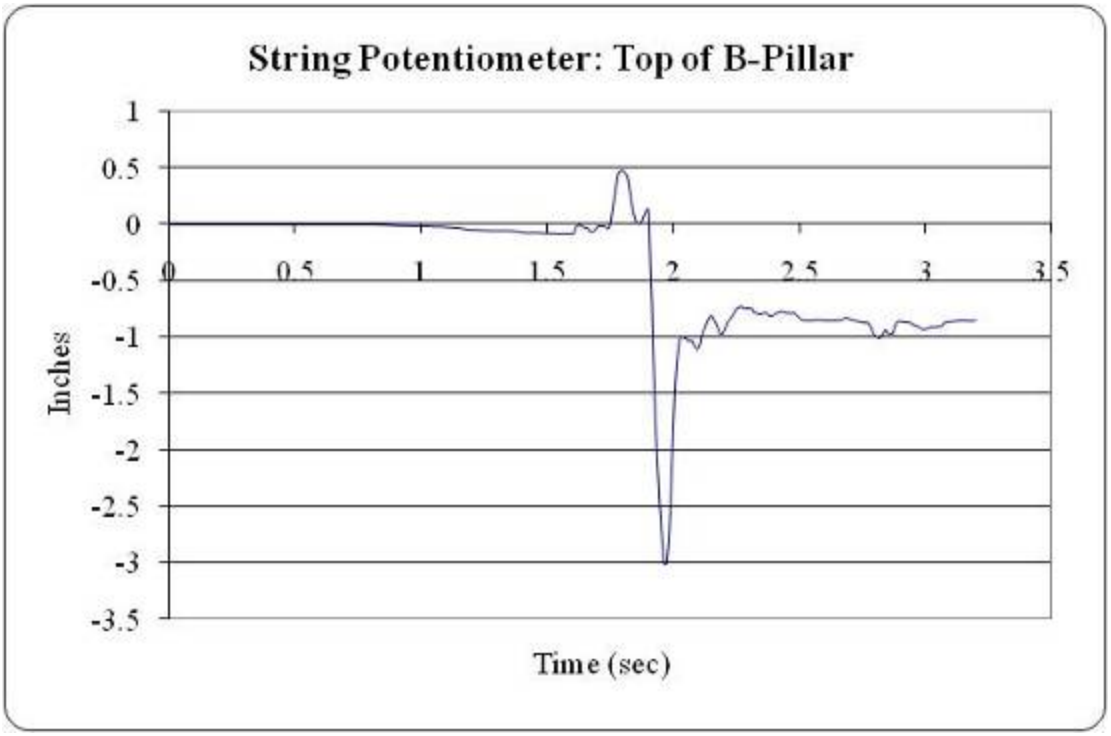
Data Sampling Rate: 10 kHz

Roll 2 Data Plots – 8/12/2010



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

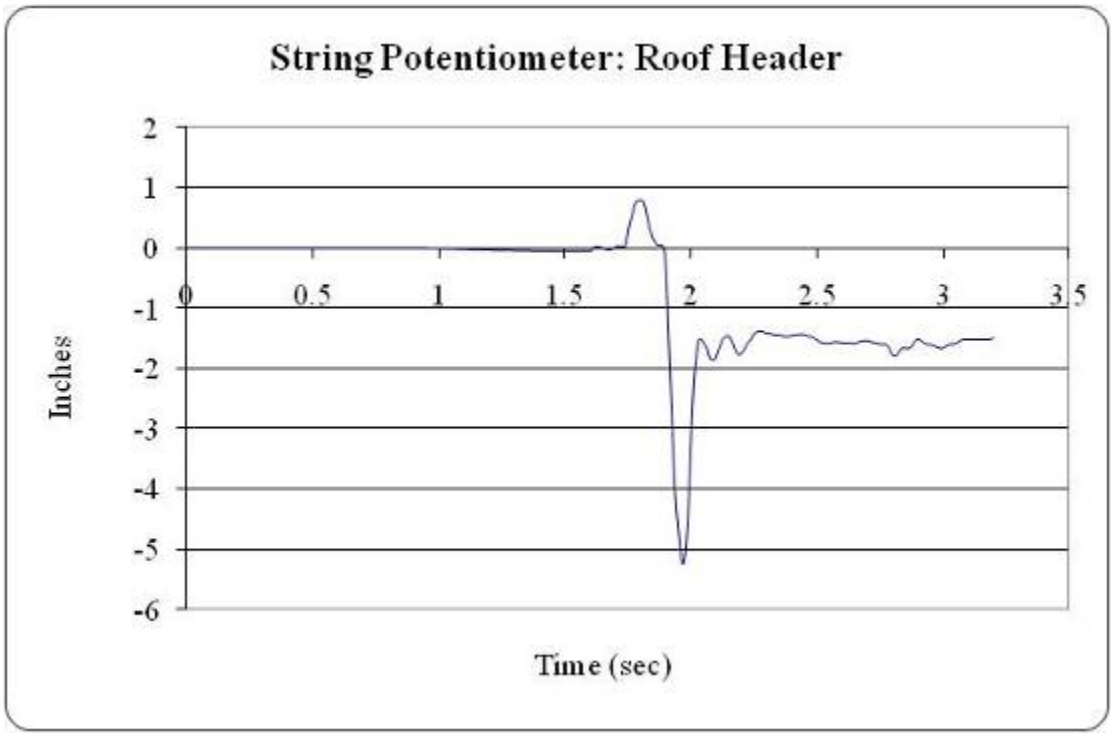
Data Sampling Rate: 10 kHz



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

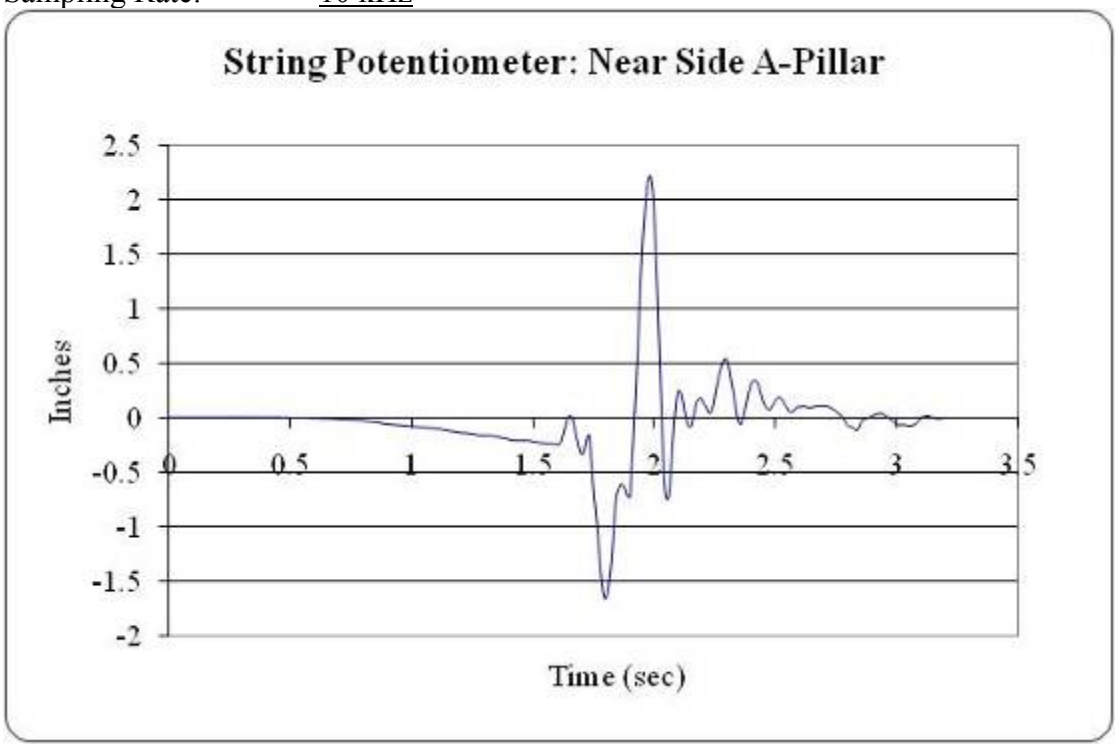
Data Sampling Rate: 10 kHz

Roll 2



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

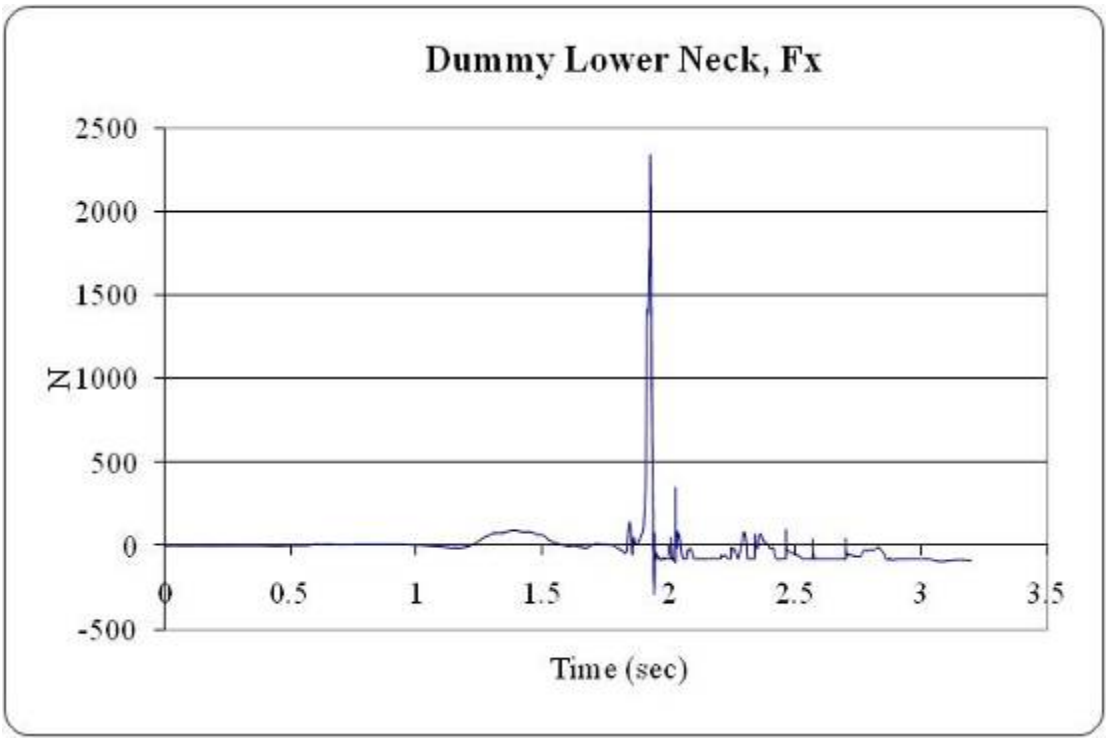
Data Sampling Rate: 10 kHz



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

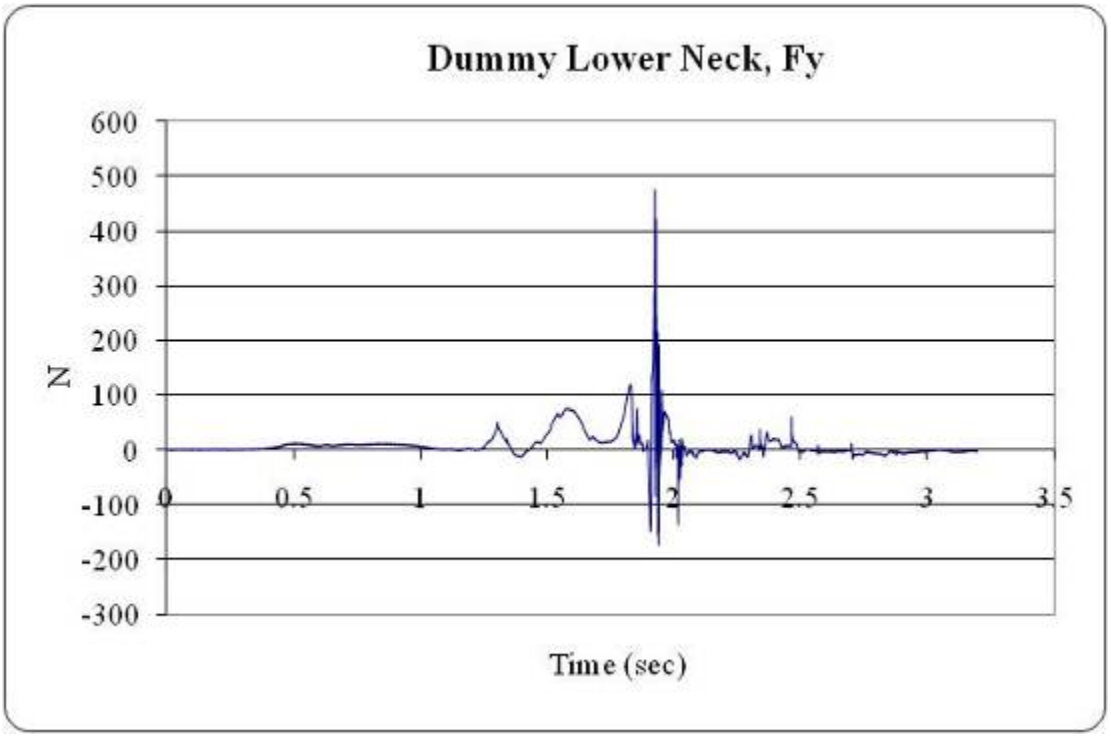
Data Sampling Rate: 10 kHz

Roll 2



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

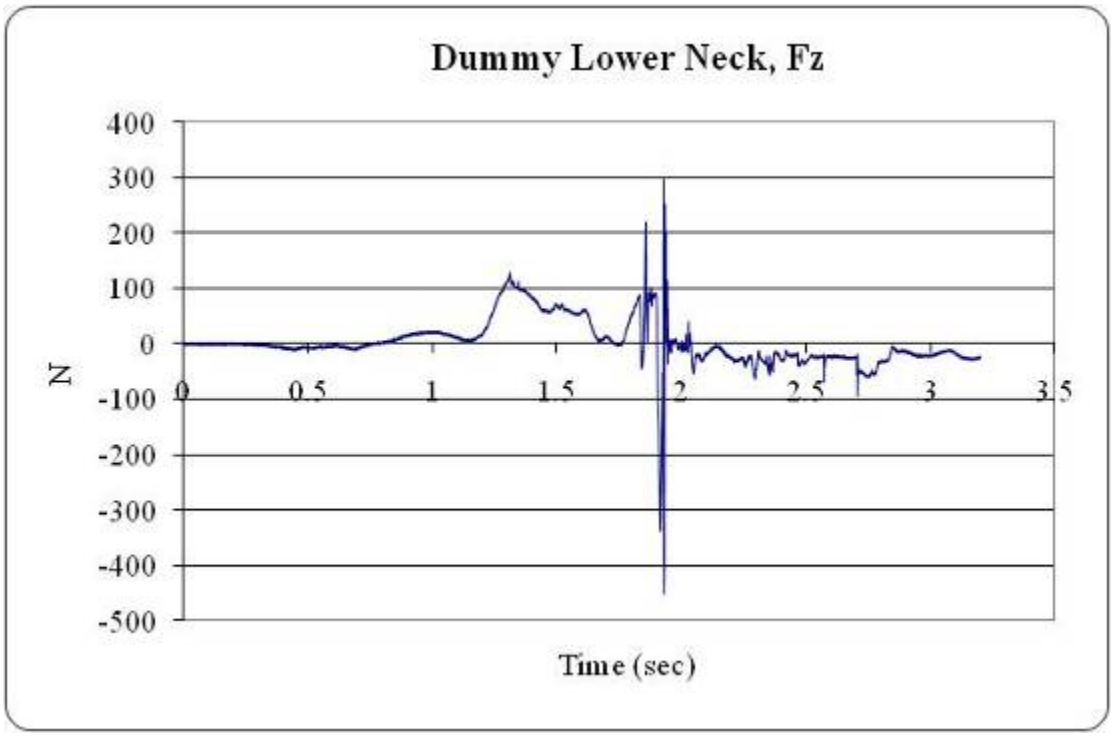
Data Sampling Rate: 10 kHz



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

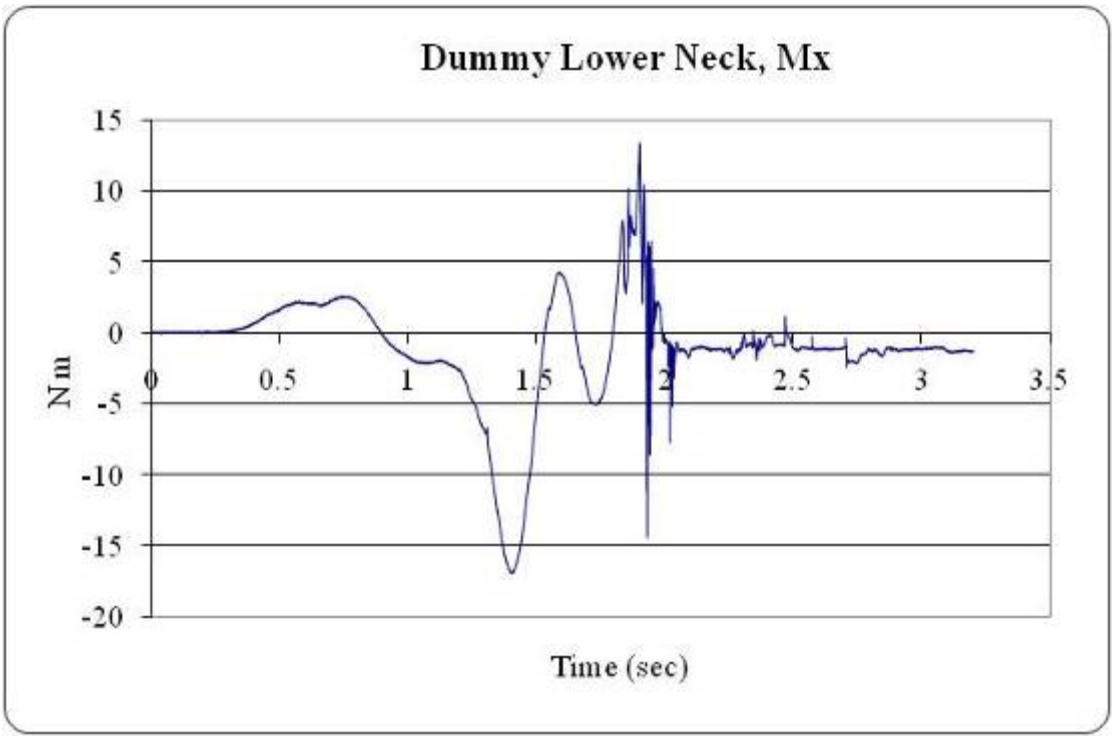
Data Sampling Rate: 10 kHz

Roll 2



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

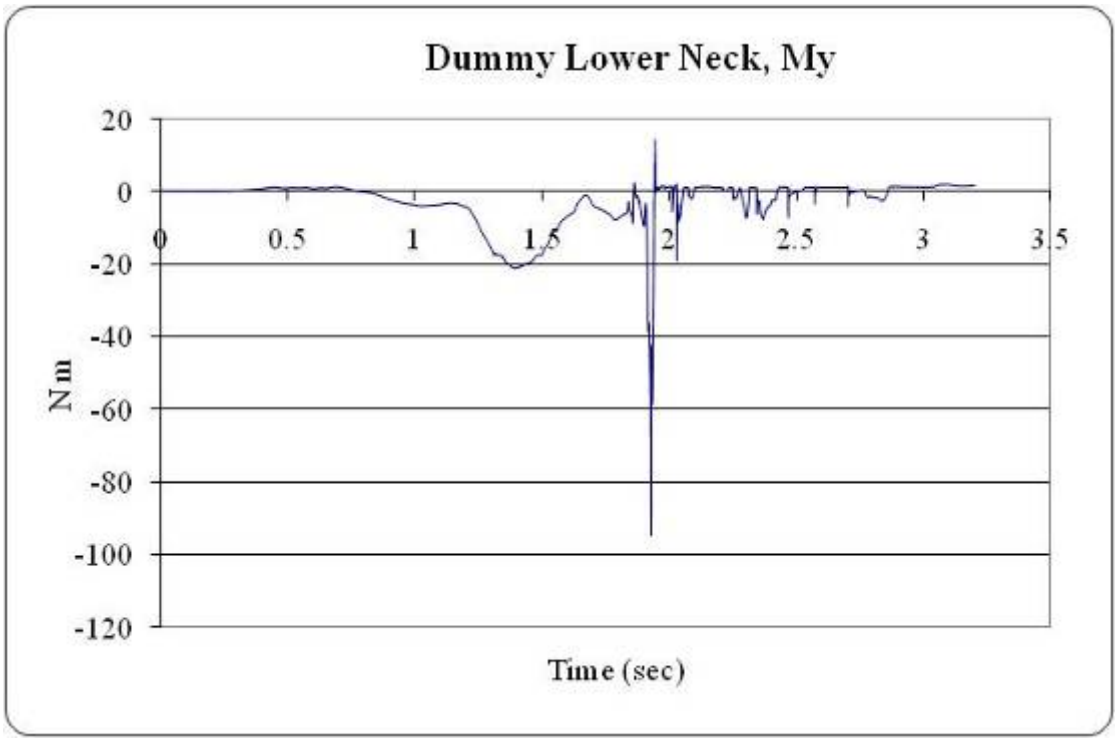
Data Sampling Rate: 10 kHz



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

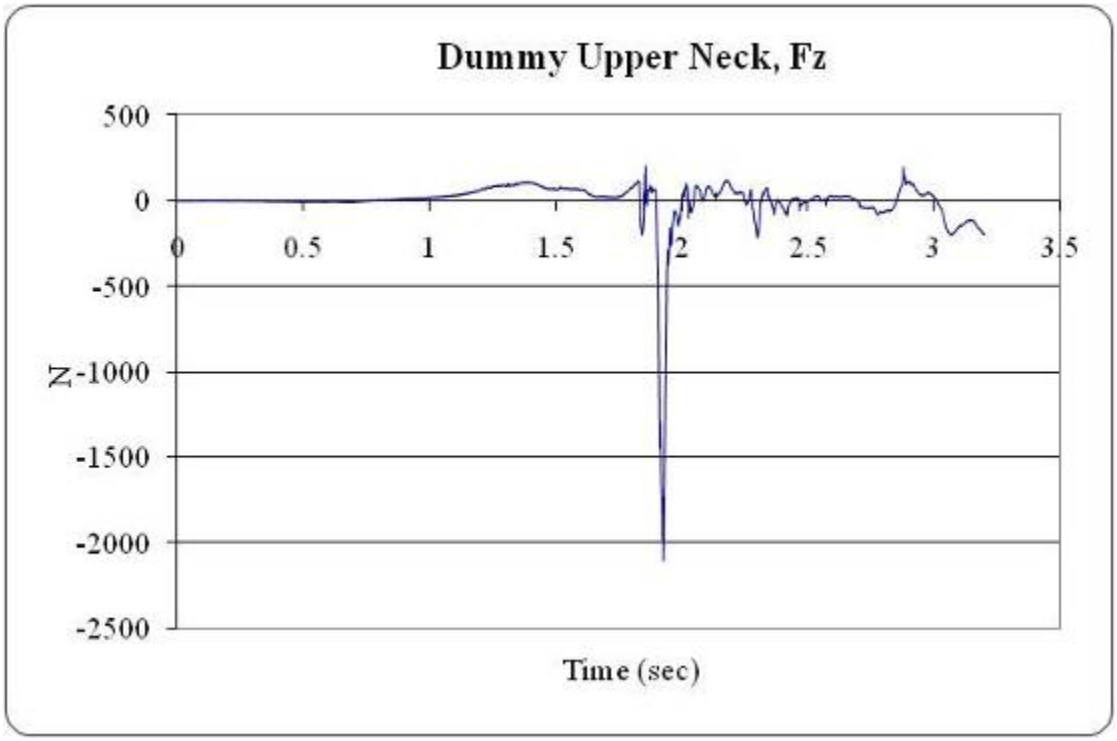
Data Sampling Rate: 10 kHz

Roll 2



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

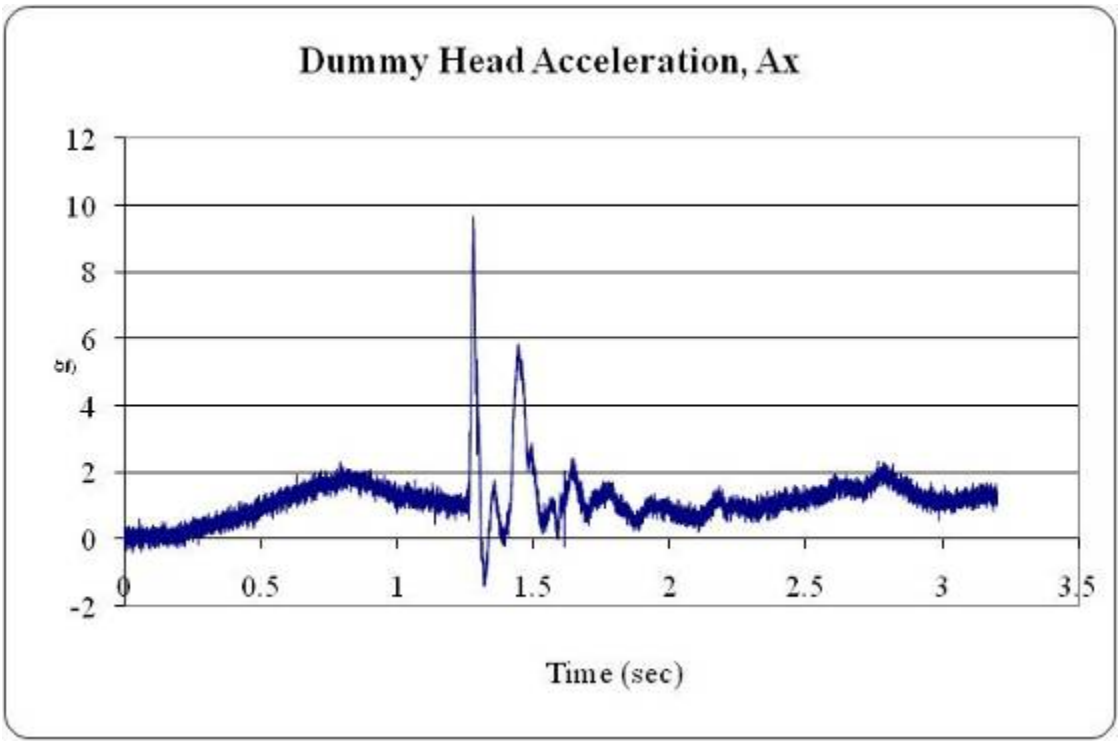
Data Sampling Rate: 10 kHz



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

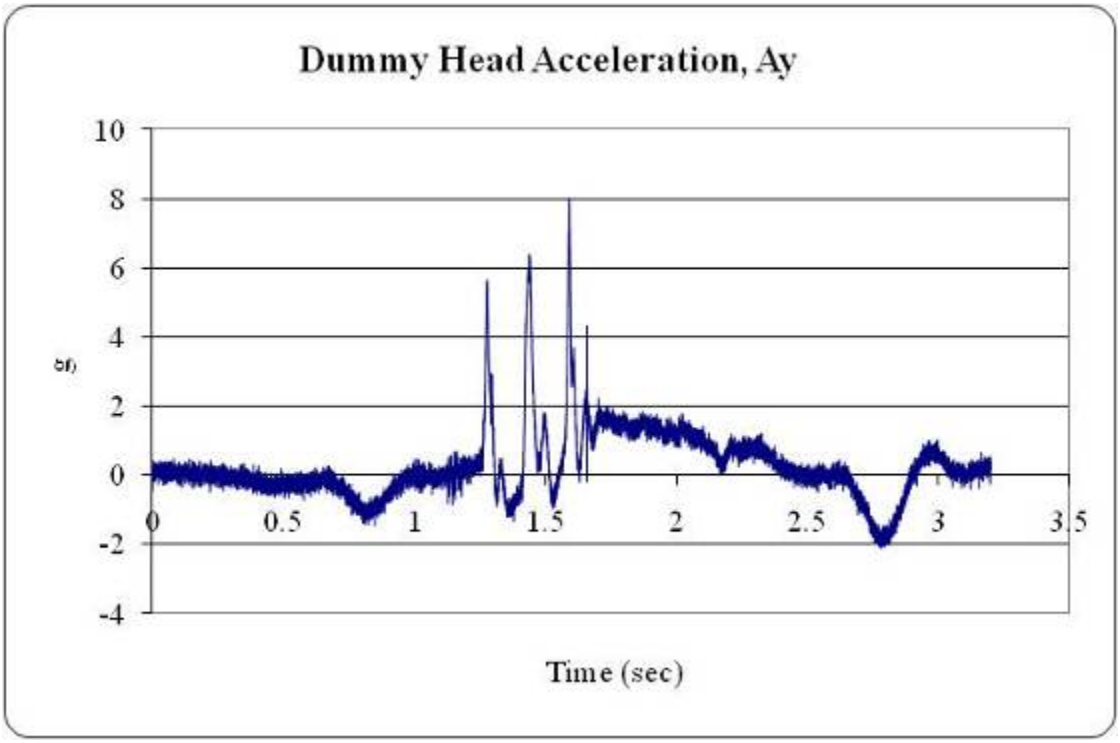
Data Sampling Rate: 10 kHz

Roll 2



Plot 34: Head Acceleration, Ax, vs. Time

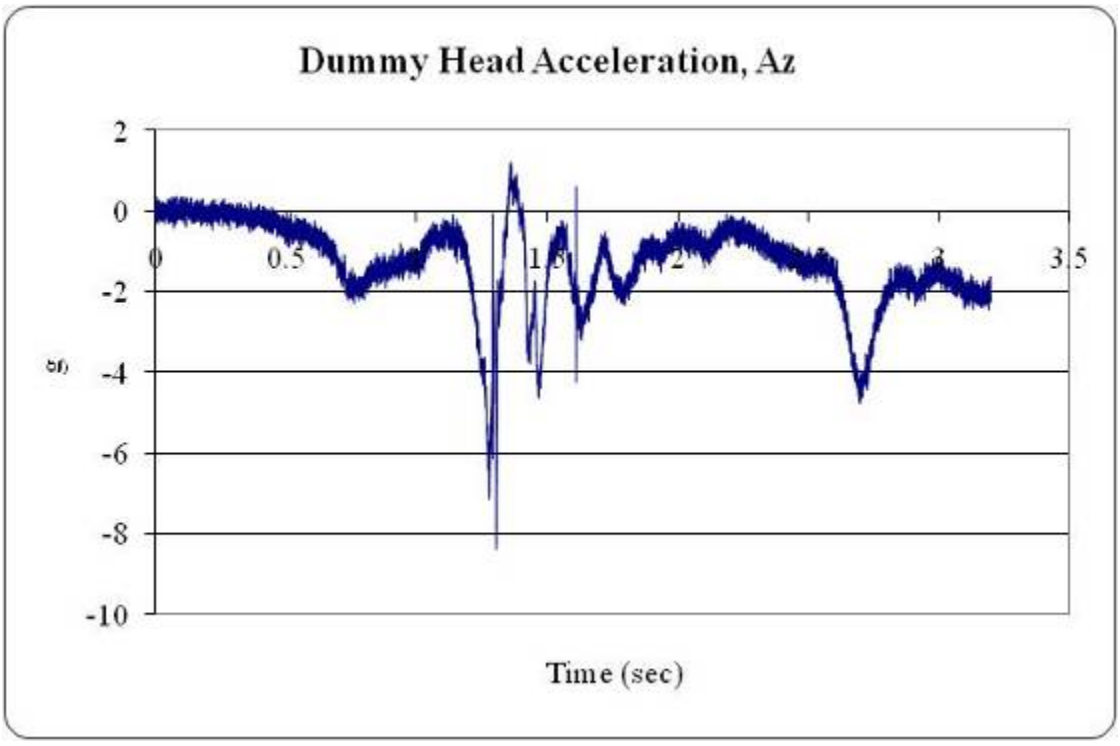
Data Sampling Rate: 10 kHz



Plot 35: Head Acceleration, Ay, vs. Time

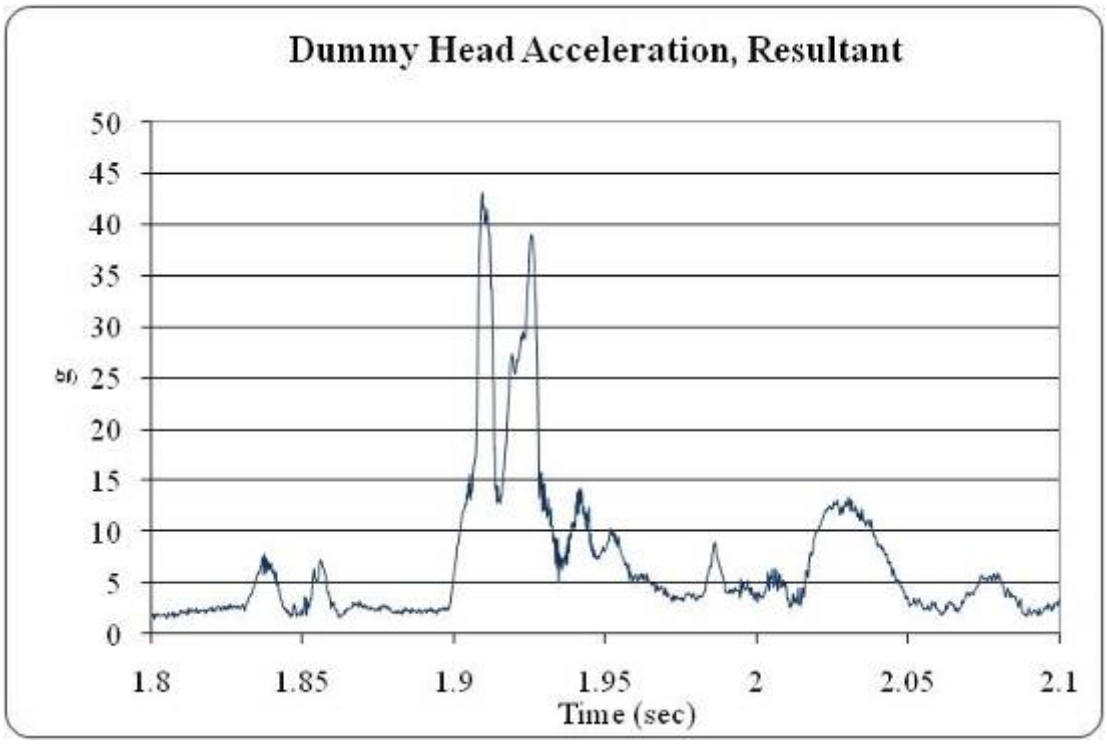
Data Sampling Rate: 10 kHz

Roll 2



Plot 36: Head Acceleration, Az, vs. Time

Data Sampling Rate: 10 kHz

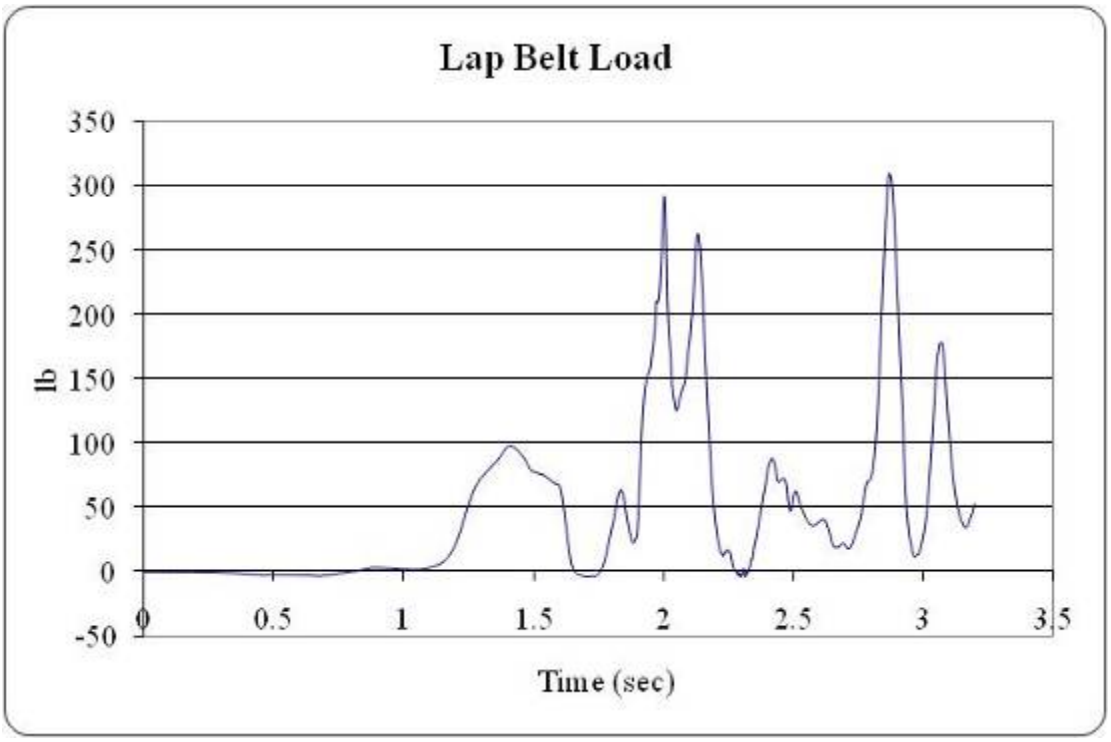


Plot 37: Resultant Head Acceleration vs. Time

HIC = 89

Data Sampling Rate: 10 kHz

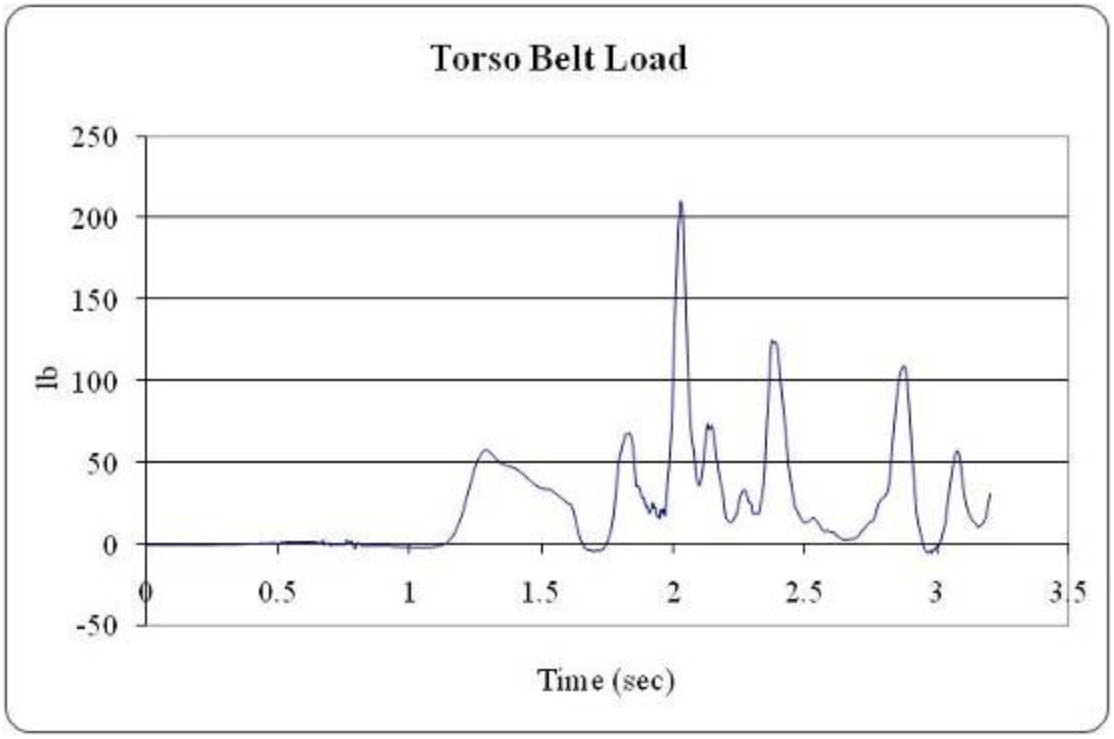
Roll 2



Plot 38: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

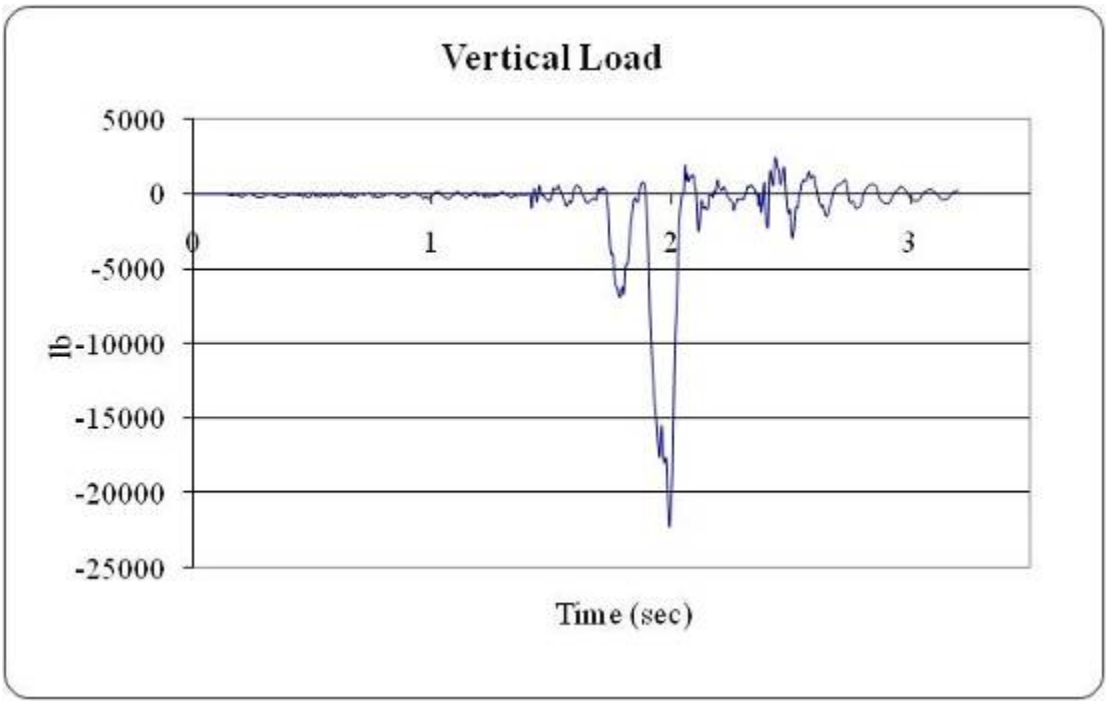


Plot 39: Torso Belt Load* vs. Time

*Measured on one side of the belt

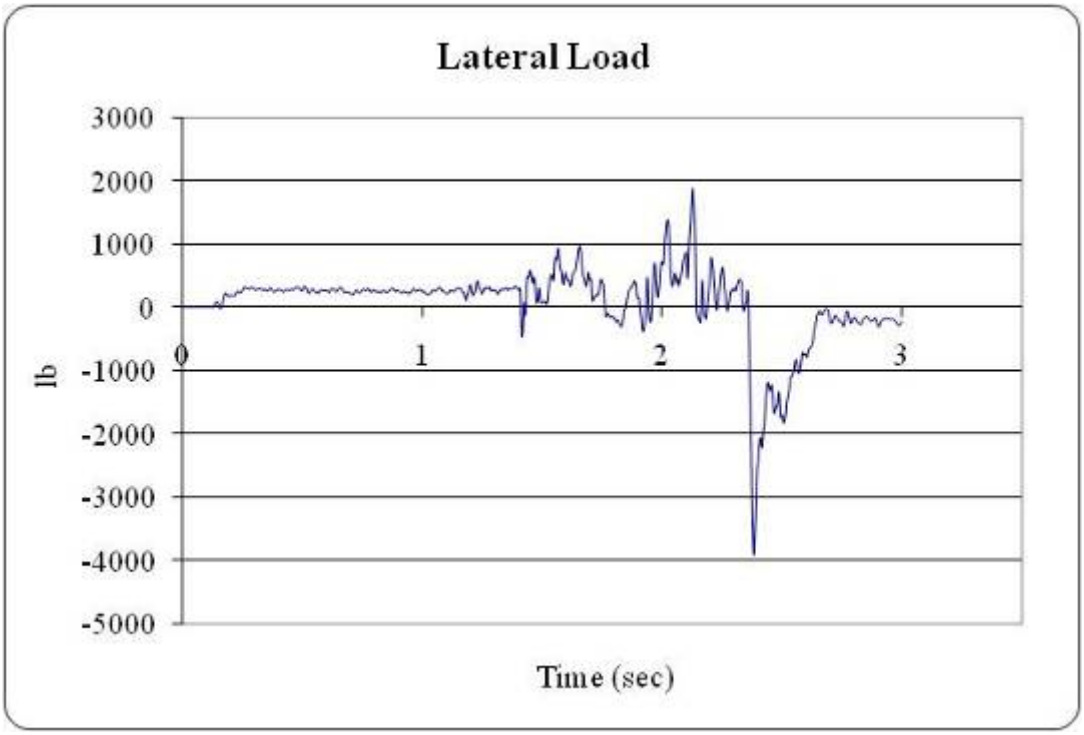
Data Sampling Rate: 10 kHz

Roll 2



Plot 40: Total Vertical Load v. Time

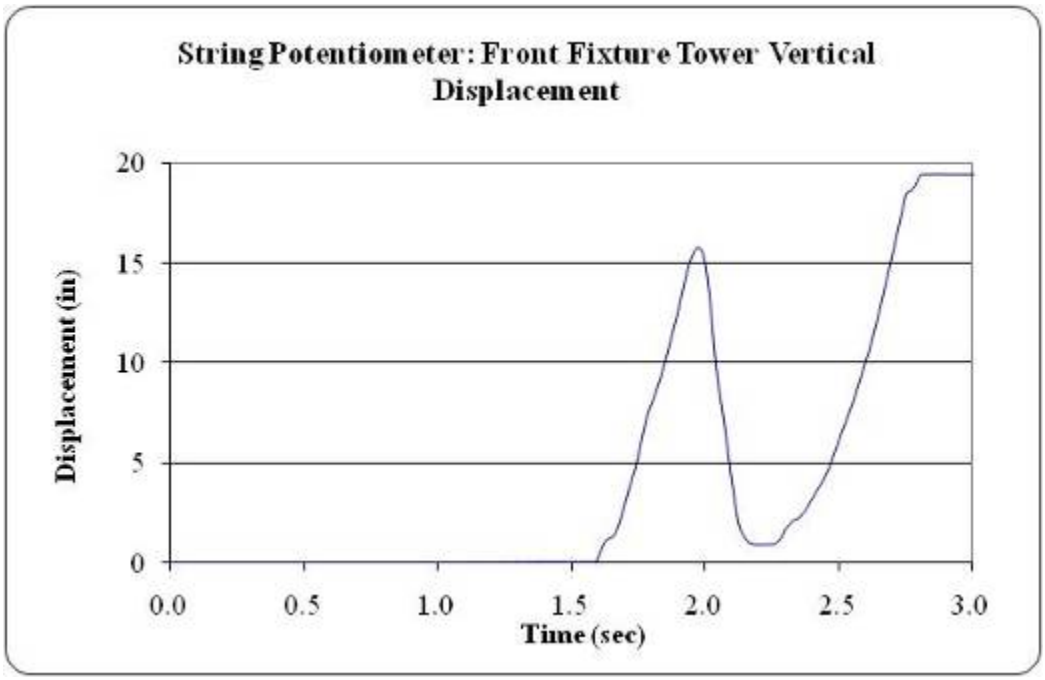
Data Sampling Rate: 10 kHz



Plot 41: Total Lateral Load v. Time

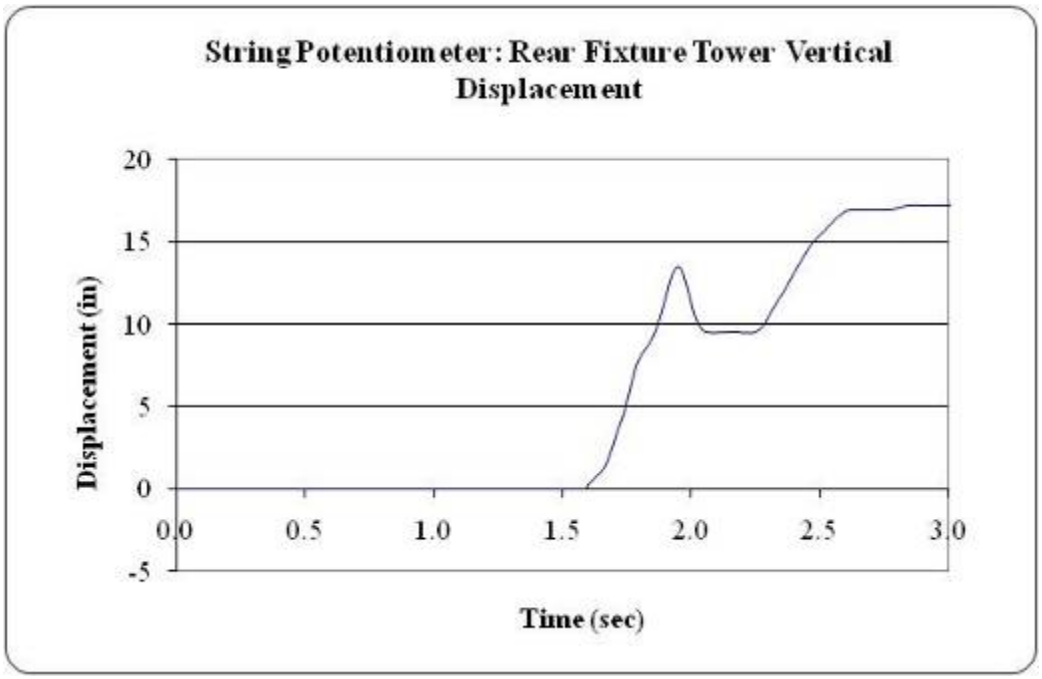
Data Sampling Rate: 10 kHz

Roll 2



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

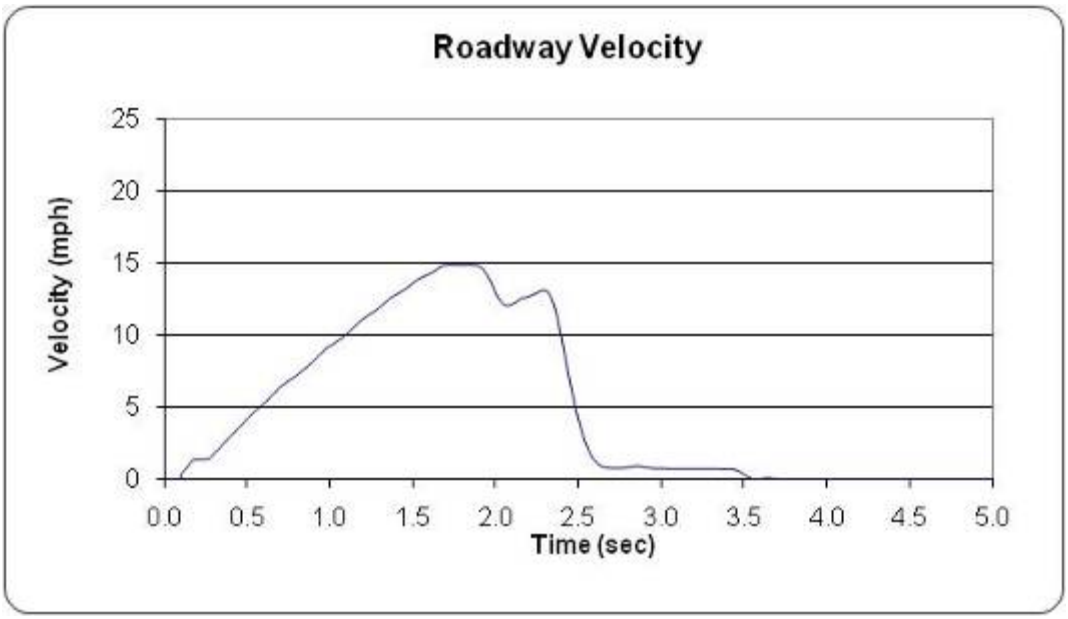
Data Sampling Rate: 1 kHz



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

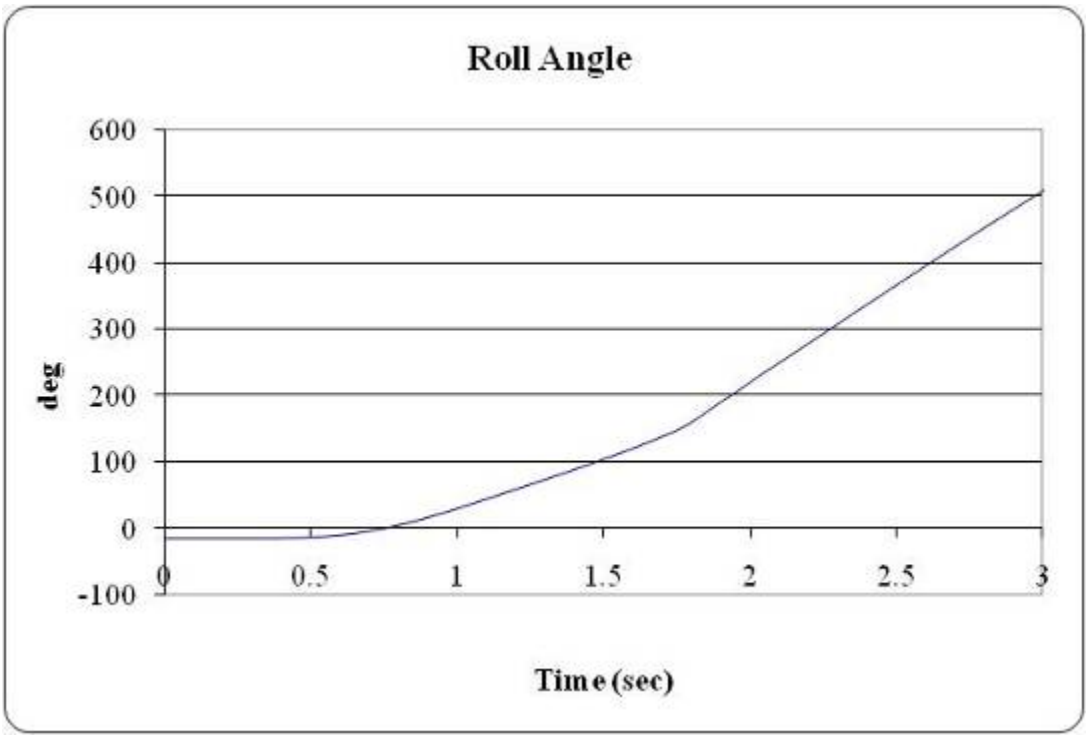
Data Sampling Rate: 1 kHz

Roll 2



Plot 44: Roll Encoder on Roadway Velocity vs. Time

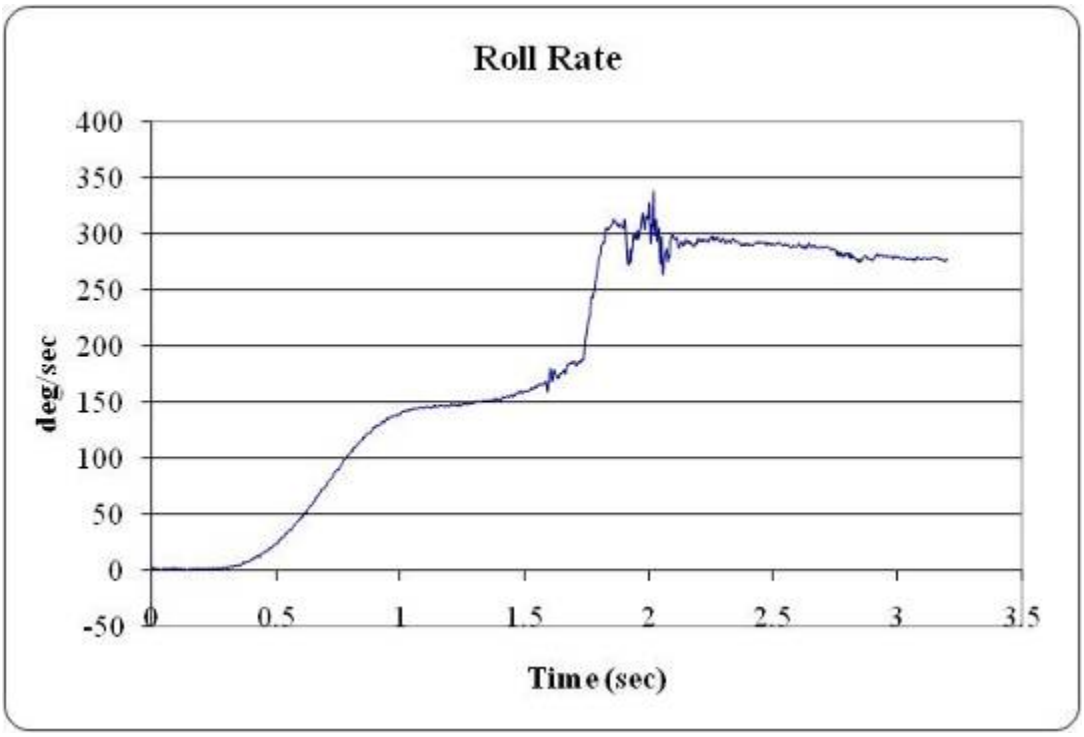
Data Sampling Rate: 1 kHz



Plot 45: Roll Angle vs. Time

Data Sampling Rate: 10 kHz

Roll 2

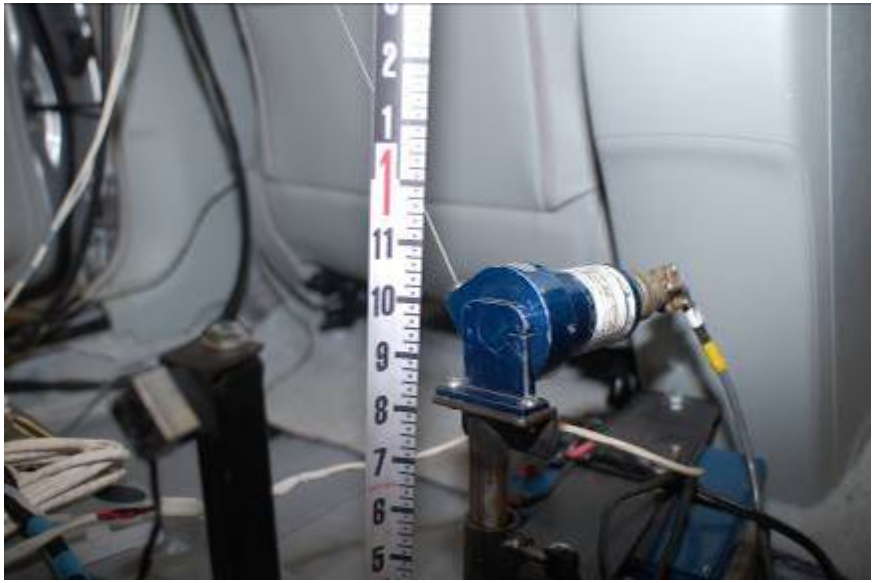


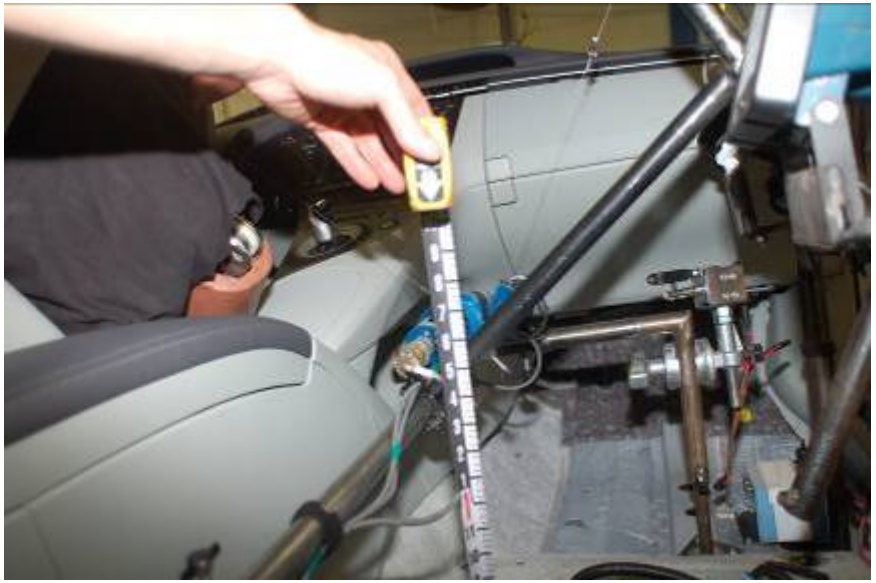
Plot 46: Roll Rate vs. Time

Data Sampling Rate: 10 kHz

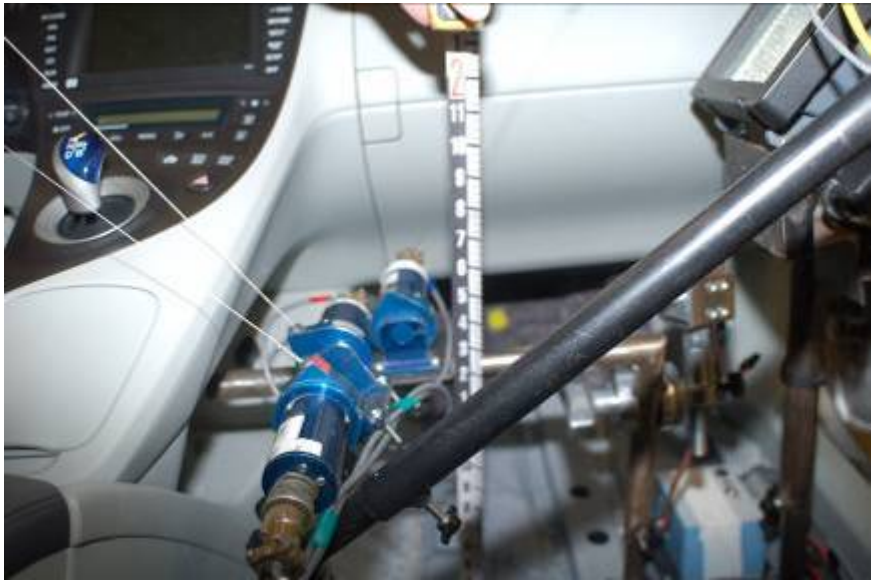
5. All Test Photographs – Test Setup

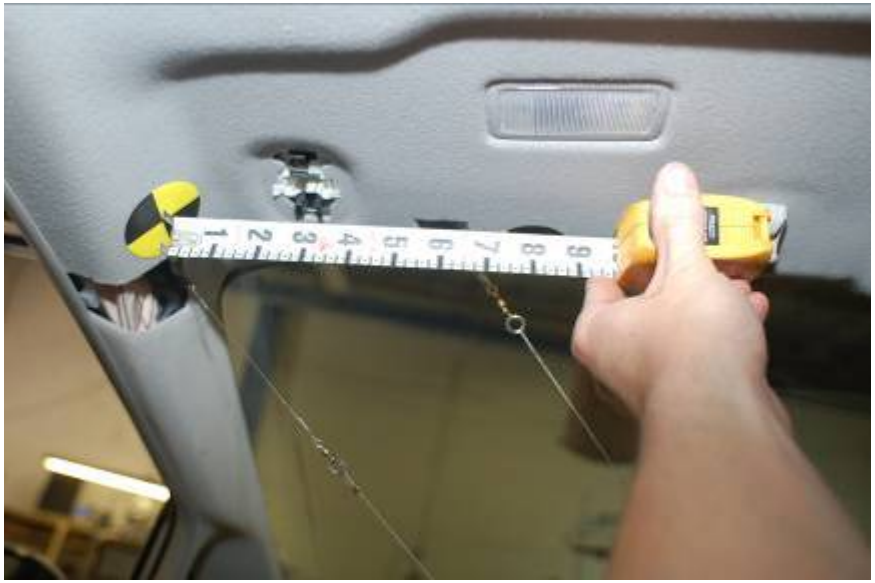
Test Setup and Vehicle Instrumentation





Vehicle Instrumentation





Vehicle Instrumentation

Roll 1 Photographs – 8/11/2010 – Dummy Inspection

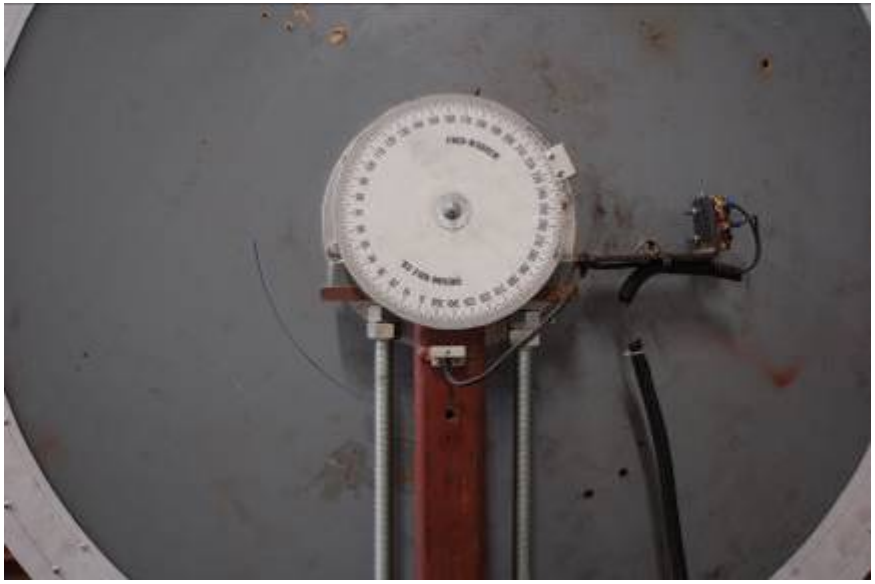



Roll 1 Photographs – 8/11/2010 – Dummy Inspection

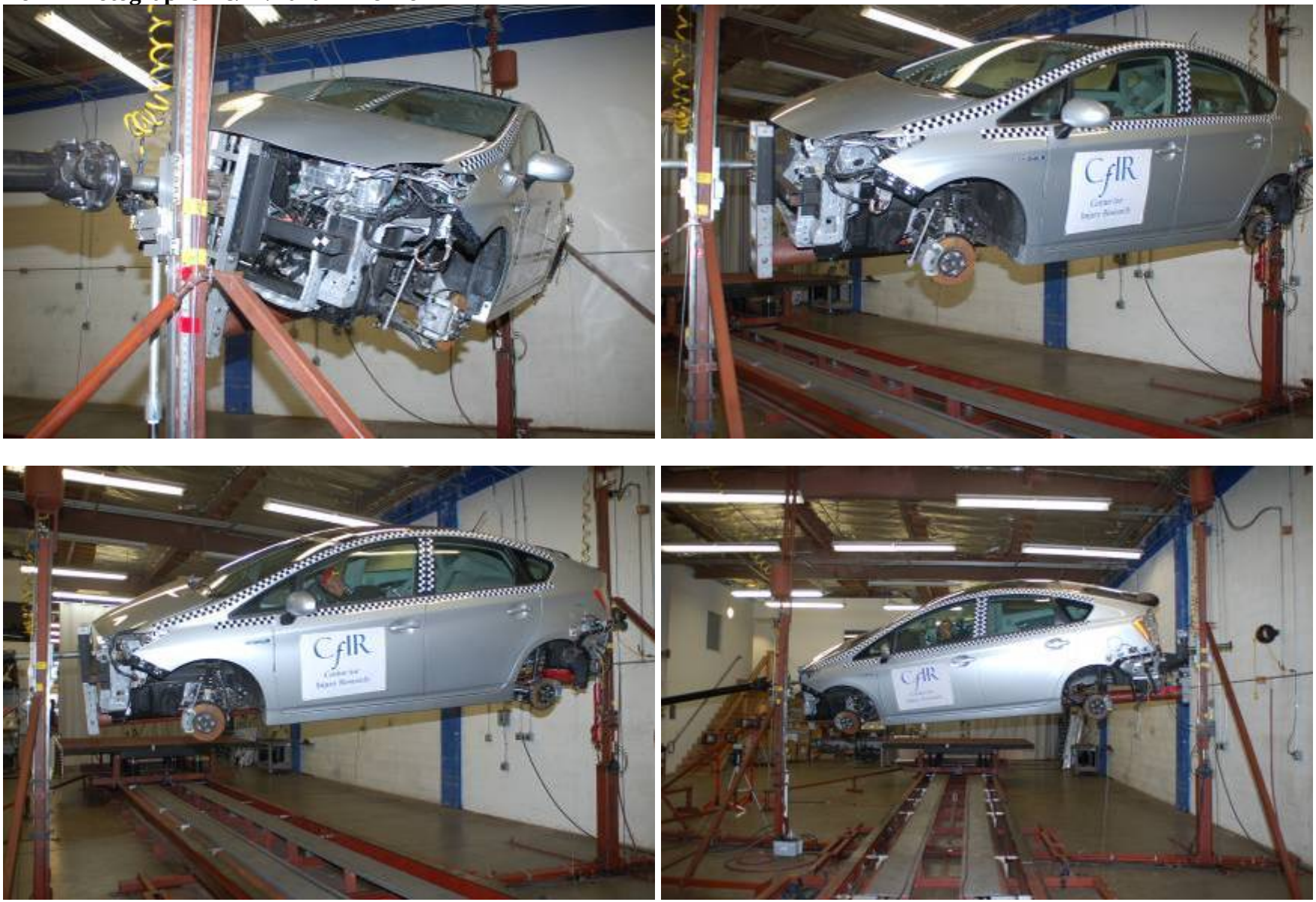
Roll 1 Photographs – 8/11/2010 – Pre-Roll



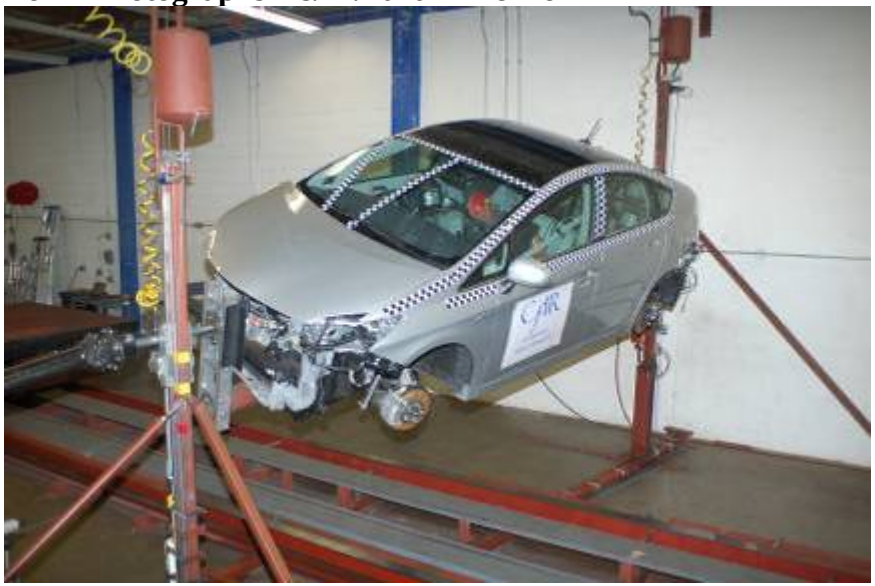

Roll 1 Photographs – 8/11/2010 – Pre-Roll

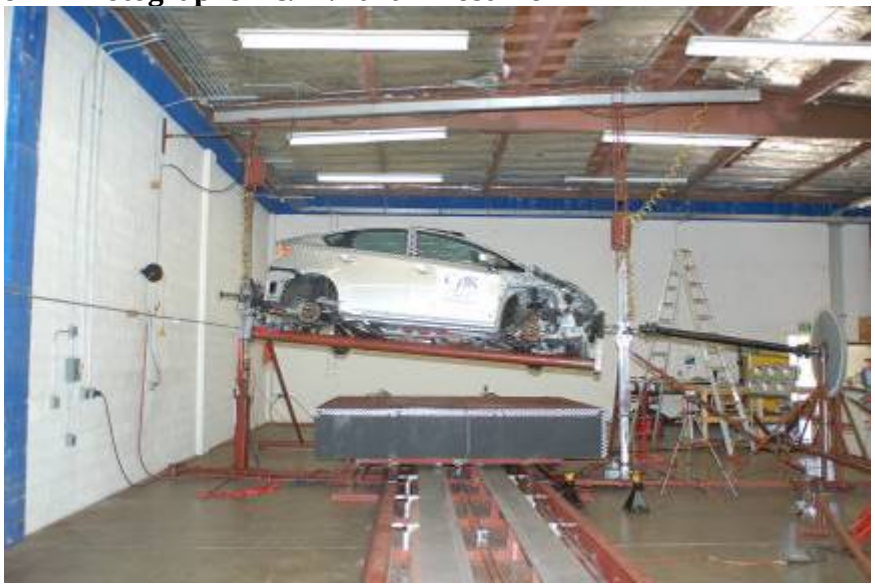
Roll 1 Photographs – 8/11/2010 – Pre-Roll



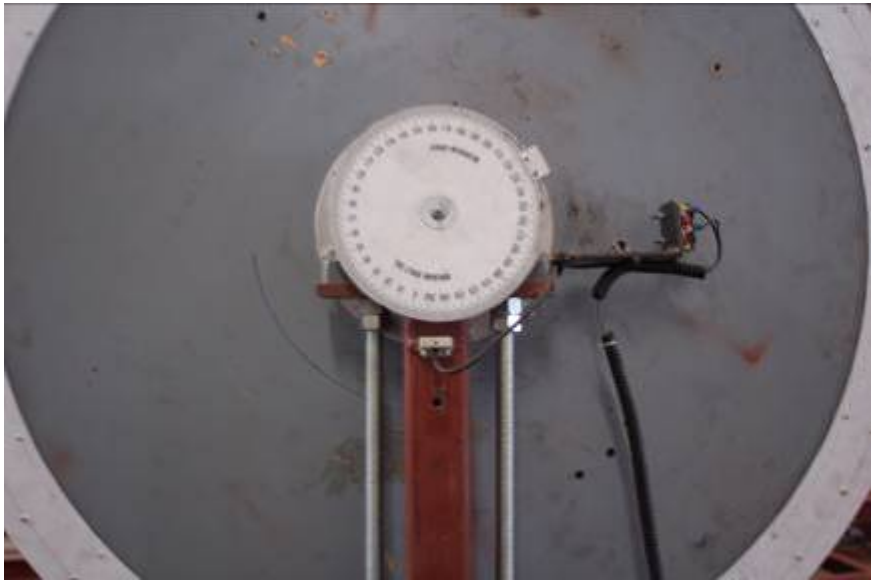
Roll 1 Photographs – 8/11/2010 – Pre-Roll

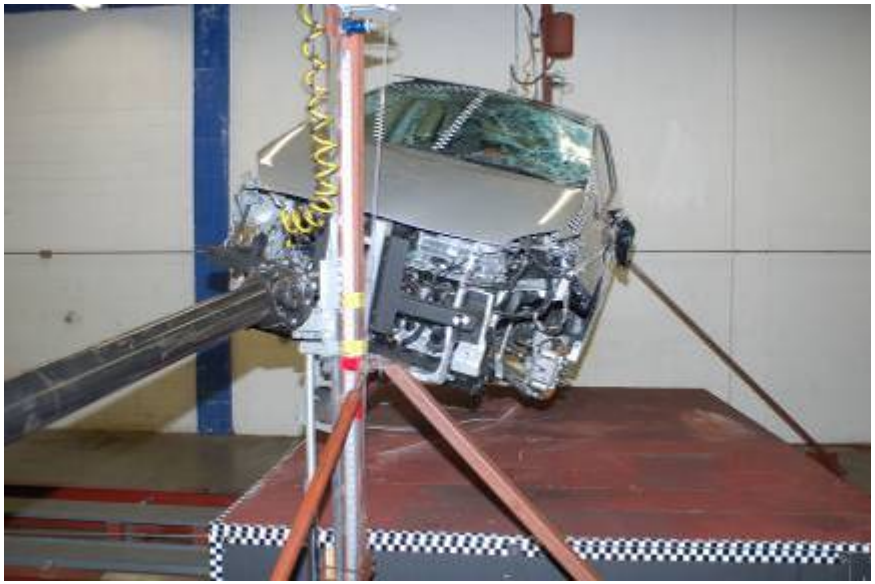


Roll 1 Photographs – 8/11/2010 – Post-Roll



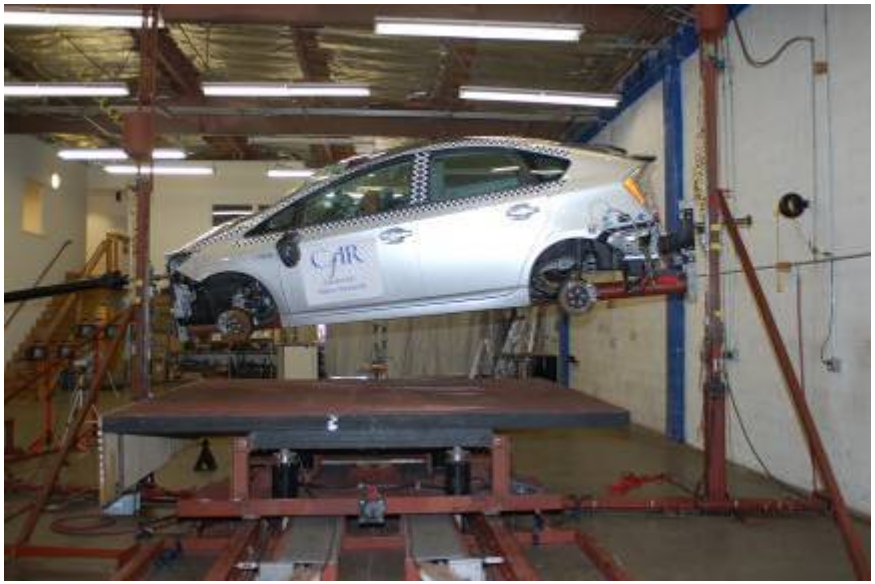

Roll 1 Photographs – 8/11/2010 – Post-Roll





Roll 1 Photographs – 8/11/2010 – Post-Roll



Roll 1 Photographs – 8/11/2010 – Post-Roll

Roll 2 Photographs – 8/12/2010 – Dummy Inspection



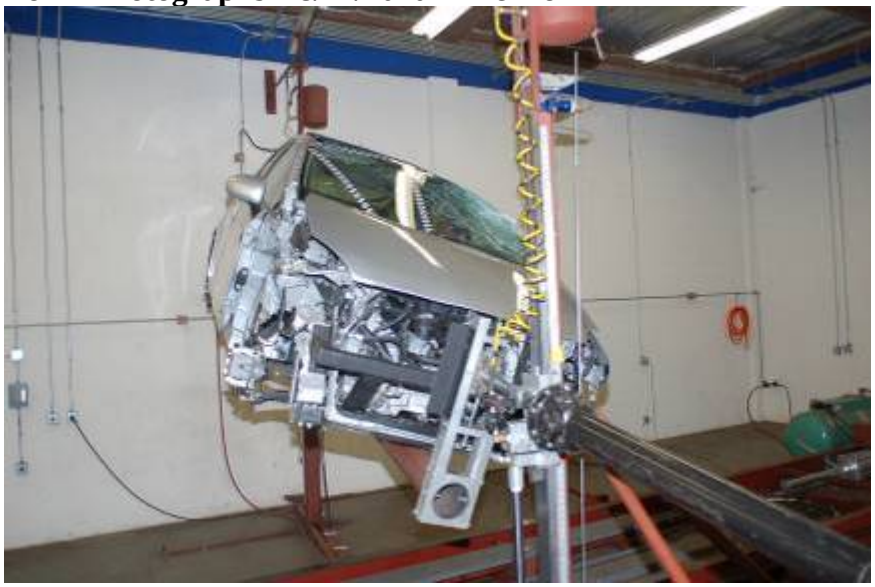

Roll 2 Photographs – 8/12/2010 – Dummy Inspection

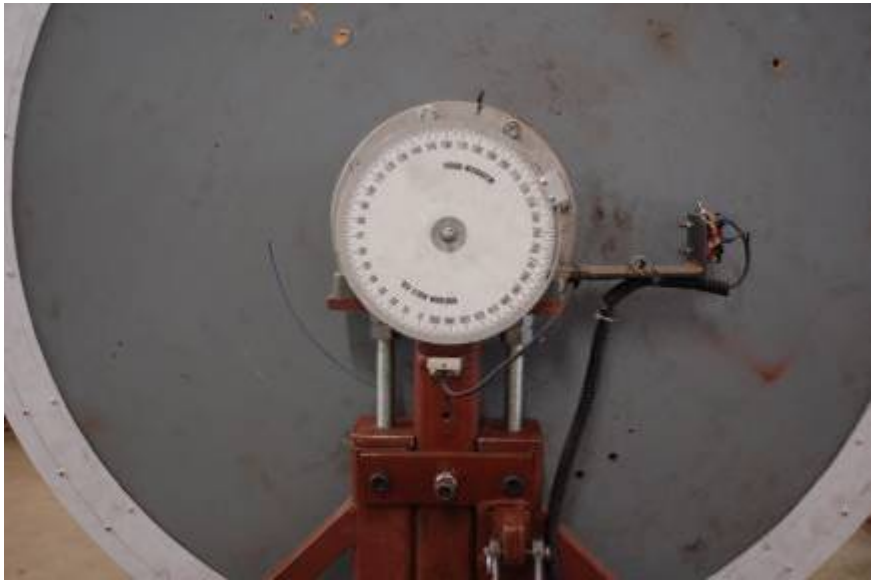



Roll 2 Photographs – 8/12/2010 – Pre-Roll

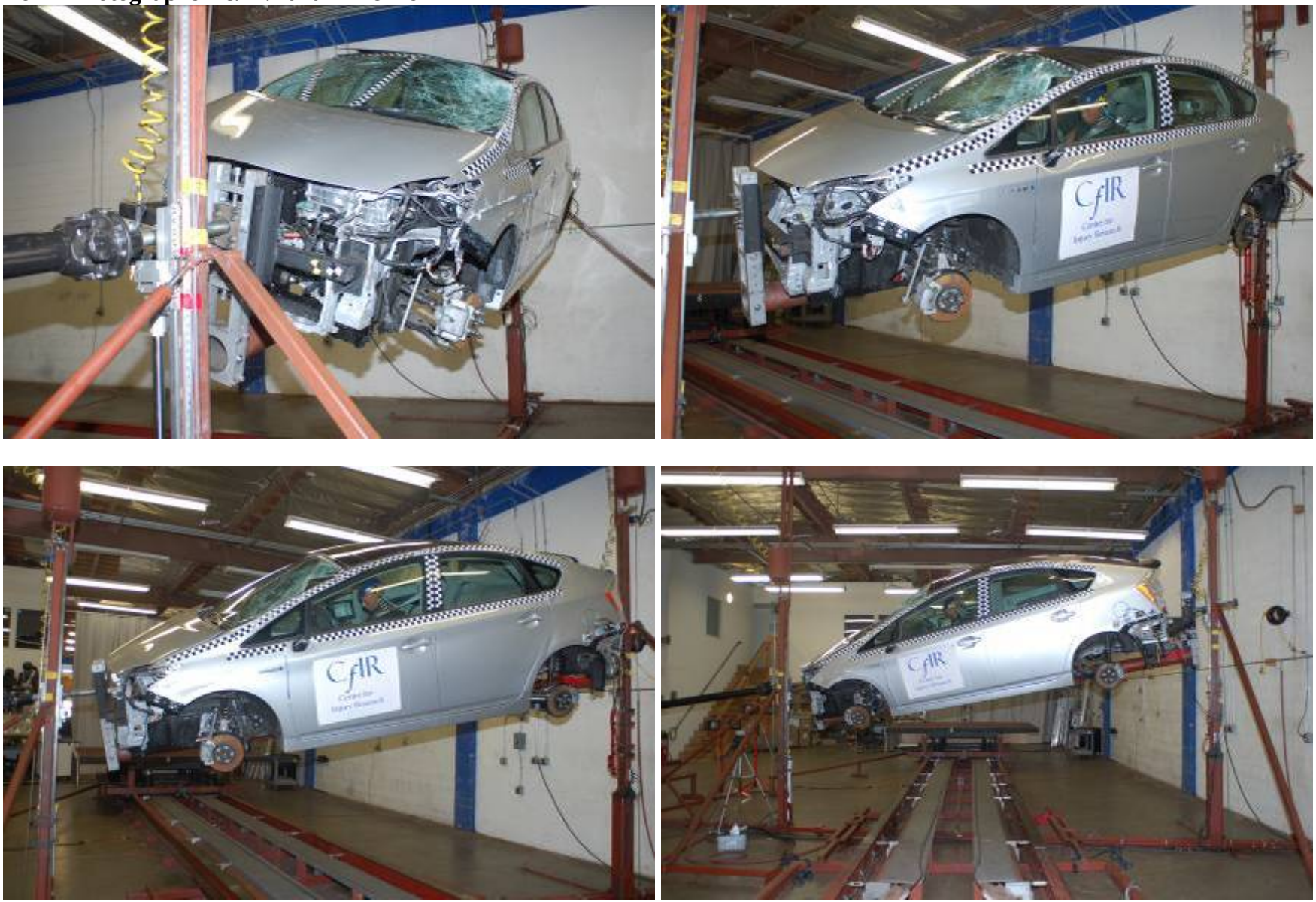



Roll 2 Photographs – 8/12/2010 – Pre-Roll



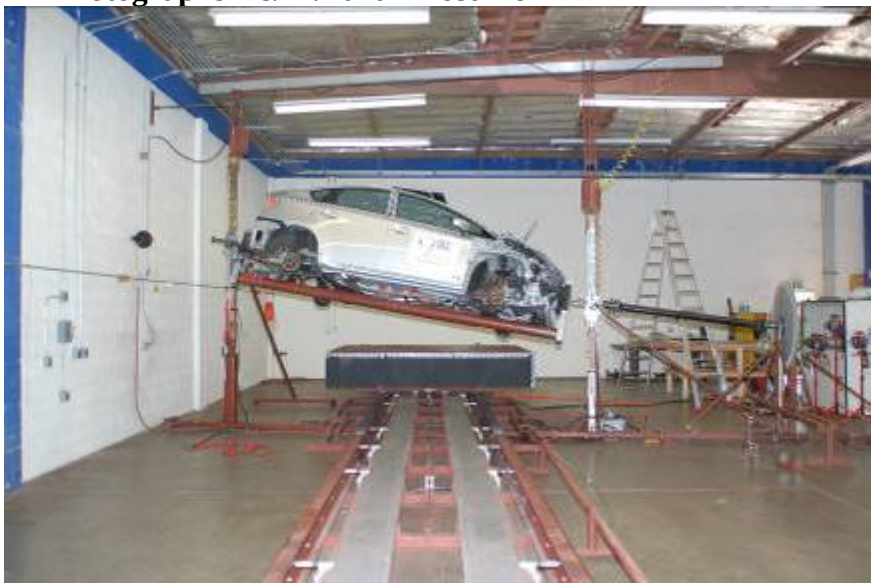
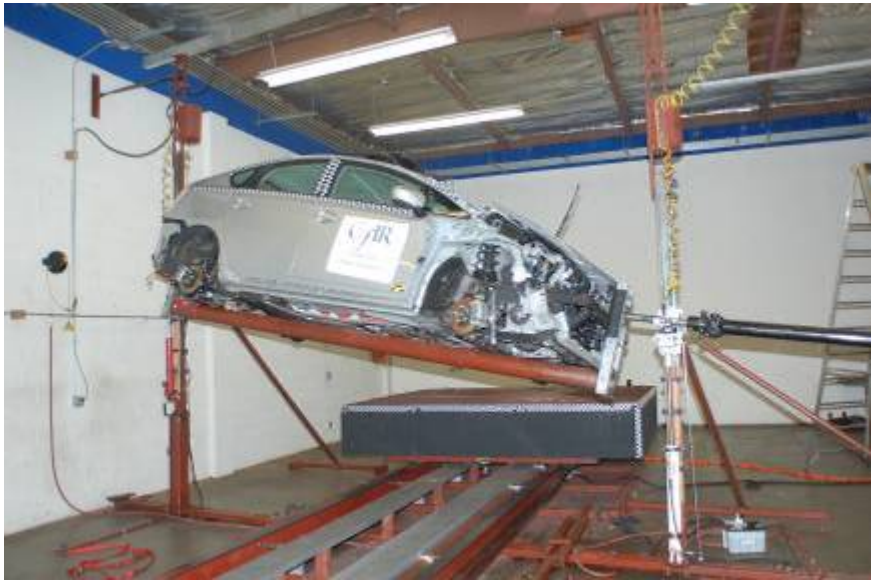


Roll 2 Photographs – 8/12/2010 – Pre-Roll



Roll 2 Photographs – 8/12/2010 – Pre-Roll

Roll 2 Photographs – 8/12/2010 – Post-Roll

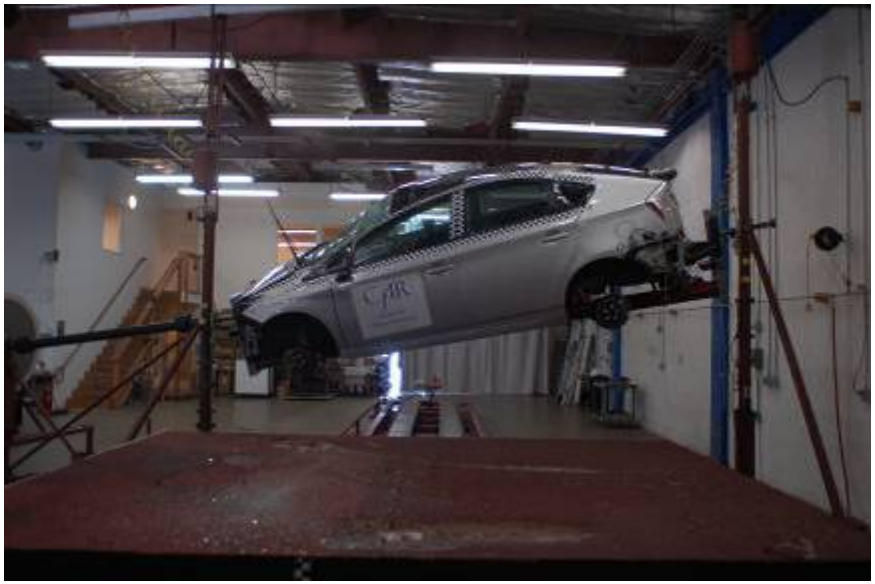



Roll 2 Photographs – 8/12/2010 – Post-Roll




Roll 2 Photographs – 8/12/2010 – Post-Roll






Pre-Test

Pre-Test

Post-Test

Post-Test