JRS Dynamic Rollover Test
1999 Toyota Camry

Sponsored By:
Automotive Safety Research Institute

Introduction

Center for Injury Research conducted a dynamic rollover test consisting of two rolls on a 1999 Toyota Camry on October 2nd and 7th, 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 – Data Graphs

Section 5 – All Test Photographs

Enclosed with this report is a DVD of the videos and photographs of both rolls.

1999 Toyota Camry

Executive Summary

Previous to these tests, a preliminary 10% probability of AIS ≥ 3 injury measure was identified for the low durometer neck which was used as:- lower peak axial Fz of 2000 N and Lower peak bending moment My, Mx of 90 Nm. In addition JRS fixture and dummy modifications and protocols were developed to provide for an out-of-position driver and passenger and a 300 degree/ sec. roll rate.

The test was a two roll event. The planned differences between the rolls were the pitch of the vehicle; 4.9 degrees in Roll 1 and 9.9 degrees in Roll 2 and the roll rate; 302 deg/sec in Roll 1 and 202 deg/sec in Roll 2. In the first and second roll, the Hybrid III (driver) and Hybrid II (passenger) dummies were break-away tethered out of standard seating position, leaning toward the passenger side. The driver dummy neck was setup 30 degrees forward of the nominal position for tests 1 and 2.

In Roll 1, the peak neck load was 1,367 N and the peak lower neck moment was 62 N-m. The measured residual crush at the top of the A-Pillar was approximately 7 inches. In Roll 2, the peak neck load was 1,273 N and the peak lower neck moment was 171 N-m. The measured additional residual crush at the top of the A-Pillar was approximately 1 inch. The high speed rear

interior camera is equipped with tracking software such that the dynamic motion of the dummy, the intrusion and rebound can be determined.

Examination of the video records indicate that in the first 5 degree pitch, 300 deg./sec. roll the driver dummy's trajectory from the initial out-of-position location to the intersection of the side rail and A-pillar was rapid enough to be on the driver's side of the roof panel buckle where the lower neck bent laterally with a 62 N-m moment load before going outside the then broken side window and remaining there for the following three rolls. In the second test roll at 202 deg./sec and 10 degree pitch, the driver dummy's trajectory was essentially the same but slower such that the neck bent when it encountered the previously deformed residual crush of the roof panel, slowed, and bent excessively and rapidly with the dynamically intruding roof to a high probability of a major injurious lateral bending moment of 171 N-m.

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 = 4.9° and Roll 2 = 9.9°, the dummy position, and the roll rate; Roll 1 = 302 deg/sec and Roll 2 = 202 deg/sec.

The test weight of the vehicle was 3,207 pounds. The initial weight of the vehicle was 3,072 pounds. The roll moment of inertia was approximately 382 lb*ft*sec^2 for a referenced initial value of 390 lb*ft*sec^2.

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.

An instrumented, restrained Hybrid III 50th percentile male test dummy was placed in the driver's seat. The dummy had upper and lower neck load cells, a triaxial head accelerometer, chest deflector, and triaxial chest accelerometer. A non-instrumented Hybrid II 50th percentile male test dummy was placed in the passenger's seat. For the first and second roll, the dummies were located "out of position," leaning toward the passenger side. The passenger side dummy was leaned slightly forward and against the passenger (near side) door. The driver side dummy was leaned slightly forward and across the center console area . A 0.5 inch rubber insert was placed at the bottom of the lower spine of each the dummies. The two cables in the lower spine of the dummy were removed. A rubber insert was placed at the bottom of the Hybrid II neck, increasing the forward neck angle 10° degrees from the nominal position. A wedge was also placed at the base of the neck of the Hybrid III dummy which increased the neck angle by 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 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. Another roll encoder was placed on the shaft of the vehicle roll axis. In addition, a roll rate sensor was placed inside the vehicle.

The equipment used in the conduct of this test is listed in Table 1 and the test vehicle identification data is shown in Table 2 below.

Table 1 Equipment and Instrumentation

Item	MFR./Model
Upper Neck Load Cell	RA Denton 1716A
Lower Neck Load Cell	RA Denton 1794A
Triax Head Accelerometer	Endevco, 7264C-2KTZ-2-240
Triax Chest Accelerometer	ICSensors, 3031-100
Roll Rate Sensor	DTS ARS
Hybrid III, 50th Percentile Male	Denton 50th Male
Hybrid II, 50th Percentile Male	Denton
Chest Deflector	Denton 176
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 2 General Test Vehicle Data Test Vehicle: 1999 Toyota Camry

Test Vehicle Information:	
Manufacturer: Toyota	VIN: 4T1GG22K3XU603652
Gross Weight: 4,055 lbs	Curb Weight: 2,998 lbs
Sunroof: No	2WD/4WD: 2WD
Equivalent Years: 1997-2001	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 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 – 10/02/2009

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)
Sum of Vertical Load Cells (near side)	9,321 lbs	
Sum of Vertical Load Cells (far side)	24,791 lbs	
Sum of Lateral Load Cells (near side)	1,458lbs	
Sum of Lateral Load Cells (far side)	1,504 lbs	

Instrument	Maximum Value	Minimum Value
Head Accelerometer, Ay	26 g's	-13 g's
Head Accelerometer, Az	9 g's	-32 g's
Head Accelerometer, Ax	34 g's	-7 g's
Chest Deflector	4 mm	-1 mm
Chest Accelerometer, Ay	8 g's	-2 g's
Chest Accelerometer, Az	7 g's	-5 g's
Lower Neck Load Cell, Fx	1,367 N	-225 N
Lower Neck Load Cell, Fy	789 N	-182 N
Lower Neck Load Cell, Mx	15 N m	-7 N m
Lower Neck Load Cell, My	18 N m	-62 N m
Upper Neck Load Cell, Fz	675 N	-1,248 N
Upper Neck Load Cell, Fy	111 N	-512 N
Upper Neck Load Cell, Fx	725 N	-141N
Upper Neck Load Cell, Mx	40 N m	-15 N m
Upper Neck Load Cell, My	5 N m	-44 N m

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 1.45 seconds. The entire roll sequence was completed by approximately 1.75 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 4.5 inches and the rear dropped 4.8 inches prior to initial touch down. The vehicle was pitched at 4.9 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 132 degrees and the roll rate was 302 degrees per second at the roadway impact.

During the previous occupant kinematics tests the windshield slightly cracked. This did not affect the structural integrity of the windshield. During roll 1 both driver side windows broke.

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 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 – 10/07/2009

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)
Sum of Vertical Load Cells (near side)	6,584 lbs	
Sum of Vertical Load Cells (far side)	30,623 lbs	
Sum of Lateral Load Cells (near side)	1,049 lbs	
Sum of Lateral Load Cells (far side)	2,647 lbs	

Instrument	Maximum Value	Minimum Value
Head Accelerometer, Ay	40 g's	-8 g's
Head Accelerometer, Az	12 g's	-12 g's
Head Accelerometer, Ax	16 g's	-11 g's
Chest Deflector	1 mm	-1 mm
Chest Accelerometer, Ay	17 g's	-2 g's
Chest Accelerometer, Az	14 g's	-2 g's
Lower Neck Load Cell, Fx	555 N	-230 N
Lower Neck Load Cell, Fy	208 N	-1,273 N
Lower Neck Load Cell, Mx	13 N m	-171 N m
Lower Neck Load Cell, My	55 N m	-21 N m
Upper Neck Load Cell, Fz	711 N	-567 N
Upper Neck Load Cell, Fy	78 N	-458 N
Upper Neck Load Cell, Fx	177 N	-343 N
Upper Neck Load Cell, Mx	13 N m	-31 N m
Upper Neck Load Cell, My	20 N m	-21 N m

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 fender at approximately 1.44 seconds. The entire roll sequence was completed by approximately 1.74 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 5.0 inches and the rear dropped 5.5 inches prior to initial touch down. The vehicle was pitched at 9.9 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 133 degrees and the roll rate was 202 degrees per second at the roadway impact.

During the second roll, the windshield fractured further.

Roll 2 Comparison Photographs

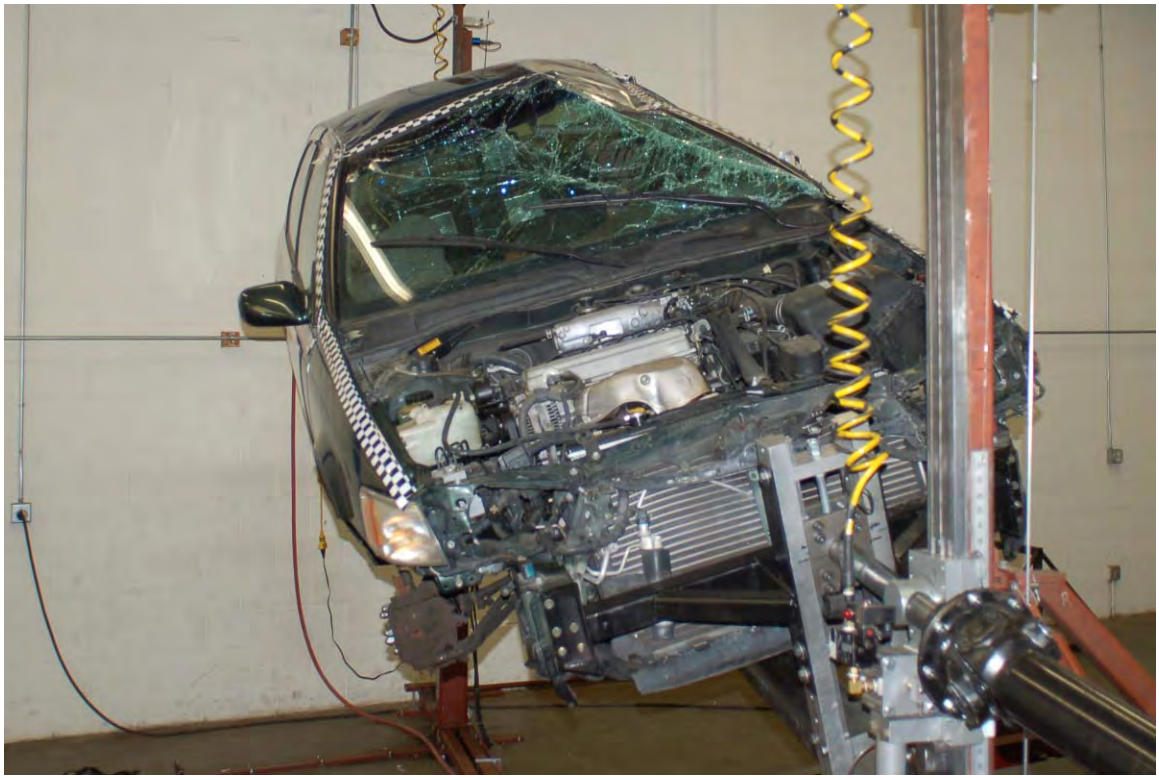
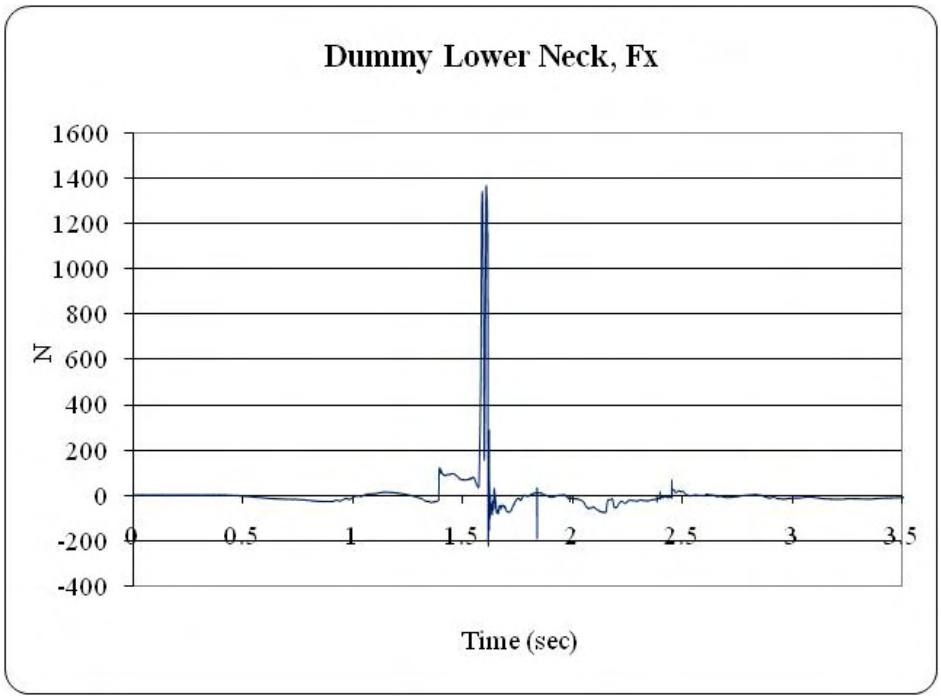


Figure 3: Vehicle Pre Roll 2

Figure 4: Vehicle Post Roll 2

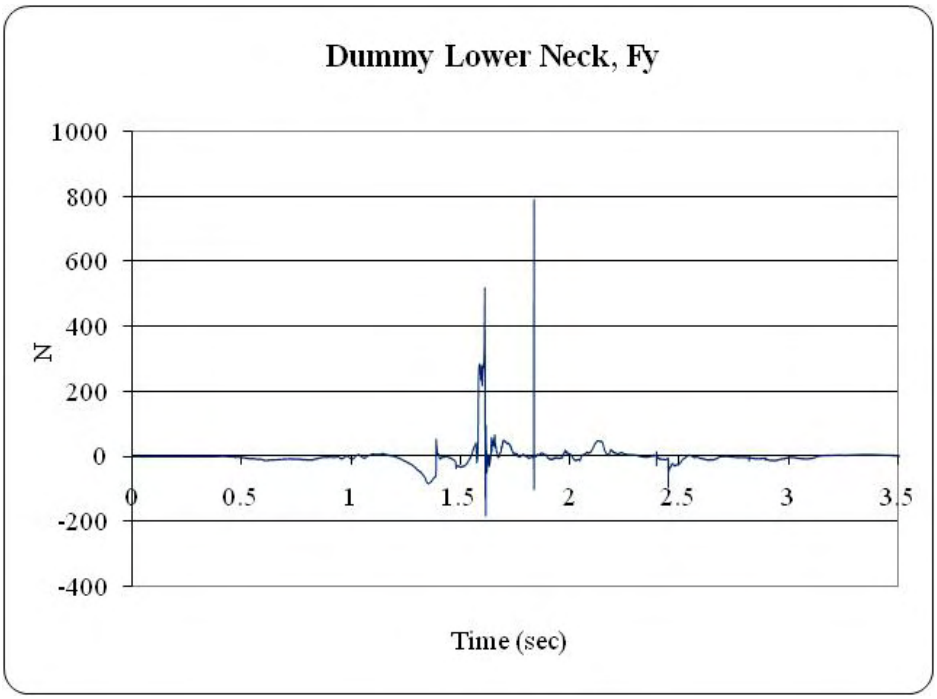
4. Data Graphs

Roll 1 Data Plots – 10/02/2009



Plot 1: Lower Neck Load, Fx, v. Time

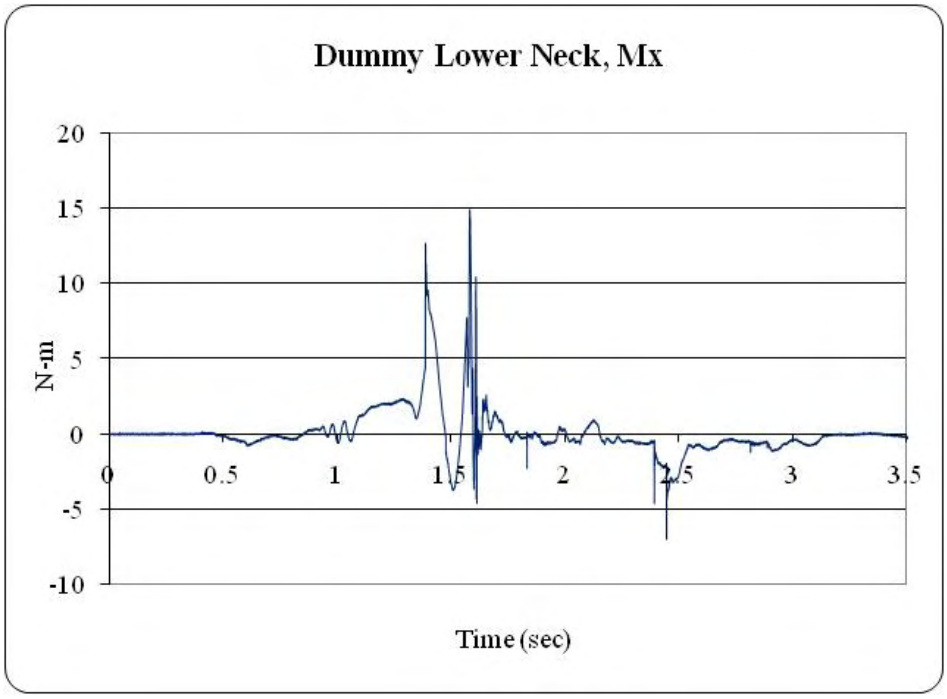
Data Sampling Rate: 10 kHz



Plot 2: Lower Neck Load, Fy, v. Time

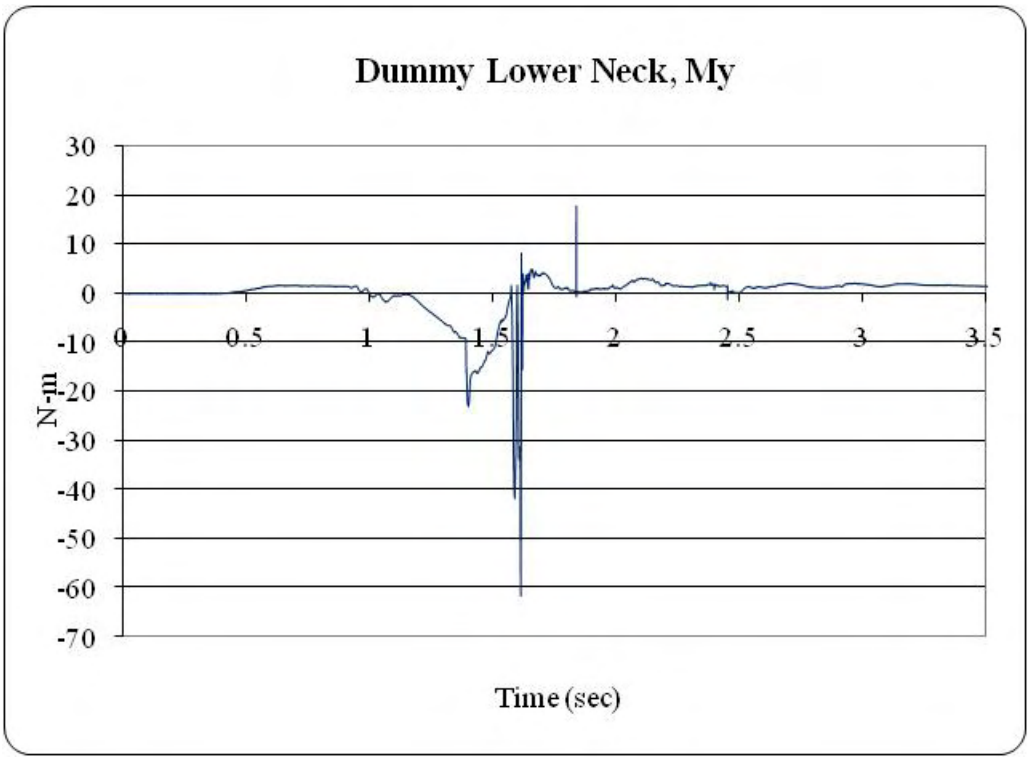
Data Sampling Rate: 10 kHz

Roll 1



Plot 3: Lower Neck Load, Mx, v. Time

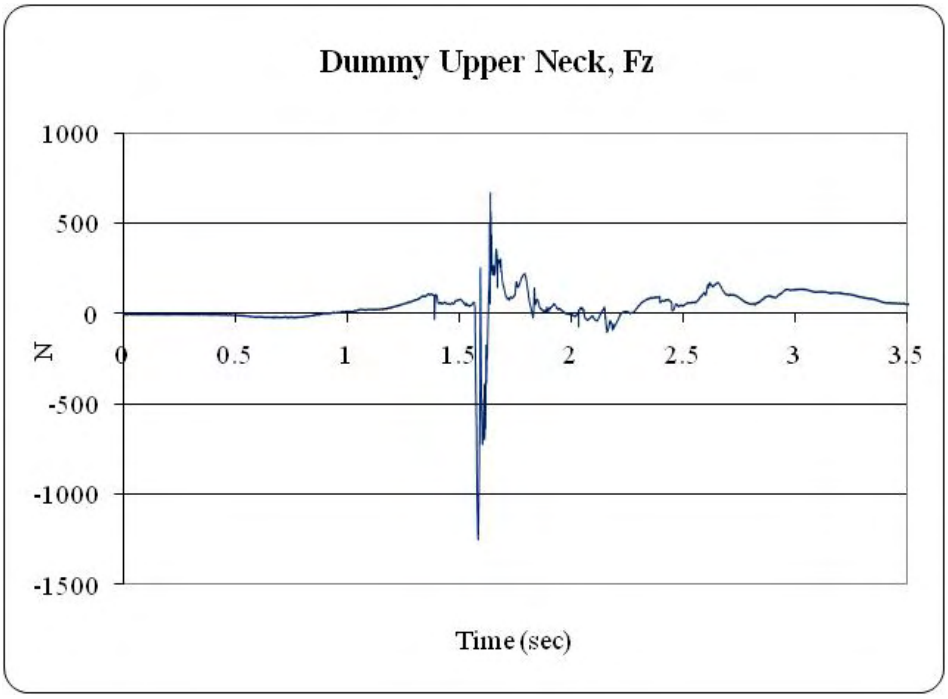
Data Sampling Rate: 10 kHz



Plot 4: Lower Neck Load, My, v. Time

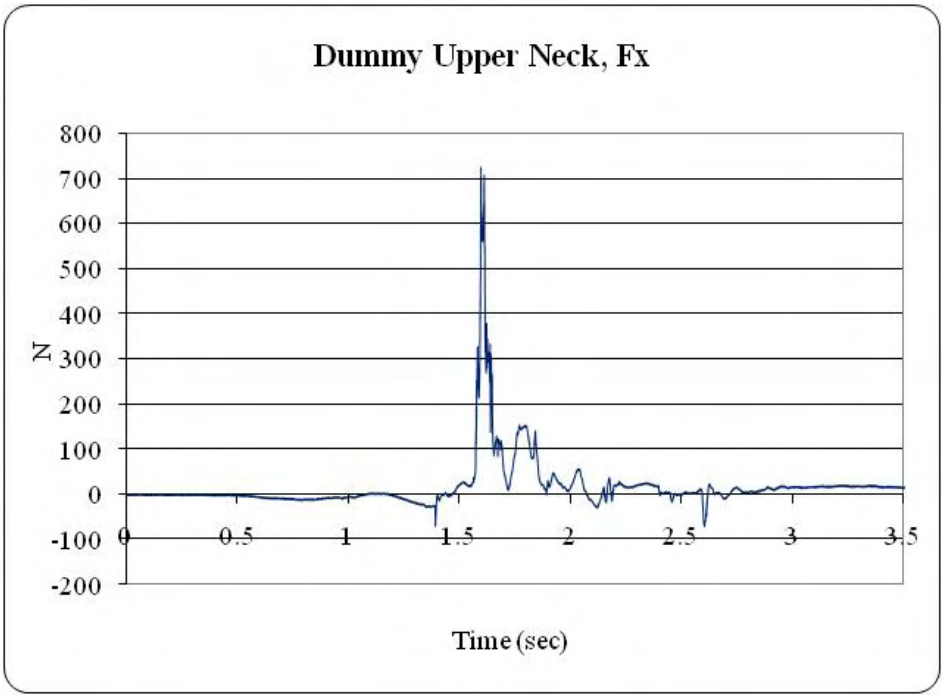
Data Sampling Rate: 10 kHz

Roll 1



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

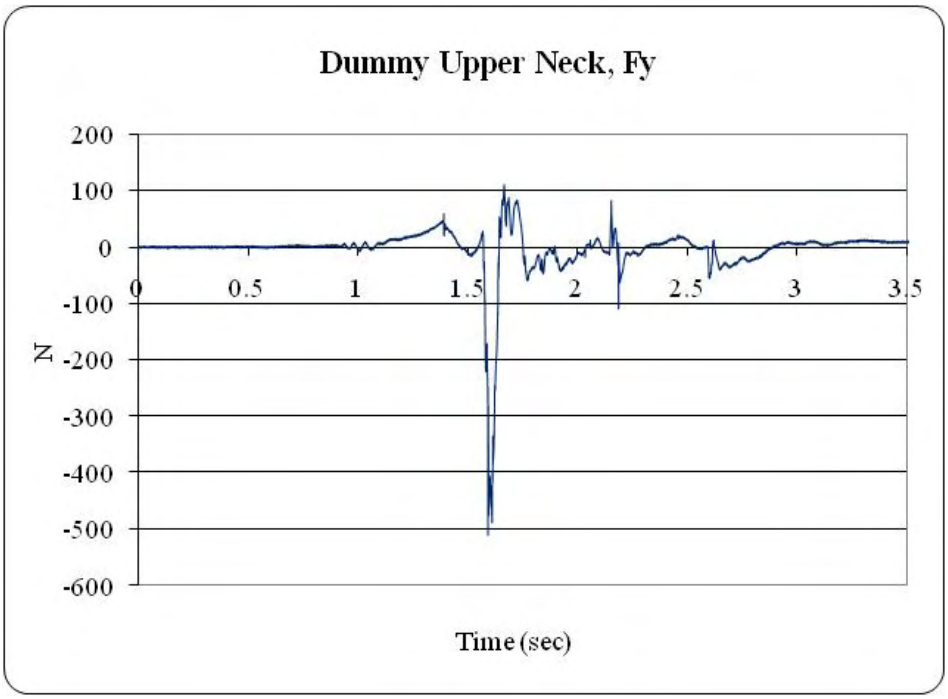
Data Sampling Rate: 10 kHz



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

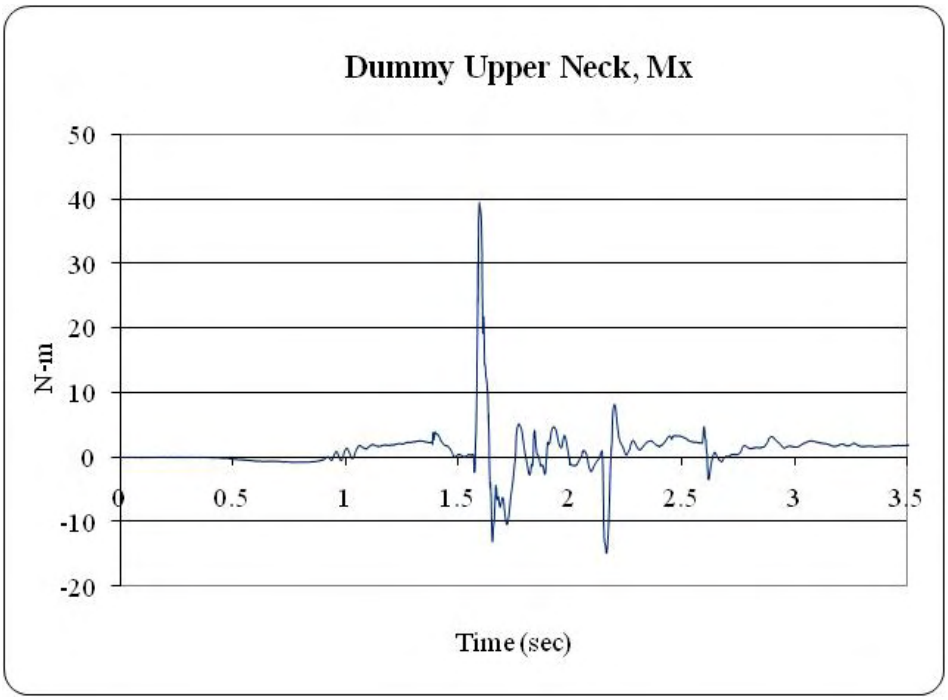
Data Sampling Rate: 10 kHz

Roll 1



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

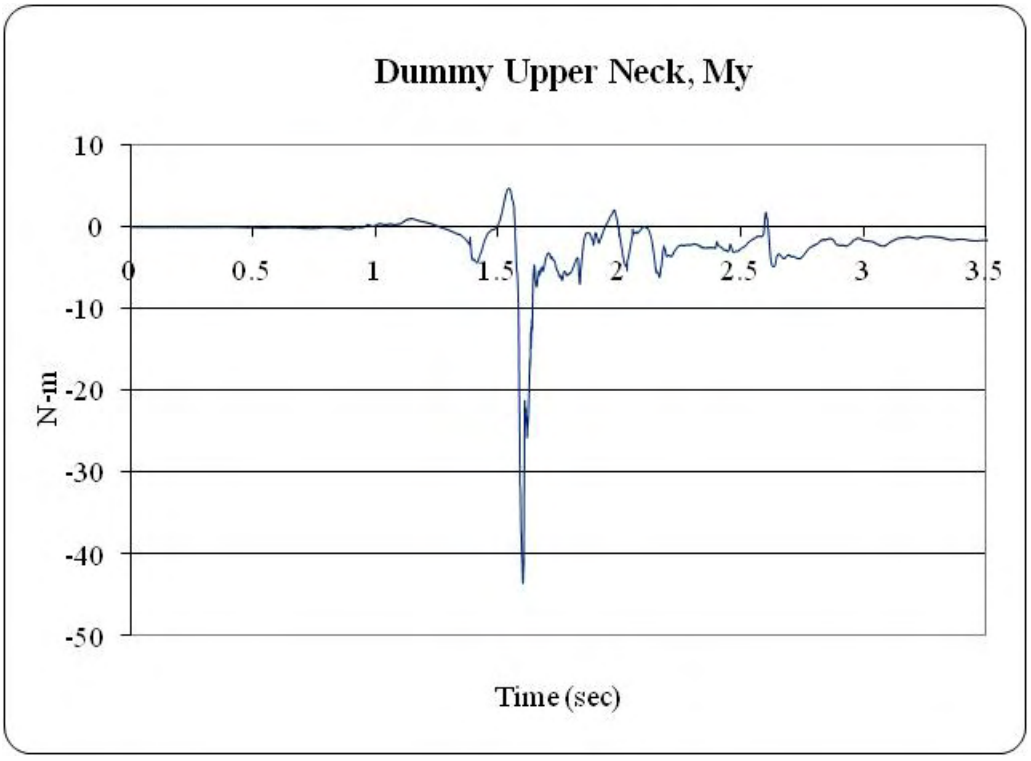
Data Sampling Rate: 10 kHz



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

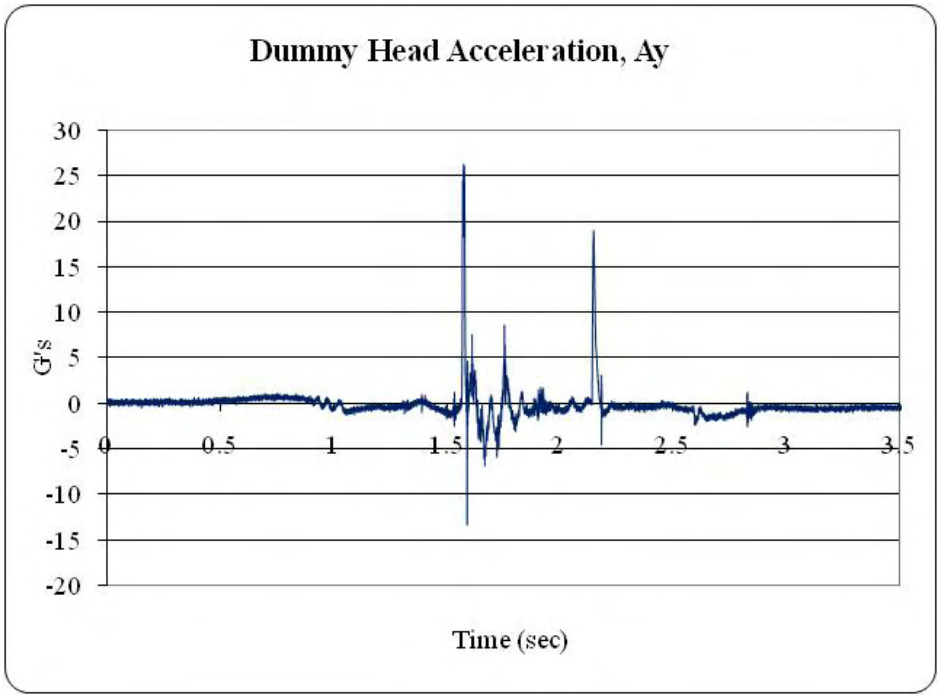
Data Sampling Rate: 10 kHz

Roll 1



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

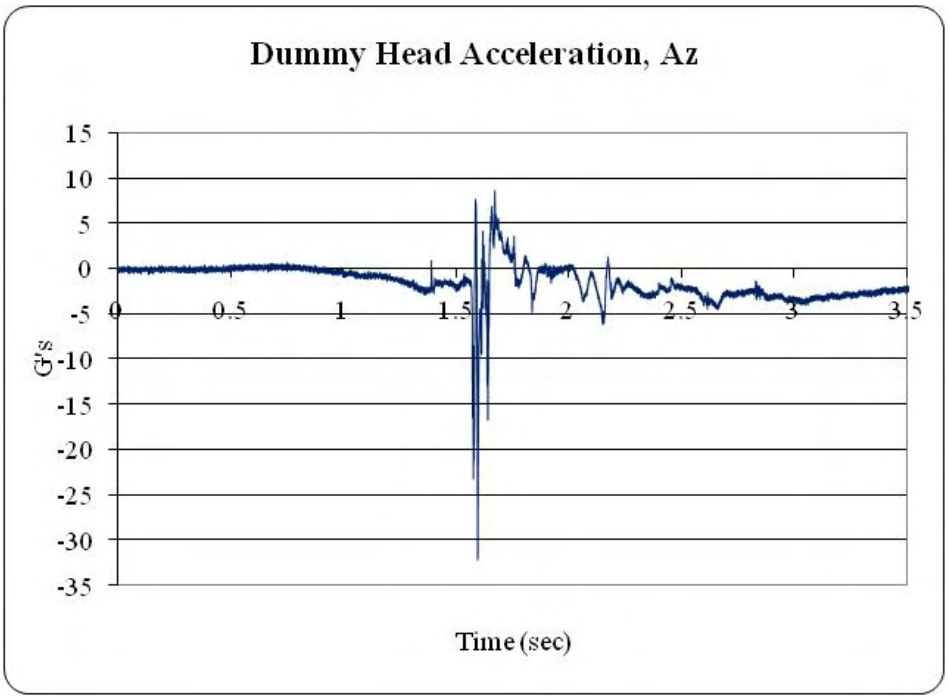
Data Sampling Rate: 10 kHz



Plot 10: Head Acceleration, Ay, vs. Time

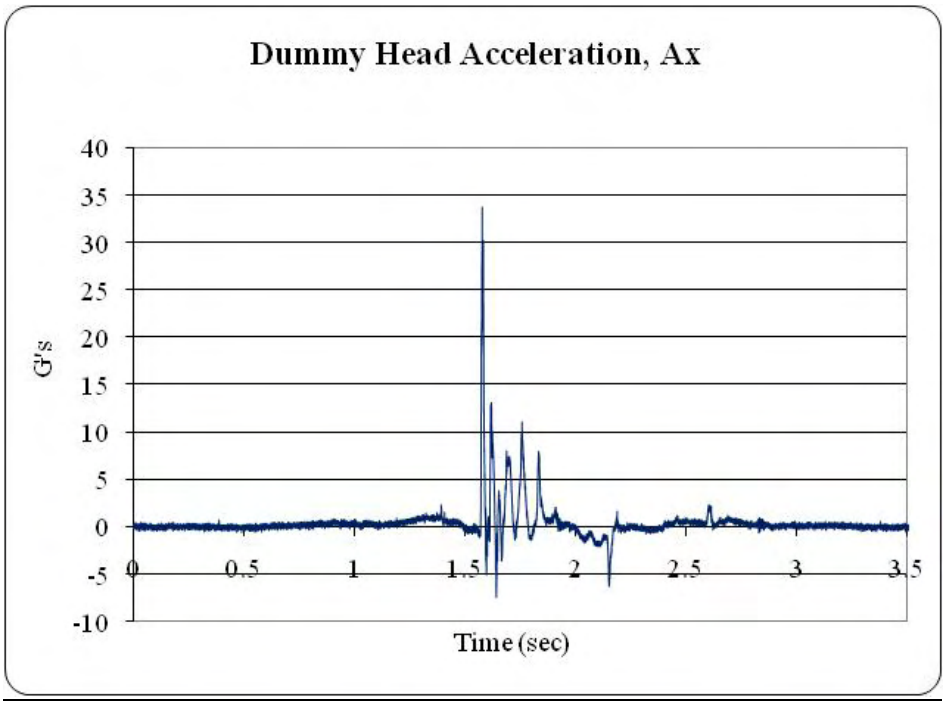
Data Sampling Rate: 10 kHz

Roll 1



Plot 11: Head Acceleration, Az, vs. Time

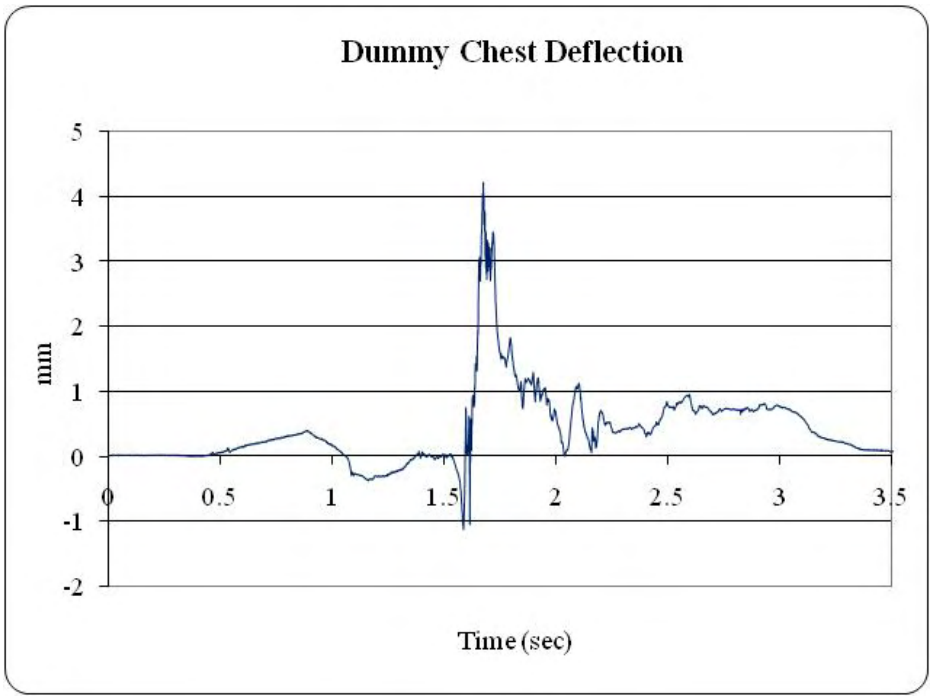
Data Sampling Rate: 10 kHz



Plot 12: Head Acceleration, Ax, vs. Time

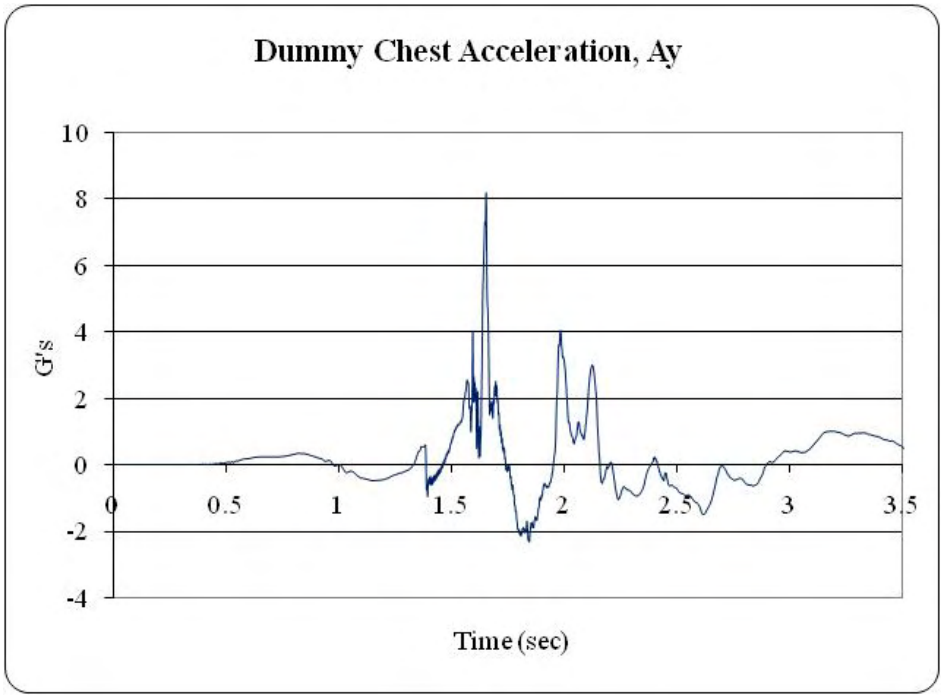
Data Sampling Rate: 10 kHz

Roll 1



Plot 13: Chest Deflection vs. Time

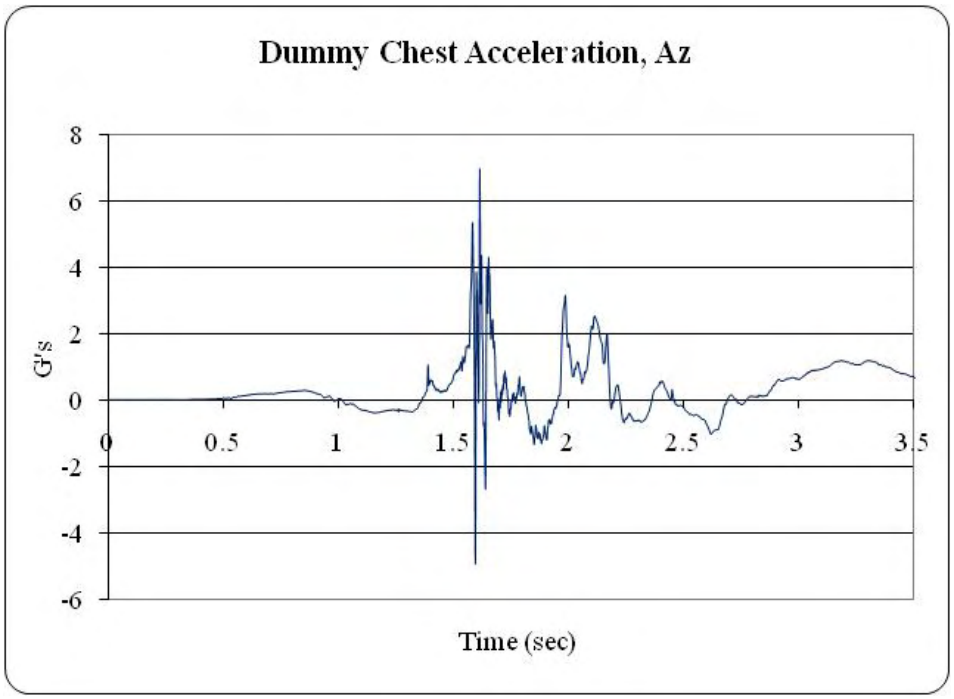
Data Sampling Rate: 10 kHz



Plot 14: Chest Acceleration, Ay, vs. Time

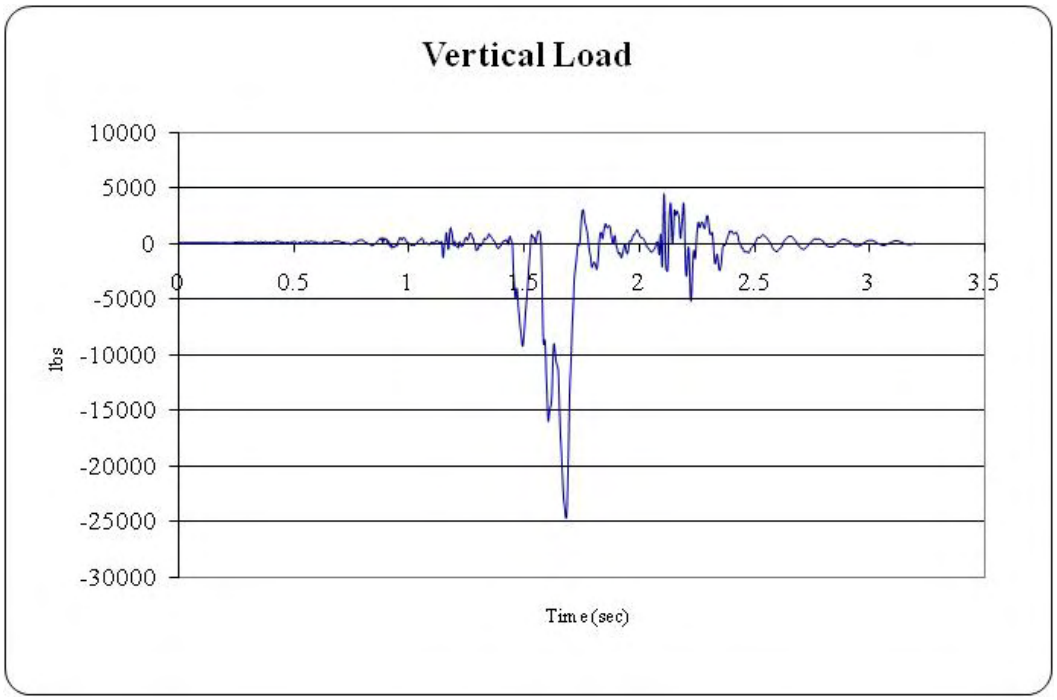
Data Sampling Rate: 10 kHz

Roll 1



Plot 15: Chest Acceleration, Az, vs. Time

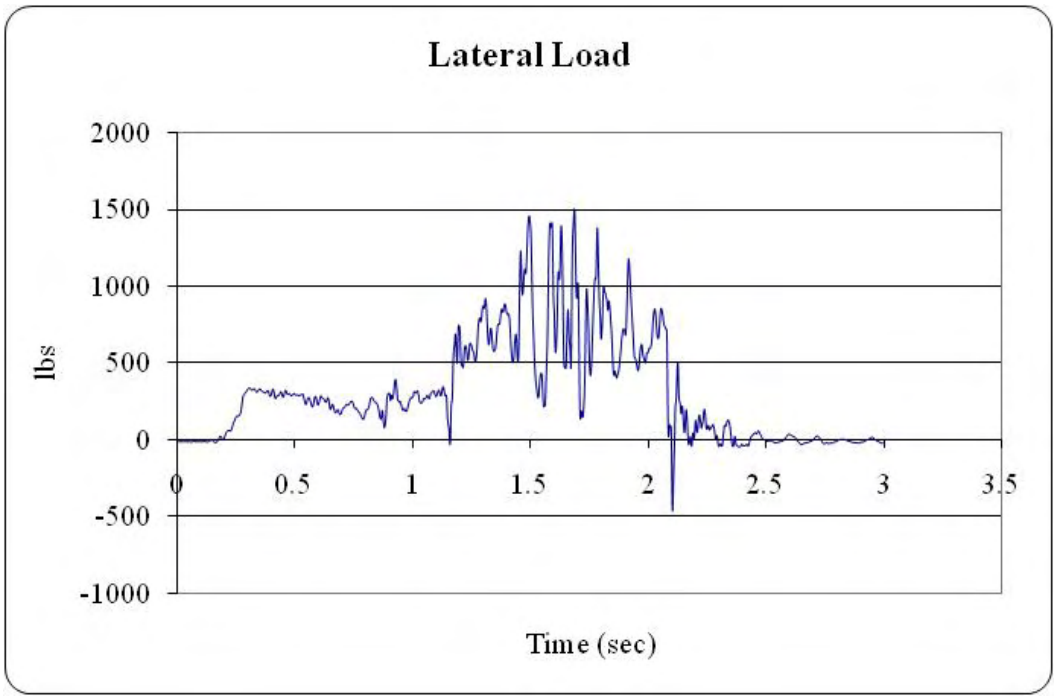
Data Sampling Rate: 10 kHz



Plot 16: Total Vertical Load v. Time

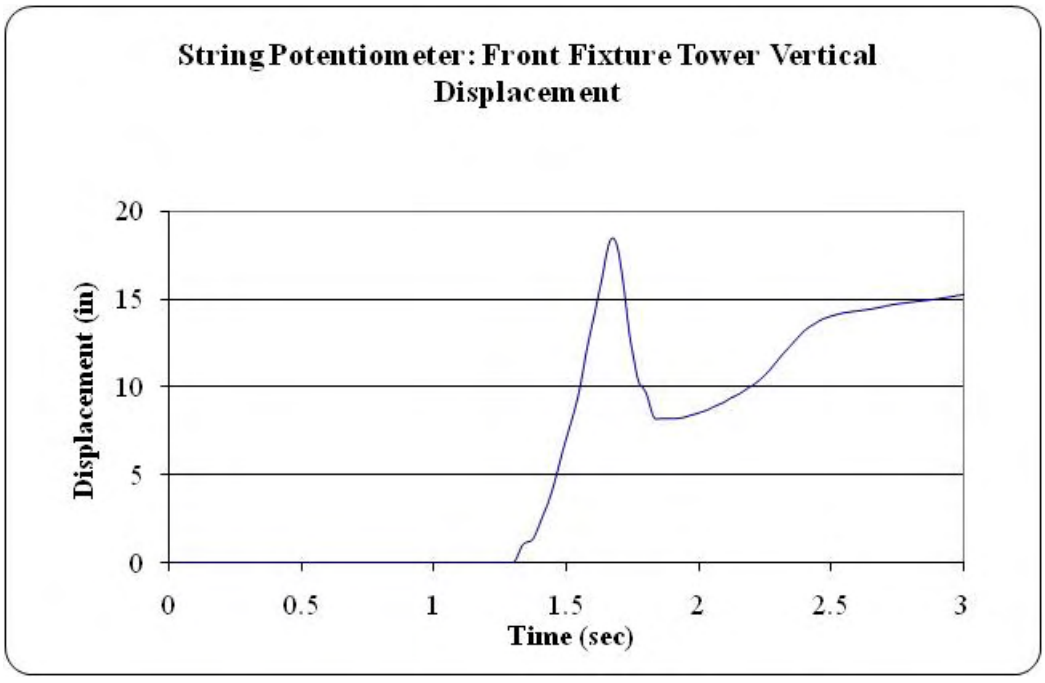
Data Sampling Rate: 10 kHz

Roll 1



Plot 17: Total Lateral Load v. Time

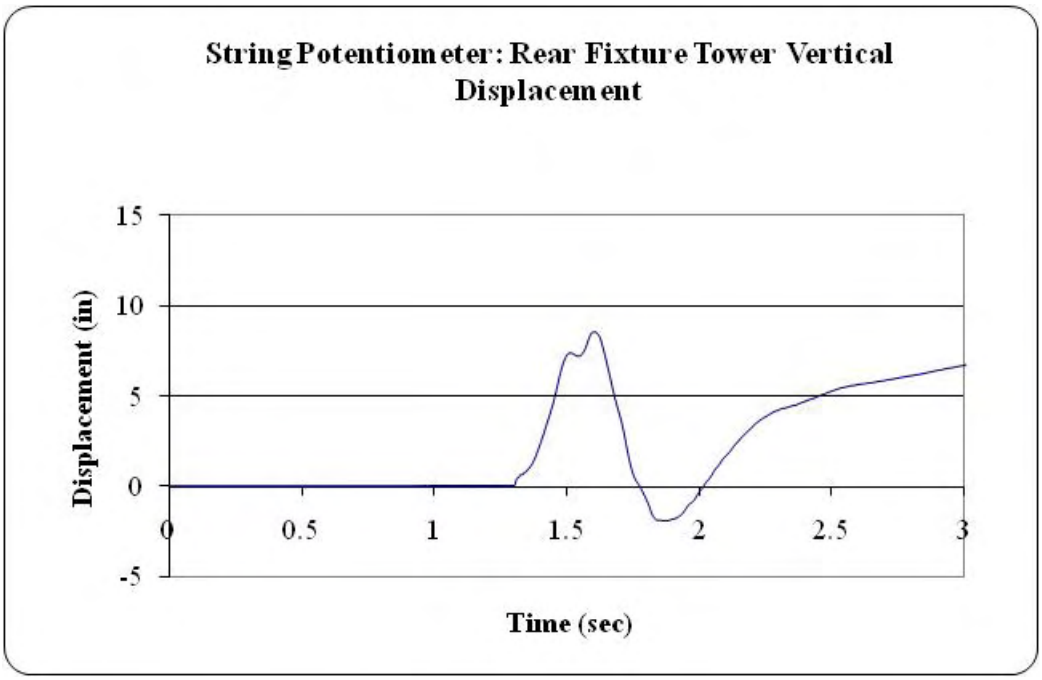
Data Sampling Rate: 10 kHz



Plot 18: String Potentiometer Front Fixture Support Tower Displacement vs. Time

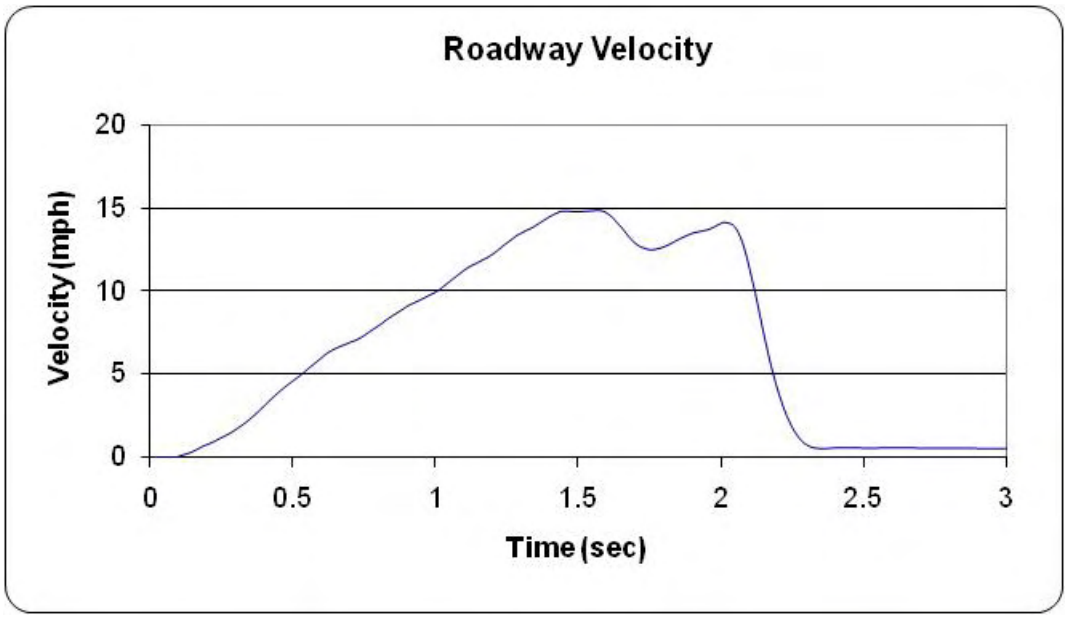
Data Sampling Rate: 1 kHz

Roll 1



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

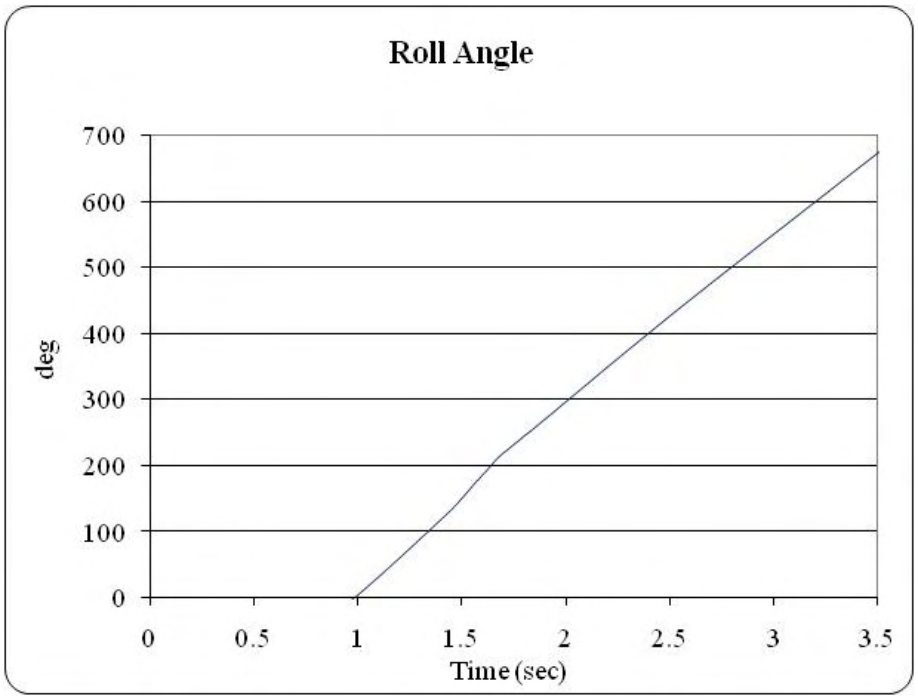
Data Sampling Rate: 1 kHz



Plot 20: Roll Encoder on Roadway Velocity vs. Time

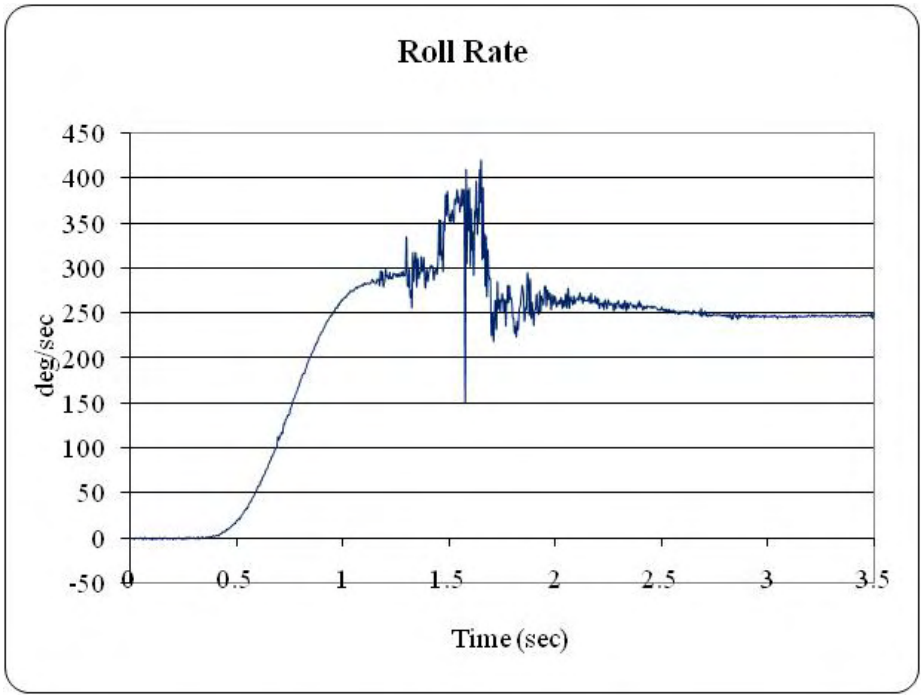
Data Sampling Rate: 1 kHz

Roll 1



Plot 21: Roll Angle vs. Time

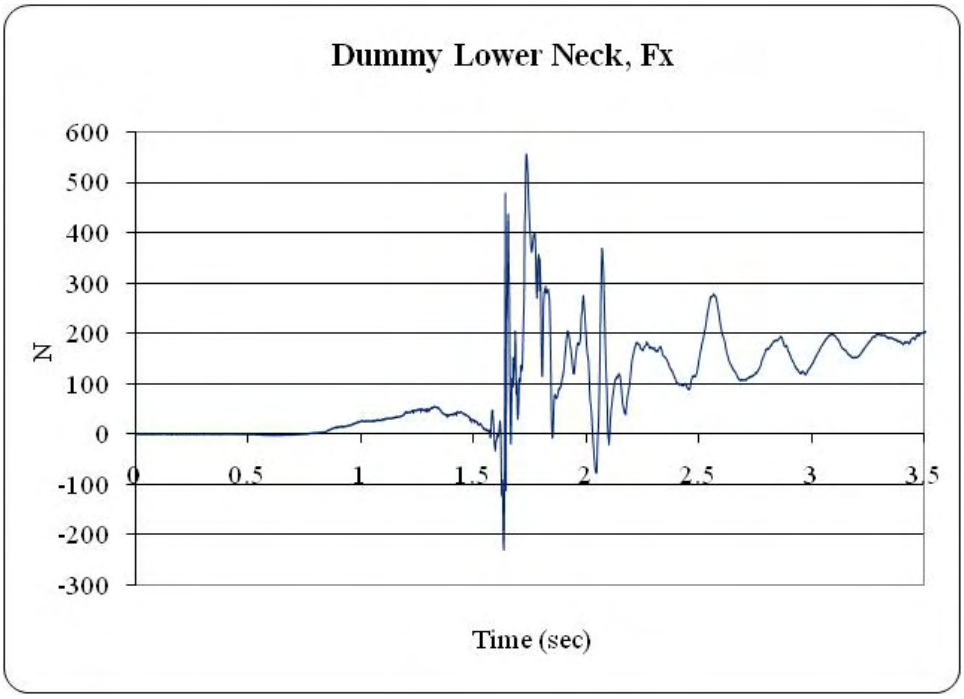
Data Sampling Rate: 10 kHz



Plot 22: Roll Rate vs. Time

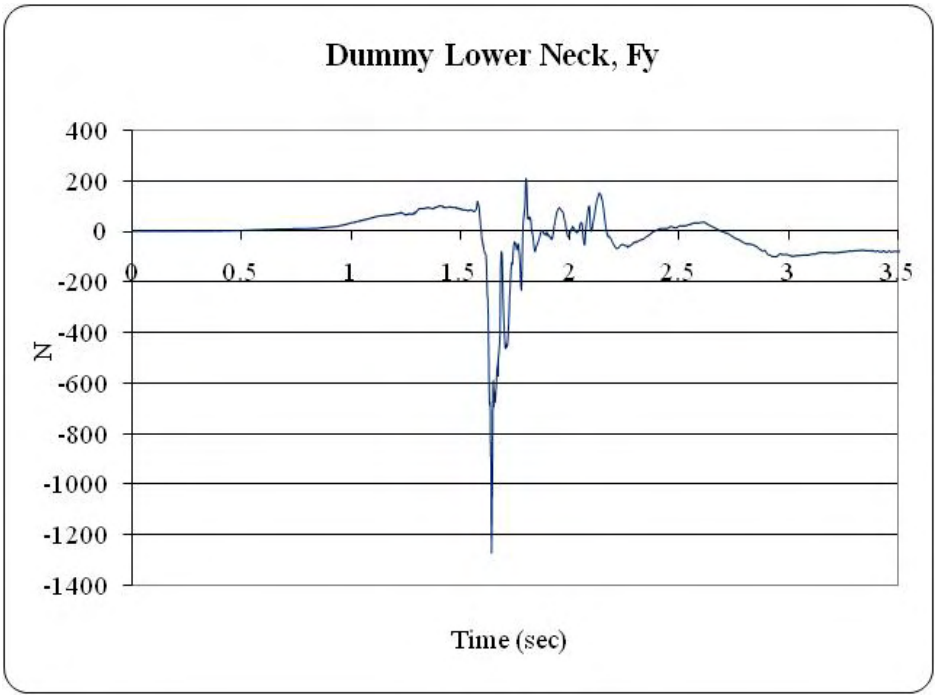
Data Sampling Rate: 10 kHz

Roll 2 Data Plots – 10/07/2009



Plot 23: Lower Neck Load, Fx, v. Time

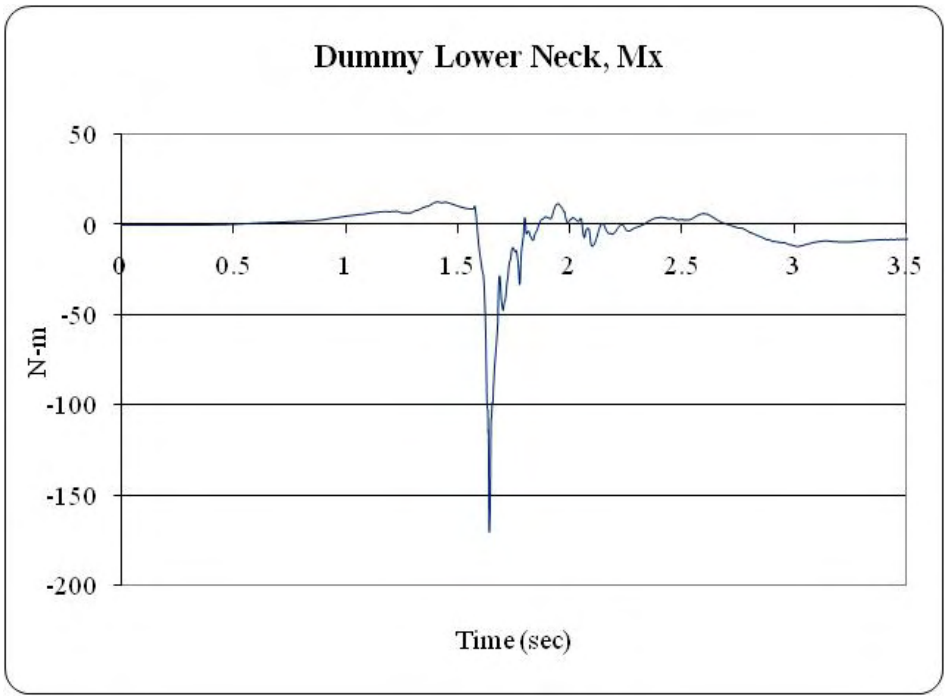
Data Sampling Rate: 10 kHz



Plot 24: Lower Neck Load, Fy, v. Time

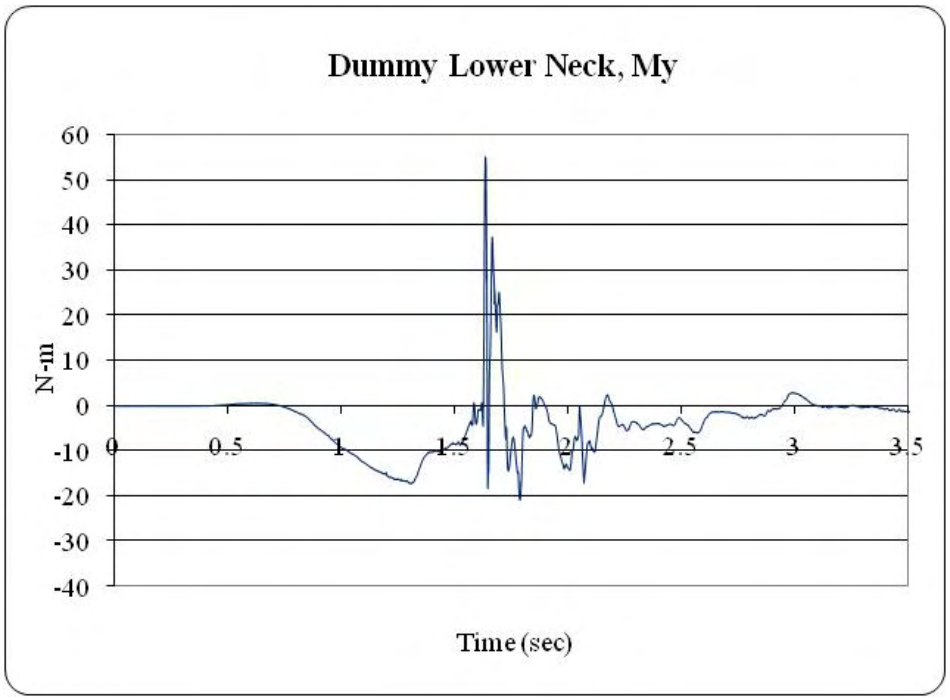
Data Sampling Rate: 10 kHz

Roll 2



Plot 25: Lower Neck Load, Mx, v. Time

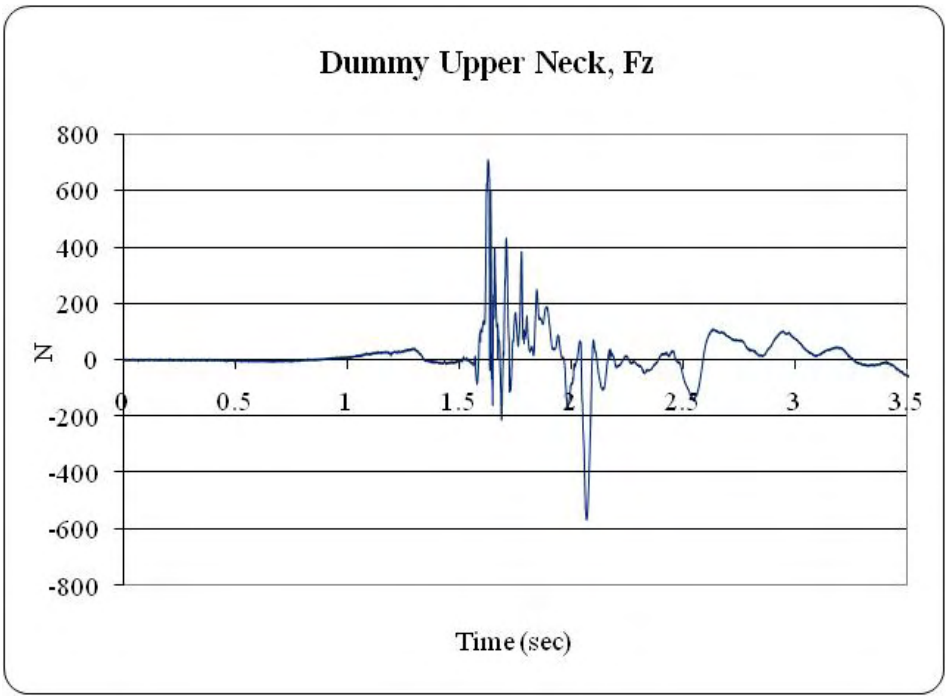
Data Sampling Rate: 10 kHz



Plot 26: Lower Neck Load, My, v. Time

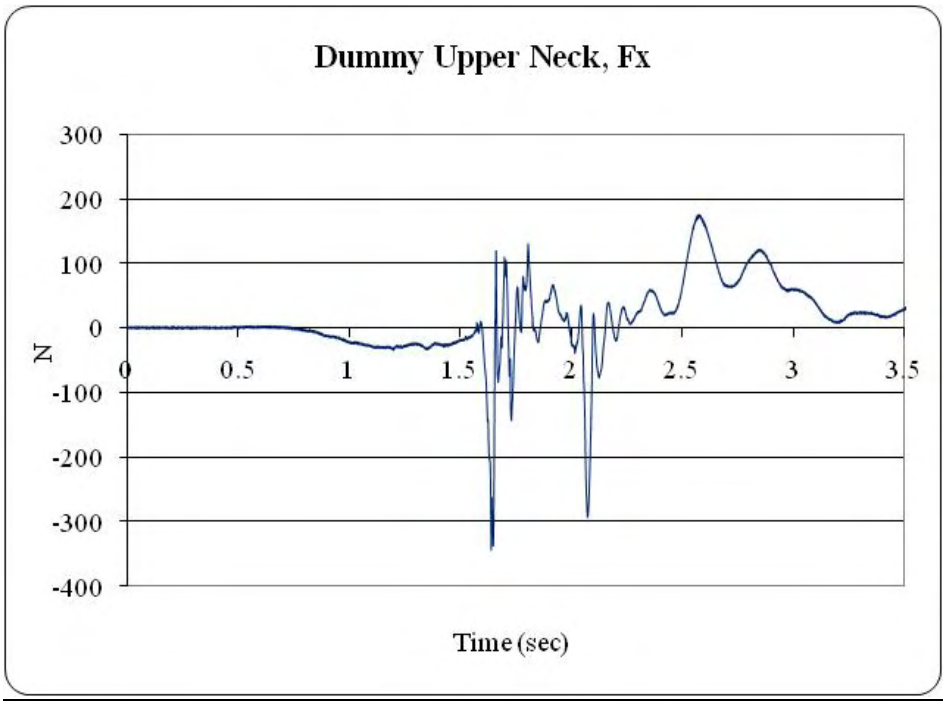
Data Sampling Rate: 10 kHz

Roll 2



Plot 27: Upper Neck Load, Fz, v. Time

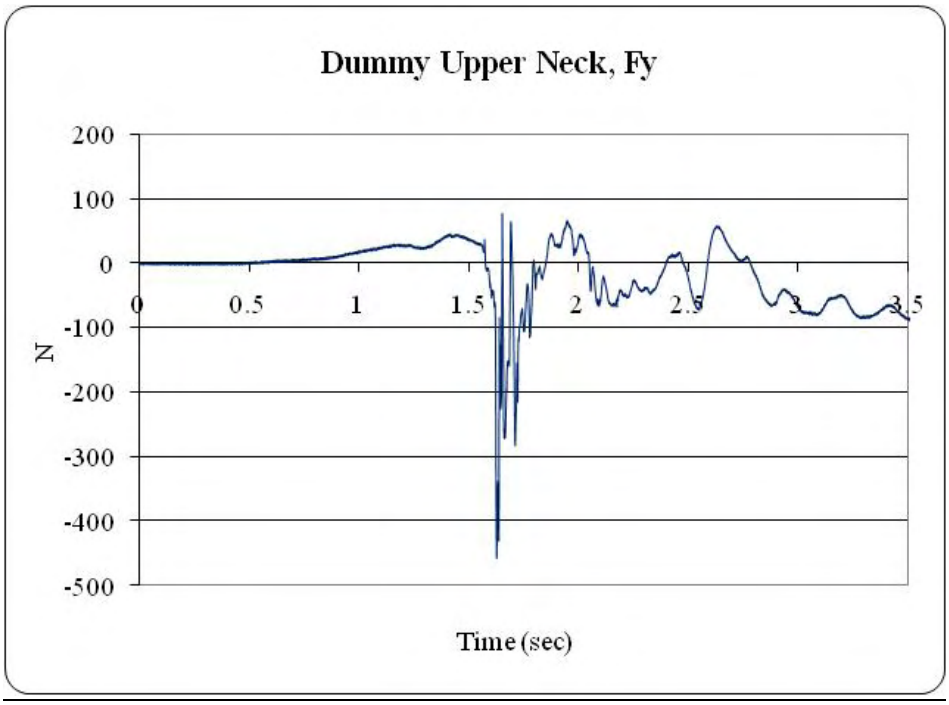
Data Sampling Rate: 10 kHz



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

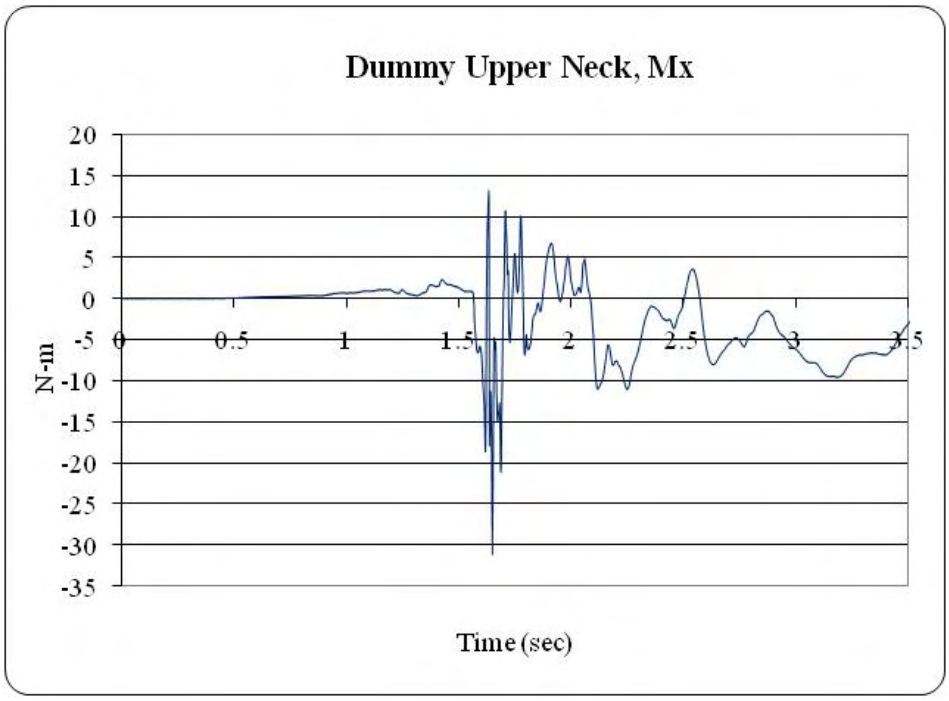
Data Sampling Rate: 10 kHz

Roll 2



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

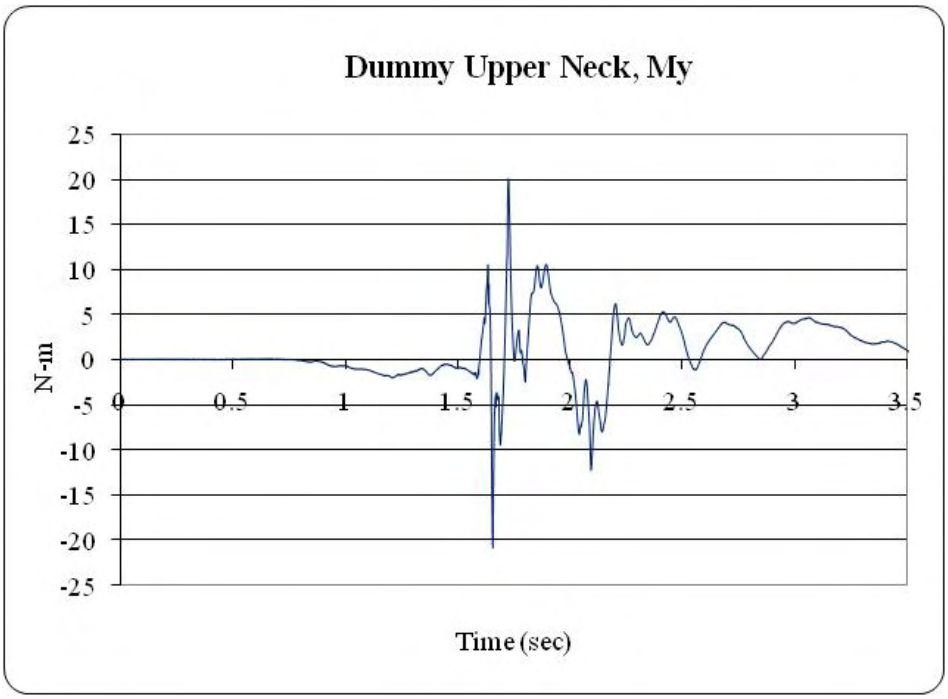
Data Sampling Rate: 10 kHz



Plot 30: Upper Neck Load, Mx, v. Time

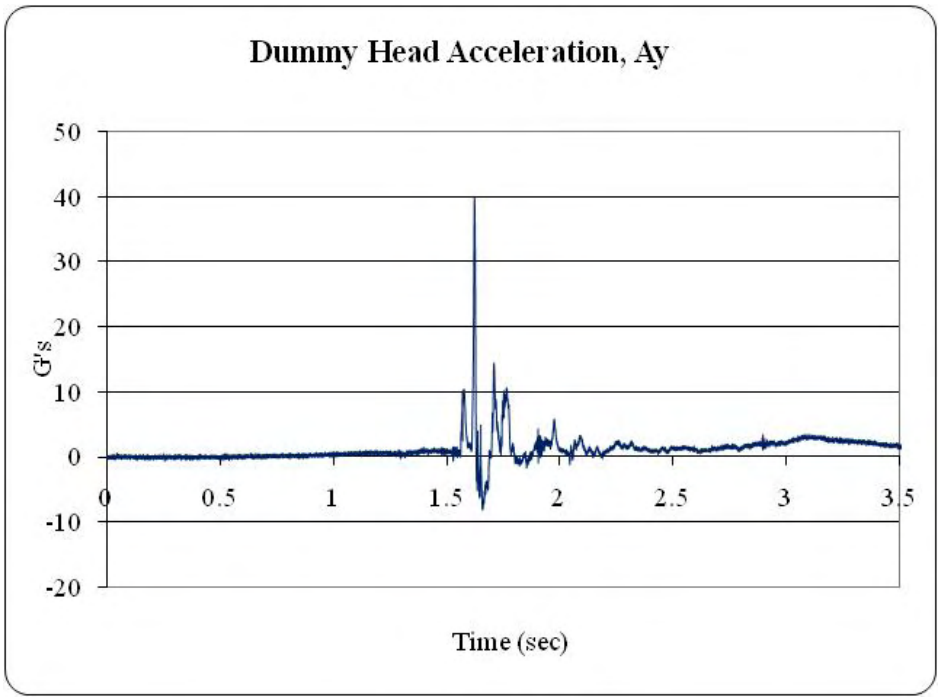
Data Sampling Rate: 10 kHz

Roll 2



Plot 31: Upper Neck Load, My, v. Time

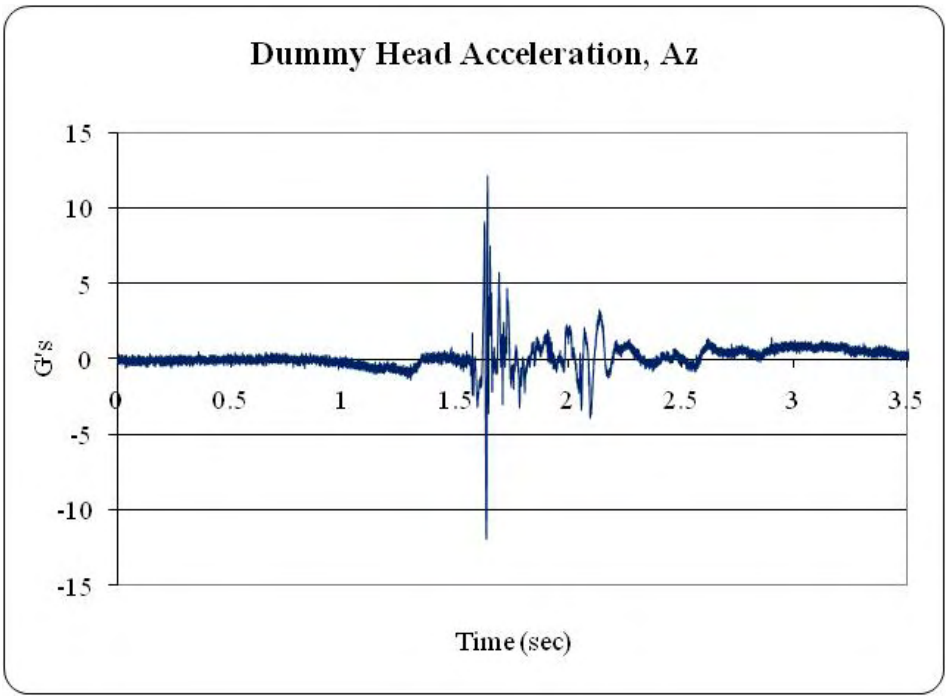
Data Sampling Rate: 10 kHz



Plot 32: Head Acceleration, Ay, vs. Time

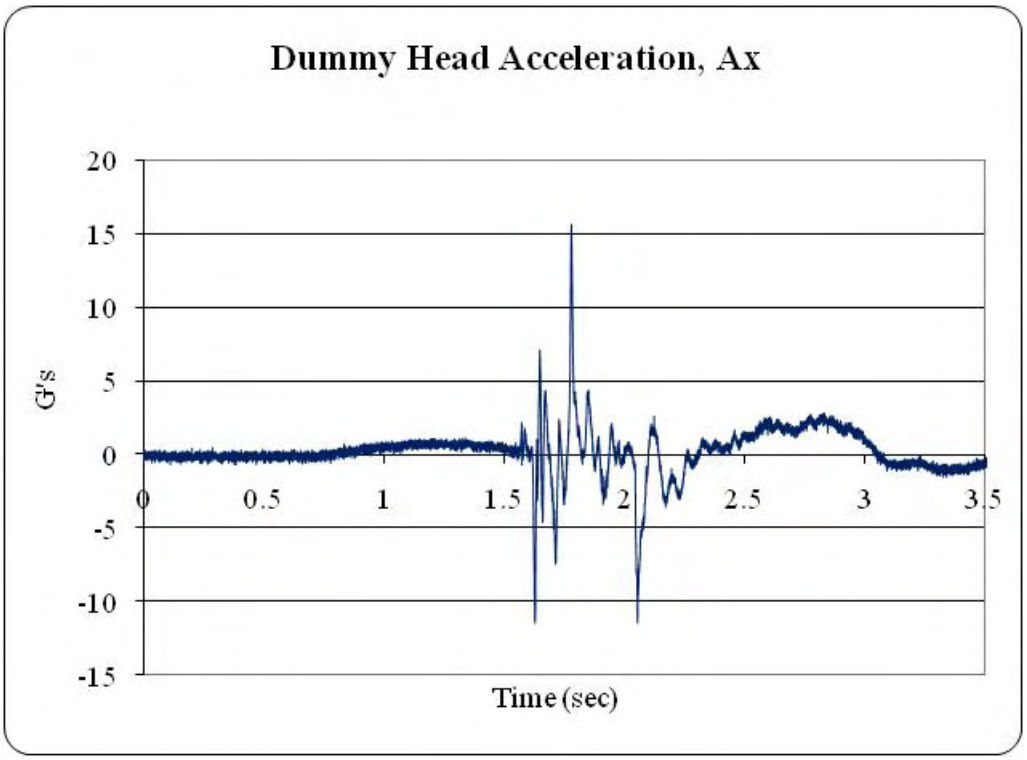
Data Sampling Rate: 10 kHz

Roll 2



Plot 33: Head Acceleration, Az, vs. Time

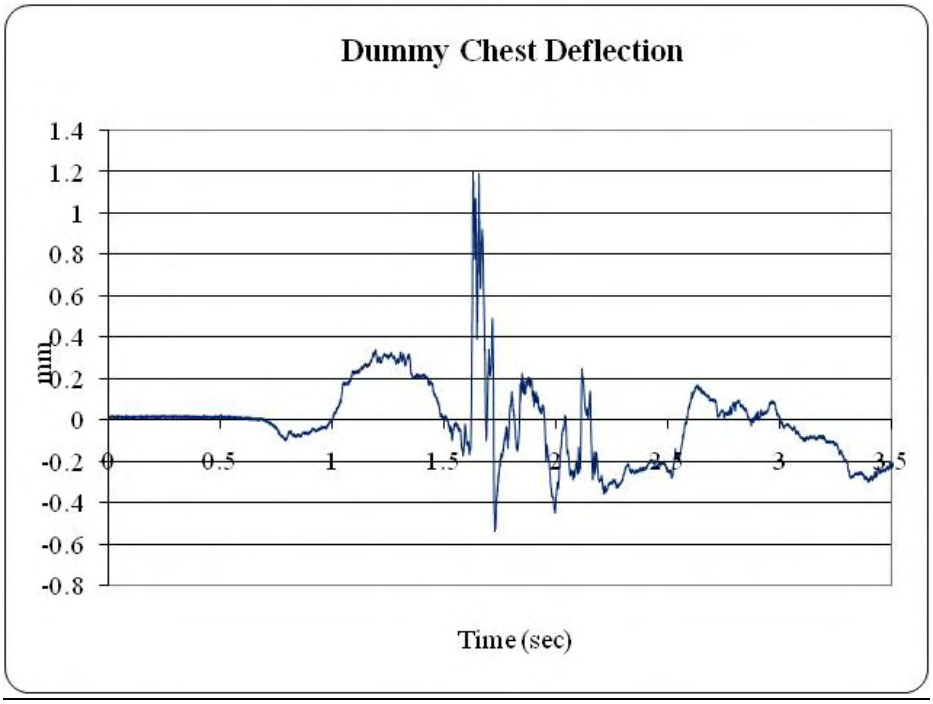
Data Sampling Rate: 10 kHz



Plot 34: Head Acceleration, Ax, vs. Time

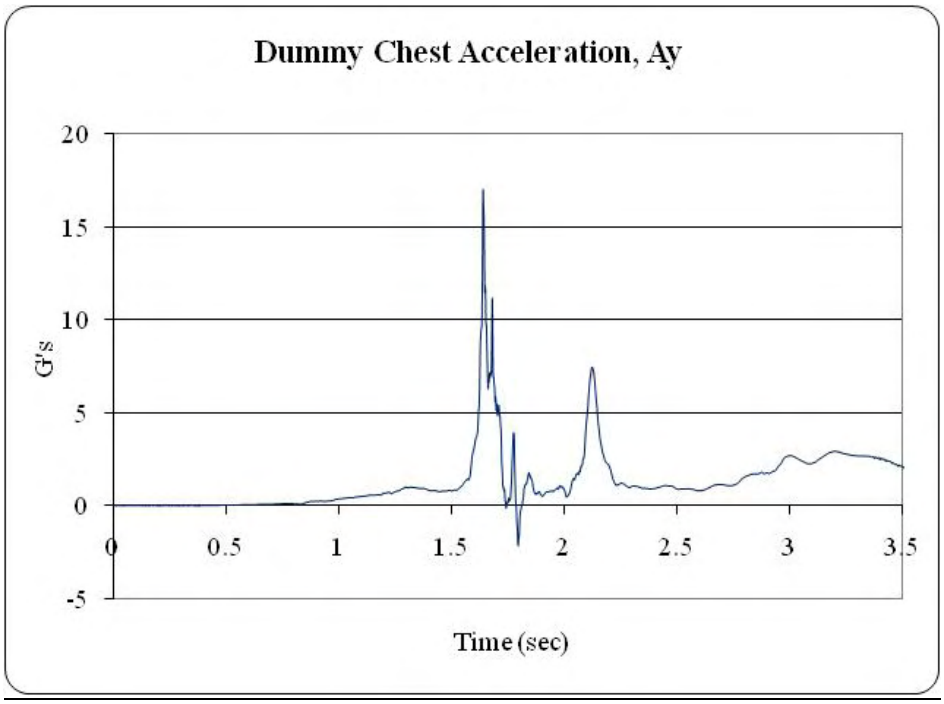
Data Sampling Rate: 10 kHz

Roll 2



Plot 35: Chest Deflection vs. Time

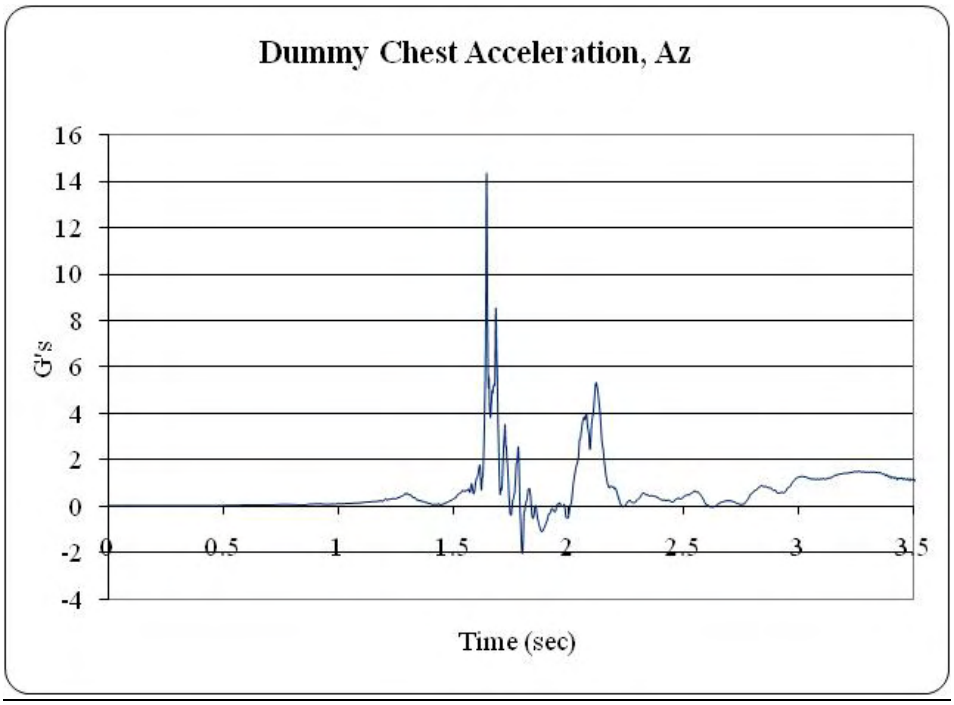
Data Sampling Rate: 10 kHz



Plot 36: Chest Acceleration, Ay, vs. Time

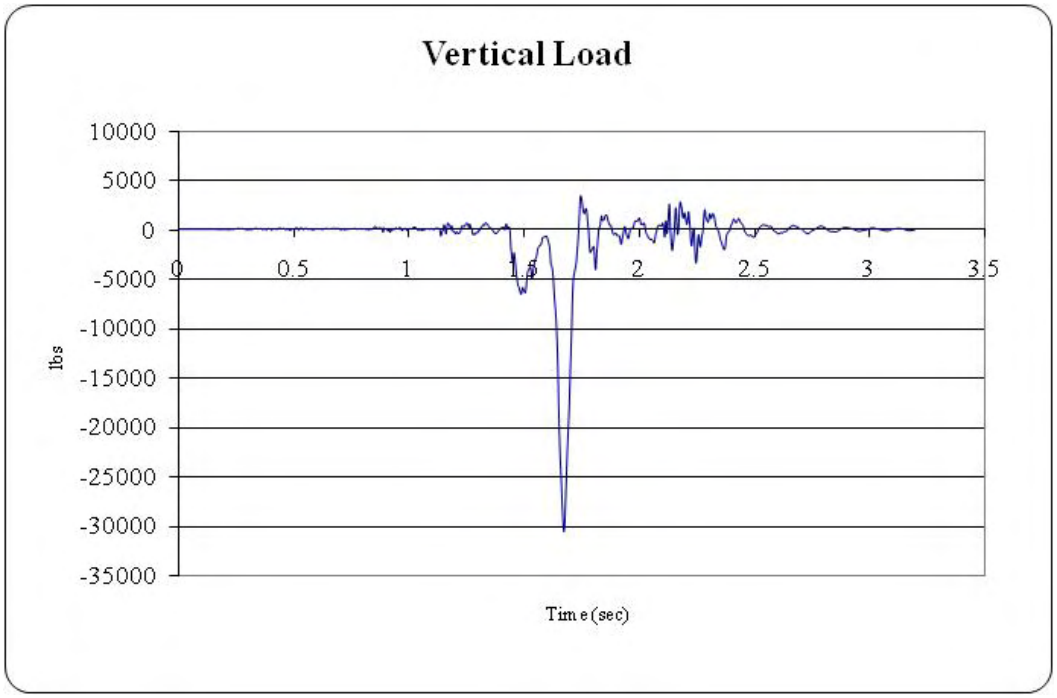
Data Sampling Rate: 10 kHz

Roll 2



Plot 37: Chest Acceleration, Az, vs. Time

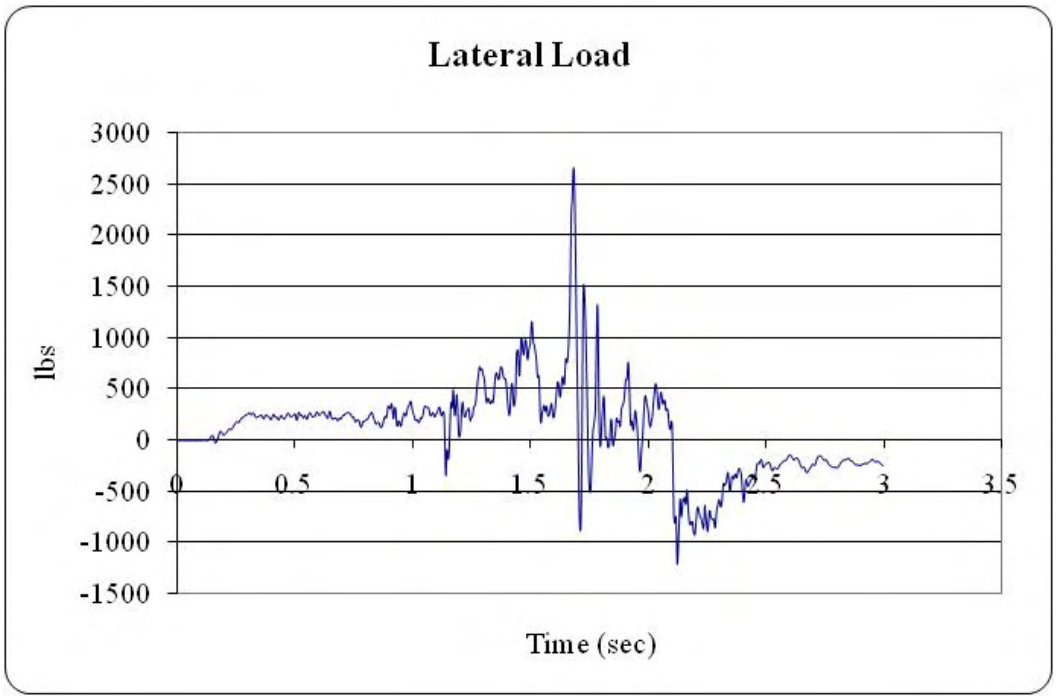
Data Sampling Rate: 10 kHz



Plot 38: Total Vertical Load v. Time

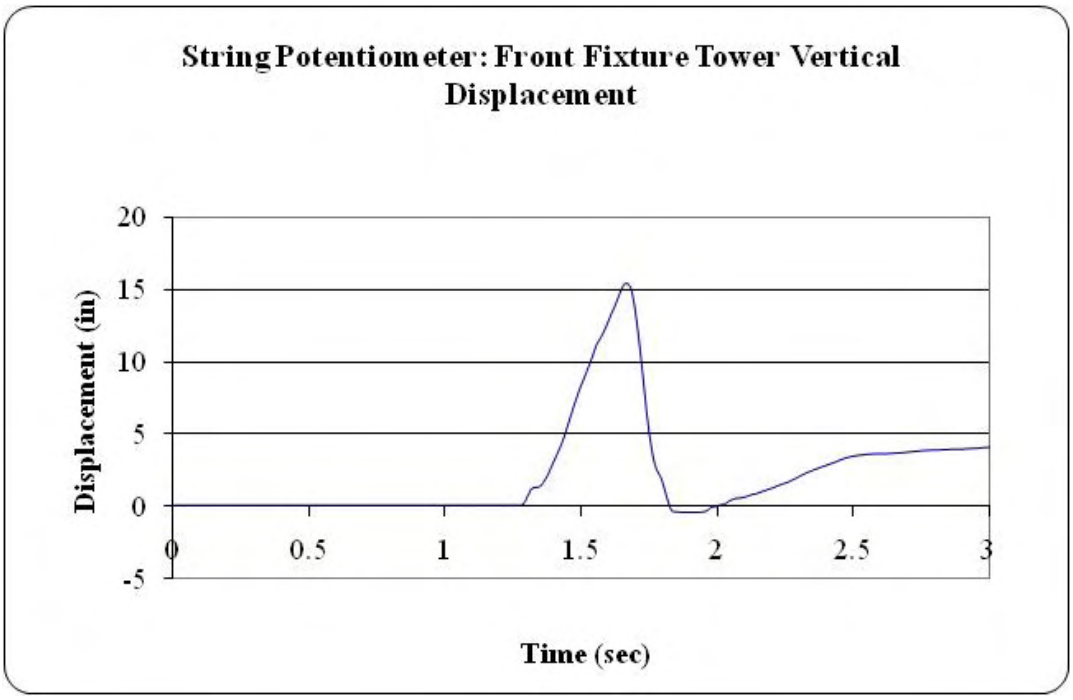
Data Sampling Rate: 10 kHz

Roll 2



Plot 39: Total Lateral Load v. Time

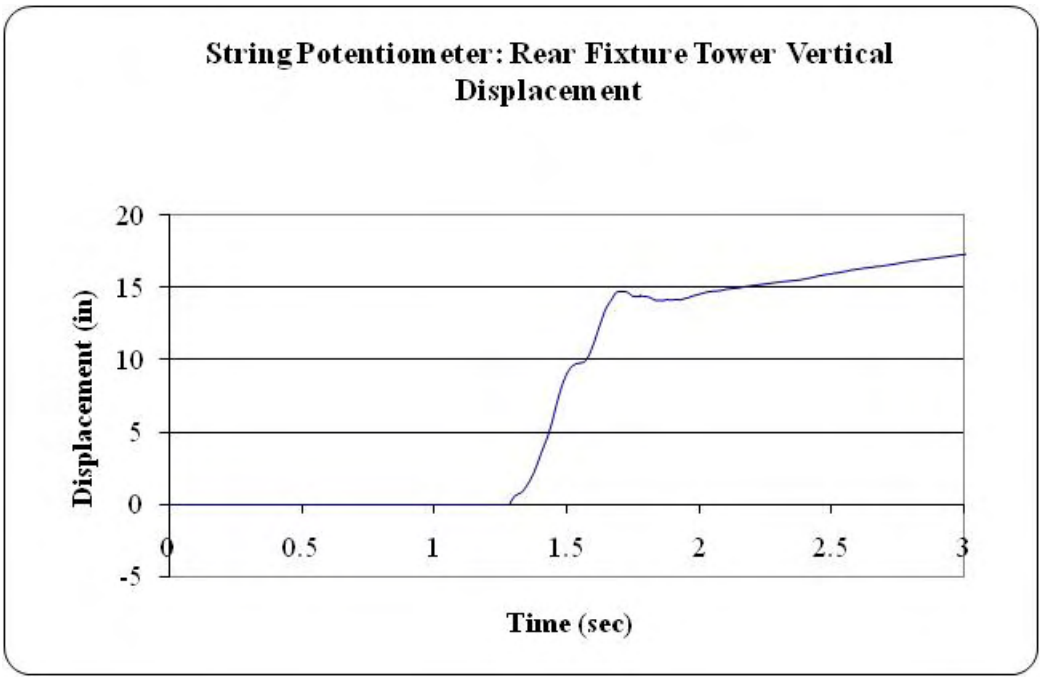
Data Sampling Rate: 10 kHz



Plot 40: String Potentiometer Front Fixture Support Tower Displacement vs. Time

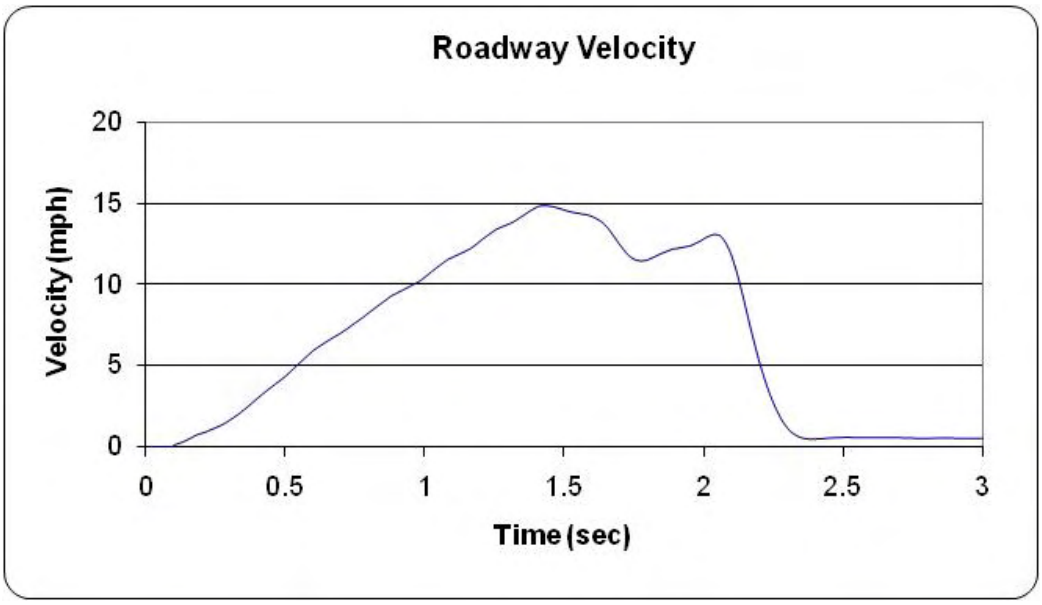
Data Sampling Rate: 1 kHz

Roll 2



Plot 41: String Potentiometer Rear Fixture Support Tower Displacement vs. Time

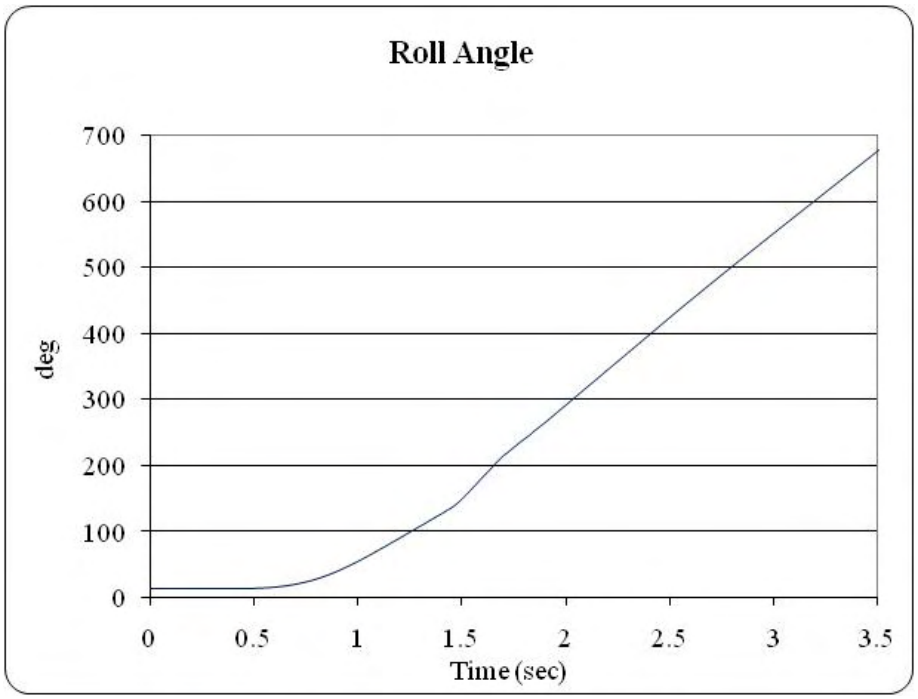
Data Sampling Rate: 1 kHz



Plot 42: Roll Encoder on Roadway Velocity vs. Time

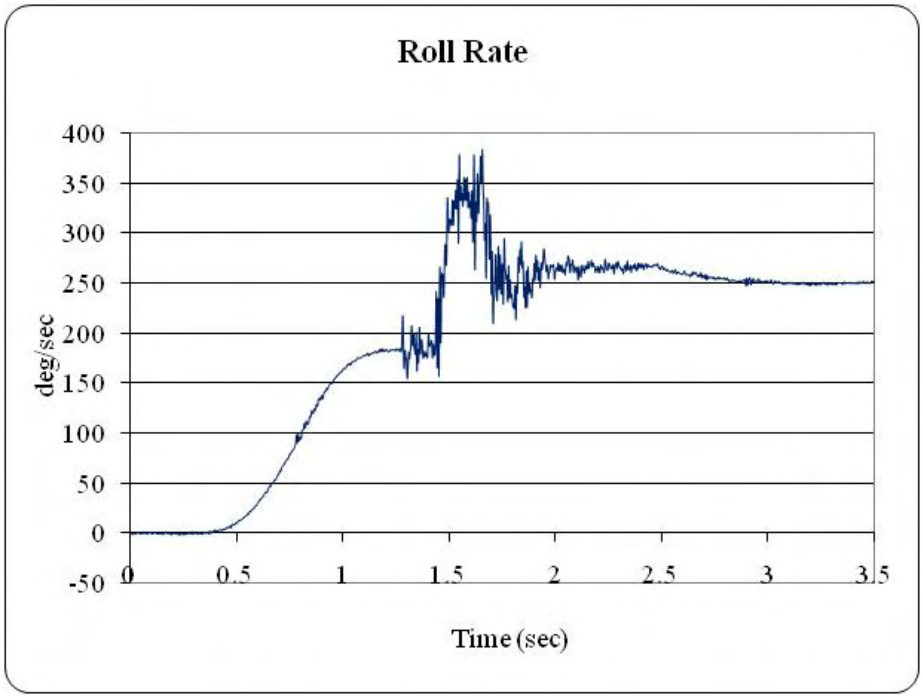
Data Sampling Rate: 1 kHz

Roll 2



Plot 43: Roll Angle vs. Time

Data Sampling Rate: 10 kHz



Plot 44: Roll Rate vs. Time

Data Sampling Rate: 10 kHz

5. All Test Photographs – Vehicle Instrumentation

Vehicle Instrumentation

Roll 1 Photographs – 10/02/2009 – Dummy Inspection

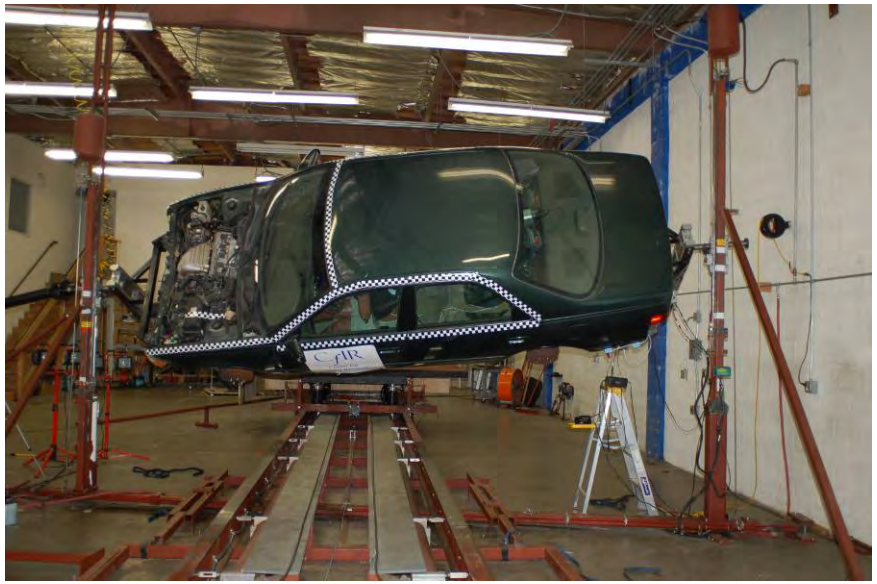
Roll 1 Photographs – 10/02/2009 – Pre-Roll



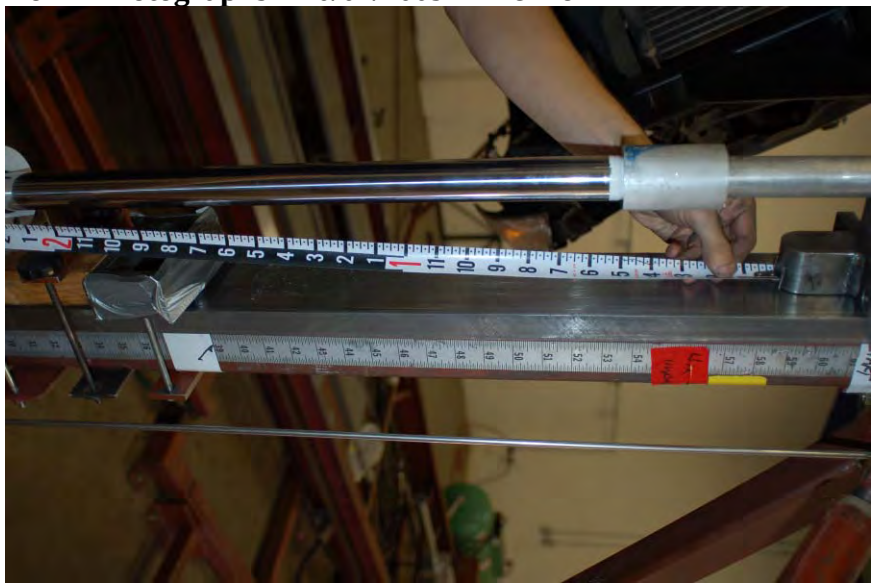

Roll 1 Photographs – 10/02/2009 – Pre-Roll

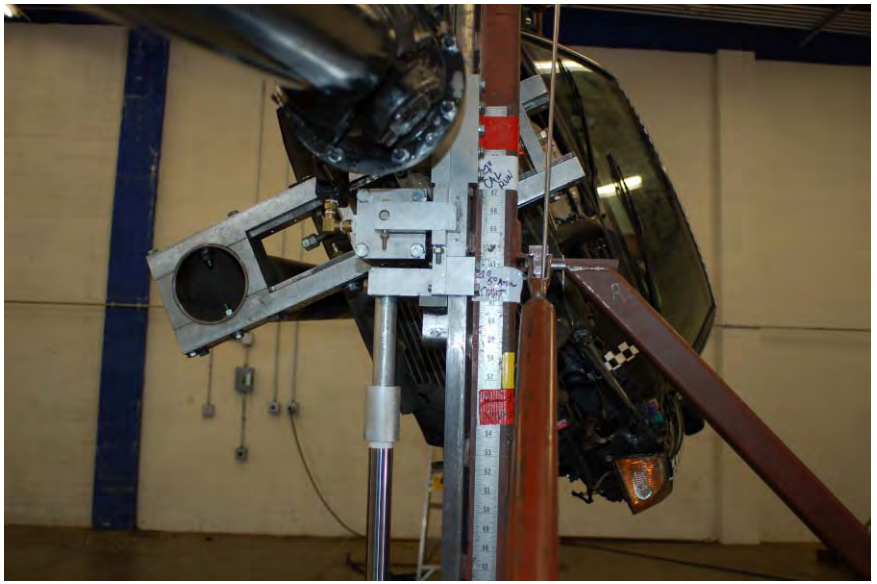
Roll 1 Photographs – 10/02/2009 – Pre-Roll

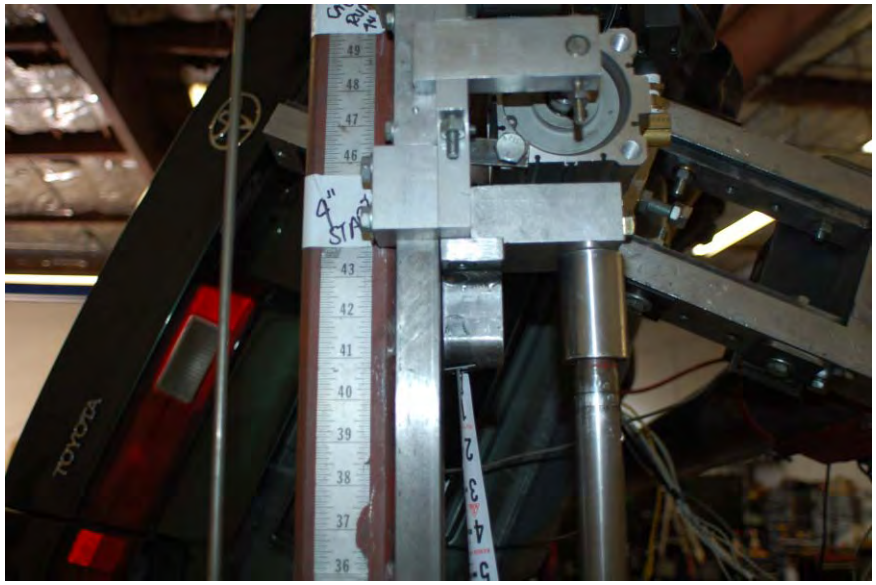


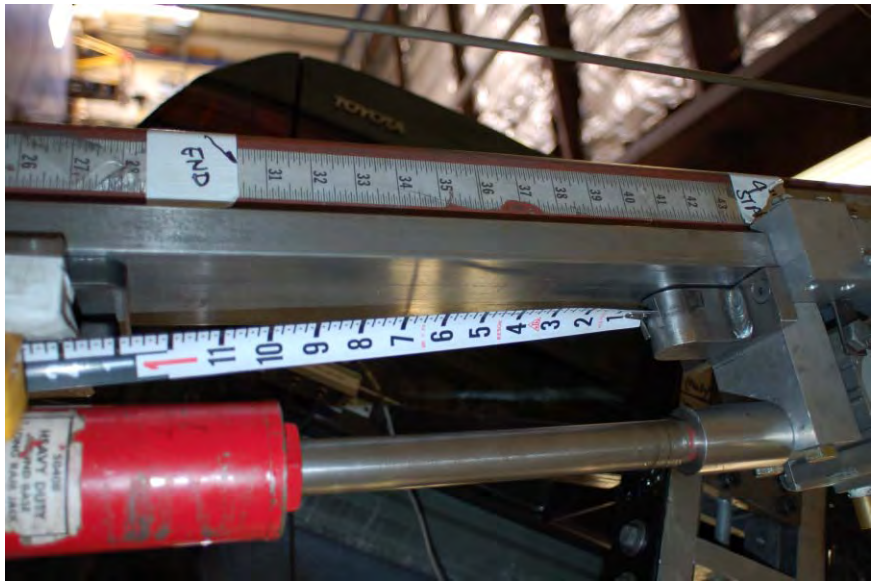



Roll 1 Photographs – 10/02/2009 – Pre-Roll

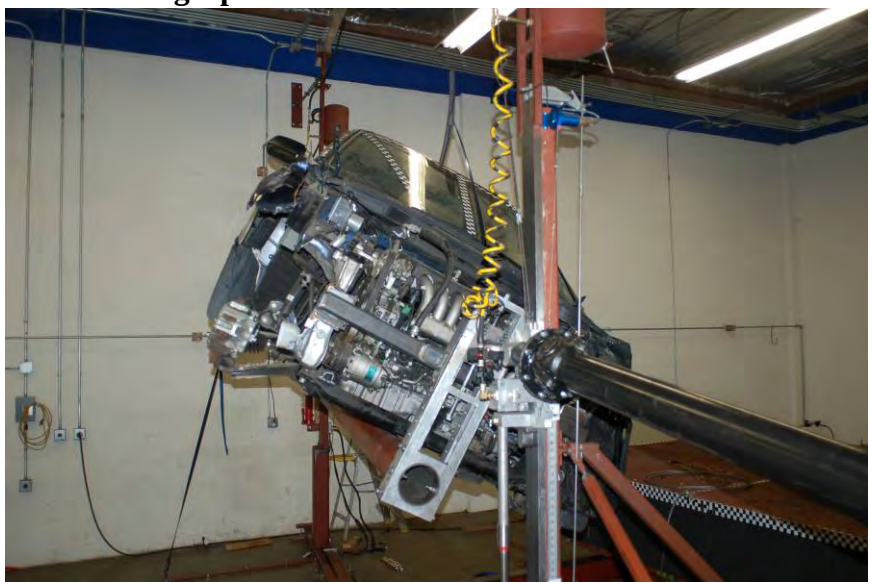








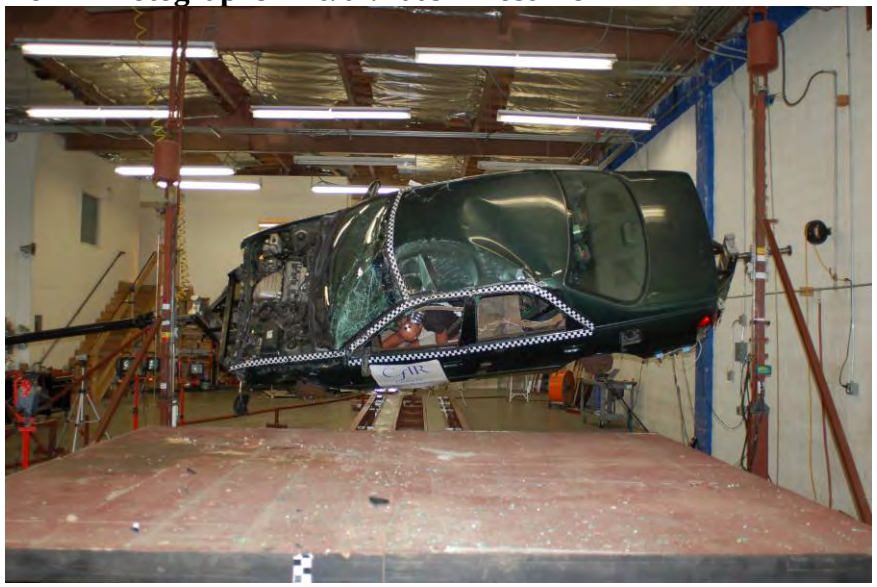
Roll 1 Photographs – 10/02/2009 – Post-Roll

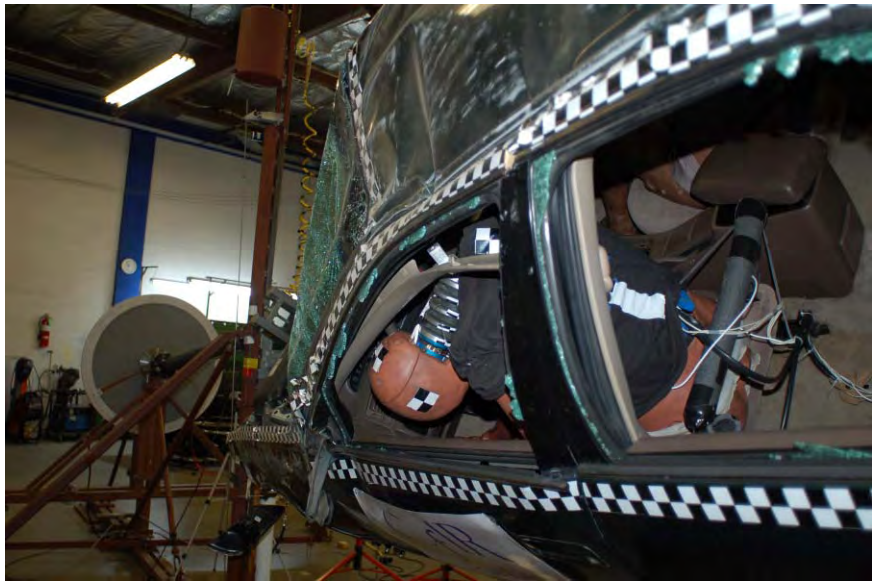


Roll 1 Photographs – 10/02/2009 – Post-Roll




Roll 1 Photographs – 10/02/2009 – Post-Roll



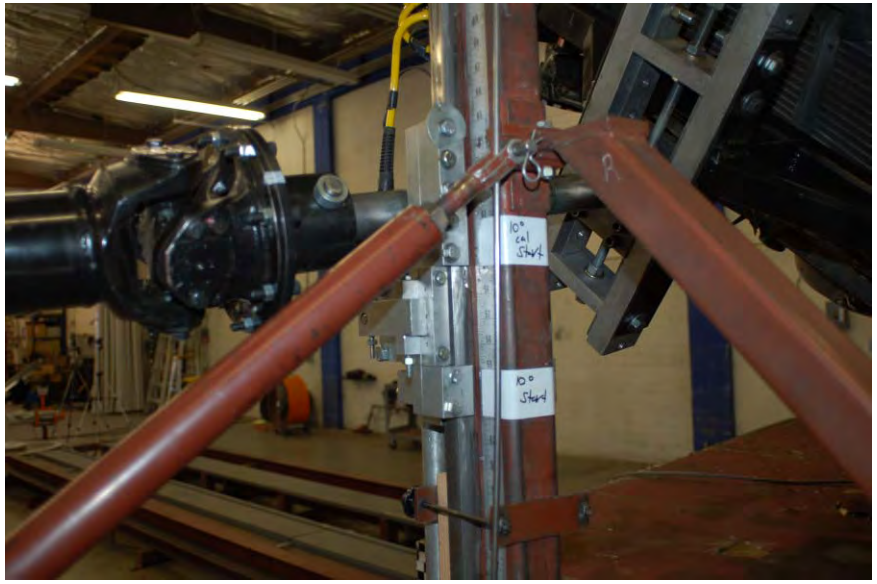


Roll 1 Photographs – 10/02/2009 – Post-Roll

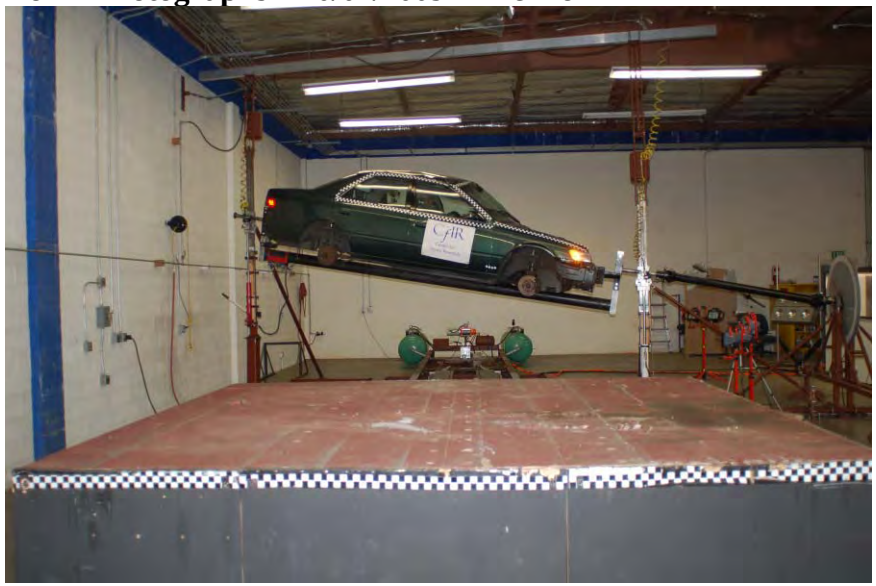
Roll 2 Photographs – 10/07/2009 – Dummy Inspection

Roll 2 Photographs – 10/07/2009 – Dummy Inspection

Roll 2 Photographs – 10/07/2009 – Pre-Roll

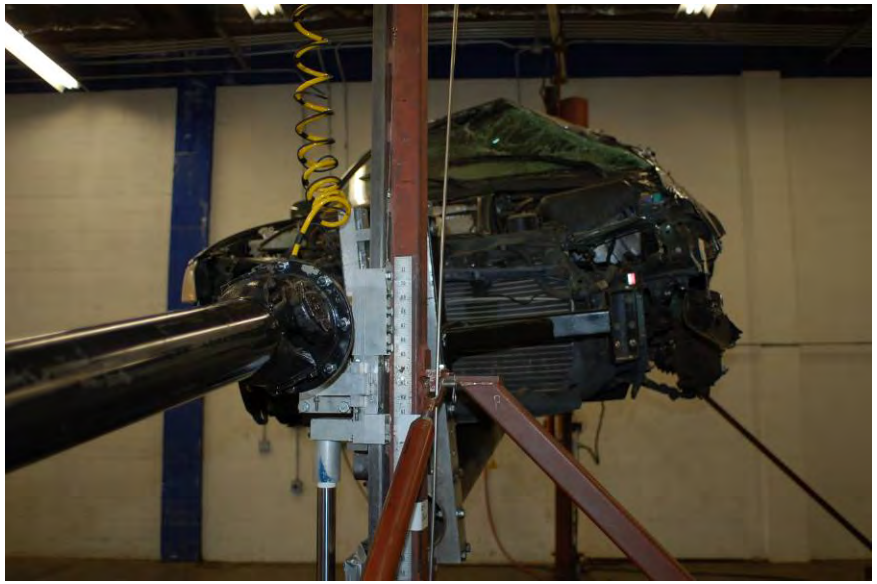


Roll 2 Photographs – 10/07/2009 – Pre-Roll



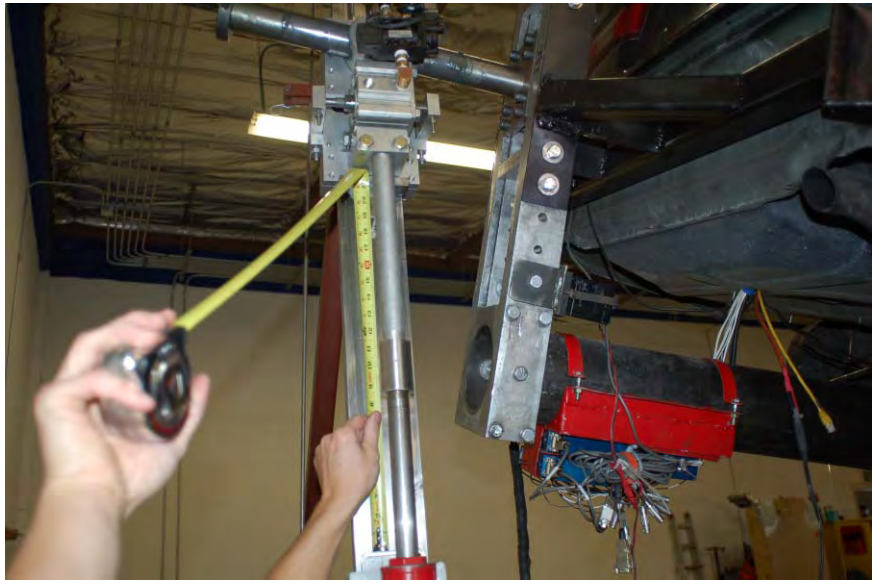
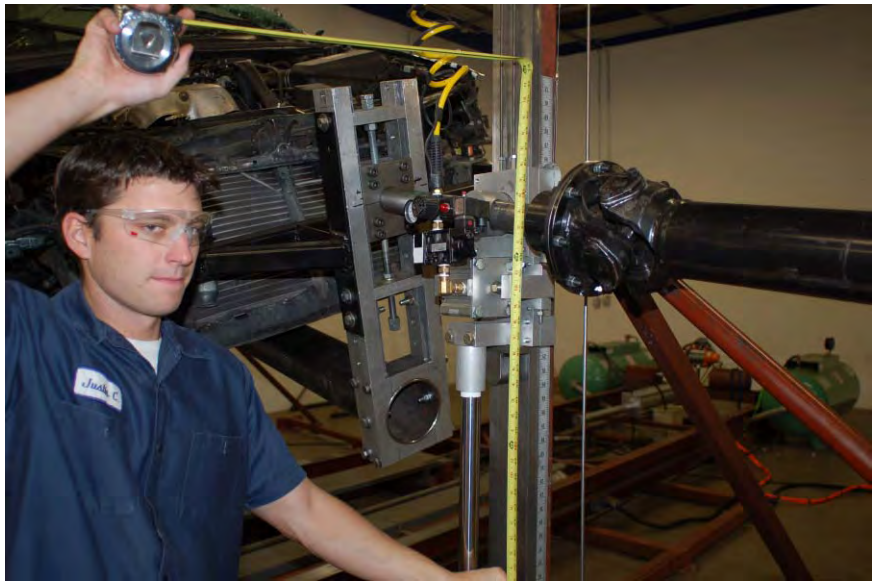
Roll 2 Photographs – 10/07/2009– Pre-Roll



Roll 2 Photographs – 10/07/2009 – Pre-Roll

Roll 2 Photographs – 10/07/2009 – Pre-Roll


Roll 2 Photographs – 10/07/2009 – Post-Roll




Roll 2 Photographs – 10/07/2009 – Post-Roll




Roll 2 Photographs – 10/07/2009 – Post-Roll

Roll 2 Photographs – 10/07/2009 – Post-Roll