

TEST REPORT FOR:

**Virginia Department of Transportation
X Tension Tangent 37.5' (11.43 m) System**



PREPARED FOR:

**Virginia Department of Transportation
1401 E. Broad St.
Richmond, VA 23219**

TEST REPORT NUMBER:

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KARCO Engineering, LLC.
Automotive and Safety Testing Facility
9270 Holly Road, Adelanto, CA 92301
Tel: (760) 246-1672 Fax: (760) 246-8112
www.KARCO.com

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SECTION 1

INTRODUCTION

1.1 OBJECTIVES

The objective of this crash test was to evaluate the impact performance of the Lindsay Corporation X Tension Tangent 37.5' (11.43 m) System. This report presents the results of one (1) full-scale crash test conducted on one X Tension Tangent 37.5' (11.43 m) system. For this test, the terminal section was installed on the front end of a 38.1 m (125.0 ft.) length of guardrail.

The test was conducted in accordance with instructions provided by the Virginia Department of Transportation.

1.2 TEST FACILITY

This test was conducted at KARCO Engineering's test facility in Adelanto, California. The tow road is a continuous level surface constructed of reinforced concrete and measures 700 ft. long by 14 ft. wide by 6 in. thick. A steel rail is embedded in the road to provide vehicle guidance. Vehicle tow propulsion is provided by a 1 ton truck using a 1-to-2 pulley system. The test vehicle is towed to within 25 ft. of the barrier by a nylon rope clamped to a 3/8 in. steel cable. The clamp is released from the cable on contact with a cable release mechanism positioned to allow the test vehicle to proceed under its own momentum for a maximum of 25 ft. before impacting the barrier.

1.3 TEST ARTICLE

The Lindsay Corporation X Tension Tangent 37.5' (11.43 m) System is a standard post guardrail terminal/end treatment. The as-tested X Tension Tangent 37.5' (11.43 m) System consisted of an impact head, hinged post, crimped post, slider panel, slider bracket cable bracket, ground strut, soil anchor, two cables, four (4) standard line post and three (3) W-beam panels. The terminal was installed with a 50:1 flare and a rail height ranging from 705 mm (27.75 in.) to 730 mm (28.75 in.) per Virginia Department of Transportation (VDOT) Road and Bridge Standards.

The soil anchor was constructed of one (1) 1.8 m (6.0 ft) long 10 mm (0.4 in.) thick steel C-channel post and soil plate. The soil plate was 355 mm (14.0 in.) tall by 470 mm (18.5 in.) wide and welded 150 mm (5.9 in.) from the top of the post. At the top of the post there are two 30 mm (1.2 in.) diameter holes that align with the ground strut.

The ground strut was constructed from 1.6 (5.2 ft.) long 10 mm (0.4 in.) thick C-channel. At the upstream end of the ground strut a 5 mm (0.2 in.) thick plate is welded to the end with two 30 mm (1.2 in.) diameter holes. The downstream end of the ground strut has a 21 mm (0.8 in.) diameter hole drilled through its width to attach to post 1.

Post 1 consisted of one (1) 1.0 m (3.1 ft) long top post and one (1) 1.7 m (5.5 ft) long bottom. Post 1 top was constructed of W6 X 8.5 I-beam with crimps located 730 mm (28.7 in.) down from the top on both of its flanges. The bottom post was constructed of a 1.4 m (4.6 ft.) long W6 x 8.5 I-beam and welded sleeve. The sleeve was constructed of a 10 mm (0.4 in) thick C-channel section and a 5 mm (0.2 in.) thick rectangular plate. The sleeve extended 300 mm (11.8 in.) from the top of the I-beam and had a 21 mm (0.8 in.) hole drilled through its width. The top and bottom of post 1 were pinned with the ground strut using an M16 X 200 mm (0.625 in. x 8.0 in.) bolt, nut and washer.

Post 2 was a 1.8 m (6.0 ft.) long W6 x 8.5 I-beam post with crimps on its flanges. Posts 3 through 6 were standard line post. All standard line post measure 1.8 m (6.0 ft.) long and are constructed of W6 x 8.5 I-beam. A slider bracket is mounted at post 3 between the blackout and the rail. The slider bracket is 5 mm (0.2 in) thick and 390 mm (15.4 in.) long by 170 mm (6.7 in.) wide. The slider bracket has a 350 mm (13.8 in.) long 50 mm x 50 mm (2.0 in. x 2.0 in.) angle iron mounted with two (2) M20 x 25 mm (0.75 in. x 1.0 in.) bolts.

Mounted at the downstream end of the first W-beam rail is a slider panel. The slider panel had an overall length of 349 mm (13.8 in.) and an overall width of 335 mm (13.2 in.). The slider panel has a W-beam shape with 5 mm (0.2 in.) thick C-channel welded on the back side of the panel to encase the end of the W-beam panel. There are four (4) 16 mm (0.625 in.) holes used to mount the panel to the downstream end of the w-beam panel. The panel is mounted with four (4) standard rail splice bolts and nuts.

Three (3) 3.8 m (12.5 ft.) long rail panels are mounted to the posts of the terminal section with the splice located at every other post. The rail panels are constructed of 12 Ga W-beam guardrails. The first rail panel is mounted to post 1 via a M16 x 50 mm (0.625 in x 2 in.) hex bolt, 50 mm (2 in.) square washer, and nut. 191 mm (7.5 in.) plastic offset blocks are placed between the remainder of the terminal's line posts and the rail panels. One (1) M16 x 254 mm (0.625 in. x 10.0 in) long bolt, washer, and nut is used to mount the rail to each of the line posts with offset blocks. The rail is not mounted to post 3. Yellow 16 mm (0.625 in.) shear bolts connect rail 2 and 3. All posts were spaced at a nominal distance of 1.9 m (6.25 ft.).

The impact head had an overall length of 600 mm (23.6 in.). The face of the impact head measured 472 mm (18.6 in.) tall by 332 mm (13.1 in.) wide. There are two (2) 40 mm (1.6 in.) diameter holes in which the cables are routed through. Inside the impact head is a 20 mm (0.8 in.) thick friction plate with three (3) 37 mm (1.5 in.) diameter holes drilled. The cables are routed through the bottom two holes of the friction plate while the top hole was used for tensioning the plate. Once the cables were properly tensioned four (4) M20 x 2.5 mm (0.75 in. x

3.0 in.) bolts hold the plate in place. The impact head is mounted to the rail with eight (8) M16 (0.625 in.) standard splice bolts.

The cables are secured at the soil anchor and routed through the impact head to the cable bracket. The cable bracket is mounted at post 7 between the blockout and the W-beam panel. The cable bracket measured 550 mm (21.7 in.) long and 5 mm (0.2 in.) thick. At the downstream end of the bracket there are two (2) 50 mm (2.0 in.) square tubes welded to secure the table.

For this test, the X Tension Tangent 37.5' (11.43 m) System was adjoined to the end of a 38.1 m (125.0 ft.) length of guardrail, measured from post 7 to post 27. The adjoining guardrail included a 3.8 m (12.5 ft.) long trailing end terminal treatment, measured from post 25 to post 27. The terminal's adjoining barrier consisted of nineteen (19) 1.8 m (6.0 ft.) long W6 x 8.5 standard I-beam line posts, one (1) 8" x 6" wood post with a soil plate and steel foundation tube, four (4) 7.6 m (25.0 ft.) long 12 Ga W-beam rail panels, one (1) 3.8 m (12.5 ft.) long 12 Ga W-beam rail panel, and one (1) cable anchor assembly. 191 mm (7.5 in.) plastic offset blocks were on all posts except the last wooden post.

With the exception of the soil anchor, Post 1 and the trailing end terminal post, the post were installed by drilling 0.3 m (1.0 ft.) diameter by 0.3 m (1.0 ft.) deep pilot holes and driving the posts into the soil. The soil anchor, post 1 and the trailing end terminal post were installed by drilling a 0.6 m (2.0 ft.) diameter hole and a depth of 1.8 m (6.0 ft.). The holes were backfilled and compacted with a pneumatic compactor.

Photographs of the as-tested unit and installation are available in Appendix A of this report. Manufacturer's drawings are available in Appendix D. The installation instructions are included on KARCO CD-R 2016-4059.

SECTION 2

TEST PROCEDURE AND INSTRUMENTATION SUMMARY

2.1 TEST PROCEDURE

To meet the recommended properties of the NCHRP 350 test vehicle requirements, a commercially available production model test vehicle was selected. The test vehicle was in free of major body damage and was not missing any structural components. The bumpers were standard equipment and were not modified for this test. All fluids were drained and the battery was removed.

The NCHRP 350 recommended test vehicle properties are shown in Table 1. The 2000P test vehicle was used for this test. The 2000P test vehicle used for this test was a front engine model with rear wheel drive and an automatic transmission.

Table 1. Recommended Properties of 700C, 820C and 2000P Test Vehicles

PROPERTY	700C (Small Car)	820C (Small Car)	2000P (Pickup Truck)
MASS (kg)			
Test Inertial Dummy	700 ± 25	820 ± 25	2000 ± 45
Maximum Ballast Gross Static	75 70 775 ± 25	75 80 895 ± 25	--- 200 2000 ± 45
DIMENSIONS (cm)			
Wheelbase	230 ± 10	230 ± 10	335 ± 25
Front Overhang	75 ± 10	75 ± 10	80 ± 10
Overall Length	370 ± 20	370 ± 20	535 ± 25
Track Width (average)	135 ± 10	135 ± 10	165 ± 15
CENTER OF MASS LOCATION (cm)			
Aft of Front Axle Above Ground	80 ± 15 55 ± 5	80 ± 15 55 ± 5	140 ± 15 70 ± 5
LOCATION OF ENGINE	Front	Front	Front
LOCATION OF DRIVE AXLE	Front	Front	Rear
TYPE OF TRANSMISSION	Manual or Automatic	Manual or Automatic	Manual or Automatic

2.2 CRASH TEST SET UP

A full-scale crash test was conducted to evaluate the impact performance of the X Tension Tangent 37.5' (11.43 m) System. The test conditions were as follows: A 2000 kg (4409 lb.) pickup truck approaching the test article at a nominal speed of 100 km/h (62 mph) with a critical impact angle of 5°. The test article was installed so that the vehicle centerline intersected the leading edge of the W-beam rail.

2.3 TEST INSTRUMENTATION AND DATA ACQUISITION PROCEDURES

All data acquisition for this certification test was performed in accordance with the NCHRP 350 Recommended Procedure requirements.

2.3.1 Test Vehicle Instrumentation: The test vehicle was instrumented with one (1) tri-axial accelerometer and one tri-axial angular rate sensor. Both the accelerometer and the angular rate sensor were installed with a 5 cm radial of the vehicle's longitudinal and lateral center of gravity. The accelerometers measured longitudinal (x), lateral (y) and vertical (z) acceleration. The angular rate sensors measured vehicle roll, pitch and yaw. Data was recorded using the on-board TDAS. Data was linked to a personal computer and processed using the TDAS Control software. All equipment used in this test meets the requirements of SAE J211.

2.3.1.2 Calibration: All instrumentation used in this test has been calibrated through standards traceable to NIST and is maintained in a calibrated condition.

2.3.2 TDAS Software: The software utilized in this system is written in National Instruments Lab Windows/CVI (C, Visual Interface) programming language, which is a Windows based software package with emphasis on ease of use and good engineering test practices.

2.3.3 SAE Compatibility: The software contains standard point and click processing options for selecting Society of Automotive Engineers (SAE) class post filters and calculating the required integrals, resultants, Head Injury Criteria (HIC), clips, and other data processing parameters that may be required.

2.3.4 Measurement Uncertainty: Measurement uncertainties have been determined for pertinent values affecting the results of this test. KARCO maintains these uncertainty budgets, which are available upon request, but are not included in this report. In certain cases the nature of the test method may preclude rigorous and statistically valid calculation of uncertainty of measurement. In these cases KARCO attempts to identify the components of uncertainty and make a reasonable estimation. Reasonable estimation is based on knowledge of the performance of the method and on the measurement scope and makes use of, for example, previous experience and validation data.

2.3.5 Photographic Documentation: Photographic documentation of this test included a minimum of two (2) real-time video camera at 30 frames per second (fps), and six (6) high-speed color digital video cameras at 1000 fps All high-speed cameras were activated by a pressure-sensitive tape switch, which was positioned on the test article to indicate the instant of contact (time zero). A digital still camera was used for documenting the pre- and post-test condition of the test vehicle and the X Tension Tangent 37.5' (11.43 m) System.

2.3.6 Anthropomorphic Test Device: An Anthropomorphic Test Device (ATD) was not used for this test.

SECTION 3 TEST RESULTS

This 100 km/h (62 mph) impact crash test was conducted using a 2005 Chevrolet 2500 pickup truck to evaluate the impact performance of the X Tension Tangent 37.5' (11.43 m) System. The test article installed at an angle of 5° relative to the test vehicle's direction of travel, with the vehicle centerline intersecting the leading edge of the W-beam rail. This crash test was documented by two (2) real-time and six (6) high-speed video cameras. Pre- and post-test photographs of the test vehicle and test article can be found in Appendix A.

The test was conducted on August 18, 2016. The as-tested test inertial weight of the vehicle was 2,039.5 kg (4,496.2 lbs.). The height of the front bumper was 465 mm (18.3 in.) to the lower edge and 790 mm (31.1 in.) to the upper edge. Additional dimensions and test vehicle information are presented in Data Sheets No. 1 and 2.

The test vehicle impacted the X Tension Tangent 37.5' (11.43 m) System at a velocity of 99.19 km/h (61.63 mph). The test vehicle impacted the X Tension impact head and pushed rail 1 down rail 2. When the slider panel reached rail 3 the shear bolts connecting rail 2 and 3 were sheared. Rail 1 came to rest approximately mid span between post 5 and 6. The vehicle continued to the non traffic side of the article. The vehicle began tracking toward the article and impacted the non-traffic side of the system between post 21 and 22. The vehicle came to rest 46.1 m (151.2 ft.) downstream from the initial impact point and resting on the non-traffic side of the article. As a result of the impact the article sustained damage from post 1 through 7. Post 1 folded to the ground, post 2 tore at the crimp and post 3 and 4 bent towards the ground. The impact head and slider bracket sustained deformation. The top cable tore at the face of the impact head. An overhead illustration of the test vehicle and test article in their pre-test and post-test condition is shown in figure 2 in Appendix D. Sequential photographs of the test sequence are shown on Data Sheet 4.

The vehicle sustained damage to the front end including the front bumper, grill, radiator and front left quarter panel. The front left spindle broke and the wheel detached from the vehicle. The left rear tire was also punctured as a result of the impact with the X Tension Tangent 37.5' (11.43 m) System. The occupant compartment was not penetrated as a result of the impact.

A summary of the electronic data is presented in Data Sheet No. 6; data plots are presented in Appendix B.

SECTION 4
DATA SHEETS

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16

CONVERSION FACTORS

Quantity	Typical Application	Std Units	Metric Unit	Multiply By
Mass	Vehicle Weight	lb	kg	0.4536
Linear Velocity	Impact Velocity	miles/hr	km/hr	1.609344
Length or Distance	Measurements	in	mm	25.4
Volume	Fuel Systems	gal	liter	3.785
Volume	Small Fluids	oz	mL	29.574
Pressure	Tire Pressures	lbf/in ²	kPa	6.895
Temperature	General Use	°F	°C	$=(T_f - 32)/1.8$
Force	Dynamic Forces	lbf	N	4.448
Moment	Torque	lbf-ft	N•m	1.355

DATA SHEET 1

TEST VEHICLE INFORMATION

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16

TEST VEHICLE INFORMATION

Make	Chevrolet	Cylinders	V8
Model	2500	Engine Displacement (L)	6.5
Body Style	2-Door Truck	Engine Placement	Longitudinal
VIN	1GCH24U55E212096	Fuel Type	Gasoline
Color	White	Transmission	Automatic
Odometer Reading (mi)		Final Drive	Rear
Previous Damage to Vehicle	Minor Scratches and Dents		

DATA FROM CERTIFICATION LABEL

Manufactured By	General Motors Corp	GVWR (kg)	4173
		GAWR Front (kg)	2000
Date of Manufacture	Dec-04	GAWR Rear (kg)	2760

TEST VEHICLE WEIGHTS

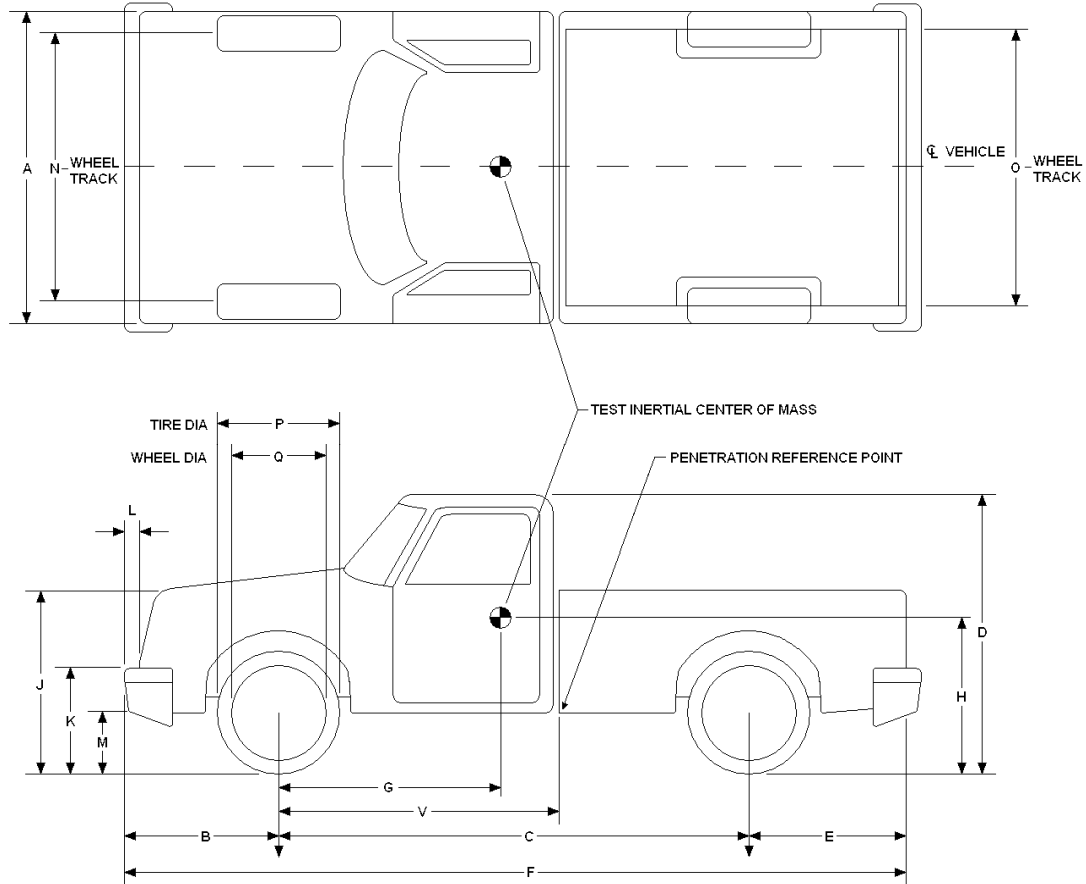
	As Received (kg)			Test Inertial (kg)			Gross Static (kg)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	702.5	483.5	1186.0	656.5	380.0	1036.5	656.5	380.0	1036.5
Right	615.0	527.5	1142.5	578.0	425.0	1003.0	578.0	425.0	1003.0
Ratio (%)	56.6	43.4	100.0	60.5	39.5	100.0	60.5	39.5	100.0
Total	1317.5	1011.0	2328.5	1234.5	805.0	2039.5	1234.5	805.0	2039.5

	As Received (lb)			Test Inertial (lb)			Gross Static (lb)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	1548.7	1065.9	2614.6	1447.3	837.7	2285.0	1447.3	837.7	2285.0
Right	1355.8	1162.9	2518.7	1274.3	936.9	2211.2	1274.3	936.9	2211.2
Ratio (%)	56.6	43.4	100.0	60.5	39.5	100.0	60.5	39.5	100.0
Total	2904.5	2228.8	5133.3	2721.6	1774.6	4496.2	2721.6	1774.6	4496.2

DATA SHEET 2

TEST VEHICLE GEOMETRY

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16



TEST VEHICLE GEOMETRY

	mm	in.		mm	in.		mm	in.		mm	in.
A	2001	78.8	E	1159	45.6	J	1100	43.3	N	1755	69.1
B	992	39.1	F	5534	217.9	K	790	31.1	O	1685	66.3
C	3383	133.2	G	1335	52.6	L	85	3.3	P	750	29.5
D	1920	75.6	H	728	28.7	M	465	18.3	Q	440	17.3

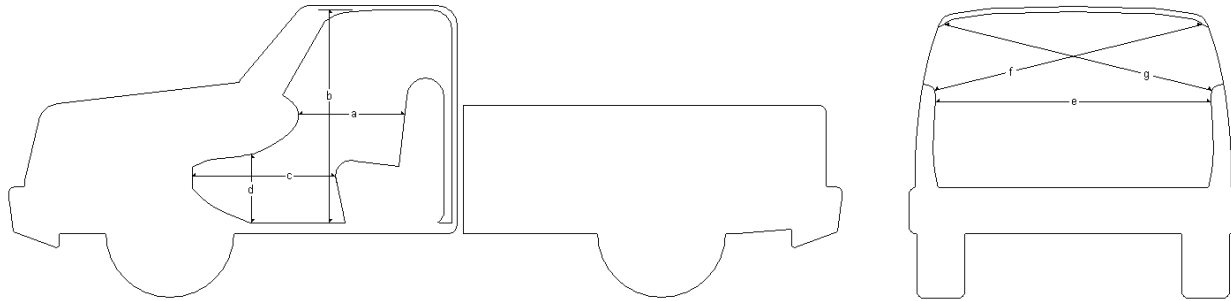
DATA SHEET 3

OCCUPANT COMPARTMENT DEFORMATION INDEX

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01

Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16

The seven subindices a, b, c, d, e, f and g indicate the percentage of reduction of seven interior dimensions shown on the following figure:



where,

- a = distance between the dashboard and a reference point at the rear of the occupant compartment, such as top of rear seat, or the rear part of the cab on a pickup;
- b = distance between the roof and the floor panel;
- c = distance between a reference point at the rear of the occupant compartment and the motor panel;
- d = distance between the lower dashboard and the floor panel;
- e = interior width;
- f = distance between the lower edge of right window and the upper edge of left window; and
- g = distance between the lower edge of left window and the upper edge of right window

Sub-Indices	Pre-Test		Post-Test		Percent Reduction
	mm	in.	mm	in.	
A	1049	41.3	1050	41.3	-0.10%
B	1137	44.8	1125	44.3	1.06%
C	1617	63.7	1612	63.5	0.31%
D	393	15.5	394	15.5	-0.25%
E	1720	67.7	1728	68.0	-0.47%
F	1603	63.1	1610	63.4	-0.44%
G	1576	62.0	1574	62.0	0.13%
Max Deformation	1137	44.8	1125	44.3	1.06%
OCDI	FS0000000				
Comments:	None				

DATA SHEET 4
SUMMARY OF RESULTS

Test Article: X Tension Tangent 37.5' (11.43 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

Project No.: P36134-01
 Test Date: 08/18/16



0 ms 200 ms 500 ms 750 ms 1033 ms 2400 ms

GENERAL INFORMATION		OCCUPANT RISK VALUES	
TEST AGENCY	KARCO Engineering, LLC.	FLAIL SPACE VELOCITY (m/s)	
TEST ARTICLE		X DIRECTION	7.5
TYPE	Terminal	Y DIRECTION	0.9
TERMINAL LENGTH ¹	11.4 m (37.5 ft.)	THIV (Optional) (m/s)	7.5
ADJOINING BARRIER LENGTH ²	38.1 m (125.0 ft.)	RIDEDOWN ACCELERATION (g)	
TEST VEHICLE		X DIRECTION	-11.3
TYPE	Production Model	Y DIRECTION	-2.7
DESIGNATION	2000P	PHD (Optional) (g)	11.3
MODEL	Chevrolet 2500	ASI (Optional)	0.69
MASS (CURB)	2,328.0 kg (5,133.3 lbs)	VEHICLE DAMAGE	
MASS (TEST INERTIAL)	2,039.5 kg (4,496.2 lbs)	INTERIOR	
MASS (GROSS STATIC)	2,039.5 kg (4,496.2 lbs)	OCDI	FS0000000
IMPACT CONDITIONS		POST-IMPACT VEHICULAR BEHAVIOR	
VELOCITY (km/h)	99.19 km/h (61.63 mph)	MAXIMUM ROLL ANGLE (°)	31.1
ANGLE (°)	5.3	MAXIMUM PITCH ANGLE (°)	-12.9
IMPACT SEVERITY (kJ)	771.2	MAXIMUM YAW ANGLE (°)	7.7

¹ Terminal Length measured from Post 1 to Post 7

² Adjoining Barrier Length measured from Post 7 to Post 27

DATA SHEET 5
IMPACT CONDITIONS

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16

Item	Value
Test Time	10:49 PM
Temperature (°C)	27.8 *
Wind Velocity (km/h)	12.9 *
Wind Direction	South *
Impact Speed (km/h)	99.19

*Information provided for reference only

DATA SHEET 6

TEST DATA SUMMARY

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16

TEST VEHICLE DATA SUMMARY

Tested Parameter	Axis	Units	Max	Time (ms)	Min	Time (ms)
Vehicle Impact Velocity	X	m/s	27.5			
Flail Space Velocity	X	m/s	7.5	191.2		
Flail Space Velocity	Y	m/s	0.9	191.2		
Ridedown Acceleration	X	g	2.6	316.2	-11.3	234.1
Ridedown Acceleration	Y	g	1.5	247.0	-2.7	2128.1

TEST VEHICLE ACCELEROMETER PEAK DATA

Location	Axis	Units	Max	Time (ms)	Min	Time (ms)
Vehicle CG	X	g	3.7	277.9	-12.5	48.0
Vehicle CG	Y	g	4.2	83.5	-3.3	1538.7
Vehicle CG	Z	g	28.2	102.5	-17.6	108.2

**APPENDIX A
PHOTOGRAPHS**

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FIGURE 1. Test Article, As Received



FIGURE 2. Test Article, As Received



FIGURE 3. Test Vehicle, As Received



FIGURE 4. Test Vehicle, As Received



FIGURE 5. Test Setup



FIGURE 6. Test Setup Close-Up



FIGURE 7. Test Setup

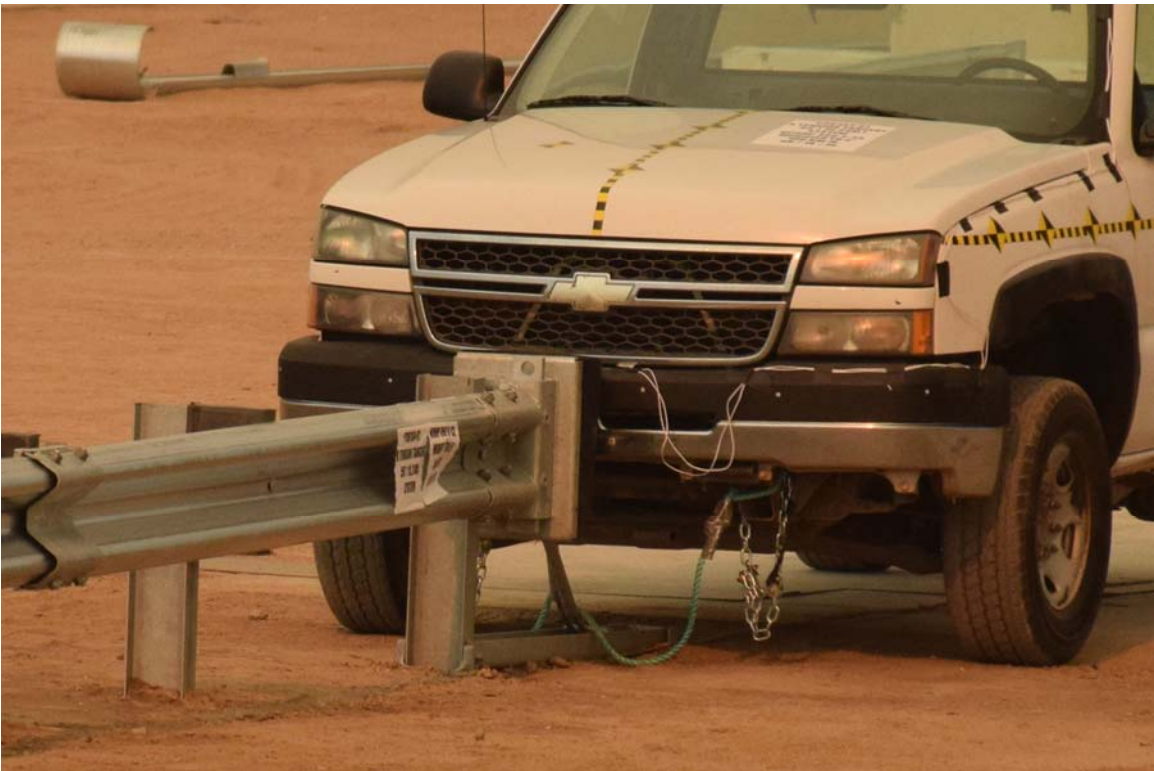


FIGURE 8. Test Setup Close-Up



FIGURE 9. Test Setup

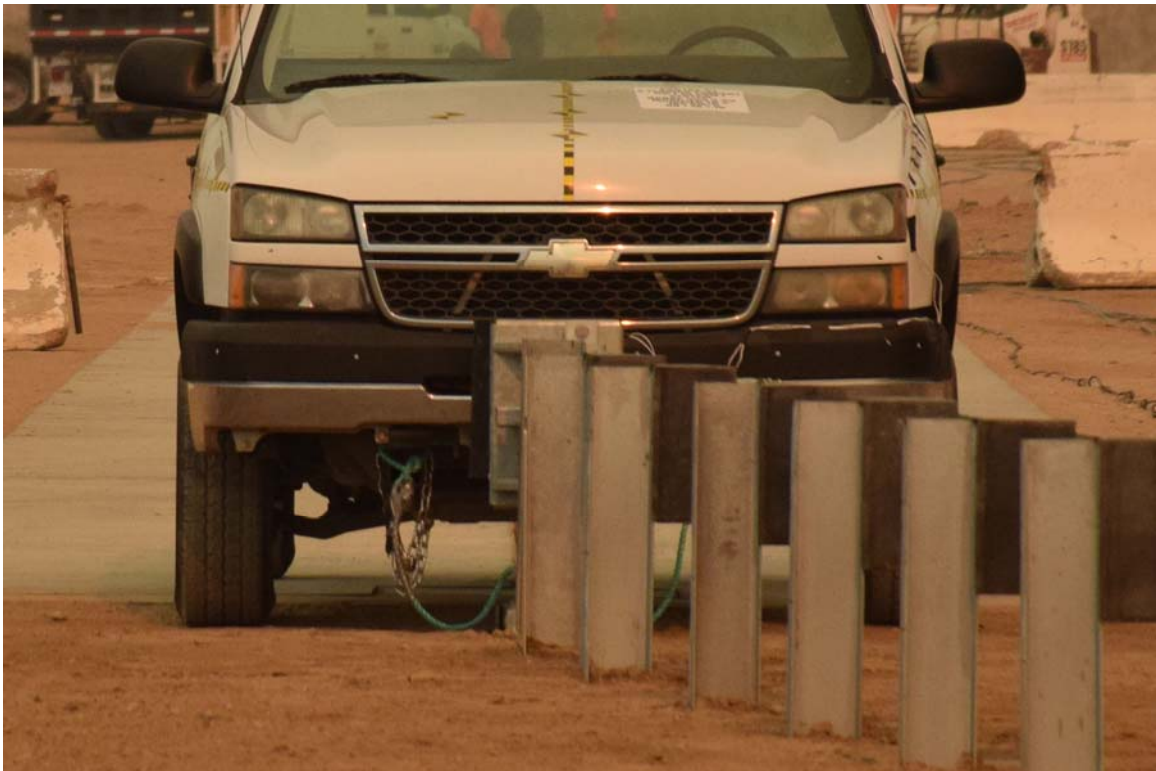


FIGURE 10. Test Setup Close-Up



FIGURE 11. Test Setup



FIGURE 12. Test Setup Close-Up



FIGURE 13. Test Setup



FIGURE 14. Test Setup Close-Up



FIGURE 15. Pre-Test



FIGURE 16. Post-Test



FIGURE 17. Post-Test



FIGURE 18. Post-Test



FIGURE 19. Pre-Test Front View of Test Article



FIGURE 20. Post-Test Front View of Test Article



FIGURE 21. Pre-Test Right Front $\frac{3}{4}$ View of Test Article



FIGURE 22. Post-Test Right Front $\frac{3}{4}$ View of Test Article



FIGURE 23. Pre-Test Right View of Test Article



FIGURE 24. Post-Test Right View of Test Article



FIGURE 25. Pre-Test Right Rear $\frac{3}{4}$ View of Test Article



FIGURE 26. Post-Test Right Rear $\frac{3}{4}$ View of Test Article



FIGURE 27. Pre-Test Rear View of Test Article



FIGURE 28. Post-Test Rear View of Test Article



FIGURE 29. Pre-Test Left Rear $\frac{3}{4}$ View of Test Article



FIGURE 30. Post-Test Left Rear $\frac{3}{4}$ View of Test Article



FIGURE 31. Pre-Test Left View of Test Article



FIGURE 32. Post-Test Left View of Test Article



FIGURE 33. Pre-Test Left Front $\frac{3}{4}$ View of Test Article



FIGURE 34. Post-Test Left Front $\frac{3}{4}$ View of Test Article



FIGURE 35. Test Article Damage



FIGURE 36. Test Article Damage



FIGURE 37. Test Article Damage



FIGURE 38. Test Article Damage



FIGURE 39. Test Article Damage



FIGURE 40. Test Article Damage



FIGURE 41. Pre-Test Left View of Test Vehicle



FIGURE 42. Post-Test Left View of Test Vehicle



FIGURE 43. Pre-Test Left Front $\frac{3}{4}$ View of Test Vehicle



FIGURE 44. Post-Test Left Front $\frac{3}{4}$ View of Test Vehicle



FIGURE 45. Pre-Test Front View of Test Vehicle

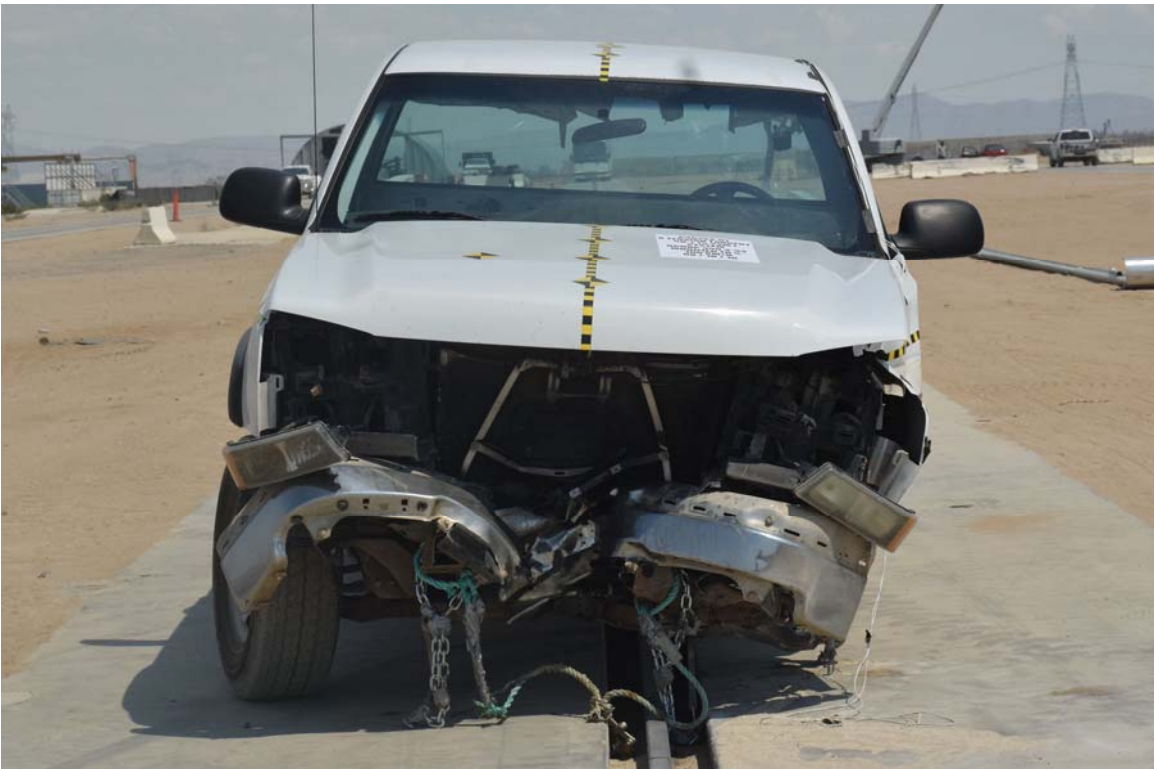


FIGURE 46. Post-Test Front View of Test Vehicle



FIGURE 47. Pre-Test Right Front ¾ View of Test Vehicle

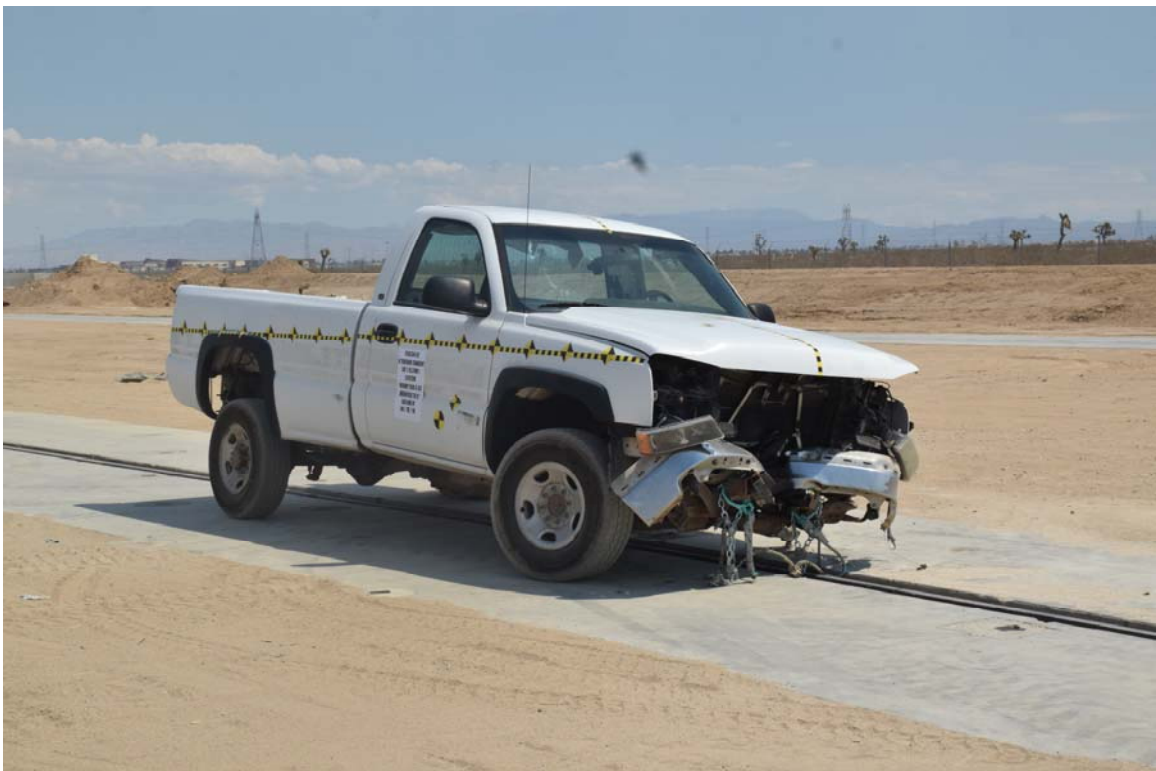


FIGURE 48. Post-Test Right Front ¾ View of Test Vehicle



FIGURE 49. Pre-Test Right View of Test Vehicle



FIGURE 50. Post-Test Right View of Test Vehicle



FIGURE 51. Pre-Test Windshield



FIGURE 52. Post-Test Windshield



FIGURE 53. Pre-Test Driver Side Occupant Compartment



FIGURE 54. Post-Test Driver Side Occupant Compartment



FIGURE 55. Post-Test Driver Side Floorpan



FIGURE 56. Post-Test Driver Side Floorpan



FIGURE 57. Pre-Test Passenger Side Occupant Compartment



FIGURE 58. Post-Test Passenger Side Occupant Compartment



FIGURE 59. Pre-Test Passenger Side Floorpan



FIGURE 60. Post-Test Passenger Side Floorpan



FIGURE 61. Test Vehicle Manufacturer's Label

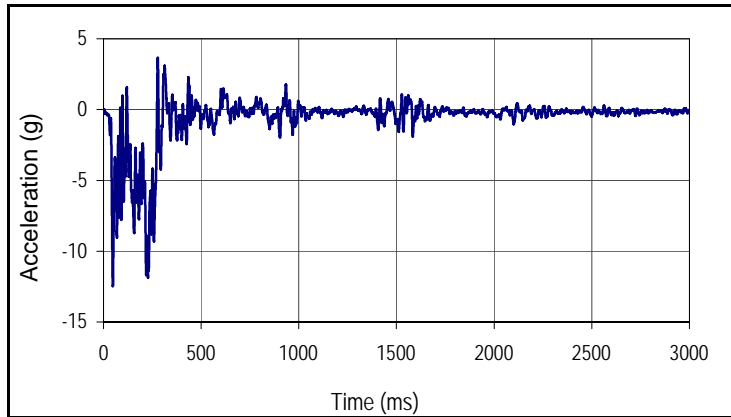
**APPENDIX B
DATA PLOTS**

LIST OF DATA PLOTS

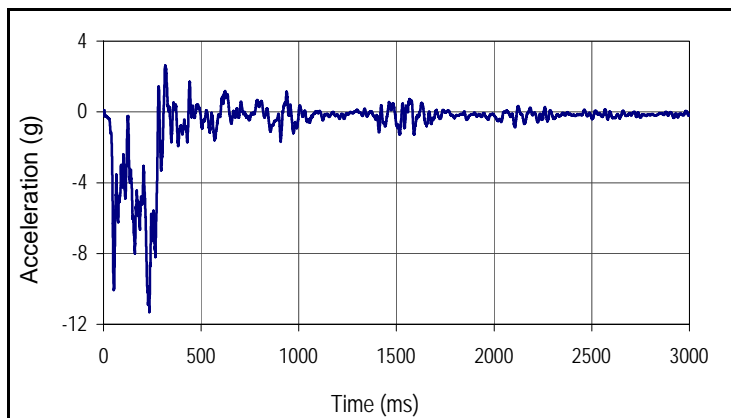
<u>Plot</u>		<u>Page</u>
1	Test Vehicle CG X	B-1
2	Test Vehicle CG X Moving Average	B-1
3	Test Vehicle CG X Velocity	B-1
4	Test Vehicle CG X Displacement	B-1
5	Test Vehicle CG Y	B-2
6	Test Vehicle CG Y Moving Average	B-2
7	Test Vehicle CG Y Velocity	B-2
8	Test Vehicle CG Y Displacement	B-2
9	Test Vehicle CG Z	B-3
10	Test Vehicle Accident Severity Index	B-3
11	Test Vehicle Roll Angle	B-4
12	Test Vehicle Yaw Angle	B-4
13	Test Vehicle Pitch Angle	B-4

Test Article: X Tension Tangent 37.5' (11.43 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

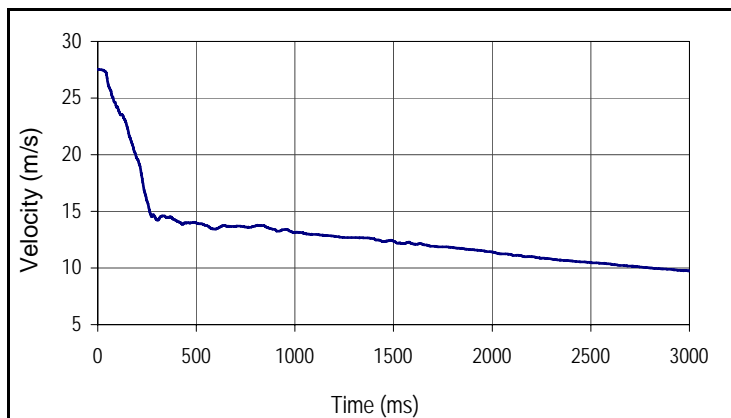
Project No: P36134-01
 Test Date.: 8/18/16



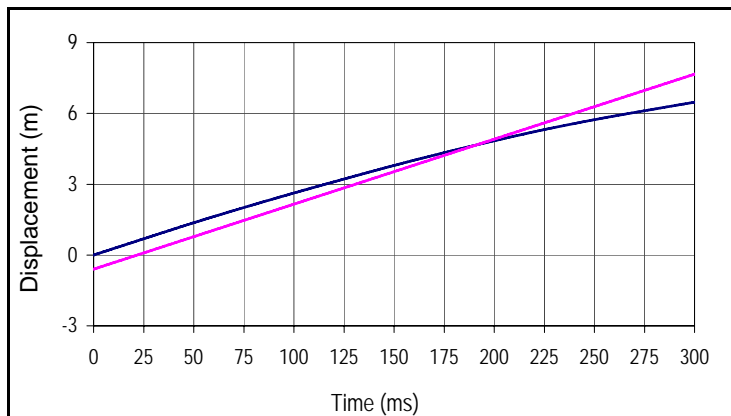
Curve Description			
Test Vehicle CG X			
Plot No.	Type	SAE Class	Units
001	FIL	60	g
Max	Time	Min	Time
3.7	277.9	-12.5	48.0



Curve Description			
Test Vehicle CG X Moving Average			
Plot No.	Type	SAE Class	Units
002	AVG	180	g
Max	Time	Min	Time
2.6	316.2	-11.3	234.1



Curve Description			
Test Vehicle CG X Velocity			
Plot No.	Type	SAE Class	Units
003	IN1	180	m/s
Max	Time	Min	Time
27.5	0.4	9.7	2999.9

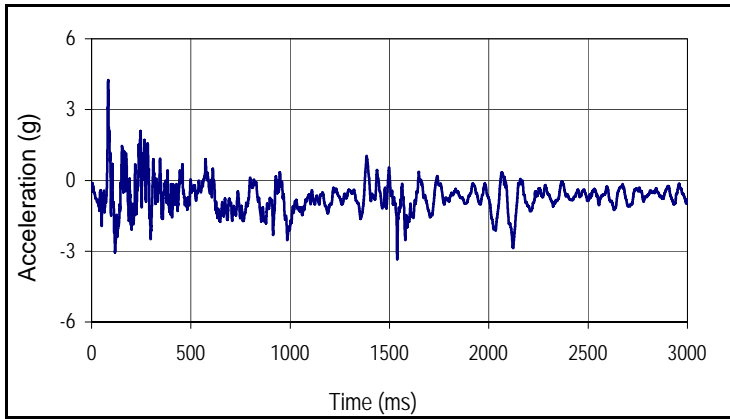


Curve Description			
Test Vehicle CG X Displacement			
Plot No.	Type	SAE Class	Units
004	IN2	180	m
Max	Time	Min	Time
38.9	2999.9	0.0	0.0

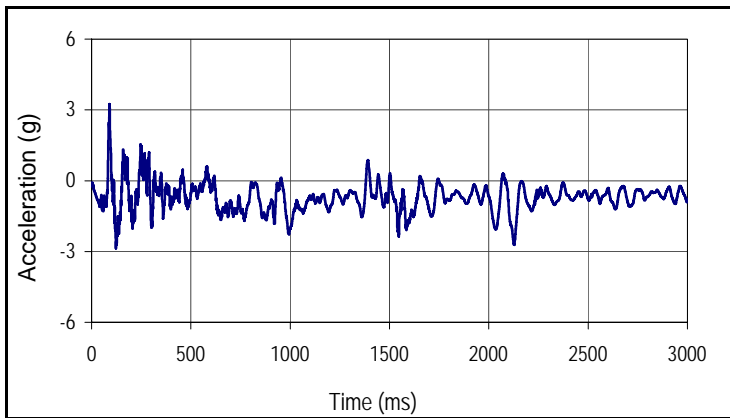
— Vehicle CG X Displacement
 — Occupant X Displacement

Test Article: X Tension Tangent 37.5' (11.43 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

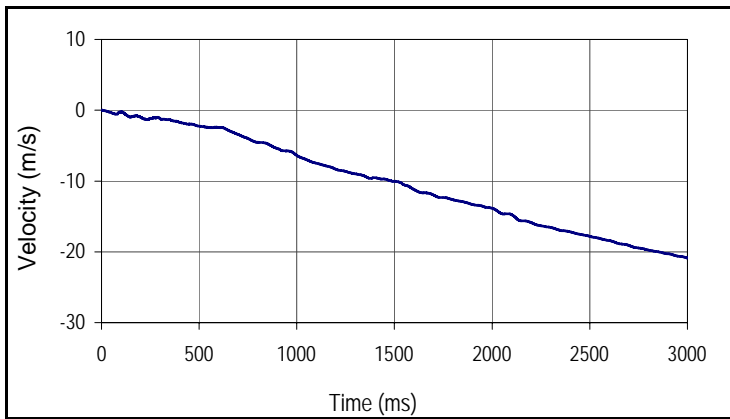
Project No: P36134-01
 Test Date.: 8/18/16



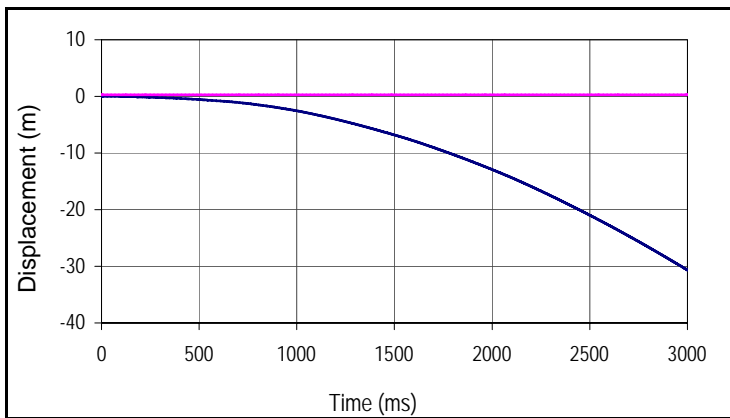
Curve Description			
Test Vehicle CG Y			
Plot No.	Type	SAE Class	Units
005	FIL	60	g
Max	Time	Min	Time
4.2	83.5	-3.3	1538.7



Curve Description			
Test Vehicle CG Y Moving Average			
Plot No.	Type	SAE Class	Units
006	AVG	180	g
Max	Time	Min	Time
3.2	90.6	-2.9	122.6



Curve Description			
Test Vehicle CG Y Velocity			
Plot No.	Type	SAE Class	Units
007	IN1	180	m/s
Max	Time	Min	Time
0.0	0.0	-20.9	2999.9

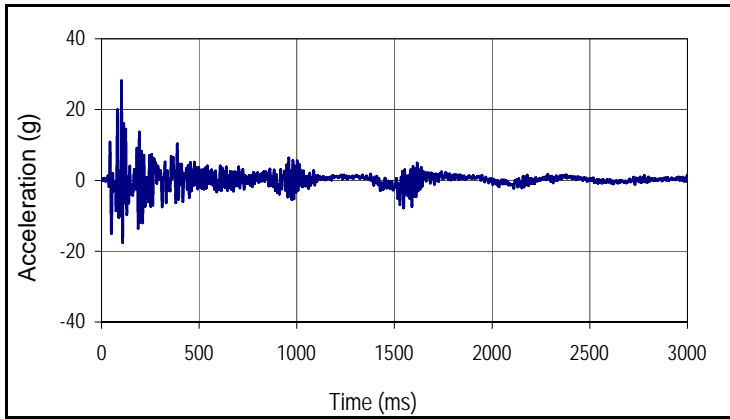


Curve Description			
Test Vehicle CG Y Displacement			
Plot No.	Type	SAE Class	Units
008	IN2	180	m
Max	Time	Min	Time
0.0	0.0	-30.7	2999.9

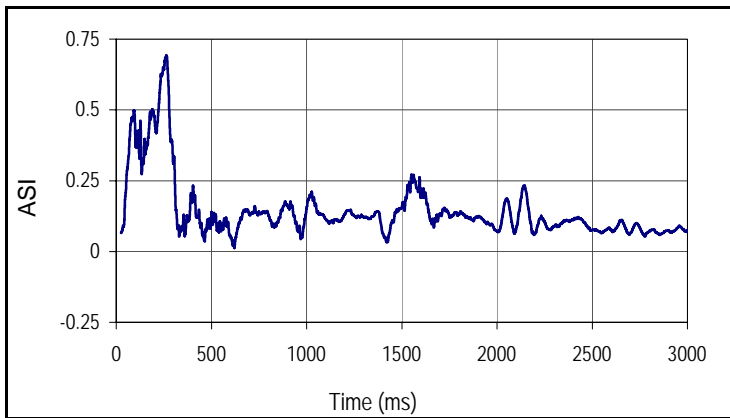
— Vehicle CG Y Displacement
 — Occupant Y Displacement

Test Article: X Tension Tangent 37.5' (11.43 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

Project No: P36134-01
 Test Date.: 8/18/16



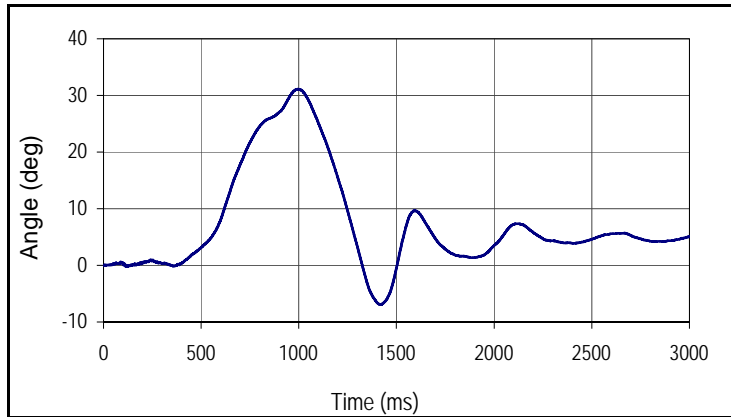
Curve Description			
Test Vehicle CG Z			
Plot No.	Type	SAE Class	Units
009	FIL	60	g
Max	Time	Min	Time
28.2	102.5	-17.6	108.2



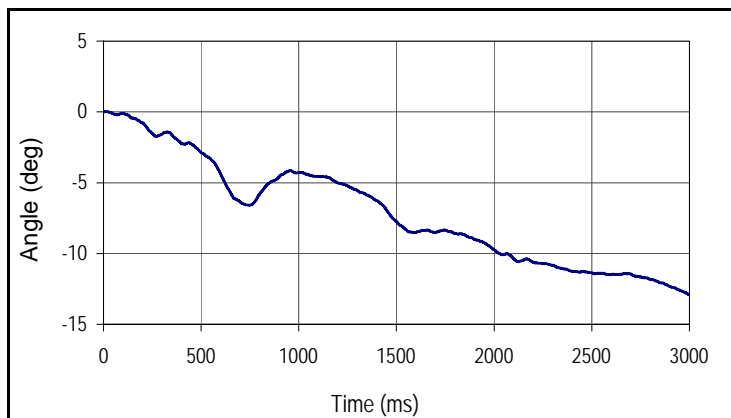
Curve Description			
Test Vehicle Accident Severity Index			
Plot No.	Type	SAE Class	Units
010	ASI	180	ASI
Max	Time	Min	Time
0.7	263.2	0.0	620.1

Test Article: X Tension Tangent 37.5' (11.43 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

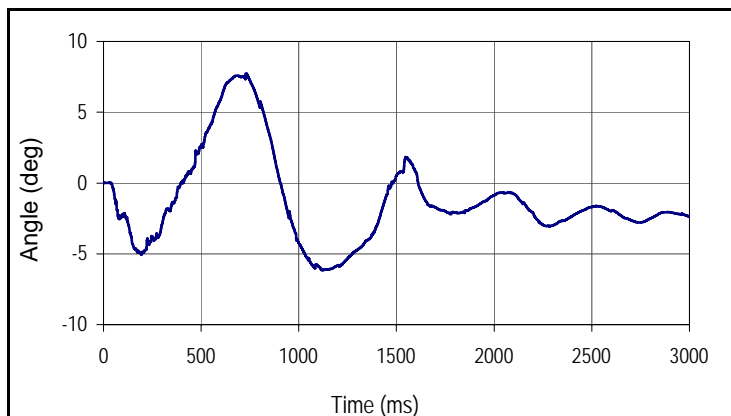
Project No: P36134-01
 Test Date.: 8/18/16



Curve Description			
Test Vehicle Roll Angle			
Plot No.	Type	SAE Class	Units
011	IN1	180	deg
Max	Time	Min	Time
31.1	996.5	-6.9	1417.1



Curve Description			
Test Vehicle Yaw Angle			
Plot No.	Type	SAE Class	Units
012	IN1	180	deg
Max	Time	Min	Time
0.0	15.4	-12.9	2999.0



Curve Description			
Test Vehicle Pitch Angle			
Plot No.	Type	SAE Class	Units
013	IN1	180	deg
Max	Time	Min	Time
7.7	731.4	-6.2	1124.6

**APPENDIX C
INSTRUMENTATION**

DATA ACQUISITION INFORMATION

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36134-01
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/18/16

VEHICLE INSTRUMENTATION

CH	Location	Axis	Ident. No.	Description	MFR	Model	Units
1	Vehicle CG	X	P51708	Accel, Half Bridge	Endevco	2000G	g
2	Vehicle CG	Y	P51700	Accel, Half Bridge	Endevco	2000G	g
3	Vehicle CG	Z	P51696	Accel, Half Bridge	Endevco	2000G	g
4	Vehicle CG	Yaw	ARS8486	Rate Gyro	DTS	ARS-18K	Deg/s
5	Vehicle CG	Pitch	ARS8532	Rate Gyro	DTS	ARS-18K	Deg/s
6	Vehicle CG	Roll	ARS8537	Rate Gyro	DTS	ARS-18K	Deg/s

APPENDIX D
MANUFACTURER DOCUMENTS

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Manufacturer's Drawing	D-1
2	Overhead Illustration	D-2

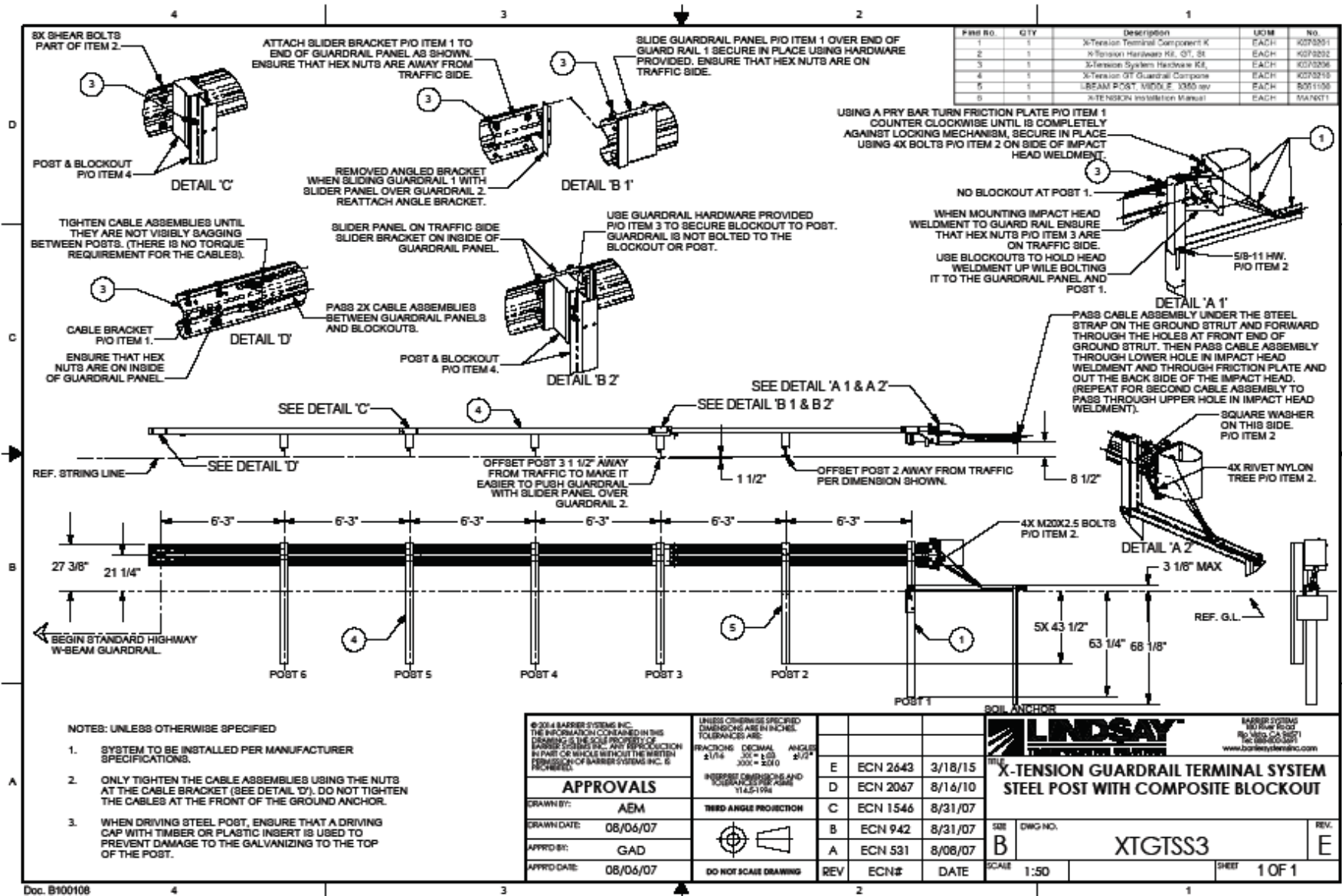


FIGURE 1. Manufacturer's Drawing

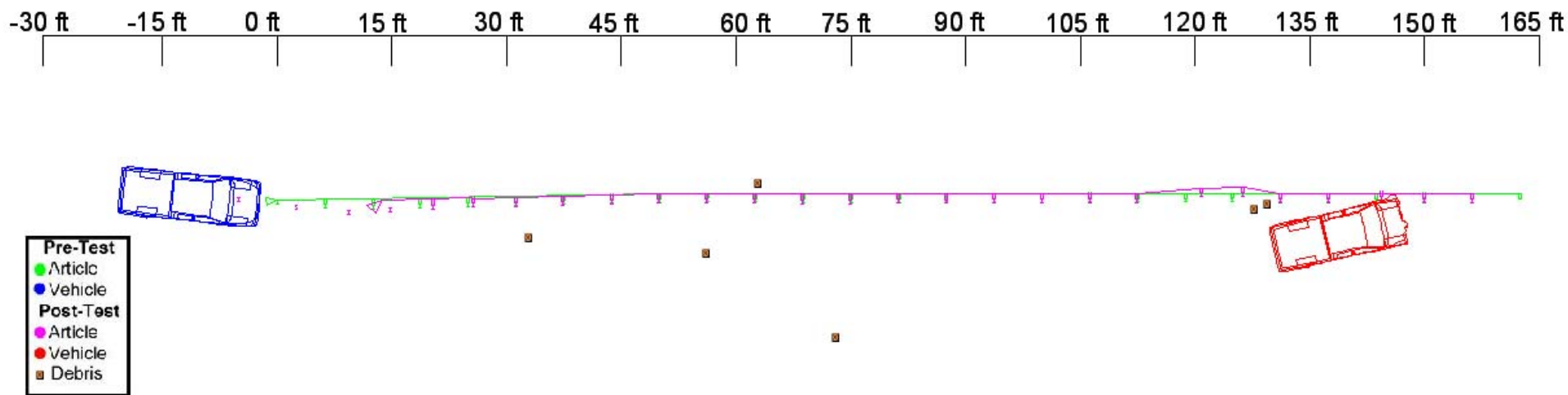


FIGURE 2. Overhead Illustration
FINAL PAGE OF REPORT