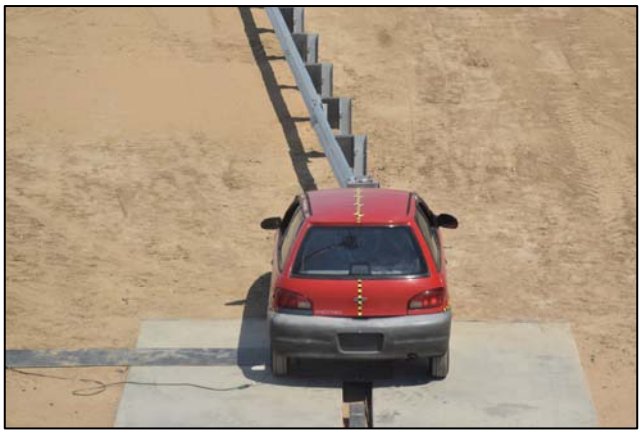
TEST REPORT FOR:

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:

TR-P36133-01-NC

REPORT DATE:

September 16, 2016

TEST DATE:

August 18, 2016

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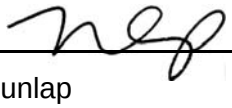
Approved By: 

Mr. Michael L. Dunlap
Director of Operations

Approval Date: September 16, 2016

REVISION CONTROL LOG

TR-P36133-01

Revision	Date	Description
-NC	09/16/16	Original Test Report

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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 blockout 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 2016-4058.

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 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 820C test vehicle was used for this test. The 820C test vehicle used for this test was a front engine model with front 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	700 ± 25	820 ± 25	2000 ± 45
Dummy	75	75	---
Maximum Ballast	70	80	200
Gross Static	775 ± 25	895 ± 25	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	80 ± 15	80 ± 15	140 ± 15
Above Ground	55 ± 5	55 ± 5	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 820 kg (1808 lb.) small car 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 INSTRUMENTAITION 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 within 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 four (4) 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 uninstrumented Hybrid III 50th percentile adult male Anthropomorphic Test Device was placed in the driver seat of the test vehicle.

SECTION 3
TEST RESULTS

This 100 km/h (62 mph) impact crash test was conducted using a 1999 Chevrolet Metro small car to evaluate the impact performance of the X Tension Tangent 37.5' (11.43 m) System. The test article was installed at an angle of 5° relative to the test vehicle's direction of travel, with the vehicle's 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 834.5 kg (1,839.8 lbs.). The height of the front bumper was 205 mm (8.1 in.) to the lower edge and 520 mm (20.5 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 100.52 km/h (64.46 mph). The test vehicle impacted the impact head and pushed the first W-beam rail down rail 2. Rail 1 kinked approximately mid-span as it slid down rail 2. The test vehicle's rear end subsequently pitched up and the vehicle rotated clockwise toward the traffic side of the article. The test vehicle came to rest 3.7 m (12.1 ft) downstream from the initial point of impact. As a result of the impact the anchor and post 1 through post 4 shifted downstream in the soil. The top of post 1 tore at the hinge; post two bent rearward and tore at the crimp. Post 4 tore from the W-beam panel and bent rearward. The impact head and slider panel sustained deformation. An overhead illustration of the test vehicle and test article in their pre-test and post-test conditions is shown in Figure 2 in Appendix D. Sequential photographs of the test sequence are shown on Data Sheet 4.

The vehicle sustained damaged to its front end as a result of the impact with the X Tension Tangent 37.5' (11.43 m) System. The test vehicle's hood and front left quarter panel sustained deformation. The front bumper beam broke at its center and the radiator was crushed. 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. P36133-01

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	^oF	^oC	=(Tf -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. P36133-01

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

TEST VEHICLE INFORMATION

Make	Chevrolet	Cylinders	Inline 4
Model	Metro	Engine Displacement (L)	1.3
Body Style	3-Door Hatchback	Engine Placement	Transverse
VIN	2C1MR2263X6726485	Fuel Type	Gasoline
Color	Red	Transmission	Automatic
Odometer Reading (mi)	158,454	Final Drive	Front
Previous Damage to Vehicle		Minor dents and scratches	

DATA FROM CERTIFICATION LABEL

Manufactured By	Cami Automotive Inc. Canada	GVWR (kg)	1175
		GAWR Front (kg)	635
Date of Manufacture	Jun-99	GAWR Rear (kg)	560

TEST VEHICLE WEIGHTS

	As Received (kg)			Test Inertial (kg)			Gross Static (kg)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	235.5	168.5	404.0	232.0	166.0	398.0	264.5	190.0	454.5
Right	250.5	148.5	399.0	273.0	163.5	436.5	274.5	178.5	453.0
Ratio (%)	60.5	39.5	100.0	60.5	39.5	100.0	59.4	40.6	100.0
Total	486.0	317.0	803.0	505.0	329.5	834.5	539.0	368.5	907.5

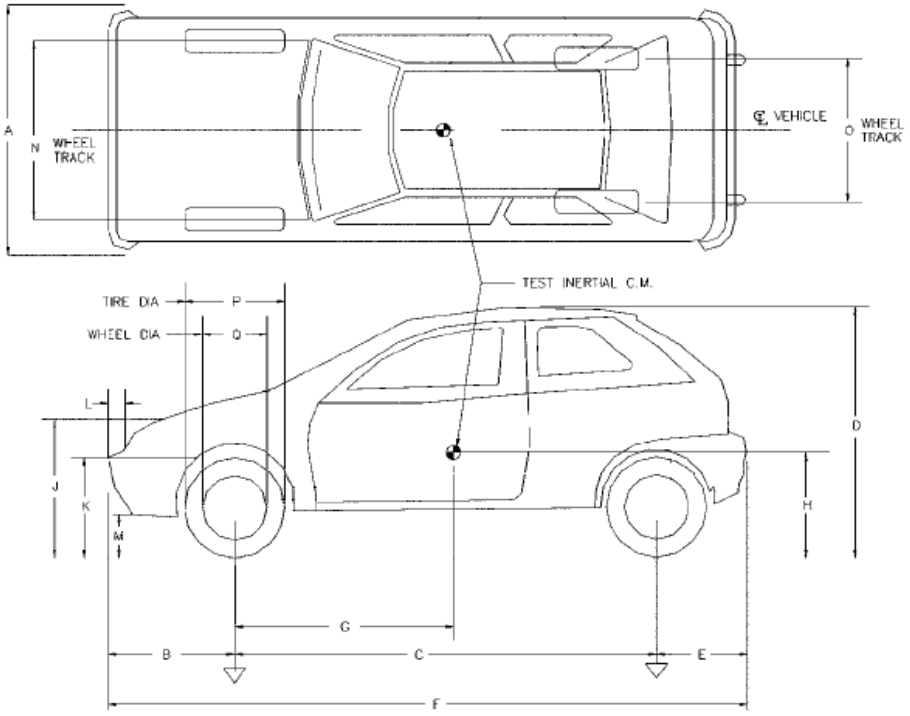
	As Received (lb)			Test Inertial (lb)			Gross Static (lb)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	519.2	371.5	890.7	511.5	366.0	877.5	583.1	418.9	1002.0
Right	552.2	327.4	879.6	601.9	360.4	962.3	605.2	393.5	998.7
Ratio (%)	60.5	39.5	100.0	60.5	39.5	100.0	59.4	40.6	100.0
Total	1071.4	698.9	1770.3	1113.4	726.4	1839.8	1188.3	812.4	2000.7

DATA SHEET 2

TEST VEHICLE GEOMETRY

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36133-01

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	1583	62.3	E	610	24.0	J	690	27.2	N	1396	55.0
B	823	32.4	F	3794	149.4	K	520	20.5	O	1380	54.3
C	2361	93.0	G	932	36.7	L	100	3.9	P	547	21.5
D	1375	54.1	H	546	21.5	M	205	8.1	Q	364	14.3

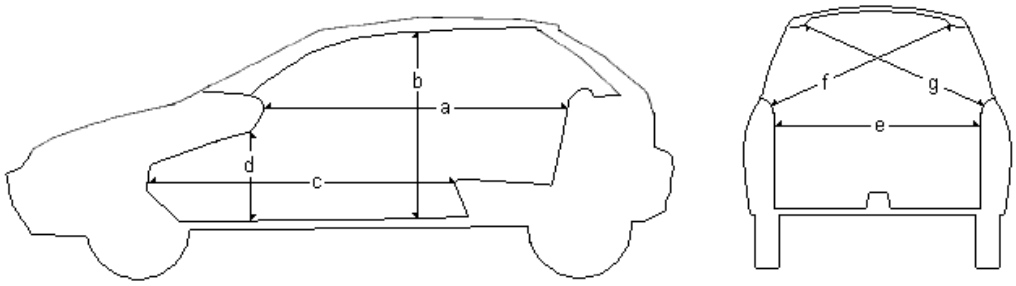
DATA SHEET 3

OCCUPANT COMPARTMENT DEFORMATION INDEX

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36133-01

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

The seven subindicies 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	1583	62.3	1577	62.1	0.38%
B	1153	45.4	1160	45.7	-0.61%
C	1576	62.0	1410	55.5	10.53%
D	293	11.5	300	11.8	-2.39%
E	1246	49.1	1260	49.6	-1.12%
F	1163	45.8	1210	47.6	-4.04%
G	1163	45.8	1169	46.0	-0.52%
Max Deformation	1576	62.0	1410	55.5	10.53%
OCDI	FS0020000				
Comments:	None				

DATA SHEET 4

SUMMARY OF RESULTS

Test Article: X Tension Tangent 37.5’ (11.43 m) System Project No.: P36133-01

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


0 ms


50 ms


150 ms


300 ms


800 ms


1500 ms

GENERAL INFORMATION	
TEST AGENCY	KARCO Engineering, LLC.
TEST ARTICLE	
TYPE	Terminal
TERMINAL LENGTH[1]	11.4 m 37.5 ft.)
ADJOINING BARRIER LENGTH[2]	38.1 m (125.0 ft.)
TEST VEHICLE	
TYPE	Production Model
DESIGNATION	820C
MODEL	Chevrolet Metro
MASS (CURB)	803.0 kg (1,770.3 lbs)
MASS (TEST INERTIAL)	834.5 kg (1,839.8 lbs)
DUMMY MASS	76.0 kg (167.5 lbs)
MASS (GROSS STATIC)	907.0 kg (2,000.7 lbs)
IMPACT CONDITIONS	
VELOCITY (km/h)	100.52 km/h (62.46 mph)
ANGLE (°)	5.3
IMPACT SEVERITY (kJ)	315.5

OCCUPANT RISK VALUES	
FLAIL SPACE VELOCITY (m/s)	
X DIRECTION	9.7
Y DIRECTION	0.4
THIV (Optional) (m/s)	9.8
RIDEDOWN ACCELERATION (g)	
X DIRECTION	-14.4
Y DIRECTION	-8.1
PHD (Optional) (g)	14.4
ASI (Optional)	1.16
VEHICLE DAMAGE	
INTERIOR	
OCDI	FS0020000
POST-IMPACT VEHICULAR BEHAVIOR	
MAXIMUM ROLL ANGLE (°)	68.7
MAXIMUM PITCH ANGLE (°)	-46.3
MAXIMUM YAW ANGLE (°)	78.2

[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. P36133-01

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

Item	Value	
Test Time	4:03 PM	
Temperature (°C)	36.1	*
Wind Velocity (km/h)	35.4	*
Wind Direction	S	*
Impact Speed (km/h)	100.52	

*Information provided for reference only

DATA SHEET 6

TEST DATA SUMMARY

Test Article: X Tension Tangent 37.5' (11.43 m) System Project No. P36133-01

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	9.7	120.1		
Flail Space Velocity	Y	m/s	0.4	120.1		
Ridedown Acceleration	X	g	2.9	1374.8	-14.4	138.5
Ridedown Acceleration	Y	g	3.0	220.0	-8.1	148.5

TEST VEHICLE ACCELEROMETER PEAK DATA

Location	Axis	Units	Max	Time (ms)	Min	Time (ms)
Vehicle CG	X	g	3.8	1369.9	-31.1	47.1
Vehicle CG	Y	g	7.4	39.2	-11.3	140.1
Vehicle CG	Z	g	18.3	41.9	-18.0	66.2

APPENDIX A
PHOTOGRAPHS

LIST OF PHOTOGRAPHS

LIST OF PHOTOGRAPHS … (CONTINUED)

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 ¾ View of Test Article

FIGURE 22. Post-Test Right Front ¾ 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 ¾ View of Test Article

FIGURE 26. Post-Test Right Rear ¾ 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 ¾ View of Test Article

FIGURE 30. Post-Test Left Rear ¾ View of Test Article

FIGURE 31. Pre-Test Left Front ¾ View of Test Article

FIGURE 32. Post-Test Left Front ¾ View of Test Article

FIGURE 33. Test Article Damage

FIGURE 34. Test Article Damage

FIGURE 35. Test Article Damage

FIGURE 36. Test Article Damage

FIGURE 37. Test Article Damage

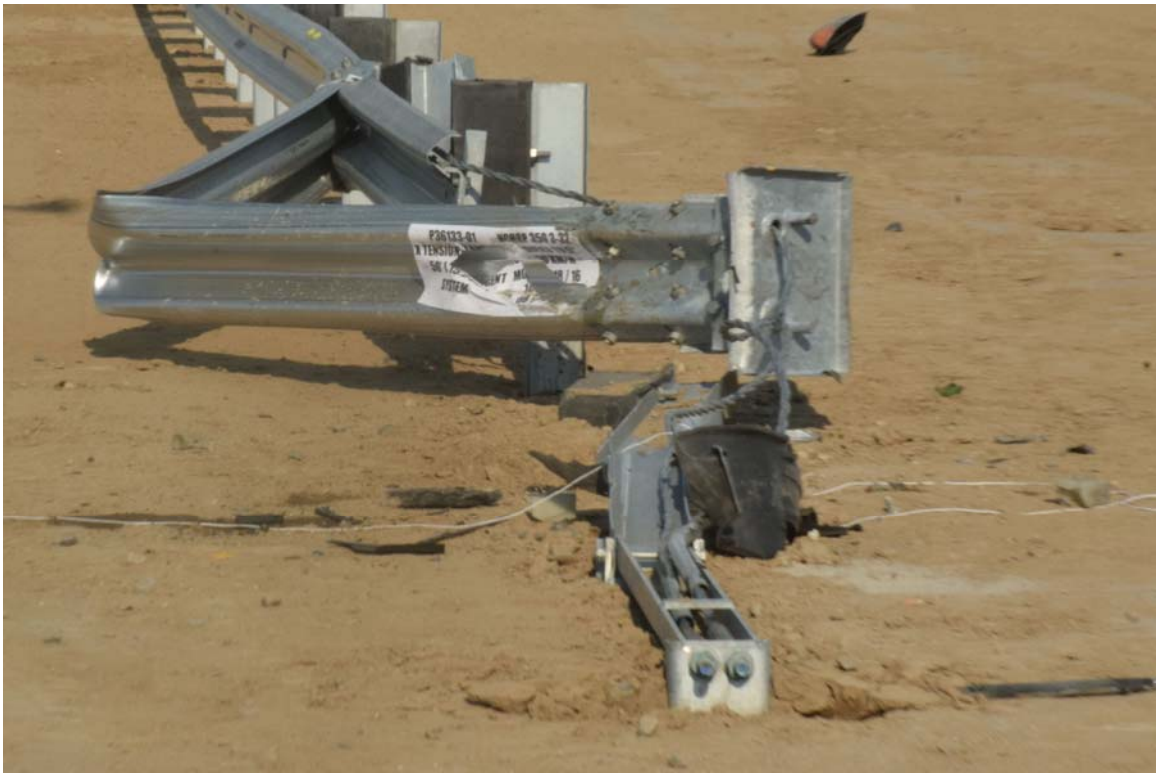


FIGURE 38. Test Article Damage

FIGURE 39. Pre-Test Left View of Test Vehicle

FIGURE 40. Post-Test Left View of Test Vehicle

FIGURE 41. Pre-Test Left Front ¾ View of Test Vehicle

FIGURE 42. Post-Test Left Front ¾ View of Test Vehicle

FIGURE 43. Pre-Test Front View of Test Vehicle

FIGURE 44. Post-Test Front View of Test Vehicle

FIGURE 45. Pre-Test Right Front ¾ View of Test Vehicle

FIGURE 46. Post-Test Right Front ¾ View of Test Vehicle

FIGURE 47. Pre-Test Right View of Test Vehicle

FIGURE 48. Post-Test Right View of Test Vehicle

FIGURE 49. Pre-Test Windshield

FIGURE 50. Post-Test Windshield

FIGURE 51. Pre-Test Driver Side Occupant Compartment

FIGURE 52. Post-Test Driver Side Occupant Compartment

FIGURE 53. Post-Test Driver Side Floorpan

FIGURE 54. Post-Test Passenger Side Occupant Compartment

FIGURE 55. Post-Test Passenger Side Floorpan

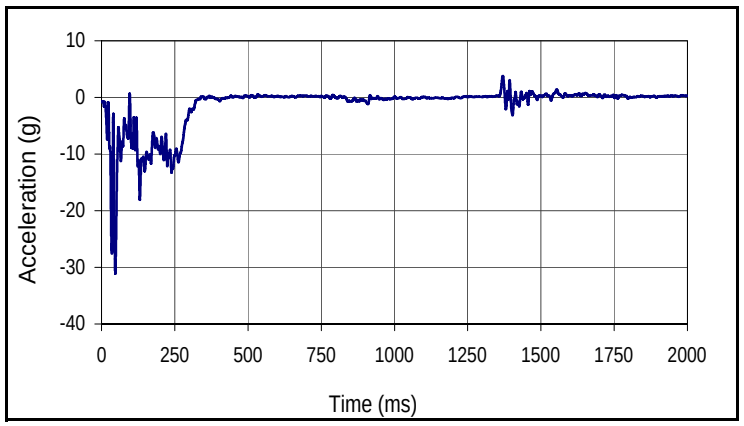
FIGURE 56. Test Vehicle Manufacturer's Label

APPENDIX B

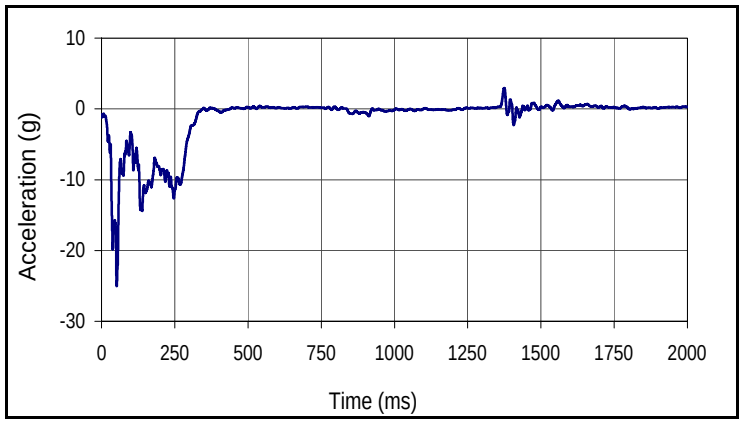
DATA PLOTS

LIST OF DATA PLOTS

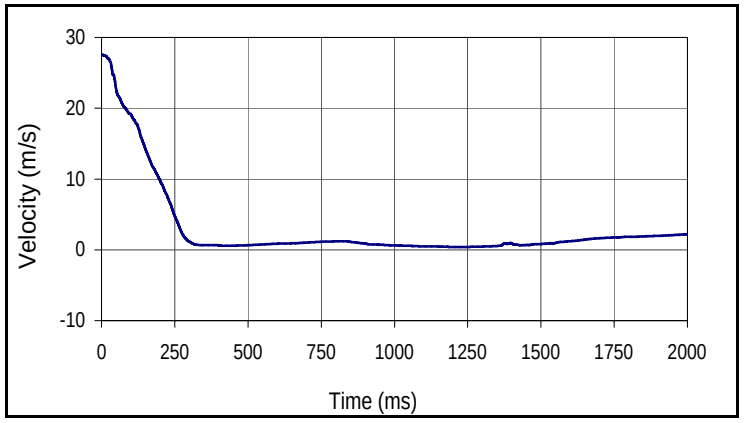
Test Article:	X Tension Tangent 37.5' (11.43 m) System	Project No:	P36133-01
Test Program:	100 km/h 5° Guardrail Terminal Impact Test	Test Date.:	8/18/16



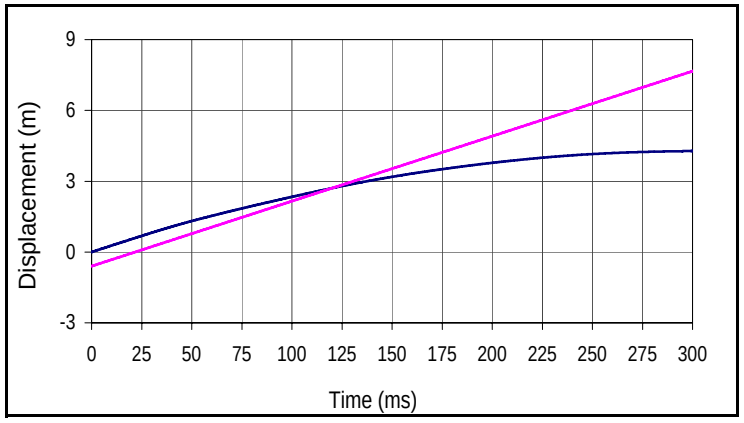
Curve Description			
Test Vehicle CG X			
Plot No.	Type	SAE Class	Units
001	FIL	60	g
Max	Time	Min	Time
3.8	1369.9	-31.1	47.1



Curve Description			
Test Vehicle CG X Moving Average			
Plot No.	Type	SAE Class	Units
002	AVG	180	g
Max	Time	Min	Time
2.9	1374.8	-25.0	52.0



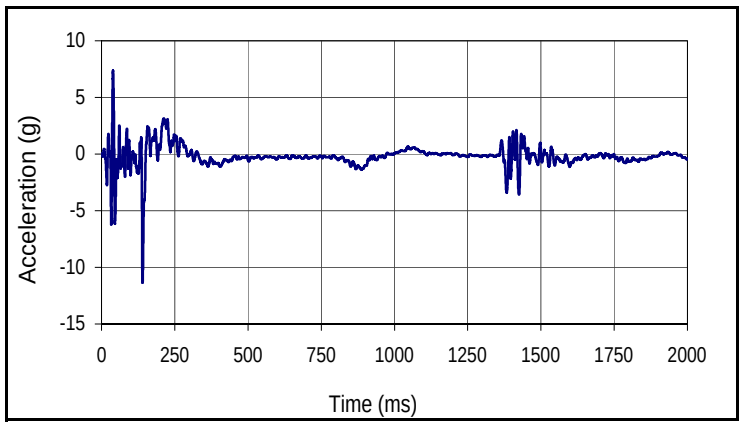
Curve Description			
Test Vehicle CG X Velocity			
Plot No.	Type	SAE Class	Units
003	IN1	180	m/s
Max	Time	Min	Time
27.5	0.0	0.4	1231.8



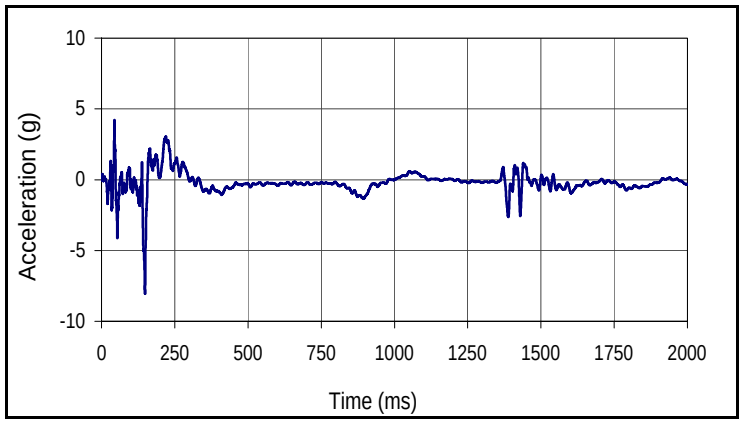
Curve Description			
Test Vehicle CG X Displacement			
Plot No.	Type	SAE Class	Units
004	IN2	180	m
Max	Time	Min	Time
6.0	1997.4	0.0	0.0

Vehicle CG X Displacement
Occupant X Displacement

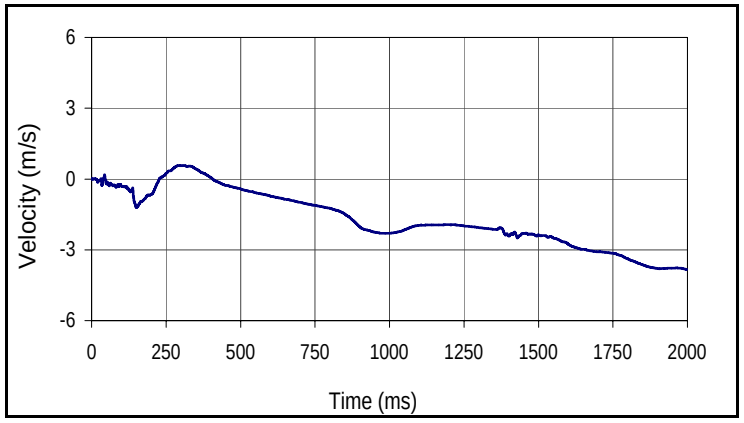
Test Article:	X Tension Tangent 37.5' (11.43 m) System	Project No:	P36133-01
Test Program:	100 km/h 5° Guardrail Terminal Impact Test	Test Date.:	8/18/16



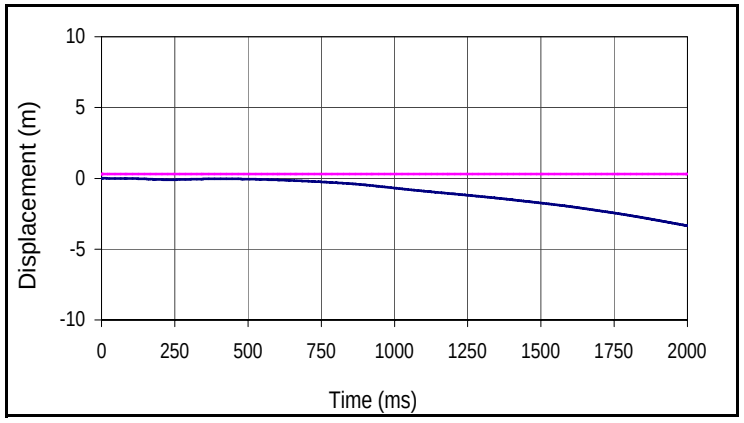
Curve Description			
Test Vehicle CG Y			
Plot No.	Type	SAE Class	Units
005	FIL	60	g
Max	Time	Min	Time
7.4	39.2	-11.3	140.1



Curve Description			
Test Vehicle CG Y Moving Average			
Plot No.	Type	SAE Class	Units
006	AVG	180	g
Max	Time	Min	Time
4.2	44.3	-8.1	148.5



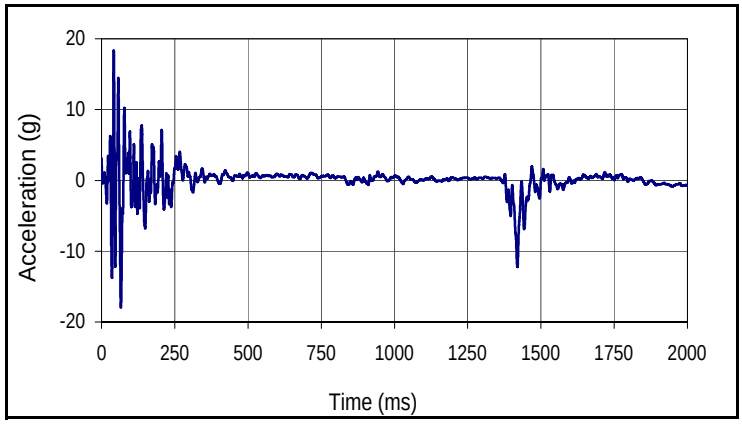
Curve Description			
Test Vehicle CG Y Velocity			
Plot No.	Type	SAE Class	Units
007	IN1	180	m/s
Max	Time	Min	Time
0.6	309.3	-3.8	1997.4



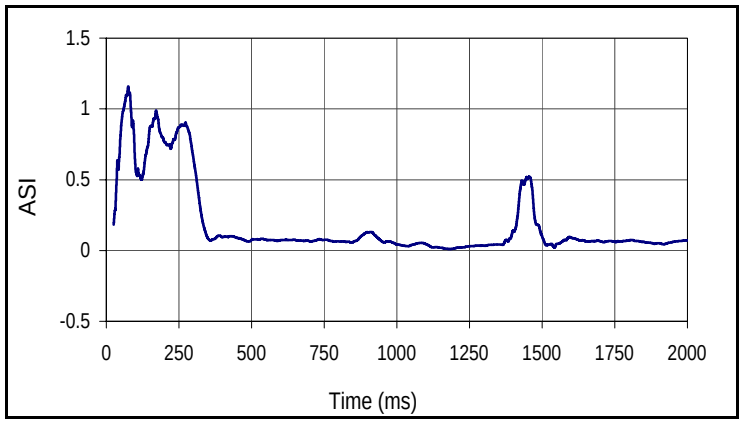
Curve Description			
Test Vehicle CG Y Displacement			
Plot No.	Type	SAE Class	Units
008	IN2	180	m
Max	Time	Min	Time
0.0	15.1	-3.3	1997.4

Vehicle CG Y Displacement
Occupant Y Displacement

Test Article:	X Tension Tangent 37.5' (11.43 m) System	Project No:	P36133-01
Test Program:	100 km/h 5° Guardrail Terminal Impact Test	Test Date.:	8/18/16

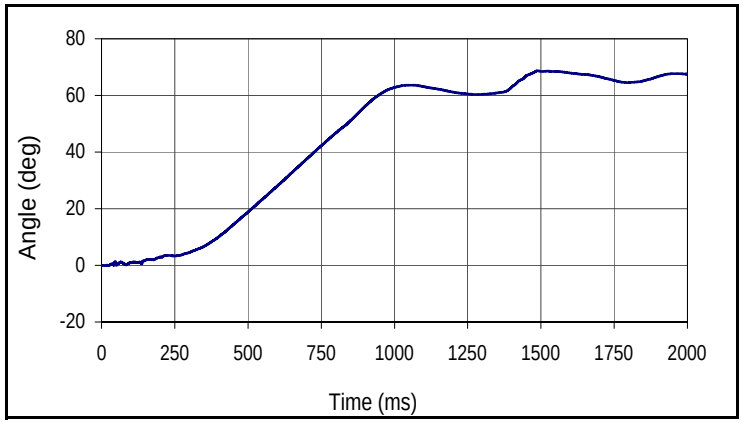


Curve Description			
Test Vehicle CG Z			
Plot No.	Type	SAE Class	Units
009	FIL	60	g
Max	Time	Min	Time
18.3	41.9	-18.0	66.2

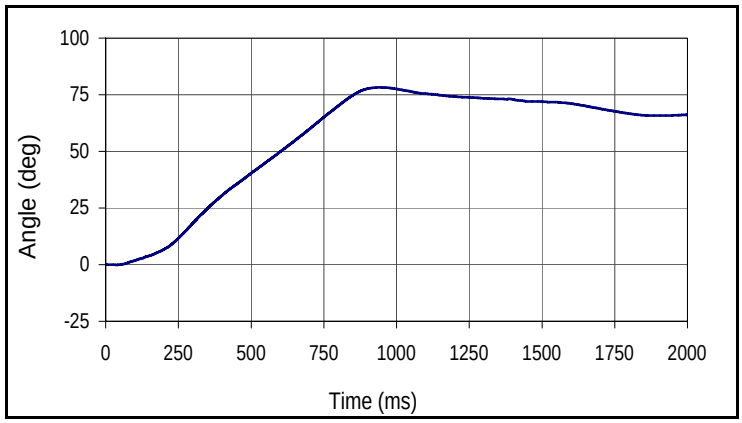


Curve Description			
Test Vehicle Accident Severity Index			
Plot No.	Type	SAE Class	Units
010	ASI	180	ASI
Max	Time	Min	Time
1.2	75.3	0.0	1182.6

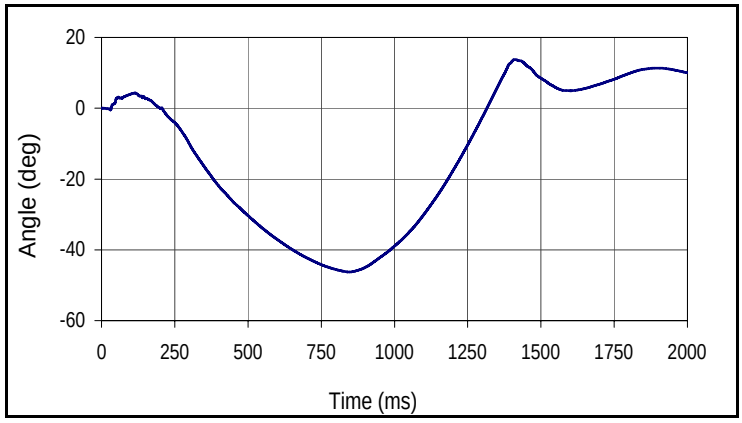
Test Article:	X Tension Tangent 37.5' (11.43 m) System	Project No:	P36133-01
Test Program:	100 km/h 5° Guardrail Terminal Impact Test	Test Date.:	8/18/16



Curve Description			
Test Vehicle Roll Angle			
Plot No.	Type	SAE Class	Units
011	IN1	180	deg
Max	Time	Min	Time
68.7	1487.4	-0.2	23.2



Curve Description			
Test Vehicle Yaw Angle			
Plot No.	Type	SAE Class	Units
012	IN1	180	deg
Max	Time	Min	Time
78.2	942.1	-0.1	39.1



Curve Description			
Test Vehicle Pitch Angle			
Plot No.	Type	SAE Class	Units
013	IN1	180	deg
Max	Time	Min	Time
13.8	1411.8	-46.3	844.9

APPENDIX C
INSTRUMENTATION

DATA ACQUISITION INFORMATION

Test Article: X Tension Tangent 37.5’ (11.43 m) System Project No. P36133-01

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

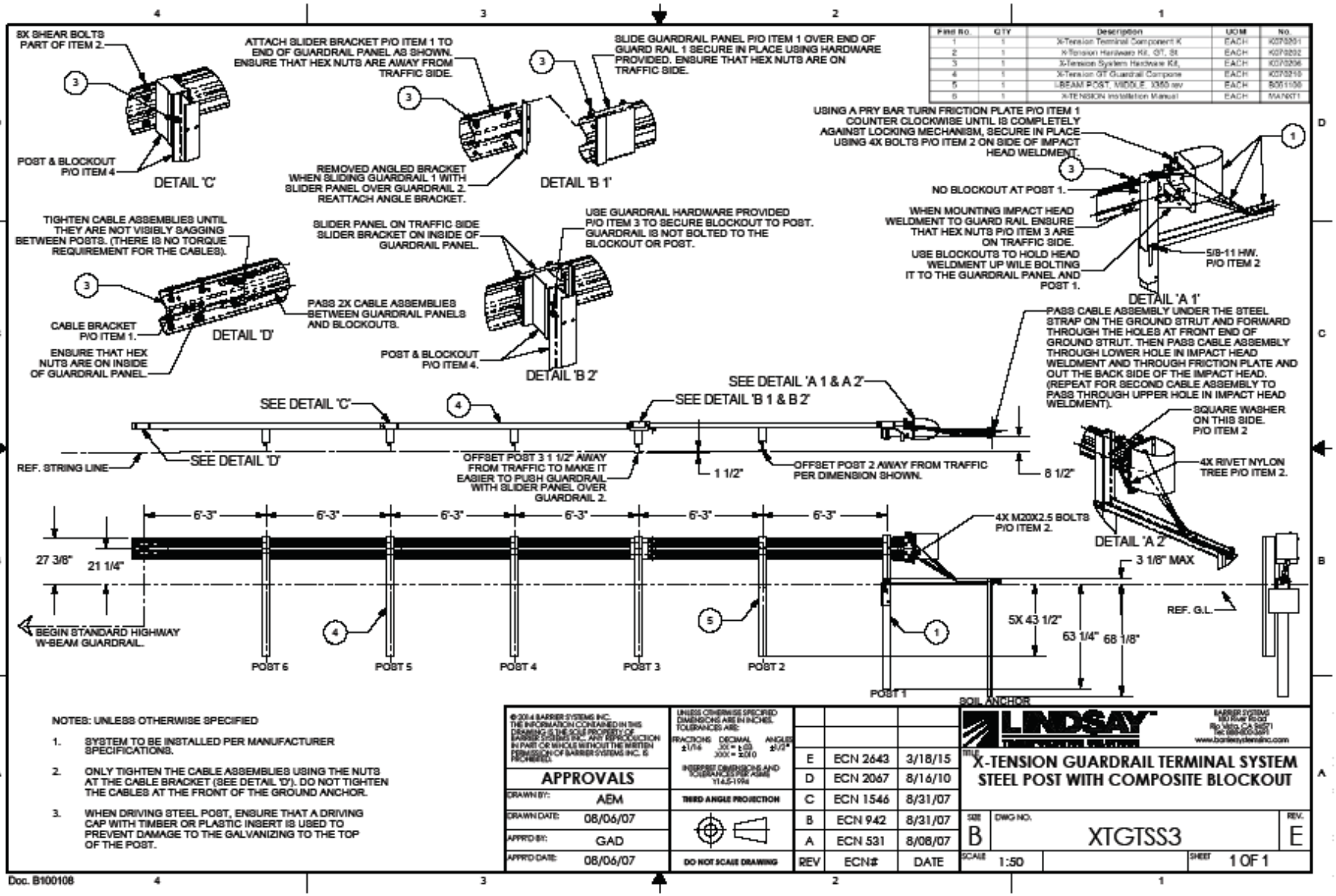


FIGURE 1. Manufacturer's Drawing

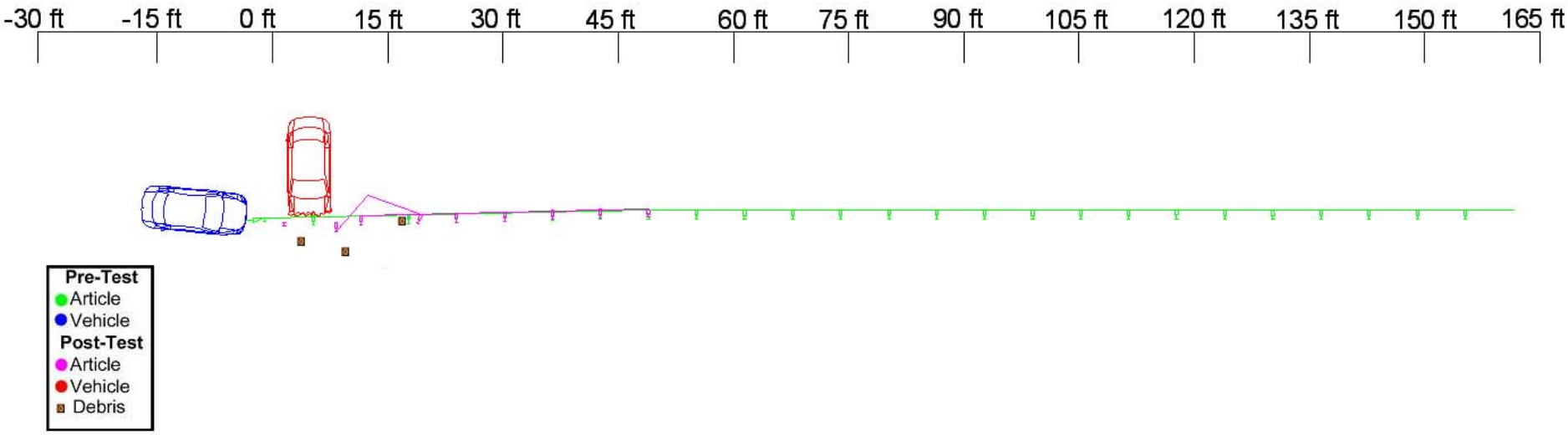


FIGURE 2. Overhead Illustration

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