

TEST REPORT FOR:

**Virginia Department of Transportation**  
**X Lite Tangent 50' (15.24 m) System**



PREPARED FOR:

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

TEST REPORT NUMBER:

**TR-P36132-01-NC**

REPORT DATE:

**September 20, 2016**


TEST DATE:


**August 11, 2016**


---


**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](http://www.KARCO.com)

KARCO Engineering compiled this publication for information gathering only. The findings and conclusions expressed in this publication are those of the authors and not necessarily those of any other organization. KARCO Engineering provides test services only and is not involved in consulting, product design or the manufacturing of any automotive products. KARCO does not warrant, supervise or monitor compliance of products or services except as specifically agreed to in writing. By their very nature, testing, analysis and other KARCO services are limited in scope and subject to expected measurement variability. No activity by KARCO Engineering can release a manufacturer from product or any other liability. The results, findings and conclusions expressed in this publication relate only to the items tested for the specific situation simulated in the test.

Tested By:   
Mr. Robert L. Ramirez  
Project Engineer

Report By:   
Mr. Robert L. Ramirez  
Project Engineer

Reviewed By:   
Mr. Andrew J. Espindola  
Quality Assurance Manager

Approved By:   
Mr. Michael L. Dunlap  
Director of Operations

Approval Date: September 20, 2016

**REVISION CONTROL LOG**

**TR-P36132-01**

<b>Revision</b>	<b>Date</b>	<b>Description</b>
-NC	09/20/16	Original Test Report

## TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1	Introduction	1
2	Test Procedure and Instrumentation Summary	4
3	Test Results	7
4	Data Sheets	8
<u>Data Sheet</u>		<u>Page</u>
1	Test Vehicle Information	9
2	Test Vehicle Geometry	10
3	Occupant Compartment Deformation Index	11
4	Summary of Results	12
5	Impact Conditions	13
6	Test Data Summary	14
<u>Appendix</u>		<u>Page</u>
A	Photographs	A
B	Data Plots	B
C	Instrumentation	C
D	Drawings and Illustrations	D
	Total Number of Pages	63
	Final Page of Report	D-2

## **SECTION 1**

### **INTRODUCTION**

#### **1.1 OBJECTIVES**

The objective of this crash test was to evaluate the impact performance of the Lindsay Corporation X Lite Tangent 50' (15.24 m) system. This report presents the results of one (1) full-scale crash test conducted on one X Lite Tangent 50' (15.24 m) System. For this test, the terminal section was installed on the front end of a 34.3 m (112.5 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 Lite Tangent 50' (15.24 m) System is a standard post guardrail terminal/end treatment. The as-tested X Lite Tangent 50' (15.24 m) System consisted of two (2) crimp posts, one (1) post 2 assembly, ground strut, slider assembly, four (4) W-beam guardrail panels, five (5) standard line posts, six (6) composite blocks, and an impact head. 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.

Post 1 and 3 each consisted of one (1) 1.8 m (6.0 ft) long post constructed of W6 X 8.5 I-beam with crimps located 820 mm (32.3 in.) down from the top on both of their flanges. Post 2 consisted of one (1) 1.8 m (6.0 ft) long post constructed of W6 X 8.5 I-beam and had one (1) 38 mm (1.5 in.) square angle welded on each flange 660 mm (26.0 in.) from the top. A 457 mm (18.0 in.) tall by 457 mm (18.0 in.) wide by 8 mm (0.3 in.) thick soil plate was bolted to the downstream end of post 2 with two (2) 0.625 in. x 3.5 in. bolts, nuts, and washers. The remaining five posts were 1.8 m (6.0 ft.) long standard line posts composed of W6 x 8.5 I-beam.

A ground strut assembly was set between post 1 and post 2. The ground strut was composed of two (2) 2.2 m (7.1 ft. m) long, 14 mm (0.6 in) diameter rods. The rods were

attached to post 1 with a 213 mm (8.375 in.) strut square angle with a thickness of 6 mm (0.25 in.). The rods were fastened to both posts with four (4) 16 mm (0.625 in.) diameter nuts.

A front slider panel 371 mm (14.625 in.) long by 3 mm (0.125 in.) thick was mounted at post 3 on the traffic side of the W-beam guardrail with four (4) 0.625 in. x 2.0 in. guardrail bolts and nuts. The slider bracket and slider panel were also mounted at post 3 between the W-beam guardrail and composite block. The slider bracket was 549 mm (21.625 in.) long by 6 mm (0.25 in.) thick and had a 64 mm (2.5 in.) square tube welded on the backside through which the cable anchor was routed. The slider panel was 445 mm (17.5 in.) long by 270 mm (10.625 in.) tall by 5 mm (0.19 in.) thick. The slider panel and composite block were mounted to post 3 with a 0.625 in. x 10 in. long bolt and a 25 mm (1.0 in.) washer.

Four (4) 3.8 m (12.5 ft.) long 12 Ga W-beam guardrail panels are mounted to the posts of the terminal section with the splice located at every other post. The first rail panel was mounted to post 1 via a 0.625 in x 2.0 in. hex bolt, 50 mm (2 in.) square washer, and nut. Post 2 is also mounted to the rail with a 0.625 in. x 2.0 in. The 191 mm (7.5 in.) offset blocks are placed between the remainder of the terminal's line posts and the rail panels. One (1) 0.625 in. x 10.0 in. long bolt, washer, and nut was used to mount the rail to each of the line posts with offset blocks. The rail was not bolted to post 3 and post 5. Yellow 16 mm (0.625 in.) shear bolts were used to splice rail 3 at both the upstream and downstream ends. All posts were spaced at a nominal distance of 1.9 m (6.25 ft.).

The face of the impact head measured 610 mm (24.0 in.) tall by 330 mm (13.0 in.) wide by 5 mm (0.19 in.) thick. A 165 mm (6.5 in.) long by 5 mm (0.19 in.) thick W-beam section was welded to the back of the impact face and was used to mount the impact head to the terminal's first W-beam rail. The W-beam section was reinforced to the impact face with two (2) 165 mm x 127 mm x 6 mm (6.5 in. x 5.0 in. x 0.25 in.) triangular gussets. The impact head was mounted to the rail with four (4) 0.625 in. x 1.25 in. bolts.

For this test, the X Lite Tangent 50' (15.24 m) System was adjoined to the end of a 34.3 m (112.5 ft.) length of guardrail, measured from post 9 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 seventeen (17) 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. The 191 mm (7.5 in.) plastic offset blocks were on all posts except the last wooden post.

With the exception of post 1, post 2 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 native soil. The post 1, post 2 and the trailing end terminal posts 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 with native soil 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 2016-4063.

## 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 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)
<b>MASS (kg)</b>			
Test Inertial Dummy	$700 \pm 25$	$820 \pm 25$	$2000 \pm 45$
Maximum Ballast Gross Static	75 70 $775 \pm 25$	75 80 $895 \pm 25$	--- 200 $2000 \pm 45$
<b>DIMENSIONS (cm)</b>			
Wheelbase	$230 \pm 10$	$230 \pm 10$	$335 \pm 25$
Front Overhang	$75 \pm 10$	$75 \pm 10$	$80 \pm 10$
Overall Length	$370 \pm 20$	$370 \pm 20$	$535 \pm 25$
Track Width (average)	$135 \pm 10$	$135 \pm 10$	$165 \pm 15$
<b>CENTER OF MASS LOCATION (cm)</b>			
Aft of Front Axle Above Ground	$80 \pm 15$ $55 \pm 5$	$80 \pm 15$ $55 \pm 5$	$140 \pm 15$ $70 \pm 5$
<b>LOCATION OF ENGINE</b>	Front	Front	Front
<b>LOCATION OF DRIVE AXLE</b>	Front	Front	Rear
<b>TYPE OF TRANSMISSION</b>	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 Lite Tangent 50' (15.24 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 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 four (4) 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 Lite Tangent 50' (15.24 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 2004 Chevrolet 2500 pickup truck to evaluate the impact performance of the X Lite Tangent 50' (15.24 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 four (4) 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 11, 2016. The as-tested test inertial weight of the vehicle was 2,042.0 kg (4,501.8 lbs.). The height of the front bumper was 465 mm (18.3 in.) to the lower edge and 752 mm (29.6 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 Lite Tangent 50' (15.24 m) System at a velocity of 97.28 km/h (60.45 mph). The test vehicle impacted the X Lite impact head and pushed rail 1 down rail 2. As the vehicle moved forward the shear bolts on the downstream end of rail 3 sheared. Rails 1 and 2 deformed and rail 3 detached from the system. The vehicle began to rotate counter clockwise about its yaw axis and subsequently rolled onto its passenger side. The vehicle came to rest 23.8 m (78.1 ft.) from the initial impact point. The test vehicle directly impacted post 1 through 11 bending them towards the ground. The remaining downstream posts shifted in the soil causing the rail to tear from all post that did not have a rail splice. The impact head and slider bracket were subject to deformation. 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 and radiator. The right side of the vehicle was damaged including damage to the right front quarter panel, bed side and door. The windshield of the vehicle was penetrated by a line post during roll over.

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 Lite Tangent 50' (15.24 m) System          Project No.     P36132-01      
 Test Program:     100 km/h 5° Guardrail Terminal Impact Test          Test Date:     08/11/16    

**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 <sup>2</sup>	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 Lite Tangent 50' (15.24 m) System          Project No.     P36132-01      
 Test Program:     100 km/h 5° Guardrail Terminal Impact Test          Test Date:     08/11/16    

**TEST VEHICLE INFORMATION**

Make	Chevrolet	Cylinders	V8
Model	2500	Engine Displacement (L)	6.0
Body Style	2-Door Truck	Engine Placement	Longitudinal
VIN	1GCHC24U54E381744	Fuel Type	Gasoline
Color	White	Transmission	Automatic
Odometer Reading (mi)	229,543	Final Drive	Rear
Previous Damage to Vehicle	None		

**DATA FROM CERTIFICATION LABEL**

Manufactured By	General Motos Corp.	GVWR (kg)	4173
		GAWR Front (kg)	2000
Date of Manufacture	Jun-04	GAWR Rear (kg)	2760

**TEST VEHICLE WEIGHTS**

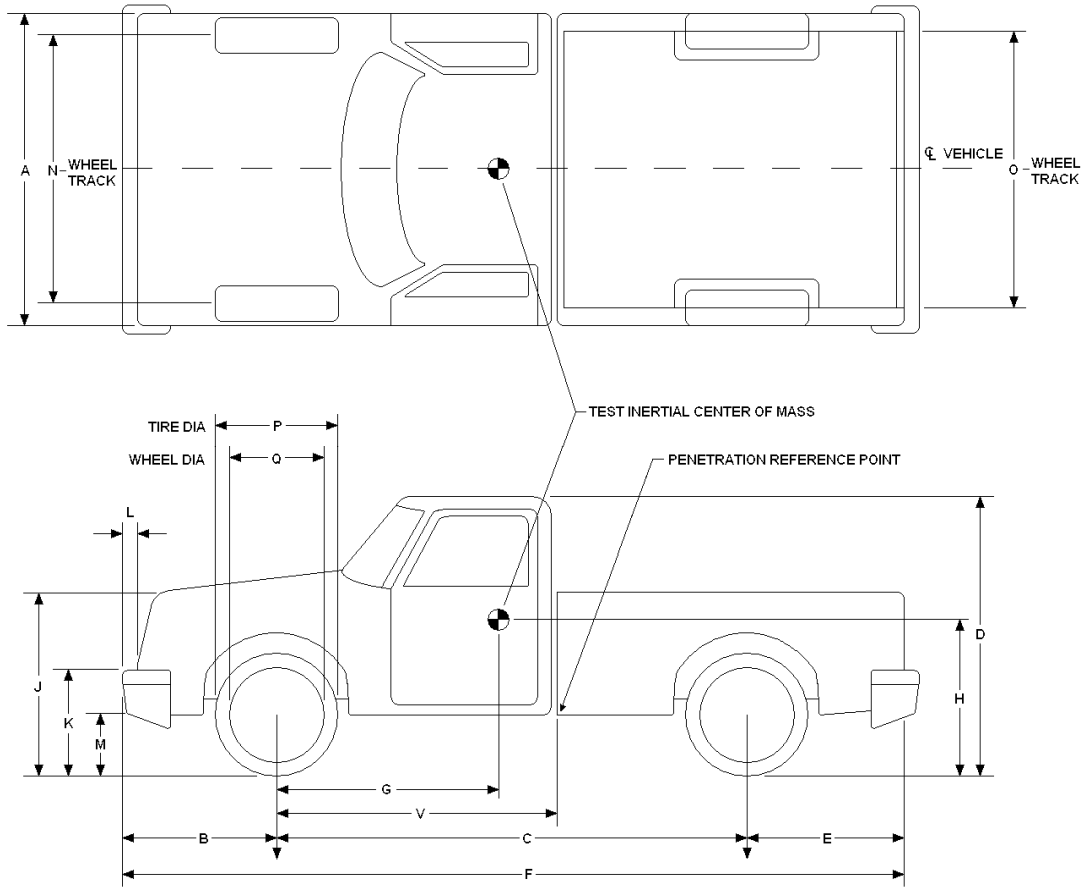
	As Received (kg)			Test Inertial (kg)			Gross Static (kg)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	648.0	406.0	1054.0	631.5	398.5	1030.0	631.5	398.5	1030.0
Right	628.5	413.0	1041.5	608.5	403.5	1012.0	608.5	403.5	1012.0
Ratio (%)	60.9	39.1	100.0	60.7	39.3	100.0	60.7	39.3	100.0
Total	1276.5	819.0	2095.5	1240.0	802.0	2042.0	1240.0	802.0	2042.0

	As Received (lb)			Test Inertial (lb)			Gross Static (lb)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	1428.6	895.1	2323.7	1392.2	878.5	2270.7	1392.2	878.5	2270.7
Right	1385.6	910.5	2296.1	1341.5	889.6	2231.1	1341.5	889.6	2231.1
Ratio (%)	60.9	39.1	100.0	60.7	39.3	100.0	60.7	39.3	100.0
Total	2814.2	1805.6	4619.8	2733.7	1768.1	4501.8	2733.7	1768.1	4501.8

## DATA SHEET 2

### TEST VEHICLE GEOMETRY

Test Article:           X Lite Tangent 50' (15.24 m) System                Project No.           P36132-01            
 Test Program:           100 km/h 5° Guardrail Terminal Impact Test                Test Date:           08/11/16          



### TEST VEHICLE GEOMETRY

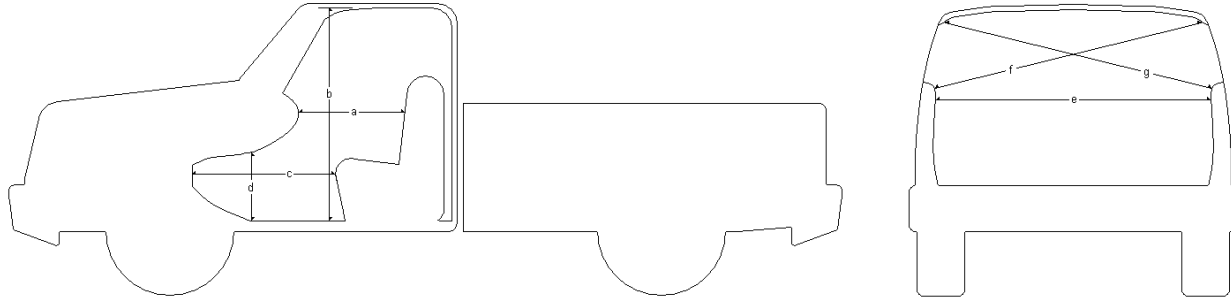
	mm	in.		mm	in.		mm	in.		mm	in.
A	2005	78.9	E	1148	45.2	J	1185	46.7	N	1745	68.7
B	1008	39.7	F	5541	218.1	K	752	29.6	O	1680	66.1
C	3385	133.3	G	1329	52.3	L	100	3.9	P	745	29.3
D	1913	75.3	H	733	28.9	M	465	18.3	Q	440	17.3

### DATA SHEET 3

#### OCCUPANT COMPARTMENT DEFORMATION INDEX

Test Article:     X Lite Tangent 50' (15.24 m) System          Project No.     P36132-01      
 Test Program:     100 km/h 5° Guardrail Terminal Impact Test          Test Date:     08/11/16    

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	1058	41.7	1055	41.5	0.28%
B	1131	44.5	1128	44.4	0.27%
C	1632	64.3	1623	63.9	0.55%
D	392	15.4	393	15.5	-0.26%
E	1717	67.6	1718	67.6	-0.06%
F	1595	62.8	1598	62.9	-0.19%
G	1597	62.9	1590	62.6	0.44%
Max Deformation	1632	64.3	1623	63.9	0.55%
OCDI	FS0000000				
Comments:	None				

**DATA SHEET 4**  
**SUMMARY OF RESULTS**

Test Article: X Lite Tangent 50' (15.24 m) System  
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

Project No.: P36132-01  
 Test Date: 08/11/16



0 ms



600 ms



1000 ms



1400 ms



1800 ms



2400 ms

GENERAL INFORMATION		OCCUPANT RISK VALUES	
TEST AGENCY	KARCO Engineering, LLC.	FLAIL SPACE VELOCITY (m/s)	
TEST ARTICLE		X DIRECTION	4.2
TYPE	Terminal	Y DIRECTION	0.1
TERMINAL LENGTH <sup>1</sup>	15.2 m (49.9 ft.)	THIV (Optional) (m/s)	4.2
ADJOINING BARRIER LENGTH <sup>2</sup>	34.3 m (112.5 ft.)	RIDEDOWN ACCELERATION (g)	
TEST VEHICLE		X DIRECTION	-9.5
TYPE	Production Model	Y DIRECTION	3.9
DESIGNATION	2000P	PHD (Optional) (g)	9.5
MODEL	Chevrolet 2500	ASI (Optional)	0.57
MASS (CURB)	2,095.5 kg (4,619.8 lbs)	VEHICLE DAMAGE	
MASS (TEST INERTIAL)	2,042.0 kg (4,501.8 lbs)	INTERIOR	
MASS (GROSS STATIC)	2,042.0 kg (4,501.8 lbs)	OCDI	FS0000000
IMPACT CONDITIONS		POST-IMPACT VEHICULAR BEHAVIOR	
VELOCITY (km/h)	97.28 km/h (60.45 mph)	MAXIMUM ROLL ANGLE (°)	140.9
ANGLE (°)	4.8	MAXIMUM PITCH ANGLE (°)	-57.6
IMPACT SEVERITY (kJ)	745.4	MAXIMUM YAW ANGLE (°)	-123.7

<sup>1</sup> Terminal Length measured from Post 1 to Post 9

<sup>2</sup> Adjoining Barrier Length measured from Post 9 to Post 27



**DATA SHEET 5**  
**IMPACT CONDITIONS**

Test Article:     X Lite Tangent 50' (15.24 m) System          Project No.     P36132-01      
Test Program:     100 km/h 5° Guardrail Terminal Impact Test          Test Date:     08/11/16    

Item	Value
Test Time	11:06 PM
Temperature (°C)	28.9 *
Wind Velocity (km/h)	8.0 *
Wind Direction	E *
Impact Speed (km/h)	97.28

\*Information provided for reference only

**DATA SHEET 6**

**TEST DATA SUMMARY**

Test Article:     X Lite Tangent 50' (15.24 m) System          Project No.     P36132-01      
Test Program:     100 km/h 5° Guardrail Terminal Impact Test          Test Date:     08/11/16    

**TEST VEHICLE DATA SUMMARY**

Tested Parameter	Axis	Units	Max	Time (ms)	Min	Time (ms)
Vehicle Impact Velocity	X	m/s	27.0			
Flail Space Velocity	X	m/s	4.2	269.4		
Flail Space Velocity	Y	m/s	0.1	269.4		
Ridedown Acceleration	X	g	2.5	1858.0	-9.5	579.6
Ridedown Acceleration	Y	g	3.9	619.7	-3.7	889.5

**TEST VEHICLE ACCELEROMETER PEAK DATA**

Location	Axis	Units	Max	Time (ms)	Min	Time (ms)
Vehicle CG	X	g	4.1	264.3	-10.7	187.2
Vehicle CG	Y	g	4.2	591.2	-4.1	566.0
Vehicle CG	Z	g	46.9	204.8	-42.6	210.0

**APPENDIX A  
PHOTOGRAPHS**

## LIST OF PHOTOGRAPHS

Figure		Page
1	Test Article, As-Received	A-1
2	Test Article, As-Received	A-1
3	Test Vehicle, As-Received	A-2
4	Test Vehicle, As-Received	A-2
5	Test Setup	A-3
6	Test Setup Close-Up	A-3
7	Test Setup	A-4
8	Test Setup Close-Up	A-4
9	Test Setup	A-5
10	Test Setup Close-Up	A-5
11	Test Setup	A-6
12	Test Setup Close-Up	A-6
13	Pre-Test	A-7
14	Post-Test	A-7
15	Post-Test	A-8
16	Post-Test	A-8
17	Pre-Test Front View of Test Article	A-9
18	Post-Test Front View of Test Article	A-9
19	Pre-Test Right Front $\frac{3}{4}$ View of Test Article	A-10
20	Post-Test Right Front $\frac{3}{4}$ View of Test Article	A-10
21	Pre-Test Right View of Test Article	A-11
22	Post-Test Right View of Test Article	A-11
23	Pre-Test Right Rear $\frac{3}{4}$ View of Test Article	A-12
24	Post-Test Right Rear $\frac{3}{4}$ View of Test Article	A-12
25	Pre-Test Rear View of Test Article	A-13
26	Post-Test Rear View of Test Article	A-13
27	Pre-Test Left Rear $\frac{3}{4}$ View of Test Article	A-14
28	Post-Test Left Rear $\frac{3}{4}$ View of Test Article	A-14
29	Pre-Test Left View of Test Article	A-15
30	Post-Test Left View of Test Article	A-15
31	Pre-Test Left Front $\frac{3}{4}$ View of Test Article	A-16
32	Post-Test Left Front $\frac{3}{4}$ View of Test Article	A-16
33	Test Article Damage	A-17
34	Test Article Damage	A-17

## LIST OF PHOTOGRAPHS ... (CONTINUED)

Figure		Page
35	Test Article Damage	A-18
36	Test Article Damage	A-18
37	Test Article Damage	A-19
38	Test Article Damage	A-19
39	Pre-Test Left View of Test Vehicle	A-20
40	Post-Test Left View of Test Vehicle	A-20
41	Pre-Test Left Front $\frac{3}{4}$ View of Test Vehicle	A-21
42	Post-Test Left Front $\frac{3}{4}$ View of Test Vehicle	A-21
43	Pre-Test Front View of Test Vehicle	A-22
44	Post-Test Front View of Test Vehicle	A-22
45	Pre-Test Right Front $\frac{3}{4}$ View of Test Vehicle	A-23
46	Post-Test Right Front $\frac{3}{4}$ View of Test Vehicle	A-23
47	Pre-Test Right View of Test Vehicle	A-24
48	Post-Test Right View of Test Vehicle	A-24
49	Post-Test Windshield	A-25
50	Post-Test Windshield	A-25
51	Pre-Test View of Driver Side Occupant Compartment	A-26
52	Post-Test View of Driver Side Occupant Compartment	A-26
53	Pre-Test View of Driver Side Floorpan	A-27
54	Post-Test View of Driver Side Floorpan	A-27
55	Pre-Test View of Passenger Side Occupant Compartment	A-28
56	Post-Test View of Passenger Side Occupant Compartment	A-28
57	Pre-Test View of Passenger Floorpan	A-29
58	Post-Test View of Passenger Floorpan	A-29
59	Test Vehicle Manufacturer's Label	A-30



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. Pre-Test



FIGURE 14. Post-Test





FIGURE 15. Post-Test



FIGURE 16. Post-Test



FIGURE 17. Pre-Test Front View of Test Article



FIGURE 18. Post-Test Front View of Test Article



FIGURE 19. Pre-Test Right Front  $\frac{3}{4}$  View of Test Article



FIGURE 20. Post-Test Right Front  $\frac{3}{4}$  View of Test Article





FIGURE 21. Pre-Test Right View of Test Article



FIGURE 22. Post-Test Right View of Test Article





FIGURE 23. Pre-Test Right Rear  $\frac{3}{4}$  View of Test Article



FIGURE 24. Post-Test Right Rear  $\frac{3}{4}$  View of Test Article



FIGURE 25. Pre-Test Rear View of Test Article



FIGURE 26. Post-Test Rear View of Test Article



FIGURE 27. Pre-Test Left Rear  $\frac{3}{4}$  View of Test Article



FIGURE 28. Post-Test Left Rear  $\frac{3}{4}$  View of Test Article





FIGURE 29. Pre-Test Left View of Test Article



FIGURE 30. Post-Test Left View of Test Article



FIGURE 31. Pre-Test Left Front  $\frac{3}{4}$  View of Test Article



FIGURE 32. Post-Test Left Front  $\frac{3}{4}$  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  $\frac{3}{4}$  View of Test Vehicle



FIGURE 42. Post-Test Left Front  $\frac{3}{4}$  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. Post-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. Pre-Test Driver Side Floorpan



FIGURE 54. Post-Test Driver Side Floorpan





FIGURE 55. Pre-Test Passenger Side Occupant Compartment



FIGURE 56. Post-Test Passenger Side Occupant Compartment



FIGURE 57. Pre-Test Passenger Side Floorpan



FIGURE 58. Post-Test Passenger Side Floorpan

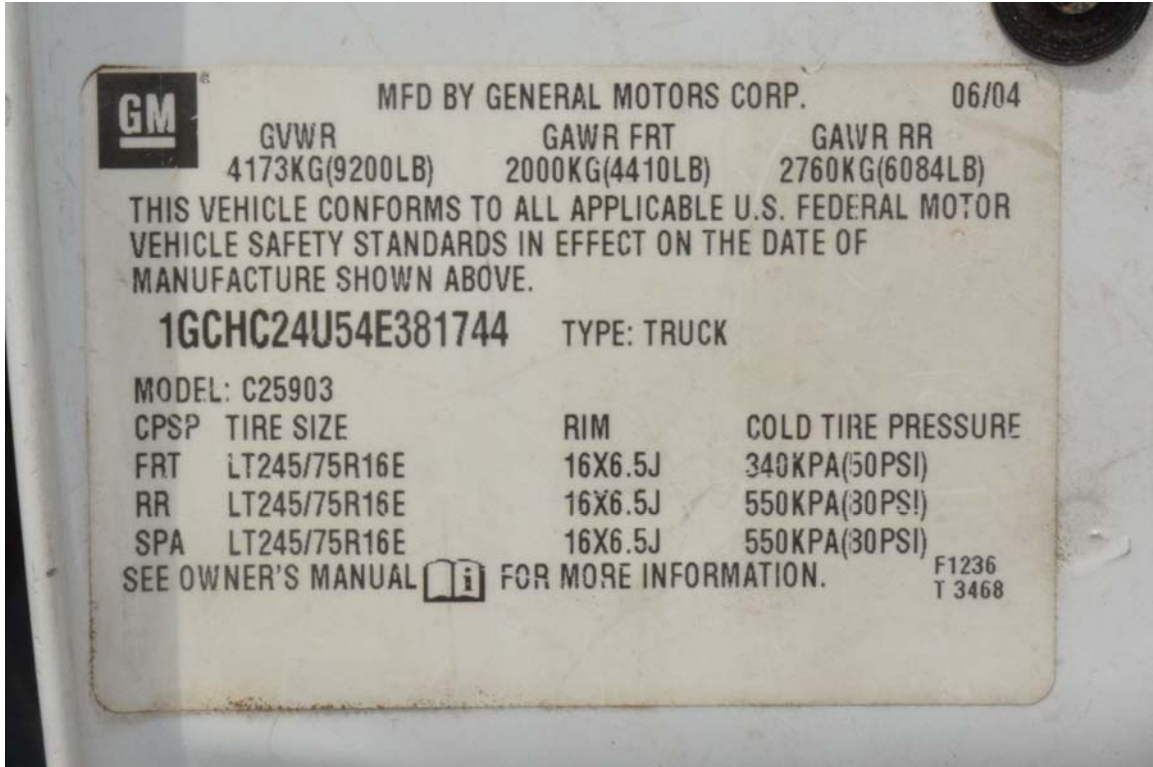


FIGURE 59. Test Vehicle Manufacturer's Label

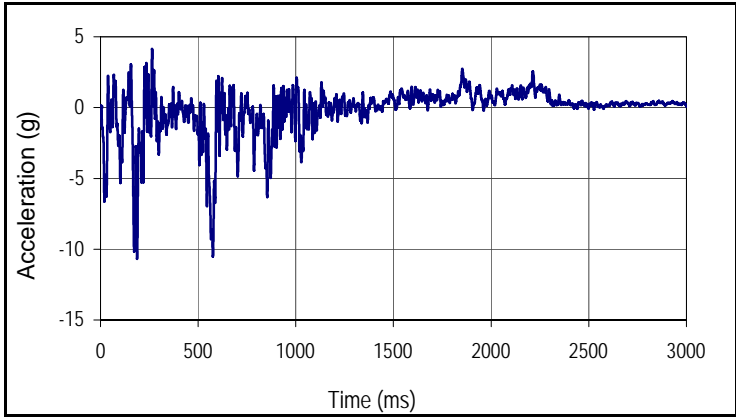
**APPENDIX B  
DATA PLOTS**

## LIST OF DATA PLOTS

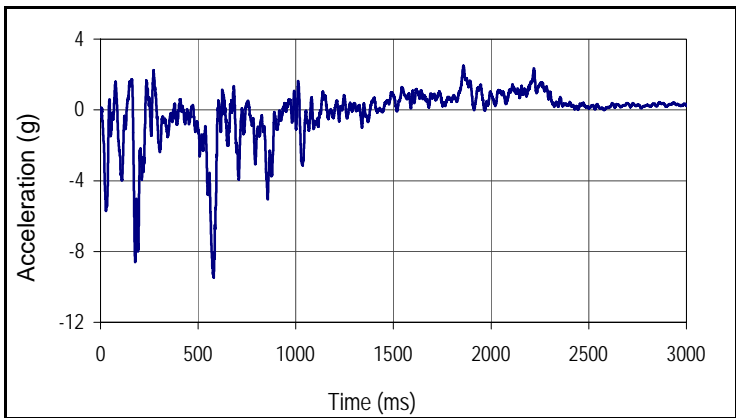
<u>Plot</u>		<u>Page</u>
1	Test Vehicle CG X	B-1
2	Test Vehicle CG X Moving Average	B-1
3	Test Vehicle CG X Velocity	B-1
4	Test Vehicle CG X Displacement	B-1
5	Test Vehicle CG Y	B-2
6	Test Vehicle CG Y Moving Average	B-2
7	Test Vehicle CG Y Velocity	B-2
8	Test Vehicle CG Y Displacement	B-2
9	Test Vehicle 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 LITE TANGENT 50' (15.24 m) System  
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

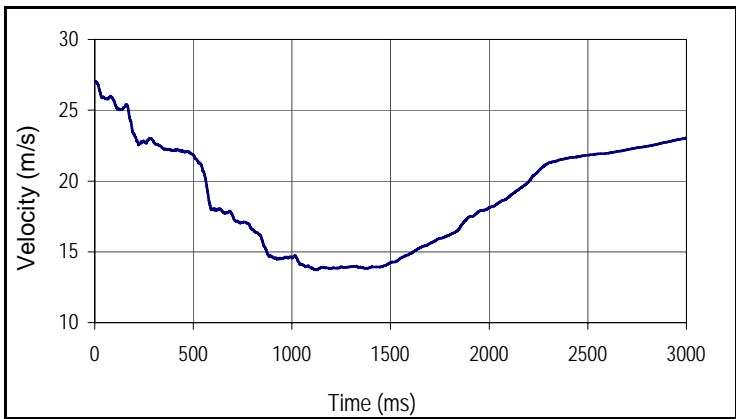
Project No: P36132-01  
 Test Date.: 8/11/16



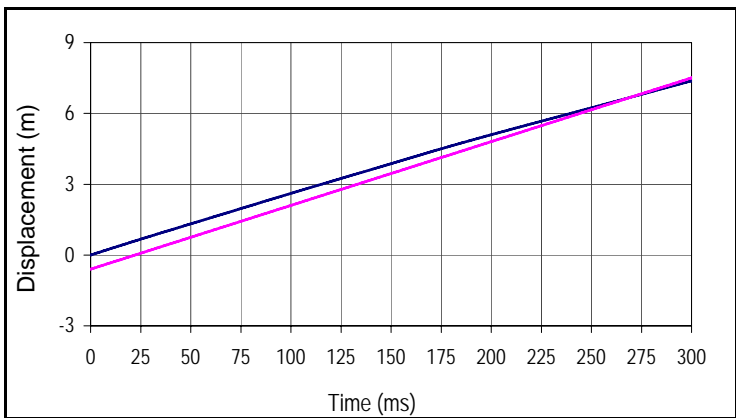
Curve Description			
Test Vehicle CG X			
Plot No.	Type	SAE Class	Units
001	FIL	60	g
Max	Time	Min	Time
4.1	264.3	-10.7	187.2



Curve Description			
Test Vehicle CG X Moving Average			
Plot No.	Type	SAE Class	Units
002	AVG	180	g
Max	Time	Min	Time
2.5	1858.0	-9.5	579.6



Curve Description			
Test Vehicle CG X Velocity			
Plot No.	Type	SAE Class	Units
003	IN1	180	m/s
Max	Time	Min	Time
27.0	3.8	13.7	1126.8



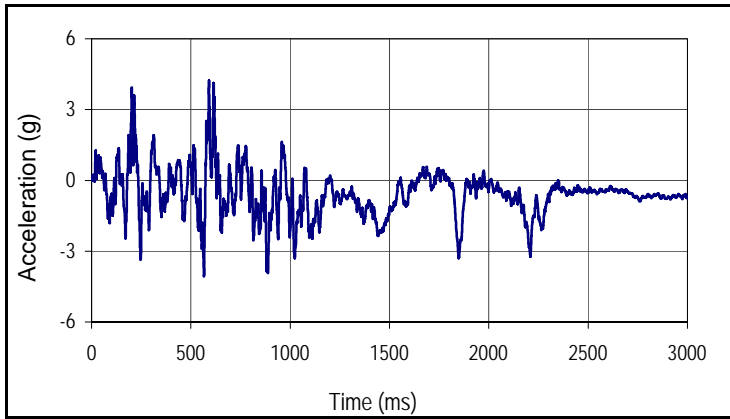
Curve Description			
Test Vehicle CG X Displacement			
Plot No.	Type	SAE Class	Units
004	IN2	180	m
Max	Time	Min	Time
56.7	2999.9	0.0	0.0

— Vehicle CG X Displacement  
 — Occupant X Displacement

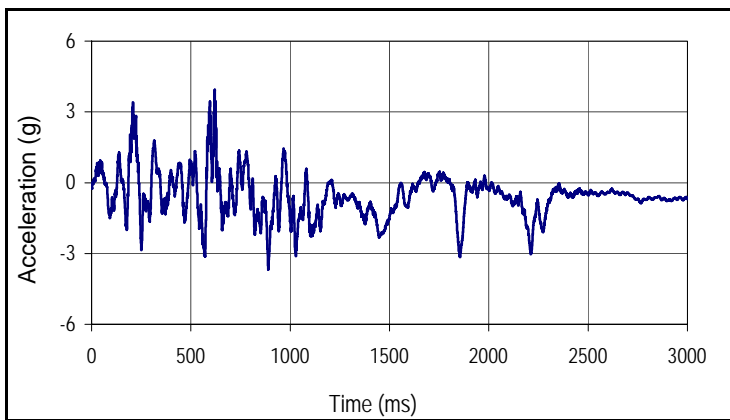


Test Article: X LITE TANGENT 50' (15.24 m) System  
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

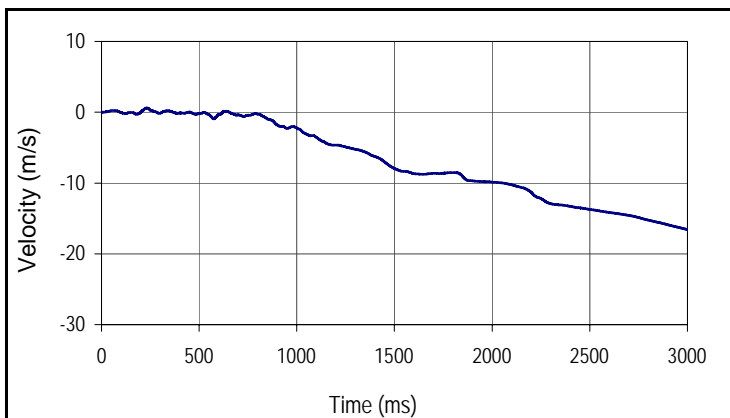
Project No: P36132-01  
 Test Date.: 8/11/16



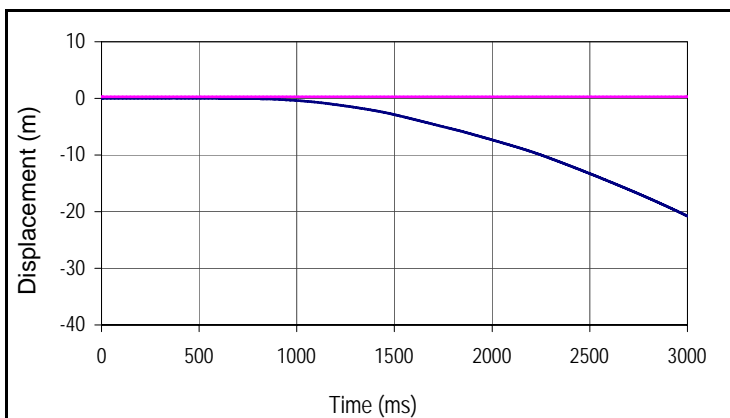
Curve Description			
Test Vehicle CG Y			
Plot No.	Type	SAE Class	Units
005	FIL	60	g
Max	Time	Min	Time
4.2	591.2	-4.1	566.0



Curve Description			
Test Vehicle CG Y Moving Average			
Plot No.	Type	SAE Class	Units
006	AVG	180	g
Max	Time	Min	Time
3.9	619.7	-3.7	889.5



Curve Description			
Test Vehicle CG Y Velocity			
Plot No.	Type	SAE Class	Units
007	IN1	180	m/s
Max	Time	Min	Time
0.6	233.7	-16.6	2999.9

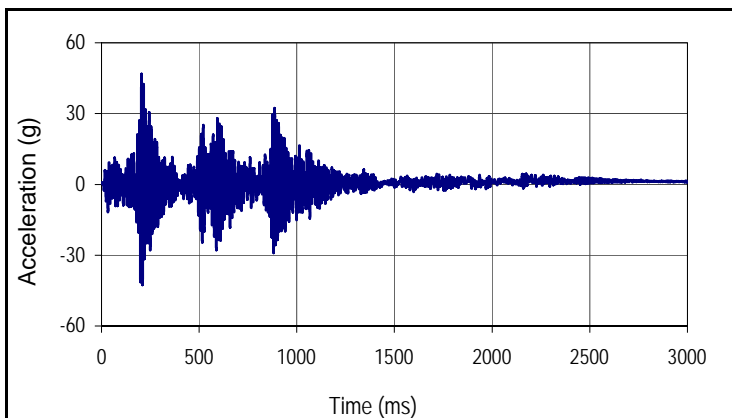


Curve Description			
Test Vehicle CG Y Displacement			
Plot No.	Type	SAE Class	Units
008	IN2	180	m
Max	Time	Min	Time
0.0	367.6	-20.8	2999.9

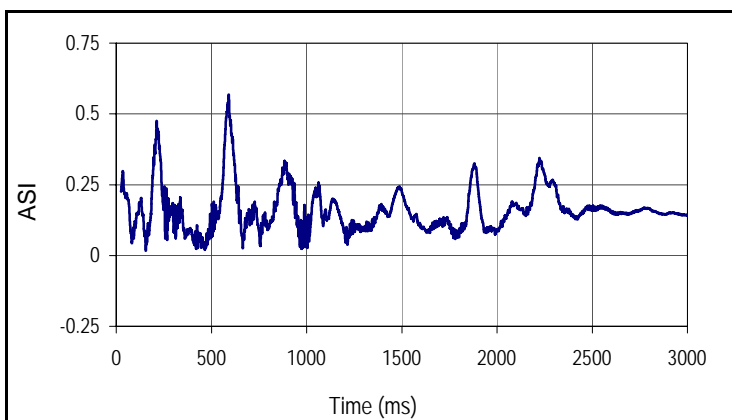
— Vehicle CG Y Displacement  
 — Occupant Y Displacement

Test Article: X LITE TANGENT 50' (15.24 m) System  
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

Project No: P36132-01  
 Test Date.: 8/11/16



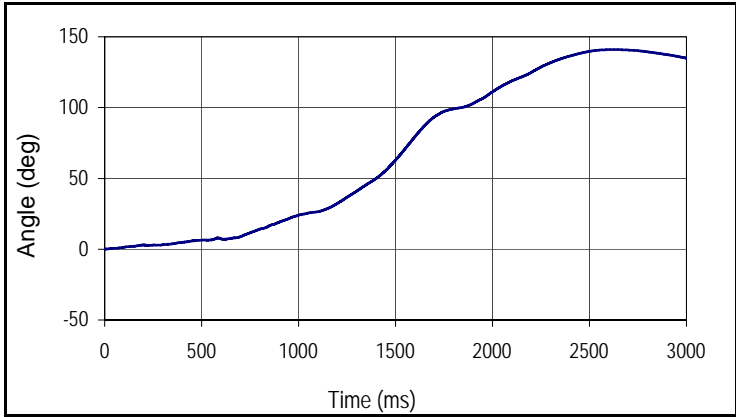
Curve Description			
Test Vehicle CG Z			
Plot No.	Type	SAE Class	Units
009	FIL	60	g
Max	Time	Min	Time
46.9	204.8	-42.6	210.0



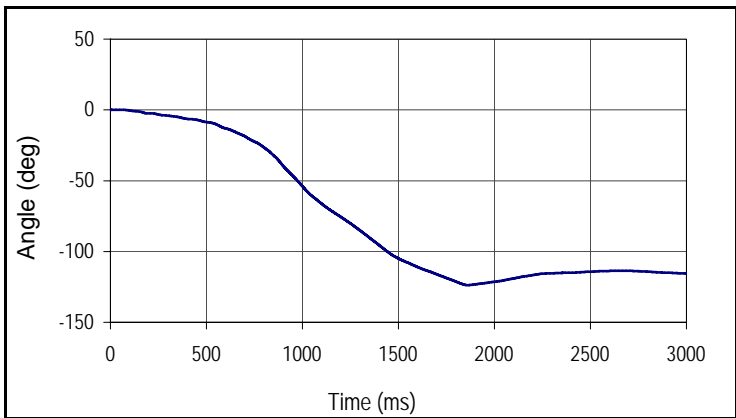
Curve Description			
Test Vehicle Accident Severity Index			
Plot No.	Type	SAE Class	Units
010	ASI	180	ASI
Max	Time	Min	Time
0.6	590.8	0.0	155.2

Test Article: X LITE TANGENT 50' (15.24 m) System  
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

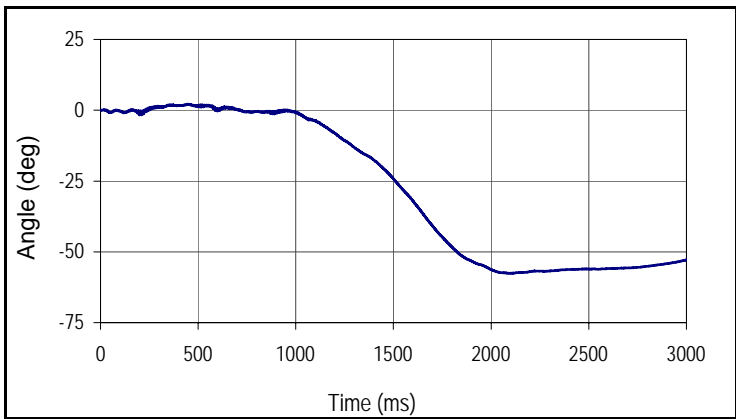
Project No: P36132-01  
 Test Date.: 8/11/16



Curve Description			
Test Vehicle Roll Angle			
Plot No.	Type	SAE Class	Units
011	IN1	180	deg
Max	Time	Min	Time
140.9	2628.4	0.0	0.0



Curve Description			
Test Vehicle Yaw Angle			
Plot No.	Type	SAE Class	Units
012	IN1	180	deg
Max	Time	Min	Time
0.1	63.9	-123.7	1859.7



Curve Description			
Test Vehicle Pitch Angle			
Plot No.	Type	SAE Class	Units
013	IN1	180	deg
Max	Time	Min	Time
2.2	445.9	-57.6	2102.8

**APPENDIX C  
INSTRUMENTATION**



### DATA ACQUISITION INFORMATION

Test Article: X Lite Tangent 50' (15.24 m) System Project No. P36132-01  
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 08/11/16

### 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

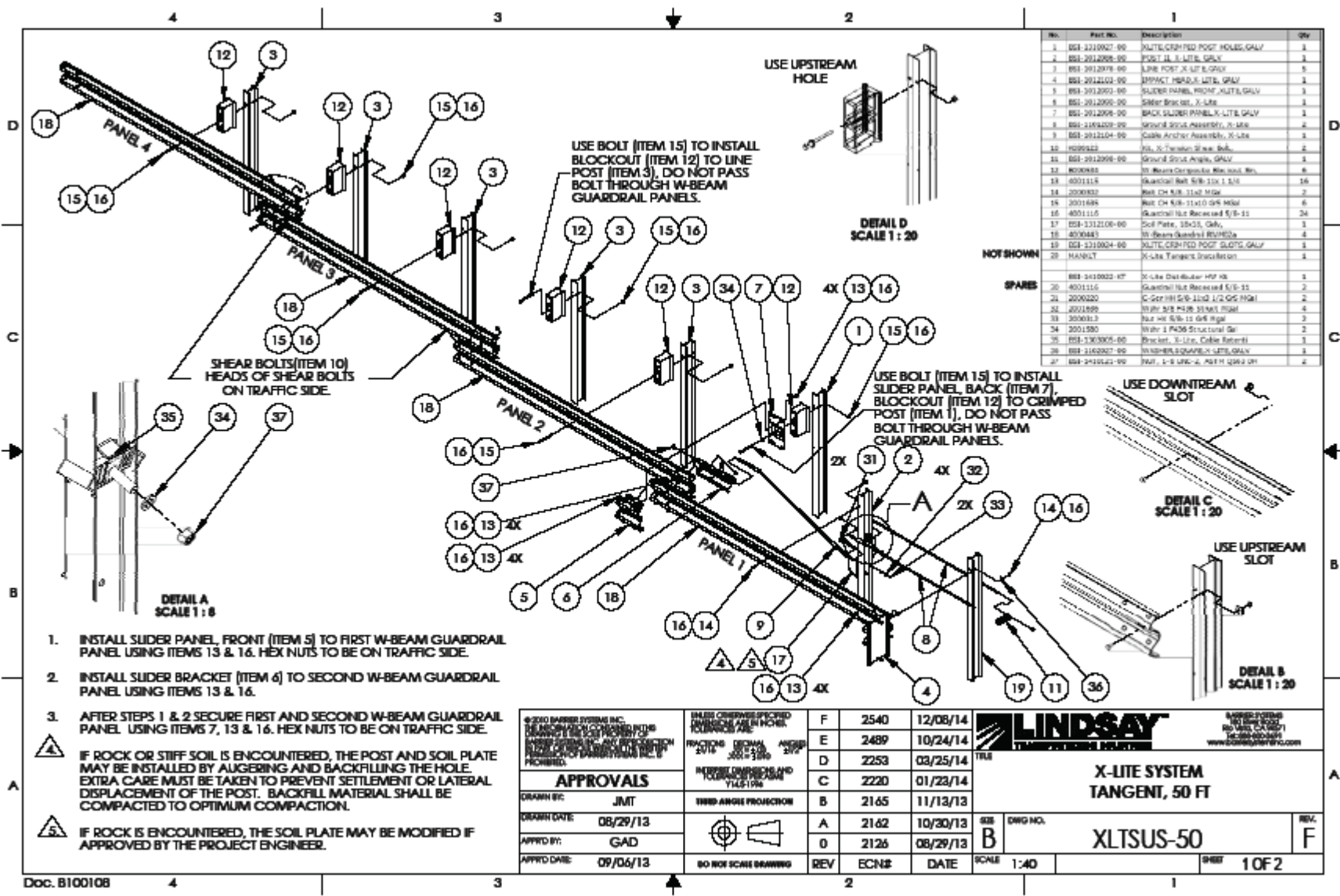


FIGURE 1. Manufacturer's Drawing



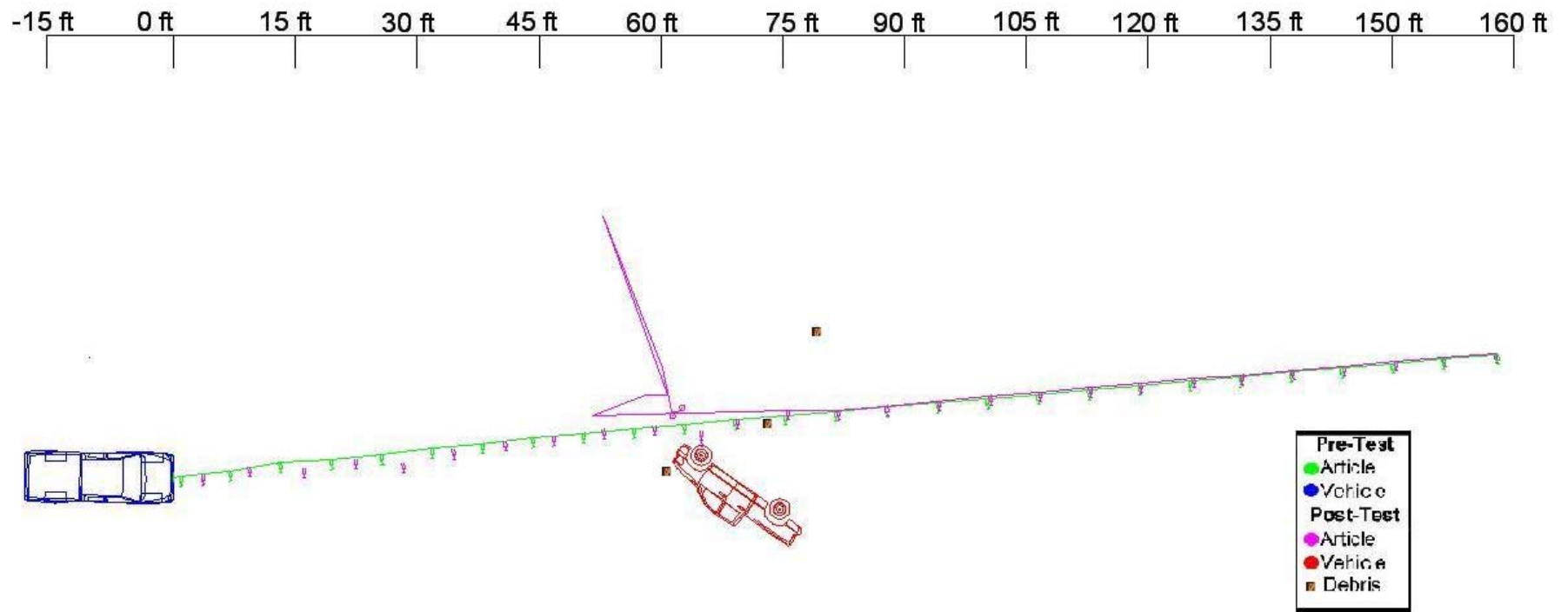


FIGURE 2. Overhead Illustration  
 FINAL PAGE OF REPORT