

TEST REPORT FOR:

Virginia Department of Transportation
SKT SP 350 50' (15.24 m) System



PREPARED FOR:

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

TEST REPORT NUMBER:

TR-P36067-01-NC

REPORT DATE:

September 16, 2016

TEST DATE:

June 30, 2016

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REVISION CONTROL LOG

TR-P36067-01

| 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 Road Systems, Inc. SKT SP 350 50' (15.24 m) System. This report presents the results of one (1) full-scale crash test conducted on one SKT SP 350 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 Road Systems, Inc. SKT SP 350 50' (15.24 m) System is a standard post guardrail terminal/end treatment. The as-tested SKT SP 350 50' (15.24 m) System consisted of one (1) SKT impact head, two (2) hinged posts, seven (7) standard I-beam line posts, two (2) W-beam rail panels, and one (1) cable anchor assembly. The terminal section 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 consisted of one (1) 0.7 m (2.4 ft.) long top post constructed of 6.0" x 6.0" x 0.125" steel tube and one (1) 1.8 m (6.0 ft.) long bottom post constructed of W6 x 15 steel I-beam. The posts were pinned together by a 229 mm (9.0 in.) long 16 mm (0.625 in.) diameter grade 5 hex head bolt, 16 mm (0.625 in.) diameter washers, and a 16 mm (0.625 in.) diameter nut. The bottom portion of post 1 had three (3) 13 mm (0.5 in.) thick plates welded at the top end, one (1) at each flange and one (1) on the upstream side of the post. A 356 mm (1.17 ft.) wide by 508 mm (1.7 ft.) tall by 5 mm (0.19 in.) thick soil plate was attached to the downstream side of the W6 x 15 steel I-beam, 152 mm (6.0 in.) down from the top end.

Post 2 consisted of one (1) 1.1 m (3.5 ft.) long bottom post and one (1) 0.9 m (2.8 ft.) long top post, both pieces were constructed of W6 x 9 steel I-beam. The bottom post had one (1) 178 mm (7.0 in.) long by 102 mm (4.0 in.) wide by 0.375 in. (10 mm) thick plate welded to each flange. The top and bottom post were pinned together by an 18 mm (0.75 in.) diameter by 216 mm (8.5 in.) long ASTM A449 hex head bolt and an 18 mm (0.75 in.) diameter nut.

The cable assembly was attached to post 1 with a 16 mm (0.625 in.) thick, 203 mm (8.0 in.) square steel bearing plate. The bearing plate had a 29 mm (1.125 in.) diameter hole drilled at the center of the plate through which the cable anchor was inserted and fastened with a washer and nut. The opposite end of the assembly was attached to the rail with a quick release cable anchor. The cable anchor attached to the rail with eight (8) 13 mm (0.5 in.) diameter shoulder bolts with washers, eight (8) 13 mm (0.5 in.) structural nuts, and eight (8) 13 mm (0.5 in.) structural washers. The cable anchor was composed of one (1) 6 mm (0.25 in.) thick cable release bracket and one (1) 13 mm (0.5 in.) cable release plate.

The SKT impact head sits on the W-beam rail between post 1 and 2. The head assembly has a total length of 2.1 m (6.9 ft.). The front impacted section of the impact head is 510 mm (20.1 in.) wide by 510 mm (20.1 in.) tall. The rear section of the SKT impact head is composed of a chute that partially encloses the rail. The chute is 185 mm (7.3 in.) wide by 349 mm (13.75 in.) tall at the downstream end. The SKT impact head has a curved deflector plate composed of a 5 mm (0.19 in.) thick plate within the impact head.

Two (2) 7.6 m (25.0 ft.) long rail panels are mounted to the posts of the terminal section with the splices located at post 5. The first rail panel was a 7.6 m (25.0 ft.) panel and composed of 12 Ga. W-beam. The leading edge of the rail had a series of thirteen (13) 0.5" x 4.0" slots. Three (3) 0.75" x 2.5" post slots were located at the center height of the rail. The posts slots were spaced 1.9 m (6.25 ft.) from one another on center. The rail also had eight (8) 19 mm (0.75 in.) diameter holes to attach the cable release bracket to the rail. The second rail was a standard 7.6 m (25.0 ft.) W-beam rail. 191 mm (7.5 in.) plastic offset blocks were used on post 3 through 9.

For this test, the SKT SP 350 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. 191 mm (7.5 in.) plastic offset blocks were on all posts except the last wooden post.

With the exception of post 1, 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 soil. The first two posts as well as the trailing end terminal post were installed by drilling a 0.6 m (2.0 ft.) diameter hole. Post 1 and the trailing end terminal post were drilled to a depth of 1.8 m (6.0 ft.) while post 2 was drilled to a depth of 1.2 m (4.0 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 2016-4054

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 SKT SP 350 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 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 SKT SP 350 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 2002 Chevrolet 2500 pickup truck to evaluate the impact performance of the SKT SP 350 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 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 June 30, 2016. The as-tested test inertial weight of the vehicle was 2,042.5 kg (4,502.8 lbs.). The height of the front bumper was 415 mm (16.3 in.) to the lower edge and 605 mm (23.8 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 SKT SP 350 50' (15.24 m) System at a velocity of 98.46 km/h (61.18 mph). The test vehicle impacted the SKT impact head and pushed it down the guardrail past the first 6 posts. After the SKT extruder head chute passed post 6 the rail buckled and the vehicle continued to the non-traffic side of the article. The test vehicle impacted the extruded section of rail and began tracking back towards the article. The test vehicle impacted the length of need section near post 17 and subsequently rode up the non-traffic side of the article. The vehicle came to rest with its left side wheels on the traffic side of the article 43.3 m (421.1 ft.) downstream from its position at the point of impact. The test article sustained damage from post 1 through post 6. Post 1 top broke away at the connection bolt, post 2 folded to the ground while post 3 through 6 bent towards the ground. The chute on the SKT impact head sustained deformation and a tear on its downstream end. The length of need section was also damaged from post 16 through 23. 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 and grill as a result of the impact with the SKT SP 350 50' (15.24 m) System. The front right tire was also punctured. 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: SKT SP 350 50' (15.24 m) System Project No. P36067-01
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16

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: SKT SP 350 50' (15.24 m) System Project No. P36067-01
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16

TEST VEHICLE INFORMATION

| | | | |
|----------------------------|-------------------|-------------------------|--------------|
| Make | Chevrolet | Cylinders | V8 |
| Model | 2500 | Engine Displacement (L) | 6.0 |
| Body Style | 2-Door Truck | Engine Placement | Longitudinal |
| VIN | 1GCHC24U62E285683 | Fuel Type | Gasoline |
| Color | White | Transmission | Automatic |
| Odometer Reading (mi) | 287,616 | Final Drive | Rear |
| Previous Damage to Vehicle | Minor Scratches | | |

DATA FROM CERTIFICATION LABEL

| | | | |
|---------------------|---------------------|-----------------|------|
| Manufactured By | General Motors Corp | GVWR (kg) | 4173 |
| | | GAWR Front (kg) | 2000 |
| Date of Manufacture | May-02 | GAWR Rear (kg) | 2760 |

TEST VEHICLE WEIGHTS

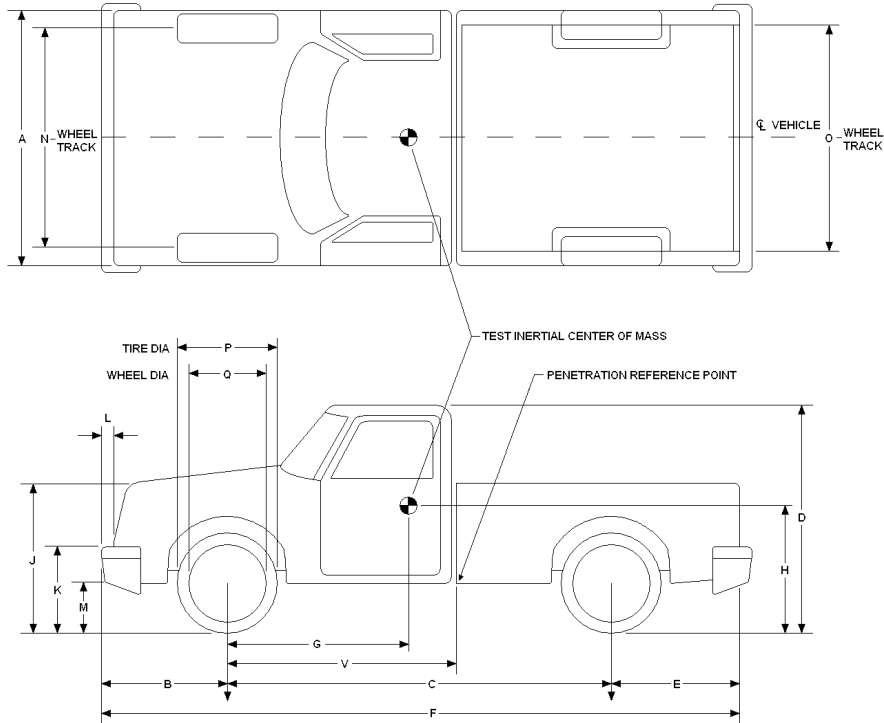
| | As Received (kg) | | | Test Inertial (kg) | | | Gross Static (kg) | | |
|-----------|------------------|--------|--------|--------------------|-------|--------|-------------------|-------|--------|
| | Front | Rear | Total | Front | Rear | Total | Front | Rear | Total |
| Left | 683.0 | 532.0 | 1215.0 | 648.0 | 401.5 | 1049.5 | 648.0 | 401.5 | 1049.5 |
| Right | 624.5 | 520.5 | 1145.0 | 594.5 | 398.5 | 993.0 | 594.5 | 398.5 | 993.0 |
| Ratio (%) | 55.4 | 44.6 | 100.0 | 60.8 | 39.2 | 100.0 | 60.8 | 39.2 | 100.0 |
| Total | 1307.5 | 1052.5 | 2360.0 | 1242.5 | 800.0 | 2042.5 | 1242.5 | 800.0 | 2042.5 |

| | As Received (lb) | | | Test Inertial (lb) | | | Gross Static (lb) | | |
|-----------|------------------|--------|--------|--------------------|--------|--------|-------------------|--------|--------|
| | Front | Rear | Total | Front | Rear | Total | Front | Rear | Total |
| Left | 1505.7 | 1172.8 | 2678.5 | 1428.6 | 885.1 | 2313.7 | 1428.6 | 885.1 | 2313.7 |
| Right | 1376.8 | 1147.5 | 2524.3 | 1310.6 | 878.5 | 2189.1 | 1310.6 | 878.5 | 2189.1 |
| Ratio (%) | 55.4 | 44.6 | 100.0 | 60.8 | 39.2 | 100.0 | 60.8 | 39.2 | 100.0 |
| Total | 2882.5 | 2320.3 | 5202.8 | 2739.2 | 1763.6 | 4502.8 | 2739.2 | 1763.6 | 4502.8 |

DATA SHEET 2

TEST VEHICLE GEOMETRY

Test Article: SKT SP 350 50' (15.24 m) System Project No. P36067-01
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16



TEST VEHICLE GEOMETRY

| | mm | in. | | mm | in. | | mm | in. | | mm | in. |
|---|------|-------|---|------|-------|---|------|------|---|------|------|
| A | 1950 | 76.8 | E | 1151 | 45.3 | J | 1202 | 47.3 | N | 1745 | 68.7 |
| B | 940 | 37.0 | F | 5478 | 215.7 | K | 605 | 23.8 | O | 1683 | 66.3 |
| C | 3387 | 133.3 | G | 1327 | 52.2 | L | 103 | 4.1 | P | 730 | 28.7 |
| D | 1925 | 75.8 | H | 689 | 27.1 | M | 415 | 16.3 | Q | 440 | 17.3 |

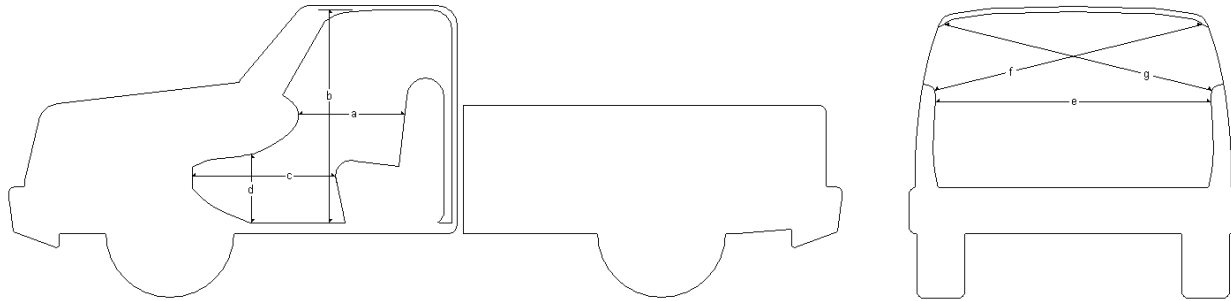
DATA SHEET 3

OCCUPANT COMPARTMENT DEFORMATION INDEX

Test Article: SKT SP 350 50' (15.24 m) System Project No. P36067-01

Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16

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,

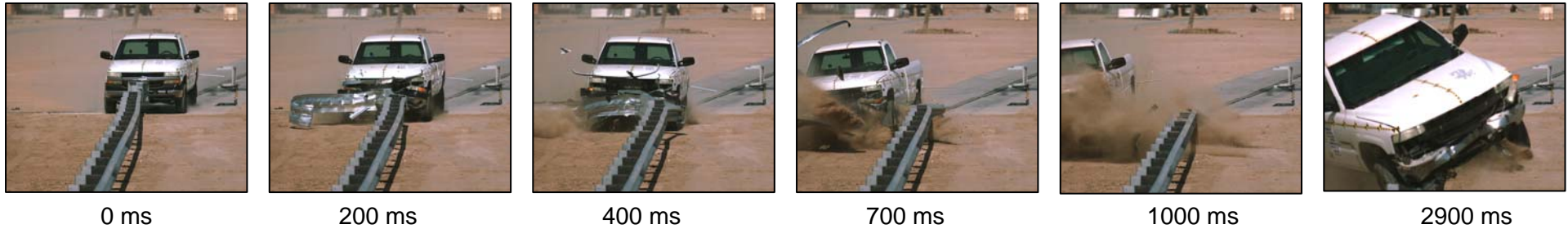
- a = distance between the dashboard and a reference point at the rear of the occupant compartment, such as top of rear seat, or the rear part of the cab on a pickup;
- b = distance between the roof and the floor panel;
- c = distance between a reference point at the rear of the occupant compartment 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 | 839 | 33.0 | 844 | 33.2 | -0.60% |
| B | 1187 | 46.7 | 1195 | 47.0 | -0.67% |
| C | 1631 | 64.2 | 1633 | 64.3 | -0.12% |
| D | 397 | 15.6 | 393 | 15.5 | 1.01% |
| E | 1666 | 65.6 | 1661 | 65.4 | 0.30% |
| F | 1527 | 60.1 | 1523 | 60.0 | 0.26% |
| G | 1513 | 59.6 | 1536 | 60.5 | -1.52% |
| Max Deformation | 397 | 15.6 | 393 | 15.5 | 1.01% |
| OCDI | FS0000000 | | | | |
| Comments: | None | | | | |

DATA SHEET 4
SUMMARY OF RESULTS

Test Article: SKT SP 350 50' (15.24 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

Project No.: P36067-01
 Test Date: 06/30/16



| GENERAL INFORMATION | | OCCUPANT RISK VALUES | |
|---------------------------------------|--------------------------|--------------------------------|-----------|
| TEST AGENCY | KARCO Engineering, LLC. | FLAIL SPACE VELOCITY (m/s) | |
| TEST ARTICLE | | X DIRECTION | 5.0 |
| TYPE | Terminal | Y DIRECTION | 0.4 |
| TERMINAL LENGTH ¹ | 15.3 m (50.0 ft.) | THIV (Optional) (m/s) | 5.0 |
| ADJOINING BARRIER LENGTH ² | 34.3 m (112.5 ft.) | RIDEDOWN ACCELERATION (g) | |
| TEST VEHICLE | | X DIRECTION | -5.2 |
| TYPE | Production Model | Y DIRECTION | 4.1 |
| DESIGNATION | 2000P | PHD (Optional) (g) | 6.3 |
| MODEL | Chevrolet 2500 | ASI (Optional) | 0.41 |
| MASS (CURB) | 2,360.0 kg (5,202.8 lbs) | VEHICLE DAMAGE | |
| MASS (TEST INERTIAL) | 2,042.5 kg (4,502.8 lbs) | INTERIOR | |
| MASS (GROSS STATIC) | 2,042.5 kg (4,502.8 lbs) | OCDI | FS0000000 |
| IMPACT CONDITIONS | | POST-IMPACT VEHICULAR BEHAVIOR | |
| VELOCITY (km/h) | 98.46 km/h (61.18 mph) | MAXIMUM ROLL ANGLE (°) | 7.3 |
| ANGLE (°) | 5.4 | MAXIMUM PITCH ANGLE (°) | -15.6 |
| IMPACT SEVERITY (kJ) | 763.9 | MAXIMUM YAW ANGLE (°) | -23.8 |

¹ Terminal Length measured from Post 1 to Post 9

² Adjoining Barrier Length measured from Post 9 to Post 27

DATA SHEET 5
IMPACT CONDITIONS

Test Article: SKT SP 350 50' (15.24 m) System Project No. P36067-01
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16

| Item | Value |
|----------------------|---------|
| Test Time | 4:13 PM |
| Temperature (°C) | 37.8 * |
| Wind Velocity (km/h) | 12.9 * |
| Wind Direction | South * |
| Impact Speed (km/h) | 98.46 |

*Information provided for reference only

DATA SHEET 6

TEST DATA SUMMARY

Test Article: SKT SP 350 50' (15.24 m) System Project No. P36067-01
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16

TEST VEHICLE DATA SUMMARY

| Tested Parameter | Axis | Units | Max | Time (ms) | Min | Time (ms) |
|-------------------------|------|-------|------|-----------|------|-----------|
| Vehicle Impact Velocity | X | m/s | 27.3 | | | |
| Flail Space Velocity | X | m/s | 5.0 | 222.6 | | |
| Flail Space Velocity | Y | m/s | 0.4 | 222.6 | | |
| Ridedown Acceleration | X | g | 2.0 | 432.8 | -5.2 | 527.6 |
| Ridedown Acceleration | Y | g | 4.1 | 532.4 | -3.1 | 701.3 |

TEST VEHICLE ACCELEROMETER PEAK DATA

| Location | Axis | Units | Max | Time (ms) | Min | Time (ms) |
|------------|------|-------|------|-----------|-------|-----------|
| Vehicle CG | X | g | 3.8 | 70.5 | -12.5 | 16.5 |
| Vehicle CG | Y | g | 4.8 | 525.3 | -3.6 | 699.7 |
| Vehicle CG | Z | g | 18.4 | 393.2 | -18.5 | 144.3 |

**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. 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. Pre-Test Left View of Test Vehicle



FIGURE 38. Post-Test Left View of Test Vehicle



FIGURE 39. Pre-Test Left Front $\frac{3}{4}$ View of Test Vehicle



FIGURE 40. Post-Test Left Front $\frac{3}{4}$ View of Test Vehicle



FIGURE 41. Pre-Test Front View of Test Vehicle



FIGURE 42. Post-Test Front View of Test Vehicle



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



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



FIGURE 45. Pre-Test Right View of Test Vehicle



FIGURE 46. Post-Test Right View of Test Vehicle



FIGURE 47. Pre-Test Windshield



FIGURE 48. Post-Test Windshield



FIGURE 49. Pre-Test Driver Side Occupant Compartment



FIGURE 50. Post-Test Driver Side Occupant Compartment



FIGURE 51. Post-Test Driver Side Floorpan



FIGURE 52. Post-Test Driver Side Floorpan



FIGURE 53. Pre-Test Passenger Side Occupant Compartment



FIGURE 54. Post-Test Passenger Side Occupant Compartment



FIGURE 55. Pre-Test Passenger Side Floorpan



FIGURE 56. Post-Test Passenger Side Floorpan

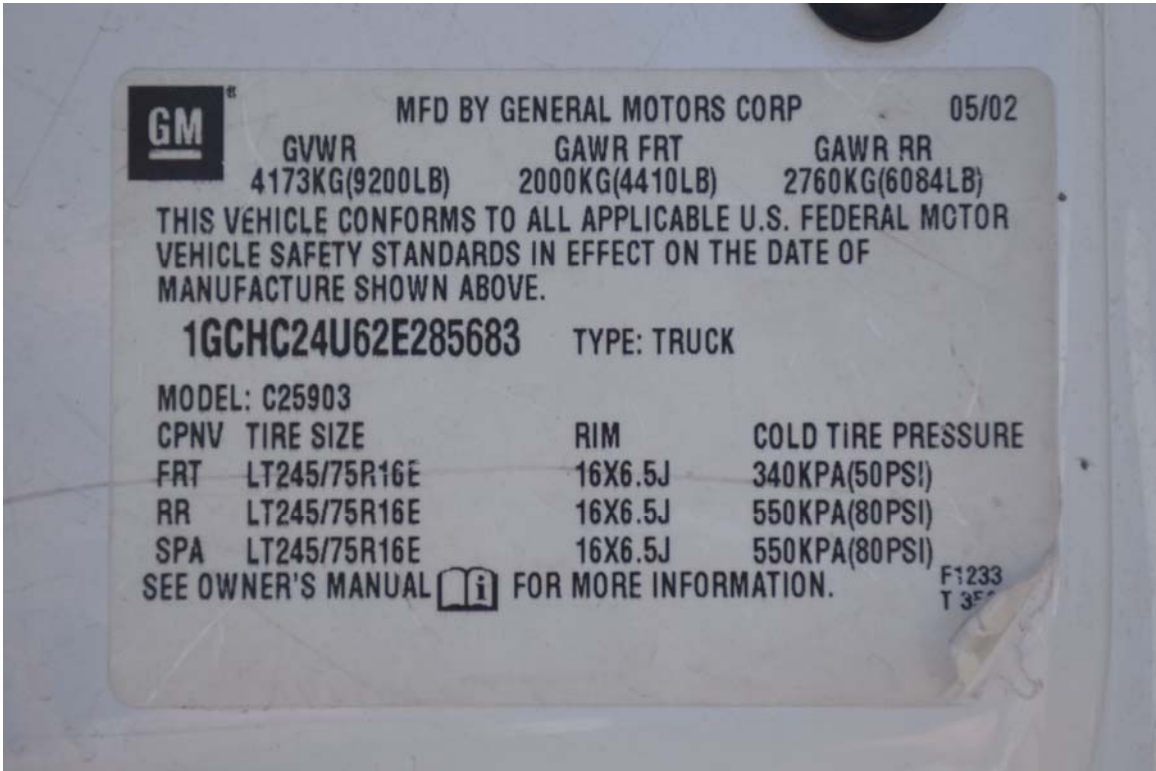


FIGURE 57. Test Vehicle Manufacturer's Label

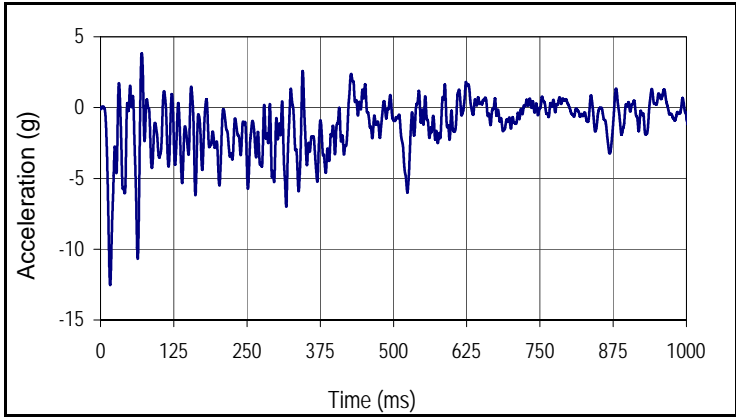
**APPENDIX B
DATA PLOTS**

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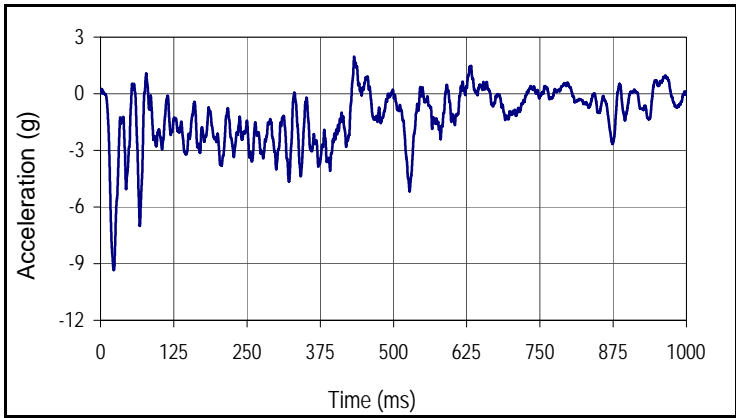
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Test Article: SKT SP 350 50' (15.24 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

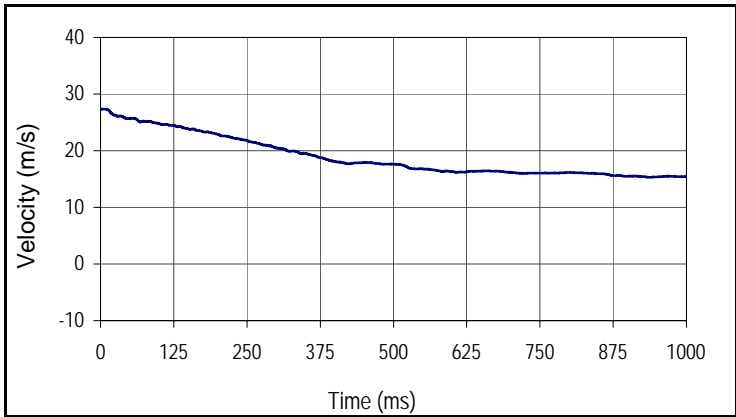
Project No: P36067-01
 Test Date.: 6/30/16



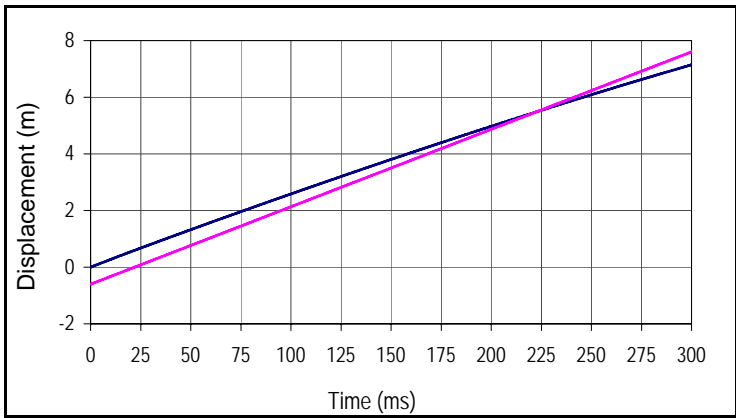
| Curve Description | | | |
|-------------------|------|-----------|-------|
| Test Vehicle CG X | | | |
| Plot No. | Type | SAE Class | Units |
| 001 | FIL | 60 | g |
| Max | Time | Min | Time |
| 3.8 | 70.5 | -12.5 | 16.5 |



| Curve Description | | | |
|----------------------------------|-------|-----------|-------|
| Test Vehicle CG X Moving Average | | | |
| Plot No. | Type | SAE Class | Units |
| 002 | AVG | 180 | g |
| Max | Time | Min | Time |
| 2.0 | 432.8 | -9.3 | 22.6 |



| Curve Description | | | |
|----------------------------|------|-----------|--------|
| Test Vehicle CG X Velocity | | | |
| Plot No. | Type | SAE Class | Units |
| 003 | IN1 | 180 | m/sec |
| Max | Time | Min | Time |
| 27.3 | 5.1 | 14.5 | 1991.1 |

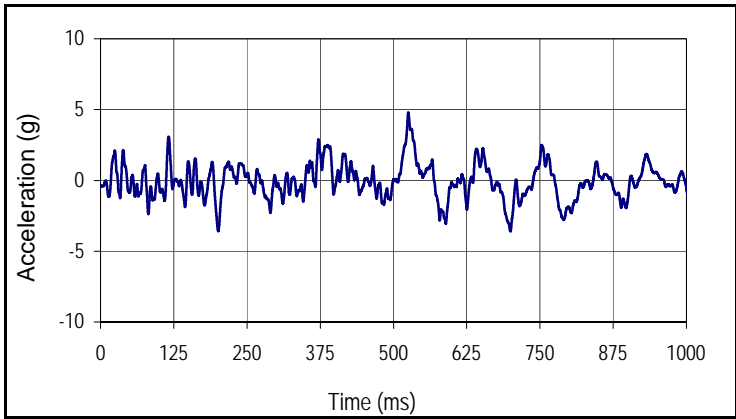


| Curve Description | | | |
|--------------------------------|--------|-----------|--------|
| Test Vehicle CG X Displacement | | | |
| Plot No. | Type | SAE Class | Units |
| 004 | IN2 | 180 | Meters |
| Max | Time | Min | Time |
| 33.8 | 1999.9 | 0.0 | 0.0 |

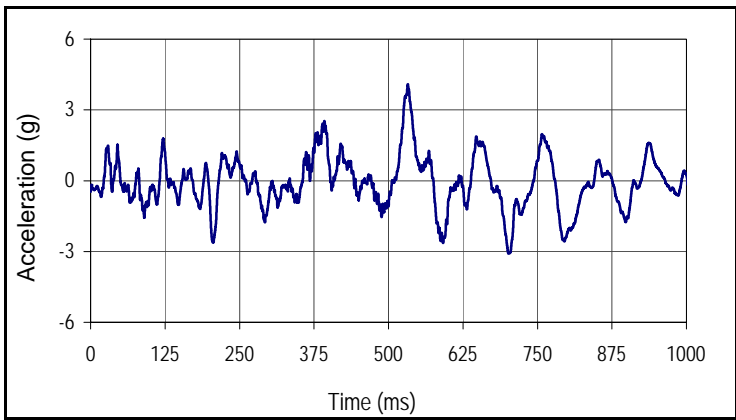
— Vehicle CG X Displacement
 — Occupant X Displacement

Test Article: SKT SP 350 50' (15.24 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

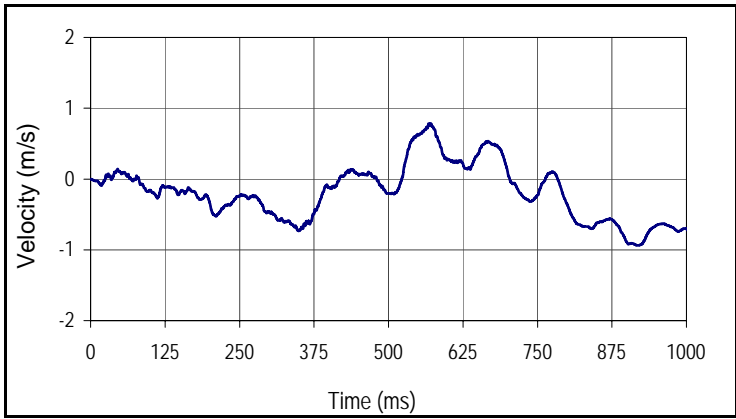
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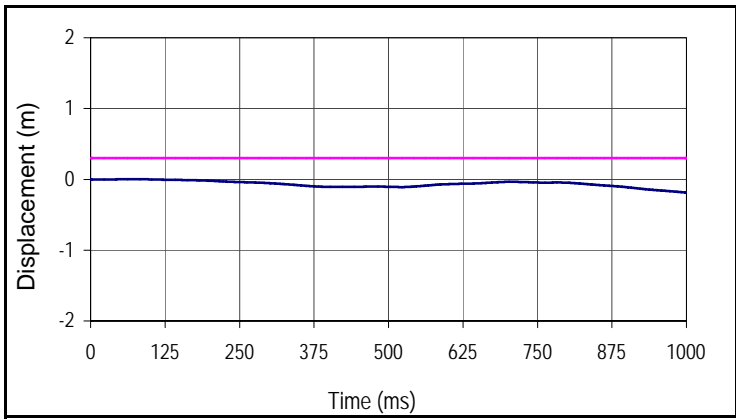
| Curve Description | | | |
|-------------------|-------|-----------|-------|
| Test Vehicle CG Y | | | |
| Plot No. | Type | SAE Class | Units |
| 005 | FIL | 60 | g |
| Max | Time | Min | Time |
| 4.8 | 525.3 | -3.6 | 699.7 |



| Curve Description | | | |
|----------------------------------|-------|-----------|-------|
| Test Vehicle CG Y Moving Average | | | |
| Plot No. | Type | SAE Class | Units |
| 006 | AVG | 180 | g |
| Max | Time | Min | Time |
| 4.1 | 532.4 | -3.1 | 701.3 |



| Curve Description | | | |
|----------------------------|-------|-----------|--------|
| Test Vehicle CG Y Velocity | | | |
| Plot No. | Type | SAE Class | Units |
| 007 | IN1 | 180 | m/sec |
| Max | Time | Min | Time |
| 0.8 | 567.9 | -7.7 | 1999.9 |

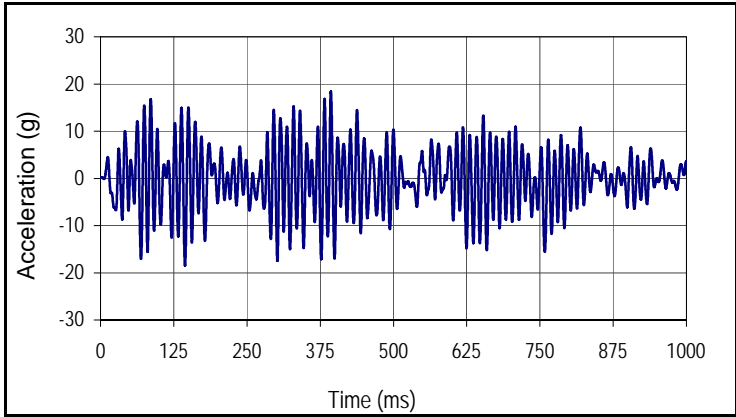


| Curve Description | | | |
|--------------------------------|------|-----------|--------|
| Test Vehicle CG Y Displacement | | | |
| Plot No. | Type | SAE Class | Units |
| 008 | IN2 | 180 | Meters |
| Max | Time | Min | Time |
| 0.0 | 81.0 | -4.5 | 1999.9 |

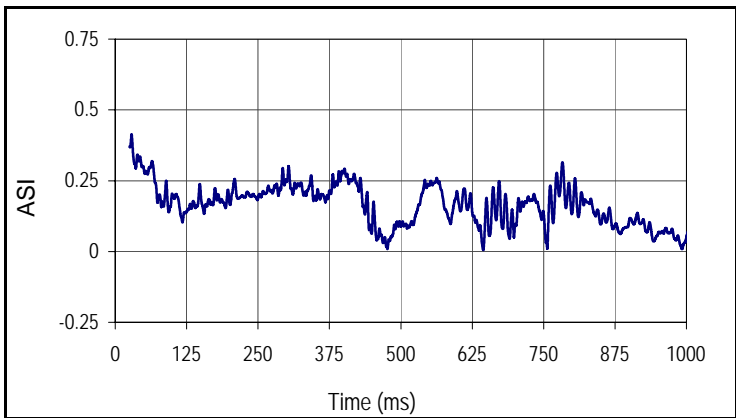
— Vehicle CG Y Displacement
 — Occupant Y Displacement

Test Article: SKT SP 350 50' (15.24 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

Project No: P36067-01
 Test Date.: 6/30/16



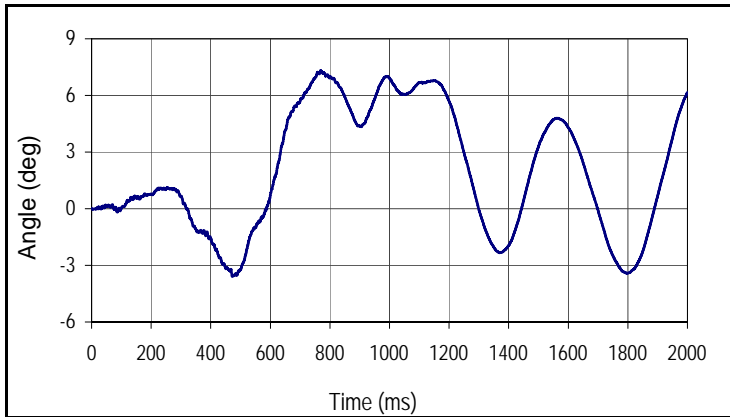
| Curve Description | | | |
|-------------------|-------|-----------|-------|
| Test Vehicle CG Z | | | |
| Plot No. | Type | SAE Class | Units |
| 009 | FIL | 60 | g |
| Max | Time | Min | Time |
| 18.4 | 393.2 | -18.5 | 144.3 |



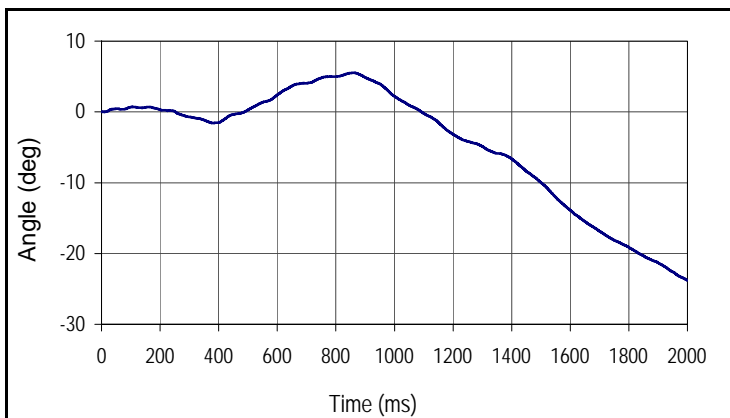
| Curve Description | | | |
|--------------------------------------|------|-----------|-------|
| Test Vehicle Accident Severity Index | | | |
| Plot No. | Type | SAE Class | Units |
| 010 | ASI | 180 | ASI |
| Max | Time | Min | Time |
| 0.4 | 28.7 | 0.0 | 644.2 |

Test Article: SKT SP 350 50' (15.24 m) System
 Test Program: 100 km/h 5° Guardrail Terminal Impact Test

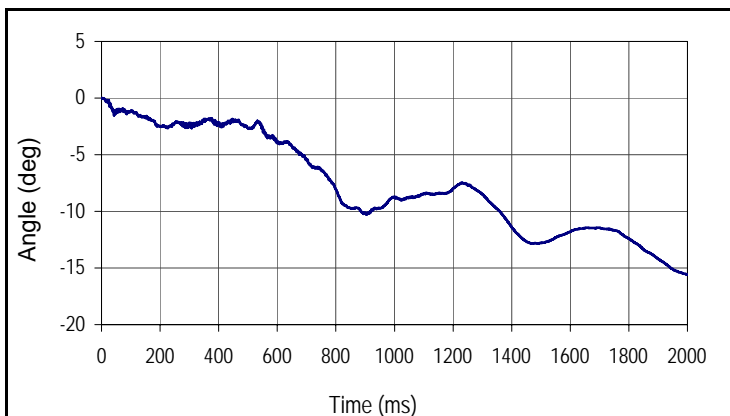
Project No: P36067-01
 Test Date.: 6/30/16



| Curve Description | | | |
|-------------------------|-------|-----------|---------|
| Test Vehicle Roll Angle | | | |
| Plot No. | Type | SAE Class | Units |
| 011 | IN1 | 180 | Degrees |
| Max | Time | Min | Time |
| 7.3 | 768.8 | -3.6 | 471.8 |



| Curve Description | | | |
|------------------------|-------|-----------|---------|
| Test Vehicle Yaw Angle | | | |
| Plot No. | Type | SAE Class | Units |
| 012 | IN1 | 180 | Degrees |
| Max | Time | Min | Time |
| 5.5 | 860.1 | -23.8 | 1999.9 |



| Curve Description | | | |
|--------------------------|------|-----------|---------|
| Test Vehicle Pitch Angle | | | |
| Plot No. | Type | SAE Class | Units |
| 013 | IN1 | 180 | Degrees |
| Max | Time | Min | Time |
| 0.0 | 0.4 | -15.6 | 1999.9 |

**APPENDIX C
INSTRUMENTATION**

DATA ACQUISITION INFORMATION

Test Article: SKT SP 350 50' (15.24 m) System Project No. P36067-01
Test Program: 100 km/h 5° Guardrail Terminal Impact Test Test Date: 06/30/16

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 |

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MANUFACTURER DOCUMENTS

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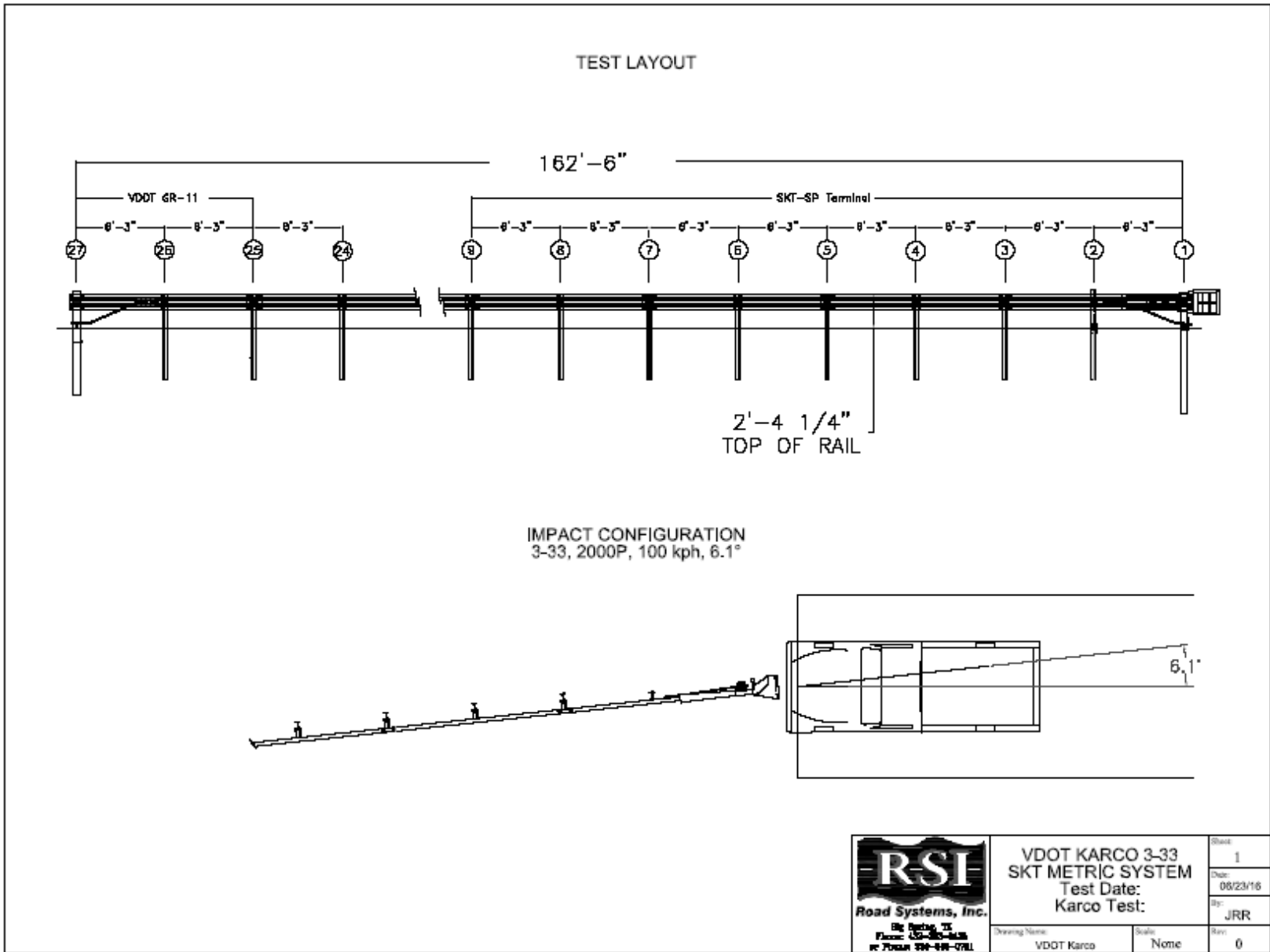


FIGURE 1. Manufacturer's Drawing

-30 ft -15 ft 0 ft 15 ft 30 ft 45 ft 60 ft 75 ft 90 ft 105 ft 120 ft 135 ft 150 ft 165 ft

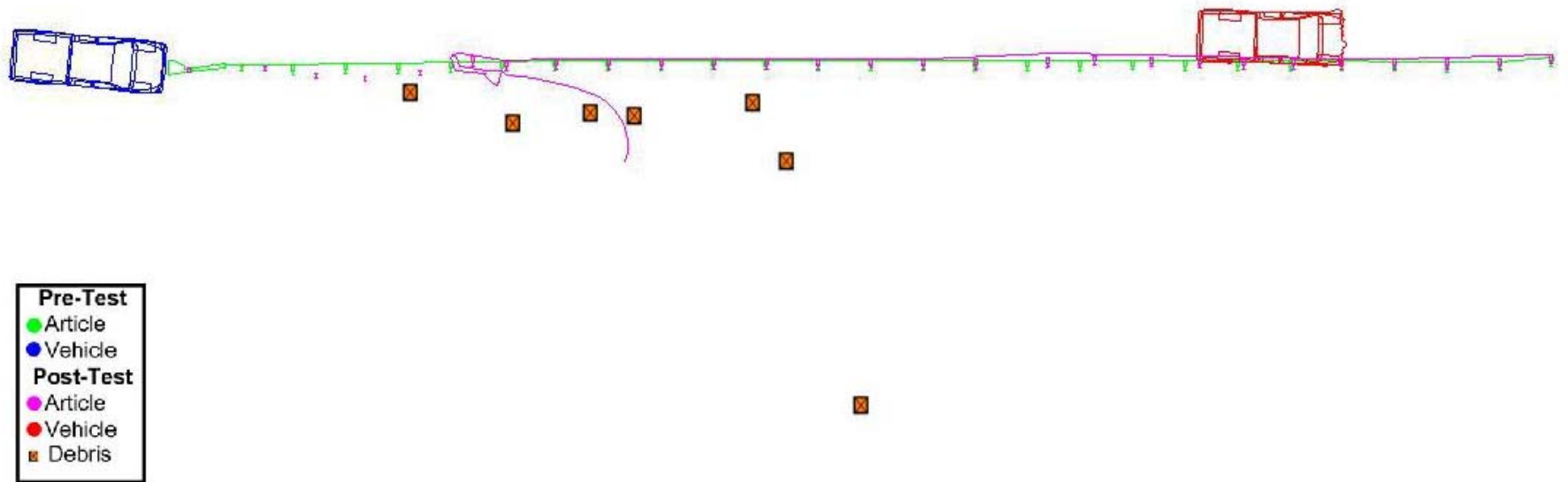


FIGURE 2. Overhead Illustration
FINAL PAGE OF REPORT