Mr. Bret R. Eckert  
Trinity Highway Products, LLC  
3617 Cincinnati Ave.  
Rocklin, CA 95765  
USA

Dear Mr. Eckert:

This letter is in response to your May 8, 2020 request for the Federal Highway Administration (FHWA) to review a roadside safety device, hardware, or system for eligibility for reimbursement under the Federal-aid highway program. This FHWA letter of eligibility is assigned FHWA control number CC-163 and is valid until a subsequent letter is issued by FHWA that expressly references this device.

Decision

The following device is eligible within the length-of-need, with details provided in the form which is attached as an integral part of this letter:

- QuadGuard M Wide

Scope of this Letter

To be found eligible for Federal-aid funding, new roadside safety devices should meet the crash test and evaluation criteria contained in the American Association of State Highway and Transportation Officials’ (AASHTO) Manual for Assessing Safety Hardware (MASH). However, the FHWA, the Department of Transportation, and the United States Government do not regulate the manufacture of roadside safety devices. Eligibility for reimbursement under the Federal-aid highway program does not establish approval, certification or endorsement of the device for any particular purpose or use.

This letter is not a determination by the FHWA, the Department of Transportation, or the United States Government that a vehicle crash involving the device will result in any particular outcome, nor is it a guarantee of the in-service performance of this device. Proper manufacturing, installation, and maintenance are required in order for this device to function as tested.

This finding of eligibility is limited to the crashworthiness of the system and does not cover other structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
Eligibility for Reimbursement

Based solely on a review of crash test results and certifications submitted by the manufacturer, and the crash test laboratory, FHWA agrees that the device described herein meets the crash test and evaluation criteria of the AASHTO’s MASH. Therefore, the device is eligible for reimbursement under the Federal-aid highway program if installed under the range of tested conditions.

- Name of system: QuadGuard M Wide
- Type of system: Crash Cushion
- Test Level: MASH Test Level 3 (TL3)
- Testing conducted by: Applus IDIADA KARCO Engineering, LLC.
- Date of request: May 08, 2020

FHWA concurs with the recommendation of the accredited crash testing laboratory on the attached form.

Full Description of the Eligible Device

The device and supporting documentation, including reports of the crash tests or other testing done, videos of any crash testing, and/or drawings of the device, are described in the attached form.

Notice

This eligibility letter is issued for the subject device as tested. Modifications made to the device are not covered by this letter. Any modifications to this device should be submitted to the user (i.e., state DOT) as per their requirements.

You are expected to supply potential users with sufficient information on design, installation and maintenance requirements to ensure proper performance.

You are expected to certify to potential users that the hardware furnished has the same chemistry, mechanical properties, and geometry as that submitted for review, and that it will meet the test and evaluation criteria of AASHTO’s MASH.

Issuance of this letter does not convey property rights of any sort or any exclusive privilege. This letter is based on the premise that information and reports submitted by you are accurate and correct. We reserve the right to modify or revoke this letter if: (1) there are any inaccuracies in the information submitted in support of your request for this letter, (2) the qualification testing was flawed, (3) in-service performance or other information reveals safety problems, (4) the system is significantly different from the version that was crash tested, or (5) any other information indicates that the letter was issued in error or otherwise does not reflect full and complete information about the crashworthiness of the system.
Standard Provisions

• To prevent misunderstanding by others, this letter of eligibility designated as FHWA control number CC-163 shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed upon request.

• This letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented system for which the applicant is not the patent holder.

• This FHWA eligibility letter is not an expression of any Agency view, position, or determination of validity, scope, or ownership of any intellectual property rights to a specific device or design. Further, this letter does not impute any distribution or licensing rights to the requester. This FHWA eligibility letter determination is made based solely on the crash-testing information submitted by the requester. The FHWA reserves the right to review and revoke an earlier eligibility determination after receipt of subsequent information related to crash testing.

Sincerely,

Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

Enclosures
Request for Federal Aid Reimbursement Eligibility of Highway Safety Hardware

Date of Request: May 08, 2020
Name: Bret R. Eckert, P.E.
Company: Trinity Highway Products, LLC
Address: 3617 Cincinnati Ave., Rocklin, CA 95765
Country: USA
To: Michael S. Griffith, Director
FHWA, Office of Safety Technologies

I request the following devices be considered eligible for reimbursement under the Federal-aid highway program.

**Device & Testing Criterion -** Enter from right to left starting with Test Level

<table>
<thead>
<tr>
<th>System Type</th>
<th>Submission Type</th>
<th>Device Name / Variant</th>
<th>Testing Criterion</th>
<th>Test Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC: Crash Cushions, Attenuators, &amp; Terminals</td>
<td>Physical Crash Testing</td>
<td>QuadGuard®M Wide</td>
<td>AASHTO MASH</td>
<td>TL3</td>
</tr>
<tr>
<td>CC: Crash Cushions, Attenuators, &amp; Terminals</td>
<td>Engineering Analysis</td>
<td>QuadGuard®M Wide</td>
<td>AASHTO MASH</td>
<td>TL3</td>
</tr>
</tbody>
</table>

By submitting this request for review and evaluation by the Federal Highway Administration, I certify that the product(s) was (were) tested in conformity with the AASHTO Manual for Assessing Safety Hardware and that the evaluation results meet the appropriate evaluation criteria in the MASH.

**Individual or Organization responsible for the product:**

Contact Name: Bret R. Eckert, P.E. Same asSubmitter
Company Name: Trinity Highway Products, LLC Same asSubmitter
Address: 3617 Cincinnati Ave., Rocklin, CA 95765 Same asSubmitter
Country: USA Same asSubmitter

Enter below all disclosures of financial interests as required by the FHWA `Federal-Aid Reimbursement Eligibility Process for Safety Hardware Devices’ document.

The QuadGuard®M Wide system technology is the commercial embodiment of intellectual property that is protected by patents owned by Trinity Highway Products, LLC (“THP”). THP does not pay royalties for sales of the QuadGuard®M Wide. The QuadGuard®M Wide system was designed and developed by engineers and employees at THP. The patent holders of record for the QuadGuard®M Wide system are Sean Thompson, Aaron J. Cox, P.E. and Patrick A. Leonhardt, P.E.; all of whom are employed by THP. The associated United States patents, numbers 8,469,626 (Dated June 25, 2013) and 9,790,653 (Dated October 17, 2017), are assigned to Energy Absorption Systems, Inc., a fully owned subsidiary of THP.

Applus IDIADA Karco Engineering, LLC (KARCO) conducted the certification tests of the QuadGuard®M Wide system. KARCO is an internationally accredited third party crash testing laboratory. Physical crash testing of the QuadGuard®M Wide system was performed in accordance with testing criteria, as set forth in the Manual for Assessing Safety Hardware (“MASH”) (2016). Other than fees paid to KARCO to conduct the tests, then analyze and report the test results, KARCO and THP do not share financial interests. The fees paid to KARCO were not dependent or contingent on the results of the tests.
PRODUCT DESCRIPTION

New Hardware or Modification to Existing Hardware

The QuadGuard®M Wide system is a redirective, non-gating, 6-bay crash cushion that consists of an engineered steel nose and crushable, energy absorbing cartridges surrounded by a framework of steel Quad-Beam™ panels. The QuadGuard®M Wide system is designed to telescope rearward during head-on impacts and redirects vehicles during angled impacts into the side of the system. The system has a center monorail that controls the rearward telescoping action and resists lateral movement during side angled impacts. The QuadGuard®M Wide system includes a self-contained back-up structure that is designed to resist movement during head-on impacts.

The QuadGuard®M Wide system has an overall length of 22'-0". The QuadGuard®M Wide system is configured with a back-up to shield fixed objects up to 69" wide. The overall height of the QuadGuard®M Wide is 32". The system uses a flared design – the nose is 30" wide, with the system width increasing to an overall width of 79" at the backup. The structural portions of the QuadGuard®M Wide consist of fender panels, diaphragm assemblies, a monorail assembly and a self-contained backup, which are hot-dipped galvanized steel. The majority of the system components are ASTMA36 steel, with the exception of the Quad-Beam™ panel material, which is composed of grade 55 steel. The QuadGuard®M Wide system utilizes two types of energy absorbing cartridges, Type M-I and Type M-II (also known as Type-1 and Type-2). The cartridges are arranged in a staged configuration to accommodate impacts by MASH2016 TL-3 vehicles.

The QuadGuard®M Wide may be placed on reinforced or non-reinforced concrete pads or foundations or asphalt substrates with specific length anchors and approved adhesive. A lightweight, aluminum placard with user-specified reflective sheeting may be attached to the steel nose panel. The reflective placard may be any color and striped with any reflective or non-reflective tape of any color, depending on customer requirements. The galvanized steel components may be stained with reactive color treatments or powder coated depending on customer specifications. During MASH Test 3-37, the QuadGuard®M Wide was tested with a transition to standard safety-shape concrete barrier, which is representative of typical concrete barrier in use on the NHS. The QuadGuard®M Wide is available with transitions to concrete barrier, guardrail, and other roadside hardware.

CRASH TESTING

By signature below, the Engineer affiliated with the testing laboratory, agrees in support of this submission that all of the critical and relevant crash tests for this device listed above were conducted to meet the MASH test criteria. The Engineer has determined that no other crash tests are necessary to determine the device meets the MASH criteria.

Engineer Name: Steven Matsusaka
Engineer Signature: [Signature]
Address: 9270 Holly Road, Adelanto, CA 92301
Country: USA
A brief description of each crash test and its result.

Help
<table>
<thead>
<tr>
<th>Required Test Number</th>
<th>Narrative Description</th>
<th>Evaluation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-30 (1100C)</td>
<td>Applus IDIADA KARCO Test No. P39149-01. Test Date May 10, 2019. Crash Test Report No. TR-P39149-01-NC for MASH Test 3-30 Crash Test of Trinity Highway Products TL-3 QuadGuard®M Wide. The crash cushion was impacted by a 2010 Kia Rio 4-door sedan. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 62.17 mph (100.06 km/h) and at an angle of 1.1°. Upon impact the vehicle's kinetic energy was absorbed by the system as the QuadGuard® cartridges were crushed. The TL-3 QuadGuard®M Wide brought the vehicle to a complete stop with a maximum Occupant Impact Velocity (OIV) of 36.1 ft/s (11.0 m/s) and a maximum ridedown acceleration of -12.9 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment. The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-30.</td>
<td>PASS</td>
</tr>
<tr>
<td>3-31 (2270P)</td>
<td>Applus IDIADA KARCO Test No. P39150-01. Test Date May 24, 2019. Crash Test Report No. TR-P39150-01-NC for MASH Test 3-31 Crash Test of Trinity Highway Products TL-3 QuadGuard®M Wide. The crash cushion was impacted by a 2013 RAM 1500 4-door pickup truck. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 62.42 mph (100.45 km/h) and at an angle of 0.9°. Upon impact the vehicle's kinetic energy was absorbed by the system as the QuadGuard® cartridges were crushed. The TL-3 QuadGuard®M Wide brought the vehicle to a complete stop with a maximum Occupant Impact Velocity (OIV) of 28.2 ft/s (8.6 m/s) and a maximum ridedown acceleration of -14.5 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment. The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-31.</td>
<td>PASS</td>
</tr>
<tr>
<td>Required Test Number</td>
<td>Narrative Description</td>
<td>Evaluation Results</td>
</tr>
<tr>
<td>----------------------</td>
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</tr>
<tr>
<td>3-32 (1100C)</td>
<td>Applus IDIADA KARCO Test No. P39151-02. Test Date May 31, 2019. Crash Test Report No. TR-P39151-02-NC for MASH Test 3-32 Crash Test of Trinity Highway Products TL-3 QuadGuard®M Wide. The crash cushion was impacted by a 2008 Kia Rio 4-door sedan. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 61.70 mph (99.30 km/h) and at an angle of 14.2°. Upon impact the vehicle's kinetic energy was absorbed by the system as the QuadGuard® cartridges were crushed. The TL-3 QuadGuard®M Wide brought the vehicle to a complete stop with a maximum Occupant Impact Velocity (OIV) of 38.4 ft/s (11.7 m/s) and a maximum ridedown acceleration of -13.4 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment. The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-32.</td>
<td>PASS</td>
</tr>
<tr>
<td>3-33 (2270P)</td>
<td>Applus IDIADA KARCO Test No. P39152-01. Test Date May 7, 2019. Crash Test Report No. TR-P39152-01-NC for MASH Test 3-33 Crash Test of Trinity Highway Products TL-3 QuadGuard®M Wide. The crash cushion was impacted by a 2013 RAM 1500 4-door pickup truck. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 62.27 mph (100.22 km/h) and at an angle of 15.5°. Upon impact the vehicle's kinetic energy was absorbed by the system as the QuadGuard® cartridges were crushed. The TL-3 QuadGuard®M Wide brought the vehicle to a complete stop with a maximum Occupant Impact Velocity (OIV) of 30.8 ft/s (9.4 m/s) and a maximum ridedown acceleration of -13.9 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment. The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-33.</td>
<td>PASS</td>
</tr>
</tbody>
</table>

The crash cushion was impacted by a 2010 Kia Rio 4-door sedan. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 62.94 mph (101.30 km/h) and at an angle of 14.5°. The TL-3 QuadGuard®M Wide contained and redirected the test vehicle with a maximum Occupant Impact Velocity (OIV) of 23.0 ft/s (7.0 m/s) and a maximum ridedown acceleration of -10.1 g. Damage to the vehicle was concentrated at its front right quarter without penetration or significant deformation into the occupant compartment.

The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-34.

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3-34 (1100C) PASS


The crash cushion was impacted by a 2013 RAM 1500 4-door pickup truck. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 61.21 mph (98.50 km/h) and at an angle of 23.7°. The TL-3 QuadGuard®M Wide contained and redirected the test vehicle with a maximum Occupant Impact Velocity (OIV) of 27.2 ft/s (8.3 m/s) and a maximum ridedown acceleration of -11.2 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment.

The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-35.

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3-35 (2270P) PASS


The crash cushion was impacted by a 2013 RAM 1500 4-door pickup truck. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 61.21 mph (98.50 km/h) and at an angle of 23.7°. The TL-3 QuadGuard®M Wide contained and redirected the test vehicle with a maximum Occupant Impact Velocity (OIV) of 27.2 ft/s (8.3 m/s) and a maximum ridedown acceleration of -11.2 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment.

The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-36.
### Test 3-36 (2270P)

**Applus IDIADA KARCO Test No. P39155-02.** Test Date September 23, 2019. Crash Test Report No. TR-P39155-02-NC for MASH Test 3-36 Crash Test of Trinity Highway Products TL-3 QuadGuard®M Wide.

The crash cushion was impacted by a 2014 RAM 1500 4-door pickup truck. The test vehicle impacted the TL-3 QuadGuard®M Wide at a velocity of 61.53 mph (99.03 km/h) and at an impact angle of 24.5°. The TL-3 QuadGuard®M Wide contained and redirected the test vehicle with a maximum Occupant Impact Velocity (OIV) of 26.9 ft/s (8.2 m/s) and a maximum ridedown acceleration of -12.9 g. Damage to the vehicle was concentrated at its front right quarter without penetration or significant deformation into the occupant compartment.

The Trinity Highway Products TL-3 QuadGuard®M Wide met all the requirements for MASH 2016 Test 3-36. **PASS**

### Test 3-37 (2270P)

**Applus IDIADA KARCO Test No. P40055-01.** Test Date February 13, 2020. Crash Test Report No. TR-P40055-01-NC for MASH Test 3-37a Crash Test of Trinity Highway Products QuadGuard®M Wide Transition to Safety Shape Concrete Median Barrier.

The transition was impacted by a 2016 RAM 1500 4-door pickup truck. The test vehicle impacted the QuadGuard®M Wide Transition at a velocity of 62.85 mph (101.14 km/h) and at an impact angle of 25.2°. The transition contained and redirected the test vehicle with a maximum Occupant Impact Velocity (OIV) of 28.9 ft/s (8.8 m/s) and a maximum ridedown acceleration of -17.5 g. Damage to the vehicle was concentrated at its front end without penetration or significant deformation into the occupant compartment.

The Trinity Highway Products QuadGuard®M Transition to Safety Shape Concrete Median Barrier met all the requirements for MASH 2016 Test 3-37a. **PASS**

### Test 3-38 (1500A)

Per MASH, Test 3-38 can be waived by performing a force versus deflection analysis from Test 3-31 data to find a theoretical value for occupant risk factors. This analysis was performed and yielded satisfactory results. **Non-Critical, not conducted**

### Test 3-40 (1100C)

Per MASH, this test intended for non-redirective crash cushions. **Non-Relevant Test, not conducted**
Full Scale Crash Testing was done in compliance with MASH by the following accredited crash test laboratory (cite the laboratory’s accreditation status as noted in the crash test reports):

**Laboratory Name:** KARCOEngineering, INC

**Laboratory Signature:** Steven Matsusaka

**Address:** 9270 Holly Road, Adelanto, CA 92301

**Country:** USA

**Accreditation Certificate Number and Dates of current Accreditation period:** International Accreditation Services (IAS) ISO 17025 Accreditation Certificate #TL-371 Expires July 1, 2022

**Submitter Signature:** Bret Eckert, P.E.

**Eligibility Letter**

1. Additional disclosures of related financial interest as indicated above.
2. A copy of the full test report, video, and a Test Data Summary Sheet for each test conducted in support of this request.
3. A drawing or drawings of the device(s) that conform to the Task Force-13 Drawing Specifications [Hardware Guide Drawing Standards]. For proprietary products, a single isometric line drawing is usually acceptable to illustrate the product, with detailed specifications, intended use, and contact information provided on the reverse. Additional drawings (not in TF-13 format) showing details that are relevant to understanding the dimensions and performance of the device should also be submitted to facilitate our review.

**FHWA Official Business Only:**

<table>
<thead>
<tr>
<th>Eligibility Letter</th>
<th>Number</th>
<th>Date</th>
<th>Key Words</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MASH 2016 Test 3-30 Summary

### General Information
- **Test Agency**: Applus IDIADA KARCO
- **Impact Velocity**: 62.17 mph (100.06 km/h)
- **Impact Angle**: 1.1°
- **Kinetic Energy**: 309.2 kip-ft (419.2 kJ)
- **Test Date**: 5/10/19
- **Test Designation**: 3-30
- **Impact Conditions**
  - Longitudinal OIV: 36.1 ft/s (11.1 m/s)
  - Lateral OIV: 1.6 ft/s (0.5 m/s)

### Test Article
- **Name / Model**: TL-3 QuadGuard M Wide
- **Exit Conditions**
  - Exit Velocity: N/A
  - Exit Angle: N/A
  - Final Vehicle Position: 12.2 ft. (3.7 m) Downstream
  - Exit Box Criteria Met: N/A
- **Test Article Deflections**
  - Static: 6.3 ft. (1.9 m)
  - Dynamic: 10.1 ft. (3.1 m)
- **Vehicle Snagging**: None
- **Working Width**: N/A
- **Debris Field**: N/A
- **Vehicle Snagging**: None
- **Vehicle Pocketing**: None
- **Vehicle Stability**: Satisfactory
- **Maximum Roll Angle**: -5.8°
- **Maximum Pitch Angle**: 11.1°
- **Maximum Yaw Angle**: -160.9°
- **Maximum Intrusion**: 0.4 in. (9 mm) at foot well

### Test Vehicle
- **Type / Designation**: 1100C
- **Year, Make, and Model**: 2010 Kia Rio
- **Curb Mass**: 2,354.5 lbs (1,068.0 kg)
- **Test Inertial Mass**: 2,393.1 lbs (1,085.5 kg)
- **Gross Static Mass**: 2,560.6 lbs (1,161.5 kg)
- **Vehicle Pocketing**: None
- **Vehicle Snagging**: None
- **Vehicle Stability**: Satisfactory
- **Maximum Roll Angle**: -5.8°
- **Maximum Pitch Angle**: 11.1°
- **Maximum Yaw Angle**: -160.9°
- **Maximum Intrusion**: 0.4 in. (9 mm) at foot well

### Occupant Risk
- **Longitudinal OIV**: 36.1 ft/s (11.0 m/s)
- **Lateral OIV**: 1.6 ft/s (0.5 m/s)
- **Longitudinal RA**: -12.9 g
- **Lateral RA**: 4.7 g
- **THIV**: 36.4 ft/s (11.1 m/s)
- **PHD**: 13.0 g
- **ASI**: 1.05

### Figure 2 Summary of Test 3-30
# MASH 2016 Test 3-31 Summary

## General Information

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<thead>
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## Impact Conditions

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<th>Impact Velocity</th>
<th>62.42 mph (100.45 km/h)</th>
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<tbody>
<tr>
<td>Location / Orientation</td>
<td>0.75 in. (19 mm) Left</td>
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<tr>
<td>Kinetic Energy</td>
<td>656.9 kip-ft (890.7 kJ)</td>
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</table>

## Exit Conditions

| Exit Velocity                | N/A                      |
| Exit Angle                   | N/A                      |
| Final Vehicle Position       | 24.5 ft. (7.5 m) Upstream|
| Exit Box Criteria Met        | N/A                      |
| Vehicle Snagging             | Satisfactory             |
| Vehicle Pocketing             | Satisfactory             |
| Vehicle Stability            | Satisfactory             |
| Maximum Roll Angle           | 5.3°                     |
| Maximum Pitch Angle          | -2.8°                    |
| Maximum Yaw Angle            | 2.3°                     |

## Test Article

| Name / Model                | TL-3 QuadGuard M Wide   |
| Type                         | Crash cushion           |
| Crash Cushion Length        | 22.0 ft. (6.7 m)        |
| Road Surface                | Smooth, clean concrete  |

## Test Vehicle

| Type / Designation           | 2270P                   |
| Year, Make, and Model.       | 2013 RAM 1500           |
| Curb Mass                    | 5,199.5 lbs (2,358.5 kg) |
| Test Inertial Mass           | 5,038.6 lbs (2,285.5 kg) |
| Gross Static Mass            | 5,038.6 lbs (2,285.5 kg) |

## Occupant Risk

| Longitudinal OIV            | 28.2 ft/s (8.6 m/s)   |
| Lateral OIV                 | 1.0 ft/s (-0.3 m/s)   |
| Longitudinal RA             | 14.5 g                |
| Lateral RA                  | 4.6 g                 |
| THIV                        | 28.2 ft/s (8.6 m/s)   |
| PHD                         | 14.7 g                |
| ASI                         | 1.16                  |

## Test Article Deflections

| Static                      | 13.1 ft. (4.0 m)       |
| Dynamic                     | 15.4 ft. (4.7 m)       |
| Working Width               | N/A                    |
| Debris Field                | N/A                    |

## Vehicle Damage

| Vehicle Damage Scale        | 12-FD-3                |
| CDC                         | 12FDEW3                |
| Maximum Intrusion           | 0.2 in. (6 mm) at foot well |
MASH 2016 Test 3-32 Summary

Figure 2 Summary of Test 3-32

<table>
<thead>
<tr>
<th>General Information</th>
<th>Impact Conditions</th>
<th>Occupant Risk</th>
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<tbody>
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<td>Longitudinal OIV…………….</td>
</tr>
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<td>Test Date………….</td>
<td>Location / Orientation…………….</td>
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<td>THIV…………………………………</td>
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<tr>
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<td>38.4 ft/s (11.7 m/s)</td>
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<td>PHD…………………………………</td>
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<td>Road Surface…………….</td>
<td>7.4 ft. (2.3 m) Downstream</td>
<td>9.5 ft. (2.9 m)</td>
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<td>Test Vehicle</td>
<td>24.9 ft. (7.6 m) Left</td>
<td>Working Width…………….</td>
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<td>Type / Designation………….</td>
<td>Exit Box Criteria Met…………….</td>
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<td>Year, Make, and Model……..</td>
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<tr>
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<td>Vehicle Snagging…………………….</td>
<td>N/A</td>
</tr>
<tr>
<td>Test Inertial Mass………….</td>
<td>Vehicle Pocketing……………………..</td>
<td>Vehicle Damage</td>
</tr>
<tr>
<td>Gross Static Mass…………..</td>
<td>Vehicle Stability…………………….</td>
<td>Vehicle Damage Scale…………….</td>
</tr>
<tr>
<td></td>
<td>Maximum Roll Angle…………………….</td>
<td>11-FD-3</td>
</tr>
<tr>
<td></td>
<td>Maximum Pitch Angle…………………….</td>
<td>CDC……………………………….</td>
</tr>
<tr>
<td></td>
<td>Maximum Yaw Angle…………………….</td>
<td>11FDEW2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum Intrusion…………….</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4 in. (10 mm) at Foot well</td>
</tr>
</tbody>
</table>

Gross Static Mass………….. 2,563.9 lbs (1,163.0 kg)
### MASH 2016 Test 3-33 Summary

**GENERAL INFORMATION**
- **Test Agency:** Applus IDIADA KARCO
- **Test No.:** P39152-01
- **Test Designation:** 3-33
- **Test Date:** 5/7/19

**TEST ARTICLE**
- **Name / Model:** TL-3 QuadGuard M Wide
- **Type:** Crash cushion
- **Crash Cushion Length:** 22.0 ft. (6.7 m)
- **Road Surface:** Smooth, clean concrete

**TEST VEHICLE**
- **Type / Designation:** 2270P
- **Year, Make, and Model:** 2013 RAM 1500
- **Curb Mass:** 4,822.5 lbs (2,187.5 kg)
- **Test Inertial Mass:** 4,941.6 lbs (2,241.5 kg)
- **Gross Static Mass:** 4,941.6 lbs (2,241.5 kg)

**Impact Conditions**
- **Impact Velocity:** 62.27 mph (100.22 km/h)
- **Impact Angle:** 15.5°
- **Location / Orientation:** at article centerline
- **Kinetic Energy:** 640.5 kip-ft (868.5 kJ)

**Exit Conditions**
- **Exit Velocity:** N/A
- **Final Vehicle Position:** 9.4 ft. (2.9 m) Downstream
- **Exit Box Criteria Met:** N/A
- **Exit Angle:** N/A
- **34.2 ft. (9.9 m) Left
- **Vehicle Pocketing:** Satisfactory
- **Vehicle Snagging:** Satisfactory
- **Vehicle Stability:** Satisfactory
- **Vehicle Damage:** CDC: 12FDEW2

**Vehicle Damage Scale:** 12-FD-3

**Test Article Deflections**
- **Static:** 10.5 ft. (3.2 m)
- **Dynamic:** 13.4 ft. (4.1 m)

**Vehicle Damage**
- **Vehicle Damage Scale:** 12-FD-3
- **CDC:** 12FDEW2

**Occupant Risk**
- **Longitudinal OIV:** 30.8 ft/s (9.4 m/s)
- **Lateral OIV:** -4.6 ft/s (-1.4 m/s)
- **Longitudinal RA:** -13.9 g
- **Lateral RA:** -2.0 g
- **THIV:** 30.8 ft/s (9.4 m/s)
- **PHD:** 13.9 g
- **ASI:** 1.03

**Vehicle Snagging**
- Satisfactory

**Debris Field**
- N/A

**Gross Static Mass**
- 4,941.6 lbs (2,241.5 kg)

**Maximum Intrusion**
- 0.2 in. (5 mm) at foot well

---

**Figure 2 Summary of Test 3-33**
MASH 2016 Test 3-34 Summary

Test Agency............ Applus IDIADA KARCO
Test No.............. P39153-01
Test Designation....... 3-34
Test Date............. 10/3/19

General Information

Impact Conditions
Impact Velocity........... 62.94 mph (101.30 km/h)
Impact Angle.............. 14.5°
Location / Orientation...... 2.2 in. (56 mm) downstream of CIP
Impact Severity........... 20.2 kip-ft (27.4 kJ)

Exit Conditions
Exit Velocity............. 50.32 mph (80.98 km/h)
Exit Angle.............. 11.4°
Final Vehicle Position.... 129.9 ft. (39.6 m) downstream
28.4 ft. (8.7 m) left

Test Article

Name / Model............... TL-3 QuadGuard M Wide
Type............................ Crash Cushion
Crash Cushion Length...... 22.0 ft. (6.7 m)
Road Surface.............. Smooth, clean concrete

Test Vehicle

Type / Designation.......... 1100C
Year, Make, and Model.... 2010 Kia Rio
Curb Mass.................... 2,354.5 lbs (1,068.0 kg)
Test Inertial Mass.......... 2,432.8 lbs (1,103.5 kg)
Gross Static Mass.......... 2,580.5 lbs (1,170.5 kg)

Vehicle Pocketing......... None
Vehicle Snagging.......... None
Vehicle Stability.......... Satisfactory
Maximum Roll Angle........ 9.8°
Maximum Pitch Angle....... -6.9°
Maximum Yaw Angle......... 32.0°

Occupant Risk
Longitudinal OIV........... 23.0 ft/s (7.0 m/s)
Lateral OIV.................. 22.6 ft/s (6.9 m/s)
Longitudinal RA............ -5.1 g
Lateral RA.................. -10.1 g
THIV.................... 34.4 ft/s (10.5 m/s)
PHD............................ 9.4 g
ASI.............................. 1.73

Test Article Deflections
Static..................... 2.6 in. (65.0 mm)
Dynamic................... 7.3 in. (185.0 mm)
Working Width.............. N/A
Debris Field................. N/A

Vehicle Damage
Vehicle Damage Scale..... 01-RFQ-4
CDC........................... 01FYEK1 and 01RDES1
Maximum Intrusion.......... 0.3 in. (8 mm) at floor pan
MASH 2016 Test 3-35 Summary

### General Information
- **Test Agency**: Applus IDIADA KARCO
- **Test No.**: P39154-04
- **Test Designation**: 3-35
- **Test Date**: 8/9/19

### Impact Conditions
- **Impact Velocity**: 61.21 mph (98.50 km/h)
- **Location / Orientation**: 1.0 in. downstream of CIP
- **Kinetic Energy**: 101.4 kip-ft (137.5 kJ)

### Test Article
- **Name / Model**: TL-3 QuadGuard M Wide

### Test Vehicle
- **Type / Designation**: 2270P
- **Year, Make, and Model**: 2013 RAM 1500
- **Curb Mass**: 4,986.8 lbs (2,262.0 kg)
- **Test Inertial Mass**: 5,013.2 lbs (2,274.0 kg)
- **Gross Static Mass**: 5,013.2 lbs (2,274.0 kg)

### Exit Conditions
- **Exit Velocity**: 36.80 mph (59.22 km/h)
- **Final Vehicle Position**: 74.4 ft. (22.7 m) Downstream

### Exit Box Criteria Met
- **Yes
- **Vehicle Snagging**: None

### Vehicle Stability
- **Satisfactory
- **Maximum Roll Angle**: -31.2 °
- **Maximum Pitch Angle**: -46.1 °
- **Maximum Yaw Angle**: -47.6 °

### Vehicle Pocketing
- **None
- **Debris Field**: N/A

### Occupant Risk
- **Longitudinal OIV**: -19.7 ft/s (-6.0 m/s)
- **Lateral OIV**: 7.4 g
- **THIV**: 36.7 ft/s (11.2 m/s)

### Vehicle Damage
- **Vehicle Damage Scale**: 11-LFQ-3
- **CDC**: 11FDEK2 and 11LYES2
- **Maximum Intrusion**: 6.4 in. (163 mm) at foot well

---

Figure 2 Summary of Test 3-35
MASH 2016 Test 3-36 Summary

General Information
Test Agency: Applus IDIADA KARCO
Test No.: P39155-02
Test Designation: 3-36
Test Date: 9/23/19

Test Article
Name / Model: TL-3 QuadGuard M Wide
Type: Crash Cushion
Crash Cushion Length: 22.0 ft. (6.7 m)
Road Surface: Smooth, clean concrete

Test Vehicle
Type / Designation: 2270P
Year, Make, and Model: 2014 RAM 1500
Curb Mass: 4,818.1 lbs (2,185.5 kg)
Test Inertial Mass: 5,016.5 lbs (2,275.5 kg)
Gross Static Mass: 5,016.5 lbs (2,275.5 kg)

Impact Conditions
Impact Velocity: 61.53 mph (99.03 km/h)
Impact Angle: 24.5°
Location / Orientation: 1.7 in. upstream of CIP
Impact Severity: 109.2 kip-ft (148.0 kJ)

Exit Conditions
Exit Velocity: 43.62 mph (70.20 km/h)
Exit Angle: 10.0°
Final Vehicle Position: 38.9 ft. (11.9 m) downstream, 38.1 ft. (11.6 m) left
Exit Box Criteria Met: Yes
Vehicle Snagging: None
Vehicle Pocketing: None
Vehicle Stability: Satisfactory
Maximum Roll Angle: 17.2°
Maximum Pitch Angle: -12.8°
Maximum Yaw Angle: 44.6°

Occupant Risk
Longitudinal OIV: 26.9 ft/s (8.2 m/s)
Lateral OIV: 24.3 ft/s (7.4 m/s)
Longitudinal RA: -12.9 g
Lateral RA: -12.1 g
THIV: 39.7 ft/s (12.1 m/s)
PHD: 14.9 g
ASI: 1.61

Test Article Deflections
Static: 0.6 ft. (0.2 m)
Dynamic: 1.0 ft. (0.3 m)
Working Width: 6.4 ft. (2.0 m)
Debris Field: N/A

Vehicle Damage
Curb Mass: 4,818.1 lbs (2,185.5 kg)
Test Inertial Mass: 5,016.5 lbs (2,275.5 kg)
Gross Static Mass: 5,016.5 lbs (2,275.5 kg)

Vehicle Damage Scale: 01-RFO-4
CDC: 01FDEK2 and 01RYES2
Maximum Intrusion: 5.0 in. (127 mm) at toe pan

Figure 2 Summary of Test 3-36
MASH 2016 Test 3-37a Summary

General Information
Test Agency: Applus IDIADA KARCO
Test No: P40055-01
Test Designation: 3-37a
Test Date: 02/13/20

Test Article
Name / Model: TL-3 QuadGuard M Wide Transition to Safety Shape Concrete Median Barrier
Type: Crash Cushion
Installation Length: 29.7 ft. (9 m)
Road Surface: Smooth, clean concrete

Test Vehicle
Type / Designation: 2270P
Year, Make, and Model: 2016 RAM 1500
Curb: 5,097.0 lbs (2,312.0 kg)
Test Inertial: 5,018.7 lbs (2,276.5 kg)
Gross Static: 5,018.7 lbs (2,276.5 kg)

Impact Conditions
Impact Velocity: 62.85 mph (101.14 km/h)
Impact Angle: 25.2°
Location / Orientation: at intended impact point
Impact Severity: 120.1 kip-ft (162.9 kJ)

Exit Conditions
Exit Velocity: 50.16 mph (80.72 km/h)
Exit Angle: 7.1°
Final Vehicle Position: 120.0 ft. (36.6 m)
Exit Box Criteria Met: Yes
Vehicle Snagging: None
Vehicle Pocketing: None
Vehicle Stability: Satisfactory
Maximum Roll Angle: 31.8°
Maximum Pitch Angle: -30.2°
Maximum Yaw Angle: 49.5°

Occupant Risk
Longitudinal OIV: 23.0 ft/s (7.0 m/s)
Lateral OIV: 28.9 ft/s (8.8 m/s)
Longitudinal RA: -4.9 g
Lateral RA: -17.5 g
THIV: 37.7 ft/s (11.5 m/s)
PHD: 17.5 g
ASI: 1.93

Test Article Deflections
Static: 1.3 in. (32.0 mm)
Dynamic: 1.8 in. (46.0 mm)
Working Width: N/A
Debris Field: N/A

Vehicle Damage
Vehicle Damage Scale: 01-RFQ-4
CDC: 01FDEK2 and 01RDAS2
Maximum Intrusion: 8.6 in. (218 mm) at toepan

Figure 2 Summary of Test 3-37a
QUADGUARD® M WIDE TL-3 (69) SYSTEM

TENSION STRUT
BACKUP

NOMINAL SYSTEM
WIDTH 69 [1753]

264 [6746] SYSTEM LENGTH

DIAPHRAGMS

FENDER PANELS

MONORAIL

STEEL NOSE

2020
INTENDED USE
The QuadGuard® M Wide System is a member of the QuadGuard® Family designed to shield wider hazards. The QuadGuard® M Wide offers impact protection for both light and heavy vehicles. The system is perfect for gore areas, bifurcations and wide hazards such as bridge piers and tollbooths. It is effective against head-on and angle hits at typical highway speeds.

FEATURES
When hit head-on, a series of cartridges, placed between QuadBeam diaphragms and surrounded by telescoping fender panels, are crushed. This action absorbs the kinetic energy from the impacting vehicle, bringing the vehicle to a controlled stop. Hit along the side at an angle, the system redirects the vehicle away from the hazard. The QuadGuard® M Wide System is approved as a MASH, Test Level 3 matrix with both the light car and high center-of-gravity pickup truck at speeds up to 62 mph [100 km/h] at angles up to 25 degrees. Only the cartridges and nose assembly are expended during a design speed head-on crash. Two types of cartridges are required, permitting convenient stocking of these easily replaceable elements. The QuadGuard® M Wide System is available for head-on design speeds up to 62 mph [100km/h], for hazards up to 69" in width.

SPECIFICATIONS
Length: 264 [6706] (6 bay)
Height: 32 [815]
Weight: 2985 lb [1354 kg]

ELIGIBILITY
The QuadGuard® M Wide has been fully tested in conformance to MASH 2016 Test Level 3 and is determined for federal reimbursement by FHWA.

FHWA Eligibility Letter(s): CC-#### dated XX/XX/XXXX for MASH 2016 Test Level 3.

REFERENCES
Manual for Assessing Safety Hardware (MASH), American Association of State Highway and Transportation Officials (AASHTO), 2016.