December 1, 2020

U.S. Department of Transportation
Federal Highway Administration

1200 New Jersey Ave., SE
Washington, D.C. 20590

In Reply Refer To:
HSST-1/CC-163

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

Submitter	Date of Request:	May 08, 2020	◉ New ○ Resubmission
	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 L ! - ! - !

System Type	Submission Type	Device Name / Variant	Testing Criterion	Test Level
'CC': Crash Cushions, Attenua Attenuators, & Terminals	◉ Physical Crash Testing ○ Engineering Analysis	QuadGuard®M Wide	AASHTO MASH	TL3

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, asset forth by the American Association of State Highway and Transportation Officials (AASHTO) in the Manual for Assessing Safety Hardware ("MASH") (2016). Other than fees paid to KARCO to conduct the tests and 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

Help

(●) New Hardware or Significant Modification ( ) 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 ASTM A36 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 MASH 2016 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:	Steven Matsusaka DN: cn=Steven Matsusaka, email=steven.matsusaka@idiada.com, c=US Digitally signed by Steven Matsusaka Date: 2020.04.24 08:43:09 -07'00'	
Address:	9270 Holly Road, Adelanto, CA 92301	Same as Submitter ☐
Country:	USA	Same as Submitter ☒

A brief description of each crash test and its result:

Help

Required Test Number	Narrative Description	Evaluation Results
3-30 (1100C)	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 KiaRio 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.	PASS
3-31 (2270P)	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.	PASS

Required Test Number	Narrative Description	Evaluation Results
3-32 (1100C)	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 KiaRio 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.	PASS
3-33 (2270P)	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.	PASS

3-34 (1100C)	Applus IDIADA KARCO Test No. P39153-01. Test Date October 3, 2019. Crash Test Report No. TR-P39153-01-NC for MASH Test 3-34 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 62.94 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.	PASS
3-35 (2270P)	Applus IDIADA KARCO Test No. P39154-04. Test Date August 9, 2019. Crash Test Report No. TR-P39154-04-NC for MASH Test 3-35 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 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.	PASS

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
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
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
3-40 (1100C)	Per MASH, this test intended for non-redirective crash cushions.	Non-Relevant Test, not conducted

3-41 (2270P)	Per MASH, this test intended for non-redirective crash cushions.	Non-Relevant Test, not conducted
3-42 (1100C)	Per MASH, this test intended for non-redirective crash cushions.	Non-Relevant Test, not conducted
3-43 (2270P)	Per MASH, this test intended for non-redirective crash cushions.	Non-Relevant Test, not conducted
3-44 (2270P)	Per MASH, this test intended for non-redirective crash cushions.	Non-Relevant Test, not conducted
3-45 (1500A)	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 DN: cn=Steven Matsusaka, email=steven.matsusaka@idiada.com, c=US Digitally signed by Steven Matsusaka Date: 2020.04.24 08:43:27 -07'00'	
Address:	9270 Holly Road, Adelanto, CA 92301	Same as Submitter ☐
Country:	USA	Same as Submitter ☒
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. Digitally signed by Bret Eckert, P.E. DN: cn=Bret Eckert P.E., o=Trinity Highway Products, email=bret.eckert@trin.net, c=US Date: 2020.04.27 10:40:29 -07'00'

Submit Form

ATTACHMENTS

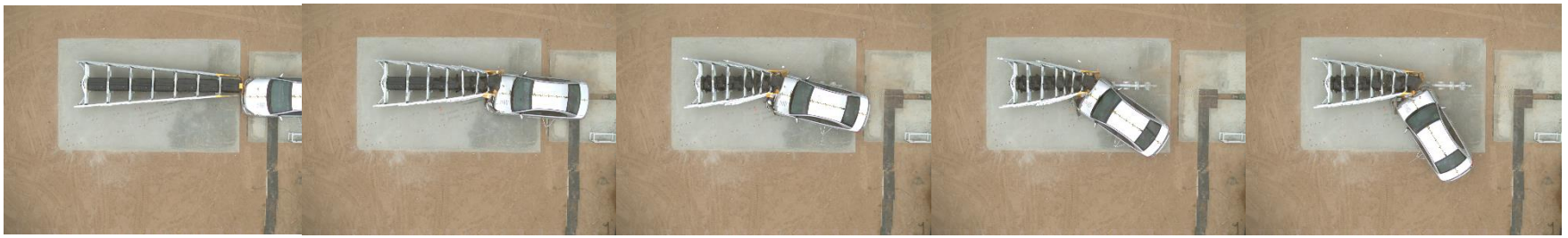
Attach to this form:

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:

Eligibility Letter		
Number	Date	Key Words

MASH 2016 Test 3-30 Summary



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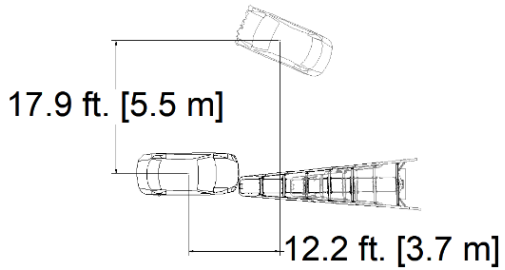

GENERAL INFORMATION

Test Agency	Applus IDIADA KARCO
Test No.	P39149-01
Test Designation	3-30
Test Date	5/10/19

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	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)

Impact Conditions

Impact Velocity	62.17 mph (100.06 km/h)
Impact Angle	1.1°
Location / Orientation	17.2 in (437 mm) to the left
Kinetic Energy	309.2 kip-ft (419.2 kJ)

Exit Conditions

Exit Velocity	N/A
Exit Angle	N/A
Final Vehicle Position	12.2 ft. (3.7 m) Downstream 17.9 ft. (5.5 m) Left
Exit Box Criteria Met	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 °

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

Test Article Deflections

Static	6.3 ft. (1.9 m)
Dynamic	10.1 ft. (3.1 m)
Working Width	N/A
Debris Field	N/A

Vehicle Damage

Vehicle Damage Scale	12-FD-4
CDC	12FDEW1
Maximum Intrusion	0.4 in. (9 mm) at foot well

Figure 2 Summary of Test 3-30

MASH 2016 Test 3-31 Summary

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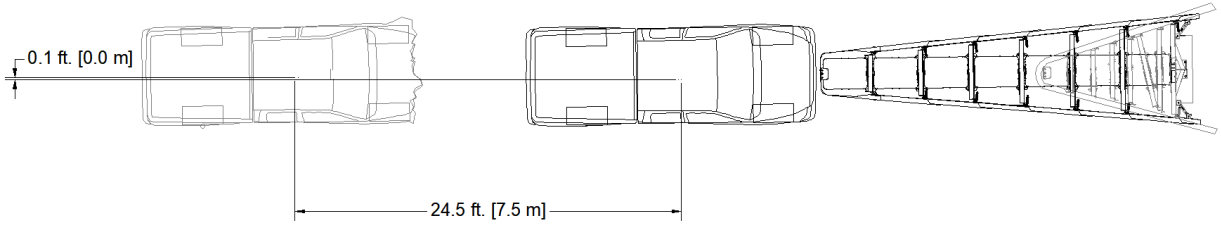

GENERAL INFORMATION

Test Agency	Applus IDIADA KARCO
Test No	P39150-01
Test Designation	3-31
Test Date	05/24/2019

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)

Impact Conditions

Impact Velocity	62.42 mph (100.45 km/h)
Impact Angle	0.9°
Location / Orientation	0.75 in. (19 mm) Left
Kinetic Energy	656.9 kip-ft (890.7 kJ)

Exit Conditions

Exit Velocity	N/A
Exit Angle	N/A
Final Vehicle Position	24.5 ft. (7.5 m) Upstream 0.1 ft. (0 m) Left
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 °

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

Figure 2 Summary of Test 3-31

MASH 2016 Test 3-32 Summary

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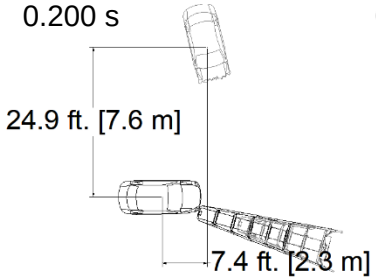


General Information	
Test Agency	Applus IDIADA KARCO
Test No	P39151-02
Test Designation	3-32
Test Date	5/31/19

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	1100C
Year, Make, and Model	2008 Kia Rio
Curb Mass	2,494.5 lbs (1,131.5 kg)
Test Inertial Mass	2,397.5 lbs (1,087.5 kg)
Gross Static Mass	2,563.9 lbs (1,163.0 kg)

Impact Conditions	
Impact Velocity	61.70 mph (99.30 km/h)
Impact Angle	14.2°
Location / Orientation	0.36 in (9 mm) left of centerline
Kinetic Energy	305.1 kip-ft (413.7 kJ)

Exit Conditions	
Exit Velocity	N/A
Exit Angle	N/A
Final Vehicle Position	7.4 ft. (2.3 m) Downstream 24.9 ft. (7.6 m) Left
Exit Box Criteria Met	N/A
Vehicle Snagging	Satisfactory
Vehicle Pocketing	Satisfactory
Vehicle Stability	Satisfactory
Maximum Roll Angle	-4.7 °
Maximum Pitch Angle	-8.7 °
Maximum Yaw Angle	-91.4 °

Occupant Risk	
Longitudinal OIV	38.4 ft/s (11.7 m/s)
Lateral OIV	-5.6 ft/s (-1.7 m/s)
Longitudinal RA	-13.4 g
Lateral RA	3.0 g
THIV	38.4 ft/s (11.7 m/s)
PHD	13.4 g
ASI	1.14

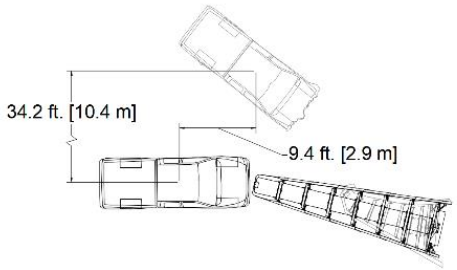
Test Article Deflections	
Static	6.8 ft. (2.1 m)
Dynamic	9.5 ft. (2.9 m)
Working Width	N/A
Debris Field	N/A

Vehicle Damage	
Vehicle Damage Scale	11-FD-3
CDC	11FDEW2
Maximum Intrusion	0.4 in. (10 mm) at Foot well

Figure 2 Summary of Test 3-32

MASH 2016 Test 3-33 Summary

0.000 s 0.100 s 0.300 s 0.450 s 0.800 s



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
Exit Angle	N/A
Final Vehicle Position	9.4 ft. (2.9 m) Downstream 34.2 ft. (9.9 m) Left
Exit Box Criteria Met	N/A
Vehicle Snagging	Satisfactory
Vehicle Pocketing	Satisfactory
Vehicle Stability	Satisfactory
Maximum Roll Angle	-3.9 °
Maximum Pitch Angle	-3.5 °
Maximum Yaw Angle	-84.6 °

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

Test Article Deflections

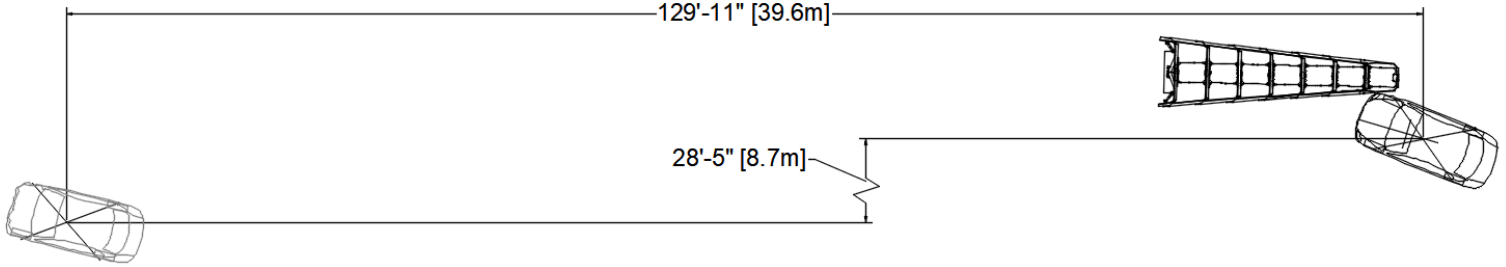
Static	10.5 ft. (3.2 m)
Dynamic	13.4 ft. (4.1 m)
Working Width	N/A
Debris Field	N/A

Vehicle Damage

Vehicle Damage Scale	12-FD-3
CDC	12FDEW2
Maximum Intrusion	0.2 in. (5 mm) at foot well

Figure 2 Summary of Test 3-33

MASH 2016 Test 3-34 Summary



General Information

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

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	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)

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
Exit Box Criteria Met	Yes
Vehicle Snagging	None
Vehicle Pocketing	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

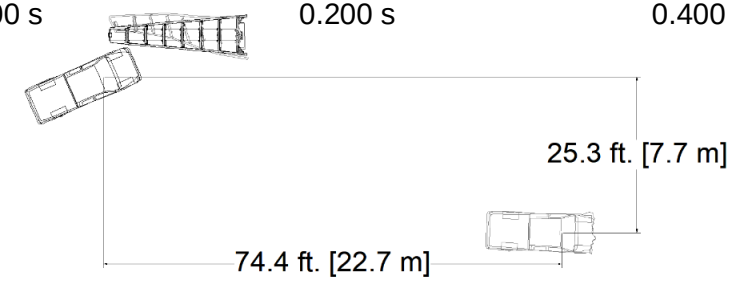
Static	2.6 in. (65.0 mm)
Dynamic	7.3 in. (185.0 mm)
Working Width	N/A
Debris Field	N/A

Vehicle Damage

Vehicle Damage Scale	01-RFQ-4
CDC	01FYEK1 and 01RDES1
Maximum Intrusion	0.3 in. (8 mm) at floor pan

Figure 2 Summary of Test 3-34

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

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	4,986.8 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)

Impact Conditions

Impact Velocity	61.21 mph (98.50 km/h)
Impact Angle	23.7°
Location / Orientation	1.0 in. downstream of CIP
Kinetic Energy	101.4 kip-ft (137.5 kJ)

Exit Conditions

Exit Velocity	36.80 mph (59.22 km/h)
Exit Angle	25.3°
Final Vehicle Position	74.4 ft. (22.7 m) Downstream 25.3 ft. (7.7 m) Right
Exit Box Criteria Met	Yes
Vehicle Snagging	None
Vehicle Pocketing	None
Vehicle Stability	Satisfactory
Maximum Roll Angle	-31.2 °
Maximum Pitch Angle	-46.1 °
Maximum Yaw Angle	-47.6 °

Occupant Risk

Longitudinal OIV	27.2 ft/s (8.3 m/s)
Lateral OIV	-19.7 ft/s (-6.0 m/s)
Longitudinal RA	-11.2 g
Lateral RA	7.4 g
THIV	36.7 ft/s (11.2 m/s)
PHD	11.7 g
ASI	1.19

Test Article Deflections

Static	1.5 ft. (0.4 m)
Dynamic	2.4 ft. (0.7 m)
Working Width	5.3 ft. (1.6 m)
Debris Field	N/A

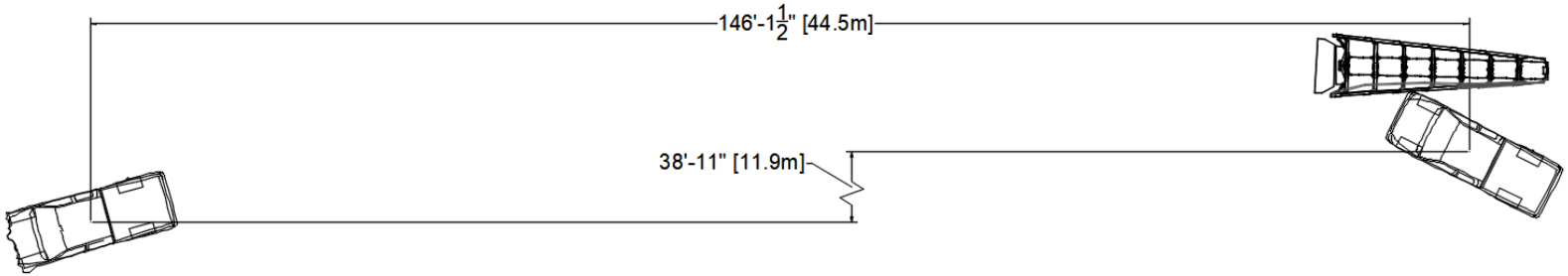
Vehicle Damage

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

0.000 s 0.090 s 0.180 s 0.270 s 0.405 s



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	146.1 ft. (44.5 m) downstream 38.9 ft. (11.9 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

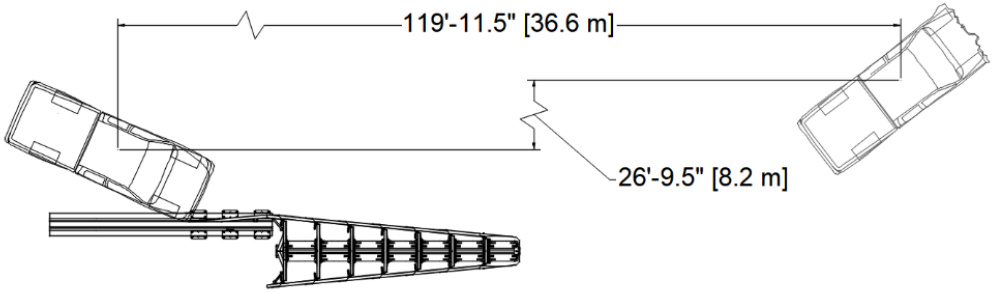
Vehicle Damage

Vehicle Damage Scale	01-RFQ-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

0.000 s 0.080 s 0.240 s 0.400 s 0.640 s



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) 26.8 ft. (8.2 m) left
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

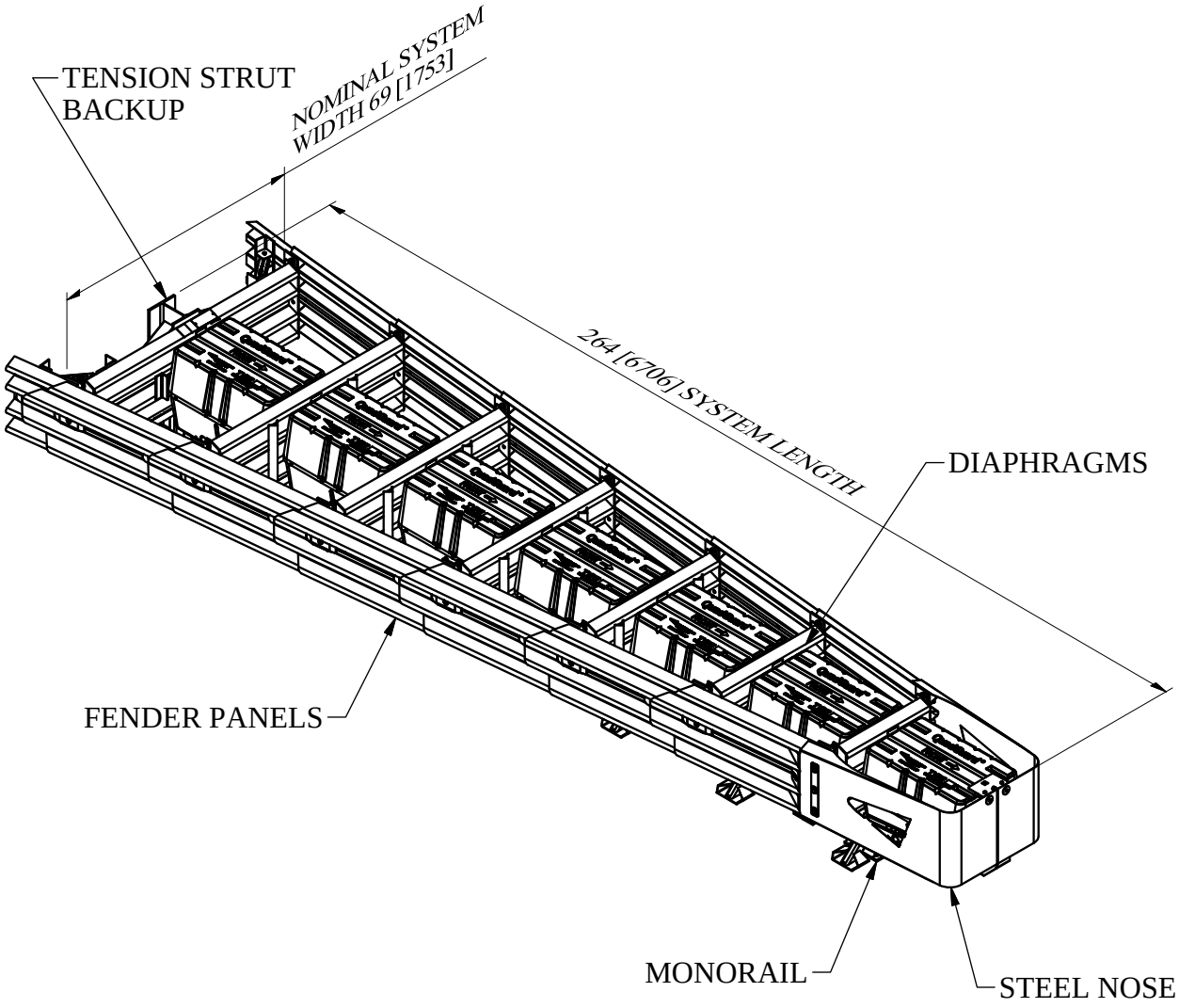
Test Article Deflections

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



2020

QUADGUARD® M WIDE TL-3 (69) SYSTEM

TRINITY HIGHWAY

SCIXX	
SHEET NO.	DATE
1 of 2	3/23/2020

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)
Width:	69 [1753] nom.
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.

CONTACT INFORMATION

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QUADGUARD® M WIDE TL-3 (69) SYSTEM

SCIXX	
SHEET NO.	DATE
2 of 2	3/23/2020

TRINITY HIGHWAY