February 9, 2011

Mr. Barry D. Stephens, P.E.
Sr. Vice President Engineering
Energy Absorption Systems, Inc.
3617 Cincinnati Avenue
Rocklin, CA  95678

Dear Mr. Stephens:

This letter is in response to your request for the Federal Highway Administration (FHWA) acceptance of a roadside safety device for use on the National Highway System (NHS).

Name of device:  6-bay QuadGuard® M10; and,
6-bay QuadGuard® M10 Wide
Type of device:  Impact Attenuator and Transitions
Test Level:    AASHTO Manual for Assessing Safety Hardware (MASH)
              Test Level 3 (TL-3)
Testing conducted by:  E-Tech Testing Services, Inc.
Date of request:   May 3, 2010
Date of completed package:  July 23, 2010
Task Force 13 Designator(s): SCI26 (M10)
                            SCI27 (M10 Wide)

You requested that we find these devices acceptable for use on the NHS under the provisions of the MASH testing standard.

Requirements
Roadside safety devices should meet the guidelines contained in the MASH.  The FHWA Memorandum “ACTION: Identifying Acceptable Highway Safety Features” of July 24, 1997, provides further guidance on crash testing requirements of longitudinal barriers.

Decision
The following devices are acceptable, with details provided below:
• 6-bay QuadGuard® M10 (M10)
• 6-bay QuadGuard M10 Wide (M10W)
• QuadGuard M10 transition to W-beam
• QuadGuard M10 transition to thrie-beam
• QuadGuard 4inch offset transition to Concrete Median Barrier
Description
The M10 and M10W are redirective, non-gating 6-bay crash cushions. The MASH design has been revised from NCHRP Report 350 (Report 350) design to now include a reinforced lower front bracket, a new upper front bracket and new cartridge types. Features of both M10 and M10W systems are shown in the enclosed drawings for reference.

The M10 and M10W systems have an overall length of 22 feet, 0 inches. [6.71 m]. The M10 can be configured with backup widths of 24 inches [610 mm], 30 inches [762 mm], and 36 inches [914 mm]. The M10W can be configured with back-up widths of 69 inches [753mm] and 90 inches [2285 mm]. The overall height of both M10 and M10W is 32 inches [817 mm]. The system consists of energy absorbing cartridges surrounded by a framework of steel Quad-Beam™ guardrail that can telescope rearward during head-on impacts. The system has a center monorail that will resist lateral movement during side angle impacts and a back up structure that will resist movement during head-on impacts.

Components from the 5-Bay QG II unit that are used on the new 6-Bay QG M10 unit are:
1. QG foundation–anchored center Monorail
2. QG Fender Panels
3. QG Diaphragms
4. QG Backup
5. MP-3™ Concrete Anchors
6. 14ga steel wrap-around sheet metal Nose
7. 50mm [2 inches] Lower Nose Cartridge Bracket
8. 10ga steel rail guide Shims

Components that were enhanced to achieve the required performance include:
1. QG Type M-I cartridges (4 required)
2. QG Type M-II cartridges (3 required)
3. A hold down bracket was added to the nose cartridge to contain the cartridge and maximize its energy absorption.
4. The bottom nose cartridge bracket attached to the diaphragm was reinforced to help restrain the cartridge to maximize its energy absorption.
5. Transition Hardware – steel posts (only) in strong soil

System drawings are also included within this correspondence for review and reference.

Crash Testing
Full-scale crash tests were conducted into the new QG M10 as required per MASH under the TL-3 guidelines. For the M10 system, MASH Tests 3-31 was conducted on the 24-inch
[610 mm] system and MASH Test 3-32 was conducted on the 36-inch [914 mm] system. The test results are as follows and can also be reviewed in enclosed MASH Test Matrix:

Test 3-31:
Impact speed = 99.0 km/h
Ridedown = -17.6 g’s
Longitudinal ΔV = 8.4 m/s

Test 3-32:
Impact speed = 97.0 km/h
Ridedown = -17.8 g’s
Longitudinal ΔV = 11.1 m/s

Due to a higher energy of the MASH test vehicles, test 3-34 and test 3-36 were conducted on the 24-inch [610 mm] system in addition to the newly specified test 3-37. The results of these tests are as follows:

Test 3-34:
Impact speed = 102.5 km/h,
Longitudinal ridedown = -10.6 g’s
Longitudinal ΔV = 8.9 m/s
OCD: AS1020000

Test 3-36:
Impact speed = 99.0 km/h,
Lateral ridedown = 14.2 g’s
Lateral ΔV = 7.4 m/s
OCD: AS1110000

Test 3-37:
Impact speed = 99.7 km/h,
Longitudinal ridedown = 7.8 g’s
Longitudinal ΔV = -7.8 m/s
OCD: LF0030000

For the M10W system, a comparison was made using existing Report 350 crash test results for the 5-bay QG II (flared) and original QG (parallel) systems. Since the results of these tests indicated that test 3-31 and 3-32 are similar for parallel and flared systems, equivalence to the Report 350 device in lieu of further testing of the M10W systems, with backup widths of 69-inch [753mm] and 90-inch is requested.

A discussion regarding the M10 and M10W transition systems was conducted with FHWA Office of Safety on March 16, 2010. It was agreed the M10 to W-beam transition represents a worst case condition for pocketing and snagging of the test vehicle. In addition and in this particular case, the MASH test 3-21 is considered equivalent to test 3-37. In addition, a successful test 3-37 would serve to represent all of the following submitted transitions with
caveat that required spacing and specification of steel posts for w-beam transition must also be the same for M10 transition to thrie-beam to provide similar system strength:

1. Transition QG M10 to W-beam
2. Transition QG M10 to thrie-Beam
3. QG 4” offset Transition to CMB
4. QG 9” offset Transition to CMB (No wide system version)
5. Transition QG to vertical wall
6. QG 6” offset transition to single slope barrier

In addition, per MASH Section G computations (using existing tests 3-31 result), a waiver is requested of test 3-38 (1500A crash test).

Findings
The M10 and M10W systems meet evaluation criteria as per MASH for a redirective, non-gating crash cushion at TL-3 impact conditions. Therefore, these systems are acceptable for use on the NHS when such use is acceptable to the contracting authority. In addition, the M10 can be installed with aforementioned transition hardware with caveat that steel posts with a specified spacing are used for W-beam and thrie-beam transitions as described in test 3-37 report. Please note the following standard provisions that apply to the FHWA letters of acceptance:

• This acceptance is limited to the crashworthiness characteristics of the devices and does not cover their structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
• Any changes that may adversely influence the crashworthiness of the device will require a new acceptance letter.
• Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals unacceptable safety problems, or that the device being marketed is significantly different from the version that was crash tested, we reserve the right to modify or revoke our acceptance.
• You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
• You will be expected to certify to potential users that the hardware furnished has essentially the same chemistry, mechanical properties, and geometry as that submitted for acceptance, and that it will meet the crashworthiness requirements of the FHWA and the MASH.
• To prevent misunderstanding by others, this letter of acceptance is designated as number CC-112, and 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 at our office upon request.
• The QuadGuard® M10 attenuators are patented products and considered proprietary. If proprietary devices are specified by highway agency for use on Federal-aid projects, except exempt, non-NHS projects, (a) they must be supplied through competitive bidding with equally suitable unpatented items: (b) the highway agency must certify that they are essential for synchronization with the existing highway facilities or that no equally suitable
• alternative exists: or (c) they must be used for research or for a distinctive type of construction on relatively short sections of road for experimental purposes. Our regulations concerning proprietary products are contained in Title 23, Code of Federal Regulations, Section 635.411.

• This acceptance letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented device for which the applicant is not the patent holder. The acceptance letter is limited to the crashworthiness characteristics of the candidate device, and the FHWA is neither prepared nor required to become involved in issues concerning patent law. Patent issues, if any, are to be resolved by the applicant.

Sincerely,

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

Enclosures
Figure 1. Summary of Results - QuadGuard M10 System Test 01-3044-004
Figure 6. Summary of Results - QuadGuard M10 System Test 01-3044-003
Figure 11. Summary of Results - QuadGuard M10 System Test 01-3044-001
General Information
Test Agency: E-TECH Testing Services, Inc.
Test Designation: MASH Test 3-36
Test No.: 01-3044-002
Date: 8/23/06

Test Article
Type: Energy Absorption System
Installation Length: 5 bay 19 ft (5790 mm) long
Material and key elements:
- 24 in. (610 mm) wide
- (6) energy absorbing cartridges
- (3) Type M-I and (3) Type M-II
- AASHTO M180 Quad Panels
- ASTM A36 other, galvanized steel construction
Foundation Type and Condition:
- Unreinforced 27.6 Mpa concrete, clean and dry, with (46) 19 mm x 178 mm ASTM A193 Grade B-7 threaded studs and
- MP-3 Anchoring System

Test Vehicle
Type: Production Model
Designation: 2270P
Model: 2002 Dodge 1500 Quadcab Pickup
Mass:
- Curb: 4885 lb (2216 kg)
- Test inertial: 4918 lb (2231 kg)
- Dummy: N/A
- Gross Static: 4918 lb (2231 kg)

Impact Conditions
- Speed: 61.5 mi/h (99.0 km/h)
- Angle (deg): 25°
- Impact Severity: 111.1 ft-kip (150.6 kJ)
- Exit conditions:
  - Speed: 45 mi/h (72 km/h)
  - Angle (deg - veh. c.g.): 6°

Occupant Risk Values
Impact Velocity:
- x-direction: 17.9 ft/s (5.4 m/s)
- y-direction: 24.3 ft/s (7.4 m/s)
- z-direction: 14.2 g

European Committee for Normalization (EN) Values
THV: 20.6 mi/h (33.2 km/h)
PHD (g’s): 14.3 g
ASI: 1.5

Post-Impact Vehicular Behavior (deg - rate gyro)
Maximum Roll Angle: -24.2°
Maximum Pitch Angle: 22.3°
Maximum Yaw Angle: 44.3°

Test Article Deflections
Dynamic:
- Permanent: 8 in. (203 mm)
- 0 in. (0 mm)
Vehicle Damage (Primary Impact)
- Exterior:
  - VDS: FLQ-4
  - CDC: III-F EW2
- Interior:
  - VCDI: FS1110000
  - Maximum Deformation: 4.3 in. (110 mm)

Figure 16. Summary of Results - QuadGuard M10 System Test 01-3044-002
Figure 21. Summary of Results - QuadGuard M10 System Test 01-3044-005
<table>
<thead>
<tr>
<th>Illustration</th>
<th>Test #</th>
<th>Completed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-30</td>
<td>NO</td>
<td>Test 3-32 was completed as “Worst Case” for 1100C.</td>
</tr>
<tr>
<td></td>
<td>3-31</td>
<td>YES</td>
<td>Passed all ORV’s. 6-Bay 610 mm [24 inches] Narrow System was tested and passed all Occupant Risk Values.</td>
</tr>
<tr>
<td></td>
<td>3-32</td>
<td>YES</td>
<td>Passed all ORV’s. 5-Bay 914 mm [36 inches] Narrow System was tested.</td>
</tr>
<tr>
<td></td>
<td>3-33</td>
<td>NO</td>
<td>Test 3-31 tested system capacity for 2270P and is considered worst case.</td>
</tr>
<tr>
<td></td>
<td>3-34</td>
<td>YES</td>
<td>Passed all ORV’s. 5-Bay 610 mm [24 inches] Narrow System was tested.</td>
</tr>
<tr>
<td></td>
<td>3-35</td>
<td>NO</td>
<td>Due to the lateral stiffness of the QuadGuard M10, this test is the same as test 3-36 and can be waived.</td>
</tr>
<tr>
<td></td>
<td>3-36</td>
<td>YES</td>
<td>Passed all ORV’s. 5-Bay 610 mm [24 inches] Narrow System with no new nose brackets was tested.</td>
</tr>
<tr>
<td></td>
<td>3-37</td>
<td>YES</td>
<td>Passed all ORV’s. 6-Bay 610 mm [24 inches] Narrow System attached to a w-beam transition.</td>
</tr>
<tr>
<td></td>
<td>3-38</td>
<td>YES</td>
<td>The recommended MASH analysis was completed and all calculated ORV’s passed.</td>
</tr>
</tbody>
</table>
**Test Matrix Summary:**

Although the QG is a family of systems in various widths and lengths, at this time, only the most popular 6-bay QG M10 in various widths was tested. Tests were chosen to be the worst case tests which demonstrated the performance of the system over various widths.

**Notes:**

1) Narrow systems have backup widths of 610 mm [24 inches], 762 mm[30 inches], and 914 mm [36 inches].
2) Wide systems have backup widths of 1755 mm [69 inches] and 2285 mm [90 inches].

**Completed Tests:**

**Tests 3-31 (2270P/100kph/0°)** was conducted on the 6-bay narrow (610 mm [24 inch] width) system. This test demonstrated the capacity of the narrow 6 bay system at the TL-3 level. The minimum width QG system was chosen for this test, because it is considered the worst case as it minimizes momentum transfer.

**Tests 3-32 (1100C/100kph/15° into nose)** was conducted on the 6-bay narrow (914 mm [36 inch] width) system. This test also demonstrated the performance of the narrow 6 bay system at the TL-3 level. This width system was chosen to maximize the potential for high delta-Vs, while also testing the capacity of the system for vehicles of this size.

**Tests 3-34 (1100C/100kph/15° @B.L.O.N)** was conducted on a standard 5-bay QG II. Although this system was shorter than the final system design and it did not have the improvements to the nose compartment hardware, the nose hardware and length do not significantly affect the ability of the system to redirect a vehicle during this test condition. In fact, the shorter length system can be judged to be “worst-case”, as it shortens the duration of vehicle contact with the QG and maximizes the snag potential at the downstream end of the system.

**Tests 3-36 (2270P/100kph/25° @ C.I.P.)** was conducted on a standard 5-bay QG II. Although this system was shorter than the final system design and it did not have the improvements to the nose compartment hardware, the nose hardware and length do not significantly affect the ability of the system to redirect a vehicle during this test condition. In fact, the shorter length system can be judged to be “worst-case”, as it shortens the duration of vehicle contact with the QG and maximizes the snag potential at the downstream end of the system.

**Test 3-37 (2270P/100kph/25° C.I.P. Transition wrong-way)** was conducted on the 6-bay narrow (610 mm [24 inch] width) system attached to a w-beam transition. The w-beam guardrail transition, shown in figure 4, is considered the “worst case” test condition of the six transition designs that are included with this submittal. The six transitions are:

1. Transition to w-beam
2. Transition to thrie-beam
3. 4” offset transition to CMB
4. 9” offset transition to CMB (No wide system version)
5. Transition to vertical wall
6. 6” offset transition to single slope barrier
Changes for the QuadGuard M10 system:

As discussed above, changes were made to the QG II system to create the QG M10 system. An illustration of the 914 mm [36 inch] backup QG M10 system tested is shown below in figure 2b. A similar 610 [24 inch] backup QG M10 system was also tested. Figure 2a shows a 2286 mm [90 inch] QG M10 system for comparison.

Fig 2a. QuadGuard® M10 Wide System 2286 mm [90 inches]
Fig. 2b. 6-Bay QuadGuard® M10 Narrow System 914 mm [36 inches] Tested to MASH TL-3.
Changes incorporated in the QG M10 are as follows:

1. **One additional bay per system**: A “bay” consists of one repeated section of the system and includes; two fender panels (sides), a cartridge (center) and a diaphragm (divider). A 6-bay QG II style system has been tested to meet the higher energy requirements of the MASH testing standard. This improvement was tested at the TL-3 requirements as specified by MASH.

2. **Use of a reinforced bottom and top bracket**: A reinforced rear lower bracket replaced the original bracket and a new upper hold down bracket was added as shown in figure 3 (The cartridge was removed for clarity).

3. **Type M-I and M-II cartridges replace the Type I and Type II cartridges respectively.** The cartridges were modified as necessary to absorb the extra energy of the larger MASH test vehicles.

![Fig.3. QuadGuard® M10 Steel Nose Compartment with new Brackets (The front cartridge is removed to show detail)]
ITEM 2 ASSEMBLY

Note: This assembly is not included in the Quad-Guard System Model Number G61737.

NOTES:
1. PACK DIVIDE SHEAR GIRDERS PER DIRECTOR SHEAR GIRDERS CROSS. EXHUST PLATE E. USE 4-1/2 BLIND BOLTS.
2. BOLTS MUST BE FALL螺丝 1/4" 20 IFL Blind Bolts.
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