



March 20, 2009

In Reply Refer To: HSSD/CC-35I

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:	5-bay QuadGuard II 5-bay QuadGuard II Wide 2-bay QuadGuard II
Type of device:	Impact Attenuators
Test Level:	NCHRP Report 350 Test Levels 2 and 3
Testing conducted by:	E-Tech Testing Services, Inc.
Date of request:	December 8, 2008

You requested that we find this device acceptable for use on the NHS under the provisions of National Cooperative Highway Research Program (NCHRP) Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features."

Requirements

Roadside safety devices should meet the guidelines contained in the NCHRP Report 350." The FHWA Memorandum "Identifying Acceptable Highway Safety Features" of July 25, 1997, provides further guidance on crash testing requirements of longitudinal barriers.

Description

The QuadGuard[®] II is a redirective, non-gating crash cushion with a reduced length of 5 bays that is otherwise identical to the previously accepted Test Level 3 (TL-3) 6-bay unit (see FHWA Acceptance Letter CC-35, dated June 21, 1996). The difference is that one bay is removed from the rear of the system and a new sheet metal front nose is used. Likewise, the QuadGuard[®] II with a reduced length of 2 bays is identical to the previously accepted TL-2 3-bay unit (ref. CC-35C, dated June 17, 1999) with the exception of one of the rear bays being removed plus a new sheet metal front nose.

Features of the 5-bay QuadGuard[®] II systems (narrow and wide) as well as the 2-bay QuadGuard[®] II narrow system are depicted in the enclosed drawings for reference. The QuadGuard[®] II 5-bay narrow system has an overall length of 5830 mm (19' 1") and can be configured with backup widths of 610 mm (24 inches), 762 mm (30 inches), 914 mm (36 inches), 1753 mm (69 inches), and 2286 mm (90 inches). The 2-bay QuadGuard[®] II system has an overall length of 3080 mm (10' 1") and can be configured with a backup width of 610 mm (24 inches). 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. Simply removing a rear Bay from an existing 6-Bay or 3-Bay system will not be adequate to meet TL-3 and TL-2 impact speeds, respectively. As noted in your report, the QuadGuard II system requires an upgraded nose assembly.

Crash Testing

The original 6-bay test data of NCHRP 350 Test 3-31 and 3-32 demonstrated that the 2000P vehicle impacting at 0 degree and a nominal speed of 100km/h (63 mph) resulted in a ridedown g's of -14.52 and Occupant Impact Velocity (ΔV) of 10.55 m/s. An engineering review of this previous data indicated excess capacity in the device and prompted a crash test to be done after removing bay 6. The NCHRP 350 Tests 3-31 and 3-32 were conducted and the results are as follows:

Narrow System 610mm (24 inches) width:

Test 3-31: Impact speed: 101.1 km/h, ridedown of -17.3 g's, and ΔV 9.6 m/s.

Test 3-32: Impact speed: 98.3 km/h, ridedown of -17.4 g's, and ΔV 12.4 m/s.

Wide System 2286mm (90 inches) width:

Test 3-31: Impact speed: 99.7 km/h, ridedown of -17.0 g's, and ΔV 10.0 m/s.

Test 3-32: Impact speed: 97.7 km/h, ridedown of -17.4 g's, and ΔV 11.7 m/s.

Similarly the 3-bay narrow system test data demonstrated that the 2000P vehicle impacting at 0 degree and a nominal speed of 70km/h (43.5 mph) resulted in a ridedown g's of -19.57 and Occupant Impact Velocity (ΔV) of 8.89. Again an engineering review indicated excess capacity in the device and prompted the following crash tests with results as follows:

Test 2-31: Impact speed: 68.3 km/h, ridedown of -19.4 g's, and ΔV 10.7 m/s.

Test 2-32: Impact speed: 67.7 km/h, ridedown of -17.8 g's, and ΔV 10.8 m/s.

Due to the elimination of one bay at the rear of each system we concur that the tests performed provide adequate capacity of head-on impacts for all widths of TL-3 5-bay QuadGuard[®] II systems. In addition we also concur that the tests performed on the TL-2 2-bay QuadGuard[®] II system provide adequate capacity for head-on impacts for the 610mm (24 inches) width system. We agree that the front of the system was adequately tested for the 820C vehicle crash

characteristics. Based upon the multiple redirective test impacts into the QuadGuard[®] and the basic structure of the reduced 5-bay and 2-bay QuadGuard[®] II being unchanged, redirective tests are not required.

Findings

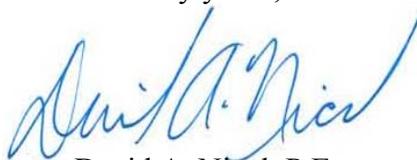
The QuadGuard[®] II 5-bay and 2-bay systems meet the evaluation criteria for NCHRP Report 350 redirective, non-gating crash cushion at TL-3 and TL-2 impact conditions respectively and are acceptable for use on the NHS when such use is acceptable to the contracting authority. It's further acknowledged that the QuadGuard[®] II can be installed with existing QuadGuard[®] Transition hardware (Reference CC-35B, dated October 17, 1996.)

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 NCHRP Report 350.
- To prevent misunderstanding by others, this letter of acceptance is designated as number CC-35I 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 and QuadGuard II families of crash cushions are patented products and considered proprietary. If proprietary devices are specified by a 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 yours,



David A. Nicol, P.E.
Director, Office of Safety Design
Office of Safety

Enclosures

Table1: Table of TL- 3 Tests (5-Bay System).

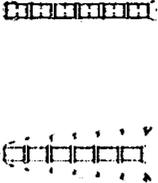
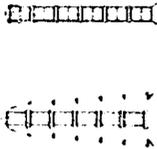
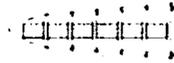
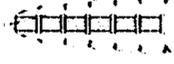
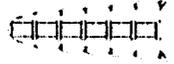
Illustration	Test #	Completed	Notes
	3-31	YES	<p>Passed all ORV's. 5-Bay 24" Wide System was tested and passed all Occupant Risk Values. 5-Bay 90" Wide system was tested and passed all Occupant Risk Values.</p>
	3-32	YES	<p>Passed all ORV's. 5-Bay 24" Wide System was tested. 5-Bay 90" Wide System was tested.</p>
	3-30	NO	<p>Test 3-32 was completed as "Worst Case" for 820c.</p>
	3-33	NO	<p>Test 3-31 tested system capacity for 2000P and is considered worst case.</p>
	3-36	NO	<p>Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware therefore performance would remain unchanged.</p>
	3-37	NO	<p>Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware – performance remains unchanged.</p>

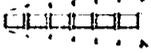
Illustration	Test #	Completed	Notes
	3-38	NO	Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware -- performance remains unchanged.
	3-39	NO	Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware / performance remains unchanged.

Table2: Table of TL-2 Tests (2-Bay System)

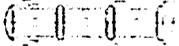
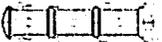
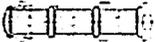
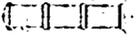
Illustration	Test#	Completed	Notes
	2-30	NO	Test 2-32 was completed as is considered "worst case" scenario for 820c.
	2-31	YES	Passed all ORV's on 2-Bay System.
	2-32	YES	Passed all ORV's on 2-Bay System.
	2-33	NO	Test 2-31 tested system capacity for 2000P and is considered worst case.

Illustration	Test#	Completed	Notes
	2-36	NO	Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware – performance remains unchanged.
	2-37	NO	Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware – performance remains unchanged.
	2-38	NO	Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware – performance remains unchanged.
	2-39	NO	Qualified under the Original QuadGuard Test Matrix. No changes in Structural Hardware – performance remains unchanged.



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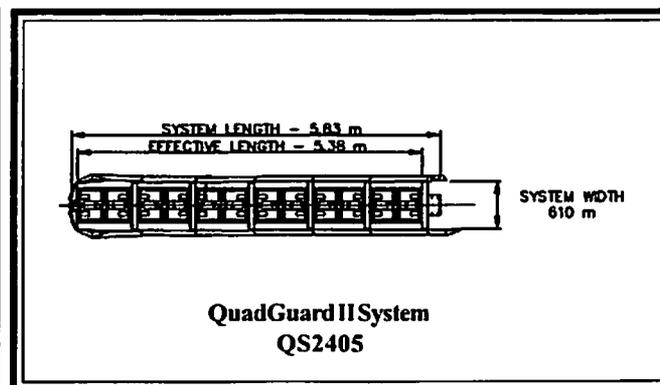
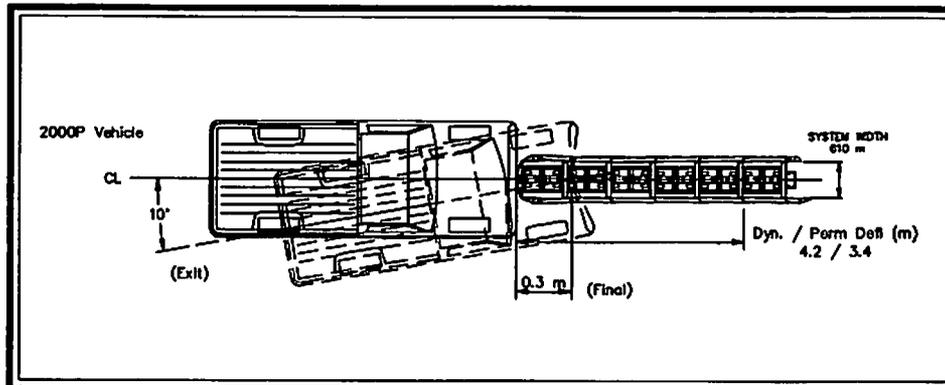
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t = 0.480 sec

t = 0.600 sec



E-TECH Testing Services, Inc.

QuadGuard II System Crash Test Results - 10 of 69

General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-31
Test No.	01-4309-001
Date	1/5/06
Test Article	
Type	Energy Absorption System
.....	QuadGuard II System QS2405
.....	
Installation Length, (mm)	5 bay 5830 mm long 610 mm wide
Material and key elements	5 bay system, 6 energy
.....	absorbing cartridges (3) Type II
.....	and (3) Type I.
.....	P.C. Concrete, clean
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	2000P
Model	1988 Chevrolet Pickup
.....	
Mass (kg)	
Curb	1861
Test inertial	1984
Dummy	N/A
Gross Static	1984

Impact Conditions

Speed (km/h)	101.1
Angle (deg)	0
Impact Severity (kJ)	781.6

Exit conditions

Speed (km/h)	N/A
Angle (deg - veh. c.g.)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	9.6
y-direction	0.5
Ridedown Acceleration (g's)	
x-direction	-17.3
y-direction	3.5

European Committee for Normalization (CEN) Values

THIV (km/h)	34.7
PHID (g's)	17.4
ASI	1.3

Post-Impact Vehicular Behavior (deg - rate gyro)

Maximum Roll Angle	3.2
Maximum Pitch Angle	-8.6
Maximum Yaw Angle	-10.2

Test Article Deflections (m)

Dynamic	4.2
Permanent	3.4

Vehicle Damage (Primary Impact)

Exterior	
VDS	FC-3
CDC	12FCEW3
Interior	
VCDI	AS0000000
Maximum Deformation (mm)	Negligible

Figure 1. Summary of Results - QuadGuard II System Test 01-4309-001



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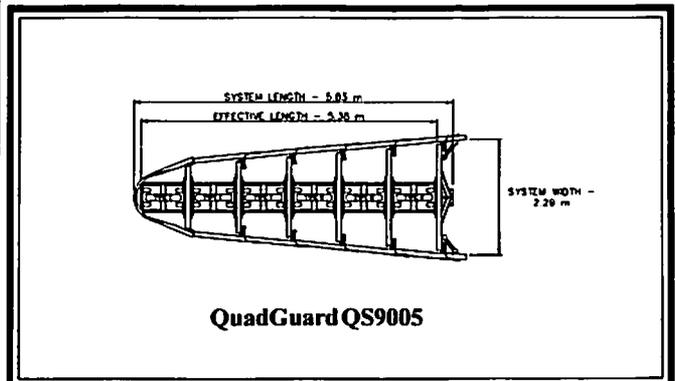
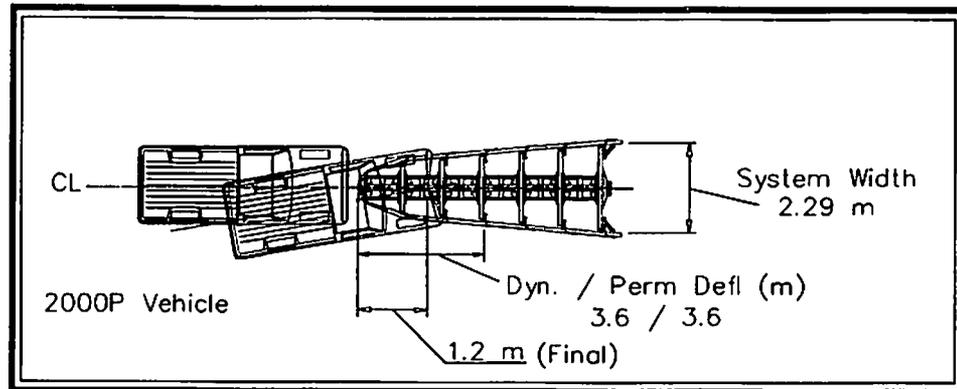
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t = 0.552 sec

t = 0.965 sec



E-TECH Testing Services, Inc.

QuadGuard II System Crash Test Results - 16 of 69

General Information

Test Agency E-TECH Testing Services, Inc.
 Test Designation NCHRP 350 Test 3-31
 Test No. 01-4309-006
 Date 11/04/08

Test Article

Type Energy Absorption System
 QuadGuard II System QS2405

Installation Length, (mm) 5 bay 5.83 m long 2.29 m wide

Material and key elements 5 bay system, 6 energy
 absorbing cartridges (3) Type II
 and (3) Type I.

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 2000P
 Model 1991 GMC C2500

Mass (kg)

Curb 1840
 Test inertial 2000
 Dummy N/A
 Gross Static 2000

Impact Conditions

Speed (km/h) 99.7
 Angle (deg) 0
 Impact Severity (kJ) 766.5

Exit conditions

Speed (km/h) N/A
 Angle (deg - veh. c.g.) N/A

Occupant Risk Values

Impact Velocity (m/s)
 x-direction 10.0
 y-direction 0.0

Ridedown Acceleration (g's)

x-direction -17.0
 y-direction -3.3

European Committee for Normalization (CEN) Values

THIV (km/h) 36.1
 PHD (g's) 17.1
 ASI 1.3

Post-Impact Vehicular Behavior (deg - rate gyro)

Maximum Roll Angle -2.6
 Maximum Pitch Angle 30.6
 Maximum Yaw Angle -2.3

Test Article Deflections (m)

Dynamic 3.6
 Permanent 3.6

Vehicle Damage (Primary Impact)

Exterior
 VDS FC-4
 CDC 12FCEW4

Interior
 VCDI AS0000000
 Maximum Deformation (mm) Negligible

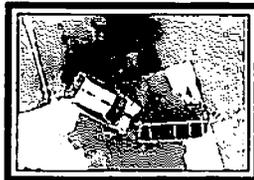
Figure 6. Summary of Results - QuadGuard II System Test 01-4309-006



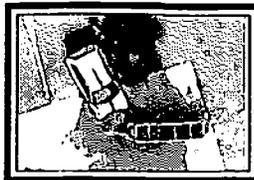
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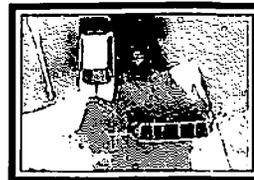
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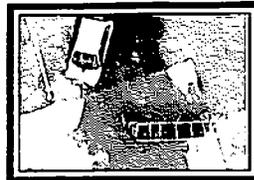
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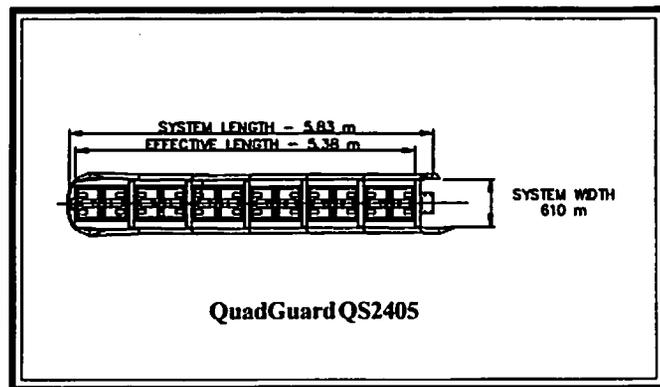
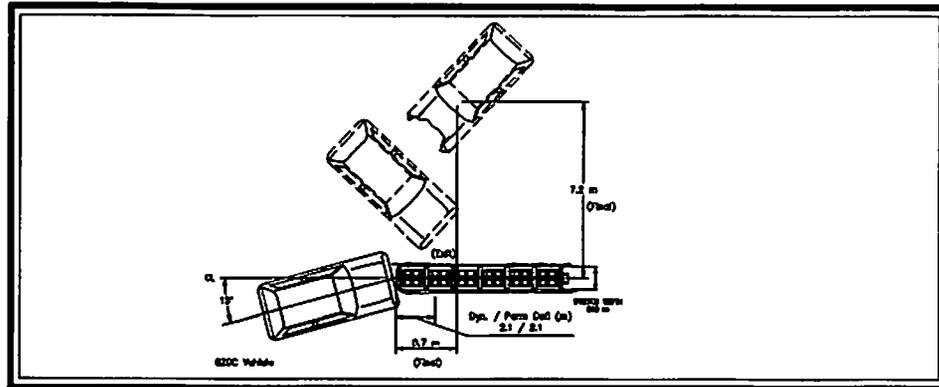
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t = 0.680 sec



t = 0.851 sec



E-TECH Testing Services, Inc.

QuadGuard II System Crash Test Results - 22 of 69

General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-32
Test No.	01-4309-002
Date	6/04/08
Test Article	
Type	Energy Absorption System
.....	QuadGuard System QS2405
.....	
Installation Length, (mm)	5 bay 5830 mm long 610 mm wide
Material and key elements	5 bay system, 6 energy absorbing cartridges (3) Type II and (3) Type I.
.....	P.C. Concrete, clean
.....	
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	820C
Model	1988 Ford Festiva
.....	
Mass (kg)	
Curb	818
Test inertial	845
Dummy	75
Gross Static	920

Impact Conditions

Speed (km/h)	98.3
Angle (deg)	15
Impact Severity (kJ)	316.6

Exit conditions

Speed (km/h)	N/A
Angle (deg - veh. c.g.)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	12.4
y-direction	0.1
Ridedown Acceleration (g's)	
x-direction	-17.4
y-direction	-5.1

European Committee for Normalization (CEN) Values

THIV (km/h)	45.4
PHD (g's)	17.4
ASI	1.3

Post-Impact Vehicular Behavior (deg - rate gyro)

Maximum Roll Angle	25.7
Maximum Pitch Angle	-12.1
Maximum Yaw Angle	191.8

Test Article Deflections (m)

Dynamic	2.1
Permanent	2.1

Vehicle Damage (Primary Impact)

Exterior	
VDS	FC-3
CDC	12FCEW3
Interior	
VCDI	AS0000000
Maximum Deformation (mm)	Negligible

Figure 11. Summary of Results - QuadGuard II System Test 01-4309-002



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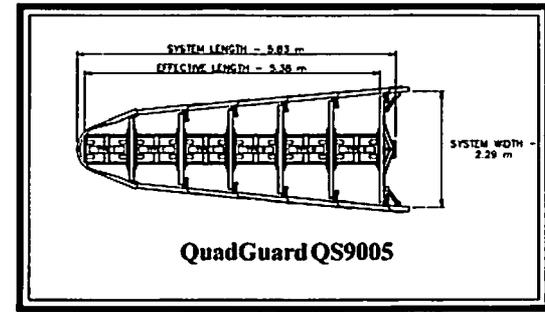
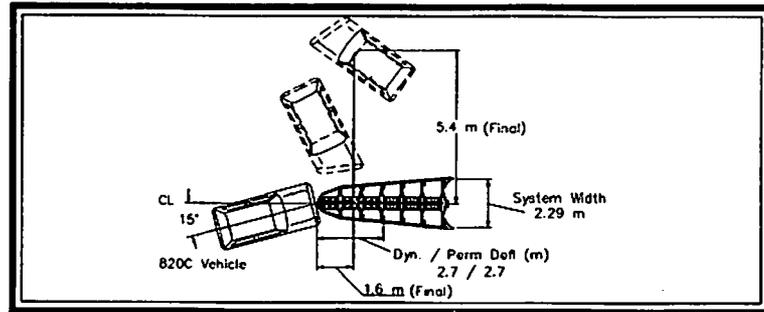
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QuadGuard QS9005

E-TECH Testing Services, Inc.

QuadGuard II System Crash Test Results - 28 of 69

General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-32
Test No.	01-4309-005
Date	8/13/08
Test Article	
Type	Energy Absorption System
.....	QuadGuard II System QS9005
.....	
Installation Length, (mm)	5 bay 5.83 m long 2.29 m wide
Material and key elements	5 bay system, 6 energy
.....	absorbing cartridges (3) Type II
.....	and (3) Type I.
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	820C
Model	1990 Ford Festiva
.....	
Mass (kg)	
Curb	852
Test inertial	827
Dummy	75
Gross Static	902

Impact Conditions

Speed (km/h)	97.7
Angle (deg)	15
Impact Severity (kJ)	304.3

Exit conditions

Speed (km/h)	N/A
Angle (deg - veh. c.g.)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	11.7
y-direction	-0.1
Ridedown Acceleration (g's)	
x-direction	-17.4
y-direction	-3.1

European Committee for Normalization (CEN) Values

THIV (km/h)	42.6
PHD (g's)	17.7
ASI	1.3

Post-Impact Vehicular Behavior (deg - rate gyro)

Maximum Roll Angle	30.9
Maximum Pitch Angle	13.7
Maximum Yaw Angle	221.1

Test Article Deflections (m)

Dynamic	2.7
Permanent	2.7

Vehicle Damage (Primary Impact)

Exterior	
VDS	FC-3
CDC	01FCEW3
Interior	
VCDI	AS0000000
Maximum Deformation (mm)	Negligible

Figure 16. Summary of Results - QuadGuard II System Test 01-4309-005



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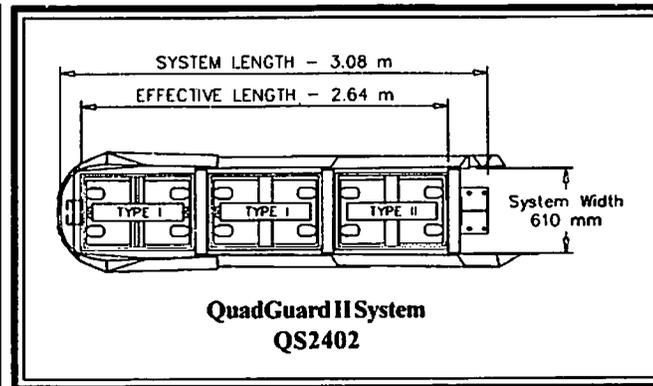
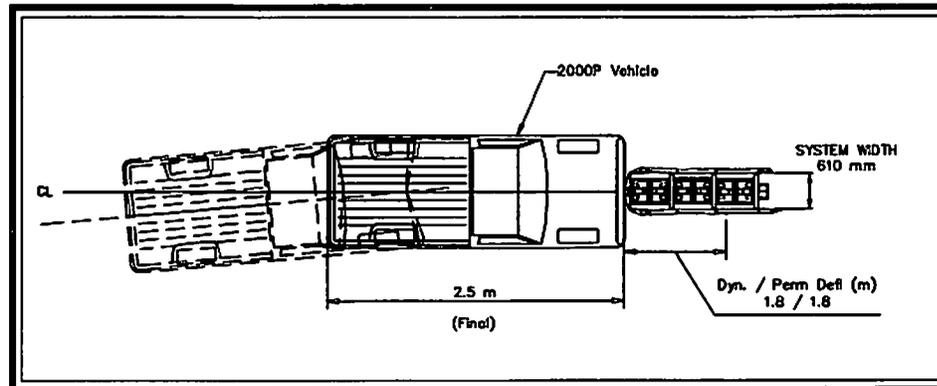
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t = 0.399 sec

t = 0.532 sec

t = 1.920 sec



QuadGuard II System
QS2402



E-TECH Testing Services, Inc.

QuadGuard II Crash Test Results - 9 of 43

General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCIHRP 350 Test 2-31
Test No.	01-4309-003
Date	7/16/08

Test Article

Type	Energy Absorption System
.....	QuadGuard II System QS2402

Installation Length, (mm)

2 bay 3080 mm long 610 mm wide

Material and key elements

2 bay system, 3 energy absorbing cartridges (1) Type II and (2) Type I.

Foundation Type and Condition

Unreinforced 27.6 Mpa concrete, clean and dry, with (26) 19 mm x 178 mm ASTM A193 Grade B-7 threaded studs and MP-3 Anchoring System

Test Vehicle

Type	Production Model
Designation	2000P
Model	1989 Chevrolet Pickup
Mass (kg)	
Curb	1961
Test inertial	2005
Dummy	N/A
Gross Static	2005

Impact Conditions

Speed (km/h)	68.3
Angle (deg)	0
Impact Severity (kJ)	361.0

Exit conditions

Speed (km/h)	N/A
Angle (deg - veh. c.g.)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	10.7
y-direction	-0.7

Ridedown Acceleration (g's)

x-direction	-19.4
y-direction	5.9

European Committee for Normalization (CEN) Values

THIV (km/h)	38.7
PHD (g's)	19.9
ASI	1.3

Post-Impact Vehicular Behavior (deg - rate gyro)

Maximum Roll Angle	1.5
Maximum Pitch Angle	5.4
Maximum Yaw Angle	-4.7

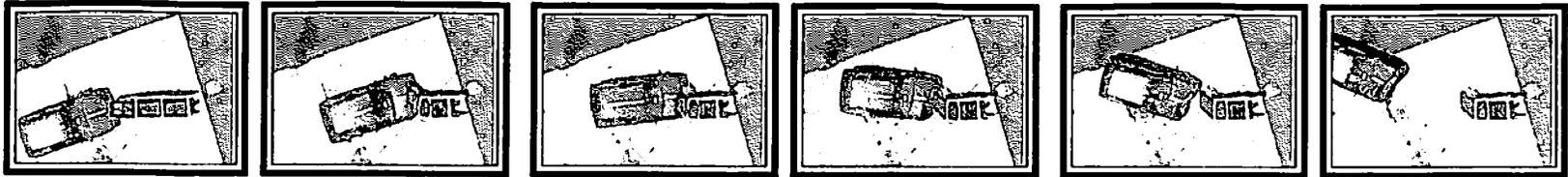
Test Article Deflections (m)

Dynamic	1.8
Permanent	1.8

Vehicle Damage (Primary Impact)

Exterior	
VDS	FC-3
CDC	12FCEW3
Interior	
VCDI	AS0000000
Maximum Deformation (mm)	Negligible

Figure 1. Summary of Results - QuadGuard II System Test 01-4309-003



t = 0.000 sec

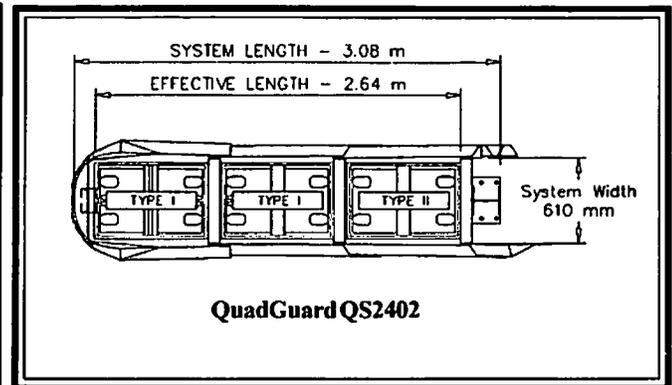
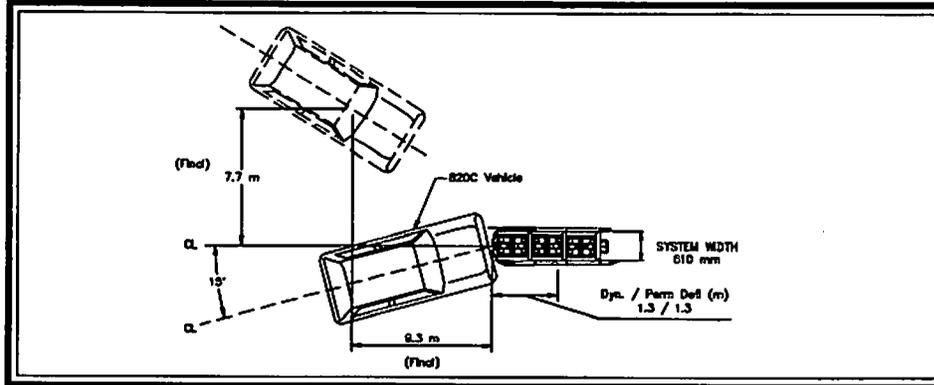
t = 0.125 sec

t = 0.250 sec

t = 0.375 sec

t = 0.500 sec

t = 1.285 sec



QuadGuard QS2402

E-TECH Testing Services, Inc.

QuadGuard II Crash Test Results - 15 of 43

General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 2-32
Test No.	01-4309-004
Date	7/22/08
Test Article	
Type	Energy Absorption System
.....	QuadGuard System QS2402
.....	
Installation Length, (mm)	2 bay 3080 mm long 610 mm wide
Material and key elements	2 bay system, 3 energy
.....	absorbing cartridges (1) Type II
.....	and (2) Type I.
.....	
Foundation Type and Condition	Unreinforced 27.6 Mpa concrete,
.....	clean and dry, with (26) 19 mm x
.....	178 mm ASTM A193 Grade B-7
.....	threaded studs and
.....	MP-3 Anchoring System

Test Vehicle

Type	Production Model
Designation	820C
Model	1990 Ford Festiva
.....	
Mass (kg)	
Curb	838
Test inertial	818
Dummy	75
Gross Static	993

Impact Conditions

Speed (km/h)	67.7
Angle (deg)	15
Impact Severity (kJ)	144.6

Exit conditions

Speed (km/h)	N/A
Angle (deg - veh. c.g.)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	10.8
y-direction	-0.5
Ridedown Acceleration (g's)	
x-direction	-17.8
y-direction	-6.2

European Committee for Normalization (CEN) Values

THIV (km/h)	39.0
PHD (g's)	18.0
ASI	1.5

Post-Impact Vehicular Behavior (deg - rate gyro)

Maximum Roll Angle	7.3
Maximum Pitch Angle	11.3
Maximum Yaw Angle	47.0

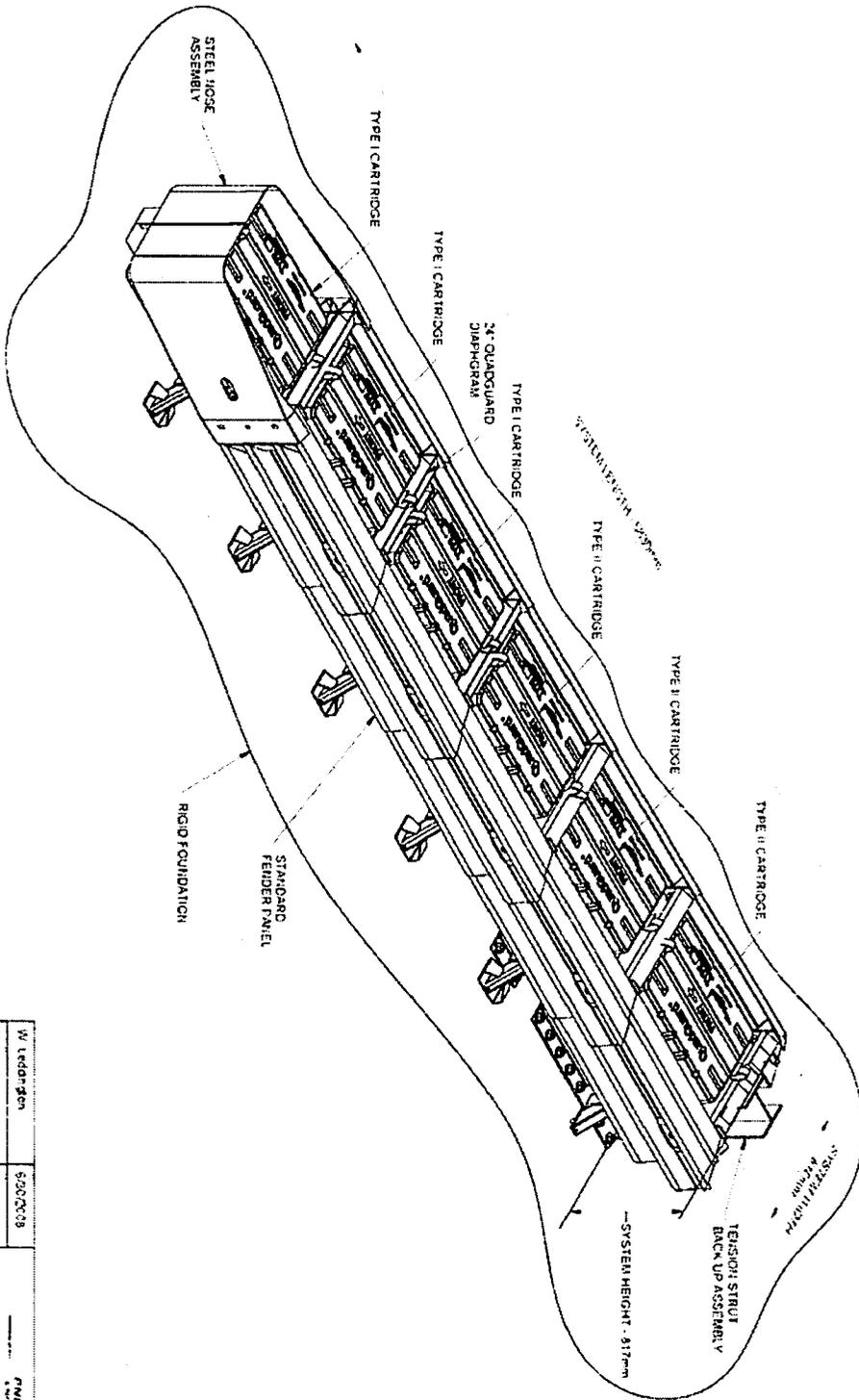
Test Article Deflections (m)

Dynamic	1.3
Permanent	1.3

Vehicle Damage (Primary Impact)

Exterior	
VDS	FC-3
CDC	12FCEW3
Interior	
VCDI	AS000000
Maximum Deformation (mm)	Negligible

Figure 6. Summary of Results - QuadGuard II System Test 01-4309-004



W. Ledderson	5/20/0008
M. Buchner	6/25/0008

5 BAY QUADGUARD II SYSTEM

1 of 1

