June 18, 1998

Refer to: HNG-14

J. M. Essex, P.E.
Senior Vice President, Sales
Energy Absorption Systems, Inc.
One East Wacker Drive
Chicago, Illinois 60601

Dear Mr. Essex:

In your April 15 letter to Mr. Henry Rentz, you requested acceptance of the QuadTrend for use on the National Highway System (NHS) at National Cooperative Highway Research Program (NCHRP) Report 350 test level 3 (TL-3). The QuadTrend is a modified version of the TREND, a product intended to function both as a gating, redirective end terminal and as a transition element to a rigid longitudinal barrier. The original TREND was formally accepted by the Federal Highway Administration for use as an NCHRP Report 230 device on January 8, 1986.

To support your request, you sent copies of your report entitled "QuadTrend-350 End Treatment: Qualification to NCHRP 350 TL- 3 - Engineering Summary," dated March 10, 1998, which included the full report prepared by E-TECH Testing Services, Inc., entitled "NCHRP Report 350 Crash Test Results for the QuadTrend-350," dated March 1998, and a video tape showing the full scale tests that you conducted on the QuadTrend. Revised copies of the two reports, both dated June 1998, were delivered to Mr. Richard Powers of my staff on June 17.

The QuadTrend-350 System is a redirective terminal/transition consisting of interlocking telescoping Quad-beam fender panels, six wide flange posts on slip base supports, sand containers on posts 1, 3, and 4, a tension strap on the field side of the unit, and a ground-level redirecting cable. The primary difference from the TREND is the use of Quad-beam fender panels in place of the original Thrie-beam panels used on the TREND. The QuadTrend system, as tested, is shown on Enclosure 1.

Since the QuadTrend is a gating terminal, NCHRP Report 350 specifies that tests 3-30 through 3-35 and test 3-39 be run to certify this device at Test Level 3 (TL-3). You stated that NCHRP Report 230 test 45 (which was run to certify the TREND) was equivalent to NCHRP Report 350 test 3-30 which need not be repeated since the Quad-beam fender panels are approximately the same weight as the Thrie-beam panels used in test 45, and there were no other significant design changes that were likely to degrade the QuadTrend's end-on performance with the 820-kg car. We reviewed the video and written summary of test 45 and agree that test 3-30 would probably be redundant and thus can be waived. You further stated that test 3-34 (small car at 15 degrees at the Critical Impact Point) need not be run because it is less critical than the NCHRP Report 230 test 30 (4500-pound car at 25 degrees 15 feet upstream from the connection to the rigid barrier). We do not believe these two tests are readily comparable. Test 3-34 is the NCHRP Report 350 equivalent of the NCHRP Report 230 test 44 (an 1800-pound car at 15 degrees midway between the nose and the beginning of the terminal's length of need) which was not run for the TREND certification. Nevertheless, we can agree to waive test 3-34 based on our comparison of the specific QuadTrend design details at the assumed critical impact point (i.e., at post 2) and the results of tests that have been run on other NCHRP Report 350 parallel terminals at the same location. A one-page summary of the tests that you did run, and summaries of each individual test, including NCHRP Report 230 test 45, are enclosed as Enclosure 2.

Two items appear critical to ensure satisfactory in-service performance of the QuadTrend - the structural rigidity of the vertical concrete barrier to which it is attached and the grading behind the terminal where the redirecting cable is located. The information you submitted did not include details on the attachment of the QuadTrend to the concrete wall or the reinforcing and embedment details of the wall itself. The concrete barrier to which the QuadTrend is attached must be a chamfered vertical wall (as tested), designed to resist a lateral ultimate load of 60 kips (414 MPa) to prevent overturning or significant deflection and a longitudinal load of 120 kips (828 MPa) to prevent pull-out or rupture of the end shoe.

Grading around the QuadTrend should conform to the recommended grading for all gating-type terminals. The roadway approaches to the terminal should be 1 to 10 (or flatter) and this grading should be extended at least one meter behind the terminal at which point it can be rounded to a somewhat steeper slope where necessary. Since a vehicle impacting the end of the QuadTrend will be guided along the redirecting cable, it is critical that this path be unobstructed and traversable. The need for a nearly flat runout path is evident in test 3-31 in which the impacting pickup truck was subjected to high roll and pitch angles as it was redirected behind the QuadTrend along the ground cable.

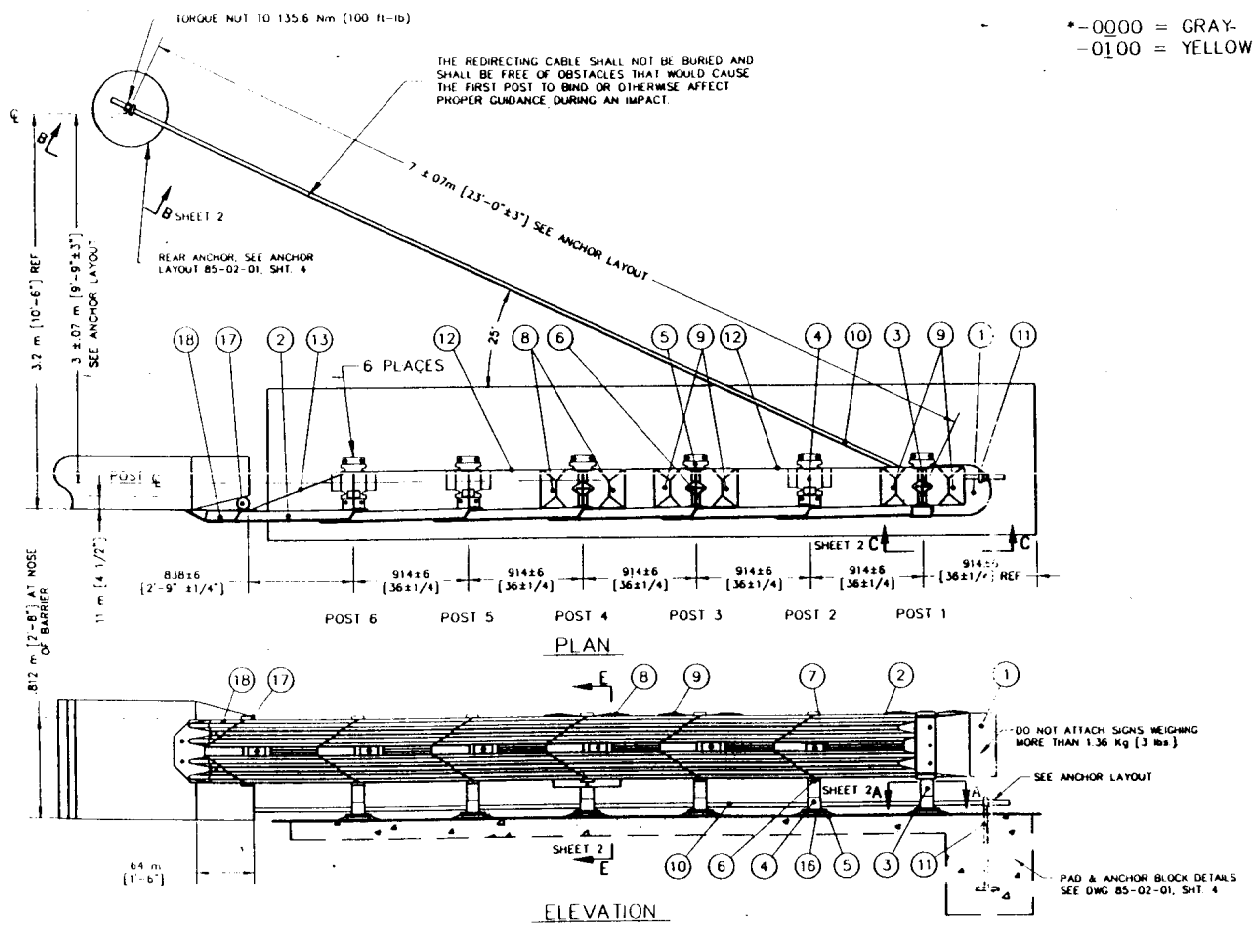
Based on our review of the information you provided, we concur that the QuadTrend, as tested, meets the acceptance criteria for an NCHRP Report 350 TL-3 terminal when used to shield the end of a rigid, vertical concrete barrier as noted above. It may be used on the National Highway System (NHS) when such use is specified by, or acceptable to, a transportation agency. Because it is a proprietary device, its use on Federal-aid projects, except exempt, non-NHS projects, remains subject to the conditions listed in Title 23, Code of Federal Regulations, Section 635.411 when its use is specified by the contracting authority.

Sincerely yours,

(original signed by Dwight A. Horne)

Dwight A. Horne
Chief, Federal-Aid and Design Division

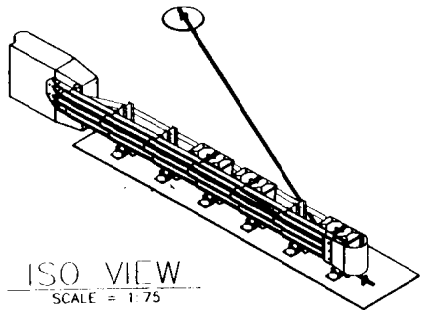
2 Enclosures
Acceptance Letter CC-49



*-0000 = GRAY
-0100 = YELLOW

PARTS LIST

ITEM	STOCK NO	DESCRIPTION	REQ'D
1	8508021-0*00	NOSE ASSY, QT-350, G or Y	1 00
2	2760081-0000	PANEL,FENDER,QG,G	6 00
3	2756011-0000	POST #1,G	1 00
4	2756021-0000	POST #2,G	5 00
5	2756111-0000	BASE,SLIP	6 00
6	2756042-0000	BLOCKOUT,TREND,QG,G	6 00
7	2708841-0000	WASHER,MUSHROOM,FORGED,QG,G	6 00
8	2020941-0000	CONTAINER,SAND,150 LB	2 00
9	2020951-0000	CONTAINER,SAND,100 LB	4 00
10	2742181-0000	CABLE,REDIRECTING,300	1 00
11	2744131-0000	ANCHOR,CABLE,EMBEDDED	2 00
12	2756291-0000	STRAP,BACK,78 1/8	2 00
13	2756331-0000	STRAP,BACK,SYSTEM TO BARRIER,88,QT-350	1 00
14	2756341-0000	STRAP, PIVOT, QT-350	5 00
15	2756141-0000	STRAP,PIVOT,MUSHROOM BOLT	1 00
16	2756081-0000	PLATE,BOLT KEEPER	6 00
17	2756351-0000	SPACER, TUBE, QT-350	1 00
18	2760271-0000	END SHOE, QG, G	1 00
19	2701731-0000	BOLT,FL,5/8X3,G8,G,SOCKET	6 00
20	2708291-0000	WASHER,FLAT,5/8X1 3/4,G	20 00
21	2704141-0000	NUT,HX,5/8,G	9 00
22	2699341-0000	BOLT,RAIL,5/8X2,G	2 00
23	2704191-0000	NUT,HX,5/8,G,RAIL	17 00
24	2699081-0500	BOLT, HX, 5/8 X 1 1/4, G5, G	18 00
25	2701651-0000	BOLT,HX,3/4X1 1/2,G2,G	20 00
26	2701621-0000	BOLT,HX,3/4X2 1/2,G2,G	28 00
27	2704091-0000	NUT,HX,3/4,G	48 00
28	2708081-0000	WASHER,FLAT,3/4X2,HVY,G	84 00
29	2701021-0300	BOLT,HX,3/8X1 1/2,G2,S	6 00
30	2708321-0300	WASHER,FLAT,3/8X1 1/2,S	12 00
31	2704031-0300	NUT,HX,3/8,S	6 00
32	3525020-0000	ANCHOR,MP-3,PT KIT,3/4X7 1/2,VERT	6 00
33	2732241-0000	BRUSH,TUBE,1	1 00
34	3525130-0000	ANCHOR, MP-3, PT KIT, 3/4 x 6 1/2, HOR	1 00
35	2735831-0100	MSDS, SENTRE/TREND	1 00
36	2750142-0000	INSTALLATION INSTRUCTIONS, QUADTREND	1 00



ISO VIEW
SCALE = 1:75

MODEL QT350ESY – YELLOW
QT350ESG – GRAY

OTES
FILL CONTAINER WITH SAND MEETING ASTM C 33 (WASHED CONCRETE SAND) OR EQUIVALENT, THEN SNAP LIDS TIGHTLY IN PLACE

ORQUE SLIP-BASE BOLT TO 81.35±6.8 Nm [60±5 ft-lb]

IE TREND SLIP-BASE MUST BE ATTACHED TO A CONCRETE PAD WHICH IS SIGNED TO RESIST THE LOADS DESCRIBED IN THE "DESIGN MANUAL" CHOR BOLTS MUST BE TORQUED TO 170 Nm [125ft-lb]

ANCHOR LAYOUT AND SHEET 2 FOR DETAIL & SECTION DRAWINGS

5 SEE THE "QuadTrend™ 350 SYSTEM DESIGN MANUAL" FOR A DESCRIPTION OF ITS IMPACT PERFORMANCE CHARACTERISTICS AND DESIGN LIMITATIONS BEFORE PLACING A SYSTEM AT A GIVEN SITE INFORMATION AND ADDITIONAL COPIES OF THE ABOVE MANUAL ARE AVAILABLE BY CALLING CUSTOMER SERVICE DEPARTMENT AT (312) 467-6750

6 USE A CONCRETE LEVELING PAD WHERE SITE CROSS SLOPE EXCEED SLOPE OF ADJACENT ROADWAY BY MORE THAN 5%

7 UNITS ARE IN MILLIMETERS [INCHES] UNLESS OTHERWISE NOTED

REFERENCES

NOSE ASSY 8508021-0000
PAD & ANCHOR LAYOUT 85-02-01 SHT. 4

DRAWN	D MILLER	DATE 3/5/98
DESIGNED		DATE
CHECKED	KRH	DATE 3-27-98
APPROVED	(RSW)	DATE 3/31/98
CAD FILE	QT350ES-1	
NEXT ASSEMBLY		

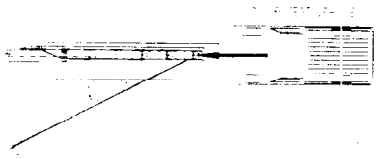
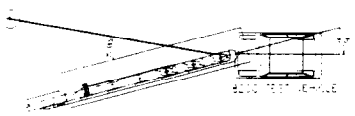
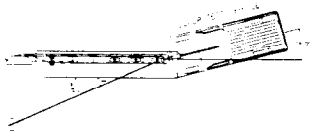
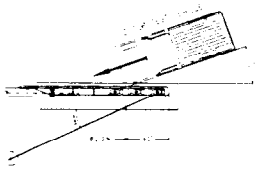
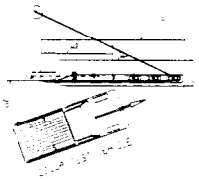
ENERGY ABSORPTION SYSTEMS, INC
ENGINEERING AND RESEARCH DEPARTMENT

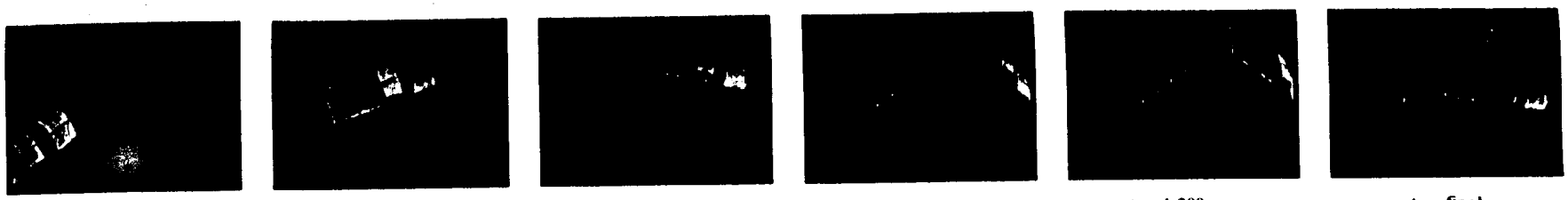
QuadTrend™ 350 SYSTEM WITH END SHOE

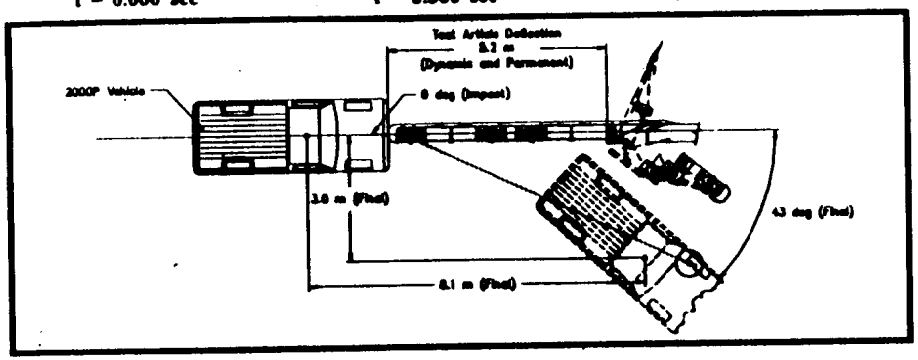
SCALE	DWG	SHEET	
1=50	QT350ES	1 of 10	

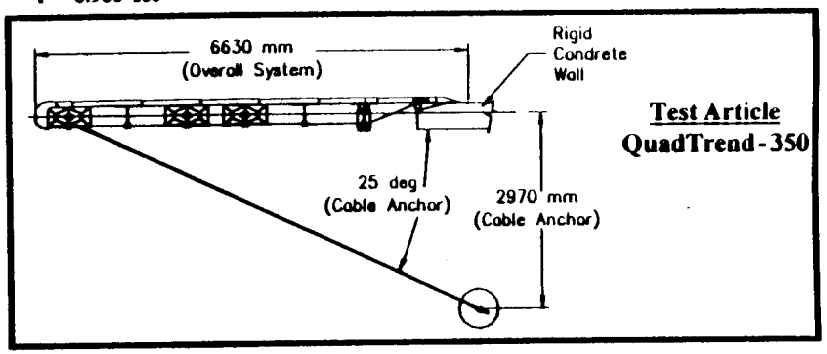
TEST MATRIX FOR CERTIFICATION OF THE Quad Trend™-350 END TREATMENT

TO NCHRP 350 TEST LEVEL 3 STANDARDS

NCHRP Evaluation Criteria	E-Tech Test ID. #	Test Conditions	Impact Speed (km/hr)	Impact Angle (deg.)	Occupant Impact Velocity		Ridedown Accelerations		Overall Assess-ment	Notes
					Long. (m/sec)	Lateral (m/sec)	Long. (G)	Lateral (G)		
350-3-31	01-7624-003		98.96	0	9.56	1.87	-10.04	11.88	PASS	
350-3-32	01-7624-002		99.36	16	11.08	1.09	-17.78	-7.28	PASS	
350-3-33	01-7624-004		97.56	15	9.17	1.93	-10.85	10.02	PASS	
350-3-35	01-7624-005		96.26	21	4.69	6.00	-7.26	9.20	PASS	
350-3-39	01-7624-001		100.95	20	5.19	7.69	-11.42	19.55	PASS	Impact wrong way.

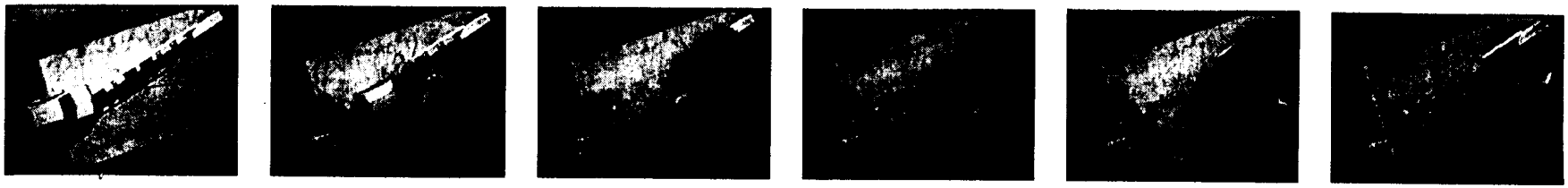






General Information	
Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-31
Test No.	01-7624-003
Date	10/7/97
Test Article	
Type	Energy Absorption QuadTrend-350
	w/rigid wall backup
Installation Length, (mm)	6630 (overall system)
Size and/or dimension and material of key elements	QuadTrend - 350
	6630 mm (overall system)
Foundation Type and Condition	Dry 203 mm deep unreinforced Portland Cement Concrete
Test Vehicle	
Type	Production Model
Designation	2000P
Model	1988 Chevrolet C-2500
	3/4T Pickup
Mass (kg)	
Curb	2000.8
Test inertial	2007.8
Dummy(s)	N/A
Gross Static	2007.8
Impact Conditions	
Speed (km/h)	98.96
Angle (deg)	0.0
Impact Severity (kJ)	758.65
Exit conditions	
Speed (km/h)	N/A
Angle (deg)	N/A
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	9.56
y-direction	1.87
Ridedown Acceleration (g's)	
x-direction	-10.04
y-direction	11.88
THIV (m/s)	9.73
PHD (g's)	12.10
ASI	1.08
Test Article Deflections (m)	
Dynamic	5.2
Permanent	5.2
Vehicle Damage	
Exterior	
VDS	FC-3
CDC	12FCEW3
Interior	
OCDI	LF0002000
Post-Impact Vehicular Behavior (film @ ground plane)	
Maximum Roll Angle	-62
Maximum Pitch Angle	-70
Maximum Yaw Angle	43

Figure 1. Summary of Results - QuadTrend - 350 Test 01-7624-003



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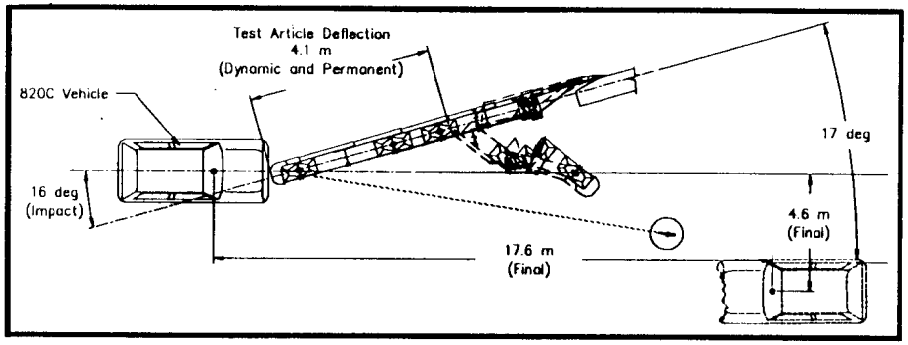
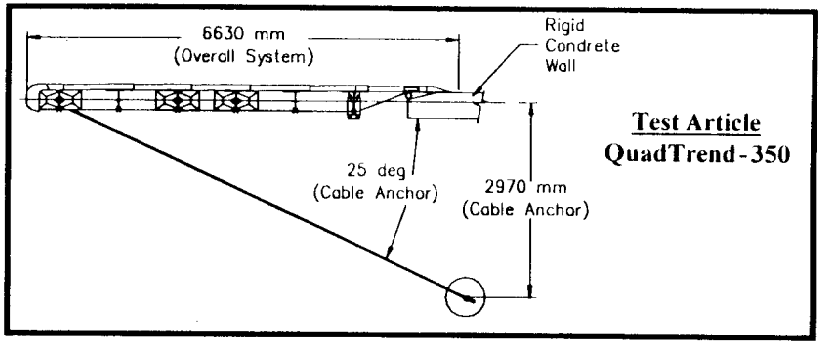




General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-32
Test No.	01-7624-002
Date	9/24/97

Test Article

Type	Energy Absorption QuadTrend-350
	w/rigid wall backup
Installation Length, (mm)	6630 (overall system)
Size and/or dimension and material of key elements	QuadTrend - 350
	6630 mm (overall system)
Foundation Type and Condition	Dry 203 mm deep unreinforced
	Portland Cement Concrete

Test Vehicle

Type	Production Model
Designation	820C
Model	1988 Ford Festiva
	Hatchback
Mass (kg)	
Curb	810.2
Test inertial	802.6
Dummy(s)	75
Gross Static	877.6

Impact Conditions

Speed (km/h)	99.36
Angle (deg)	16.0
Impact Severity (kJ)	305.69

Exit conditions

Speed (km/h)	N/A
Angle (deg)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	11.08
y-direction	1.09
Ridedown Acceleration (g's)	
x-direction	-17.78
y-direction	-7.28
THIV (m/s)	11.19
PHD (g's)	11.96
ASI	1.10

Test Article Deflections (m)

Dynamic	4.1
Permanent	4.1

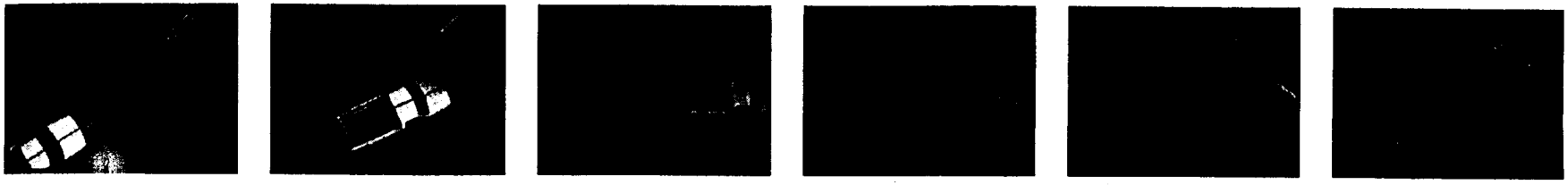
Vehicle Damage

Exterior	
VDS	FC-3
CDC	11FCEW3
Interior	
OCDI	AS0000000

Post-Impact Vehicular Behavior (rate gyro @ c.g.)

Maximum Roll Angle	-5.44
Maximum Pitch Angle	-7.77
Maximum Yaw Angle	-30.59

Figure 6. Summary of Results - QuadTrend - 350 Test 01-7624-002



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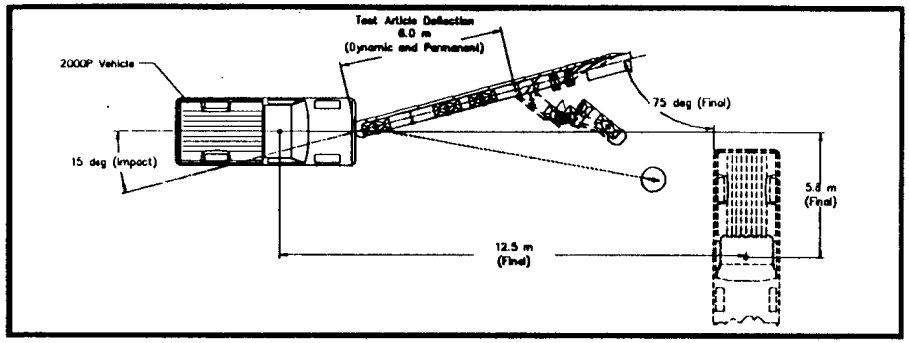
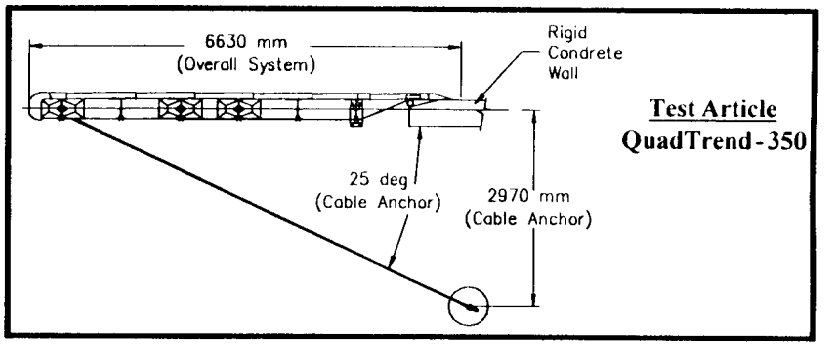




General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-33
Test No.	01-7624-004
Date	11/21/97

Test Article

Type	Energy Absorption QuadTrend-350
	w/rigid wall backup
Installation Length, (mm)	6630 (overall system)
Size and/or dimension and material of key elements	QuadTrend - 350
	6630 mm (overall system)
Foundation Type and Condition	Dry 203 mm deep unreinforced
	Portland Cement Concrete

Test Vehicle

Type	Production Model
Designation	2000P
Model	1988 Chevrolet C-2500
	3/4T Pickup
Mass (kg)	
Curb	2103.4
Test inertial	1994.0
Dummy(s)	N/A
Gross Static	1994.0

Impact Conditions

Speed (km/h)	97.56
Angle (deg)	15.0
Impact Severity (kJ)	732.20

Exit conditions

Speed (km/h)	N/A
Angle (deg)	N/A

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	9.17
y-direction	1.93
Ridedown Acceleration (g's)	
x-direction	-10.85
y-direction	10.02
THIV (m/s)	9.39
PHD (g's)	12.12
ASI	0.95

Test Article Deflections (m)

Dynamic	6.0
Permanent	6.0

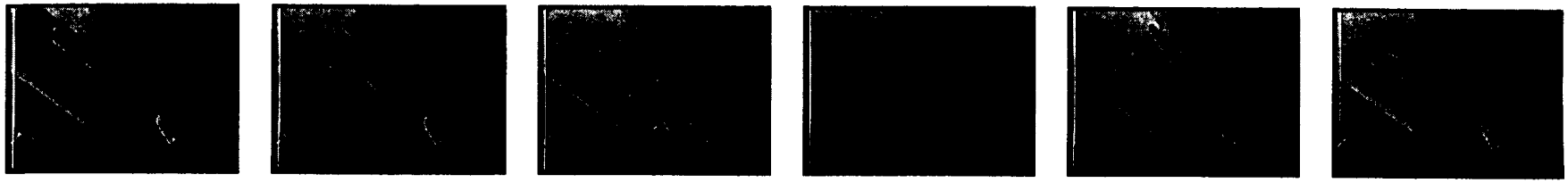
Vehicle Damage

Exterior	
VDS	FC-3
CDC	11FCEW3
Interior	
OCDI	AS0000000

Post-Impact Vehicular Behavior (rate gyro @ c.g.)

Maximum Roll Angle	-26.20
Maximum Pitch Angle	-29.44
Maximum Yaw Angle	81.72

Figure 11. Summary of Results - QuadTrend - 350 Test 01-7624-004



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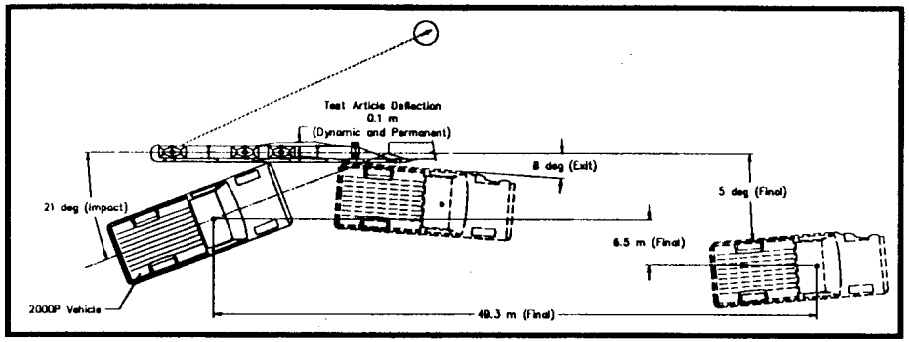
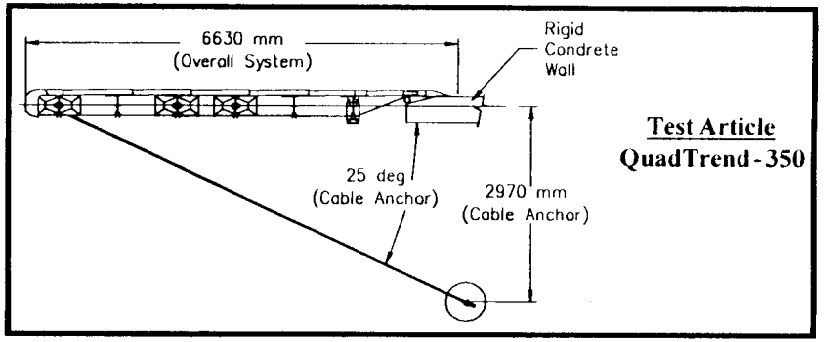




General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-35
Test No.	01-7624-005
Date	1/21/98

Test Article

Type	Energy Absorption QuadTrend-350
	w/rigid wall backup
Installation Length, (mm)	6630 (overall system)
Size and/or dimension and material of key elements	QuadTrend - 350
	6630 mm (overall system)
Foundation Type and Condition	Dry 203 mm deep unreinforced
	Portland Cement Concrete

Test Vehicle

Type	Production Model
Designation	2000P
Model	1989 Chevrolet C-2500
	3/4T Pickup
Mass (kg)	
Curb	2079.5
Test inertial	2003.4
Dummy(s)	N/A
Gross Static	2003.4

Impact Conditions

Speed (km/h)	96.26
Angle (deg)	21.0
Impact Severity (kJ)	91.98

Exit conditions

Speed (km/h)	65.5
Angle (deg)	8.0

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	4.69
y-direction	6.00
Ridedown Acceleration (g's)	
x-direction	-7.26
y-direction	9.20
THIV (m/s)	8.04
PHD (g's)	8.25
ASI	1.10

Test Article Deflections (m)

Dynamic	0.1
Permanent	0.1

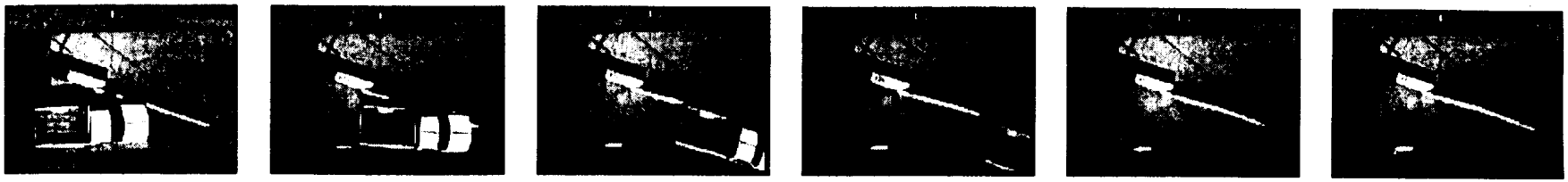
Vehicle Damage

Exterior	
VDS	LFQ-5
CDC	11LDEW4
Interior	
OCDI	AS0000000

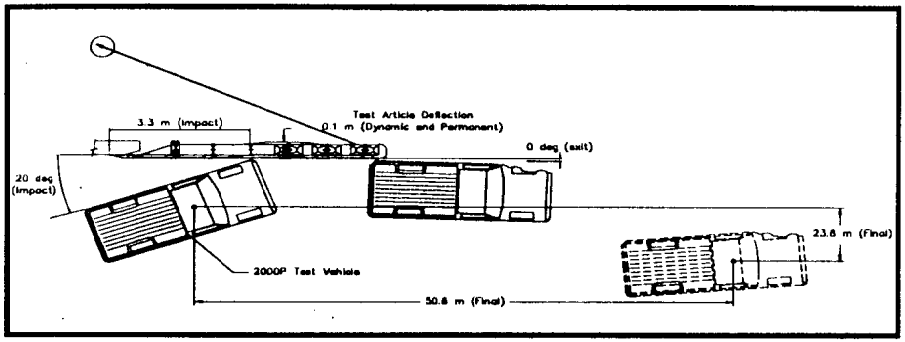
Post-Impact Vehicular Behavior (rate gyro @ c.g.)

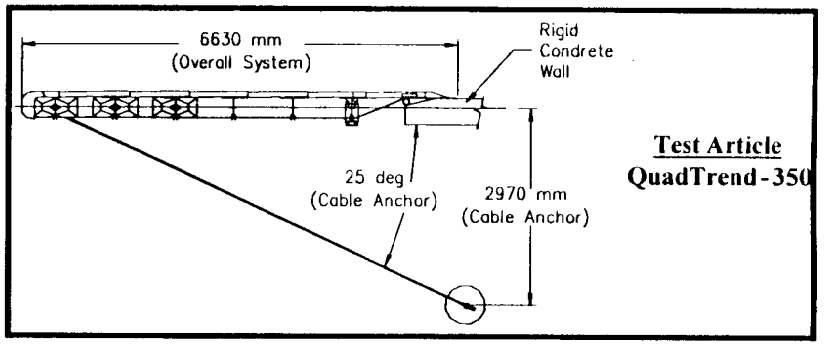
Maximum Roll Angle	-13.52
Maximum Pitch Angle	-8.15
Maximum Yaw Angle	31.34

Figure 16. Summary of Results - QuadTrend - 350 Test 01-7624-005



t = 0.000 sec | t = 0.120 sec | t = 0.240 sec | t = 0.360 sec | t = 0.480 sec | t = final





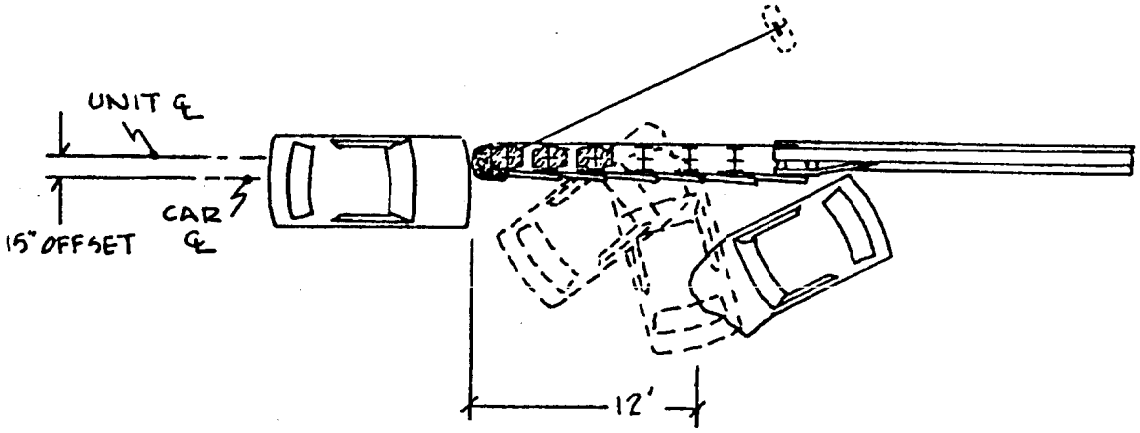
General Information

Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-39
Test No.	01-7624-001
Date	7/18/97
Test Article	
Type	Energy Absorption QuadTrend-350
	w/rigid wall backup
Installation Length, (mm)	6630 (overall system)
Size and/or dimension and material of key elements	QuadTrend - 350
	6630 mm (overall system)
Foundation Type and Condition	Dry 203 mm deep unreinforced
	Portland Cement Concrete
Test Vehicle	
Type	Production Model
Designation	2000P
Model	1988 Chevrolet C-2500
	3/4T Pickup
Mass (kg)	
Curb	1913.2
Test inertial	2007.6
Dummy(s)	N/A
Gross Static	2007.6
Impact Conditions	
Speed (km/h)	100.95
Angle (deg)	20.0
Impact Severity (kJ)	93.32

Exit conditions

Speed (km/h)	66.6
Angle (deg)	0.0
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	5.19
y-direction	7.69
Ridedown Acceleration (g's)	
x-direction	-11.42
y-direction	19.55
THIV (m/s)	9.35
PHD (g's)	13.87
ASI	1.31
Test Article Deflections (m)	
Dynamic	0.1
Permanent	0.1
Vehicle Damage	
Exterior	
VDS	LFQ-5
CDC	11LDEW2
Interior	
OCDI	AS0000000
Post-Impact Vehicular Behavior (deg)	
Maximum Roll Angle (gyro)	21.76
Maximum Pitch Angle (gyro)	10.18
Maximum Yaw Angle (film)	27.72

Figure 21. Summary of Results - QuadTrend - 350 Test 01-7624-001



Test No. 85-010
Date 6/5/85
Installation
  Drawing No. ..... TREND
  Length - ft ..... 18½'
  Maximum Penetration - ft ..... 12'
Structure
  Member ..... C.M.B. Concrete
  Length - ft ..... 20'
  Overall Length ..... 20'
Vehicle
  Model ..... 1976 Honda Civic
Mass - lb Test Inertia 1850
  Dummy 165
  Gross 2015

Target Impact Severity - ft-kips 228.4
Speed - mph
  Impact 60.8
Angle - deg
  Impact ..... 0°
Occupant Impact Velocity - fps
  Forward 37.4
  Lateral 9.6
Occupant Ridedown Acceleration - g's
  Forward 13.6
  Lateral 12.6
Max. 50 MS g's (Per TRC-191) 15.1
Vehicle
  Rebound Distance - ft 0
TAD Damage FD-4
VDI Damage 12FDEWA