November 13, 1998

Refer to: HNG-14

Mr. Don H. Johnson
President
Syro, Inc.
2525 Stemmons Freeway
P.O. Box 568887
Dallas, Texas 75356-8887

Dear Mr. Johnson:

In your October 7 letter, you asked for the Federal Highway Administration's acceptance of the Trinity/Exodyne Crash Cushion (identified as the Trinity Attenuating Crash Cushion or TRACC in your subsequent October 25 letter) as an National Cooperative Highway Research Program (NCHRP) Report 350 test level 3 (TL-3) attenuator. To support this request, you included copies of a September 1998 Texas Transportation Institute (TTI) report, "Testing and Evaluation of Syro/Trinity Crash Cushion," by Bligh, Menges and Butler, and a video tape showing the full scale tests that were conducted.

The TRACC includes four major components: a pair of guidance tracks, an impact "sled," intermediate steel frames, and 10 gauge w-beam fender panels. The guidance tracks are made from two C-channels formed into a box section by variable lengths and thicknesses of metal rip plates bolted to the outside flanges of the channels. The sled, or impact face, of the TRACC is positioned over the upstream end of the guidance tracks and contains a hardened steel blade which cuts the metal plates on the sides of the guidance tracks as it is forced backwards in an end hit. The intermediate frames support the W-beam fender panels and are free to slide backwards when the TRACC is hit on the end, but lock onto the guidance tracks to provide redirection for side impacts. The fender panels are bolted to the intermediate frames with a design that locks the inside panels in place while allowing the outer panels to slide back freely as the system telescopes rearward. Enclosure 1 shows the layout of the TRACC and the schematic design of its major components.

In reviewing the crash test data contained in the TTI report, we noted that the tests you ran included all of the NCHRP Report 350 recommended tests for a redirective, non-gating crash cushion except test 3-36 (820C vehicle at 100 km/h and 15 degrees at the beginning of the length of need). You stated that test 3-37 (2000P vehicle at 100 km/h and 20 degrees at the same location as test 3-36) was a more demanding test and that the design of the TRACC was such that the small car impacting at the same location at a shallower angle would be redundant and thus not necessary. We concur with your analysis. We also noted that several design modifications were made in the TRACC before the final design evolved. Looking at each of these changes and the tests that were subsequently run on the final design, we again concur with your analysis that the earlier tests need not be rerun since the specific changes are not likely to have had

a negative impact on the results of the earlier tests. Enclosure 2 consists of the summary results of tests 3-38, 3-33, 3-37, 3-32, 3-30, 3-31 and 3-39. This is the chronological order in which the tests were run and we noted that the last four tests were run on the final design for which you seek acceptance. In all tests, NCHRP Report 350 evaluation criteria were met. We understand that you intend to supply the TRACC to users as an assembled unit to simplify and facilitate installation.

In response to questions raised by my staff during our review, Mr. James Albritton of Exodyne Technologies, Inc. sent me additional information on October 16 and on October 26 regarding anchorage and transition designs and you provided detailed drawings and further information in your November 4 letter. The tested unit was installed on a 150-mm thick reinforced concrete base and anchored with twenty-seven 190-mm long steel anchor studs 16-mm in diameter. Mr. Albritten stated that the TRACC can also be used as a temporary crash cushion resting on 200 mm of asphalt (or 150 mm of asphalt over 150 mm of compacted subbase) if anchored with twenty-seven 460-mm long Grade 5 threaded studs set in drilled holes using a polyester resin meeting ACI 349 requirements. He also provided conceptual drawings (Enclosure 3) of the connection of the TRACC to a vertical concrete barrier and to a safety-shape concrete barrier at locations where there is bi-directional traffic. While these designs appear to minimize the snagging potential, users will need to have shop drawings showing exact dimensions, material specifications, and welding and connection details for each design before it is used and we will need copies of these drawings for our files.

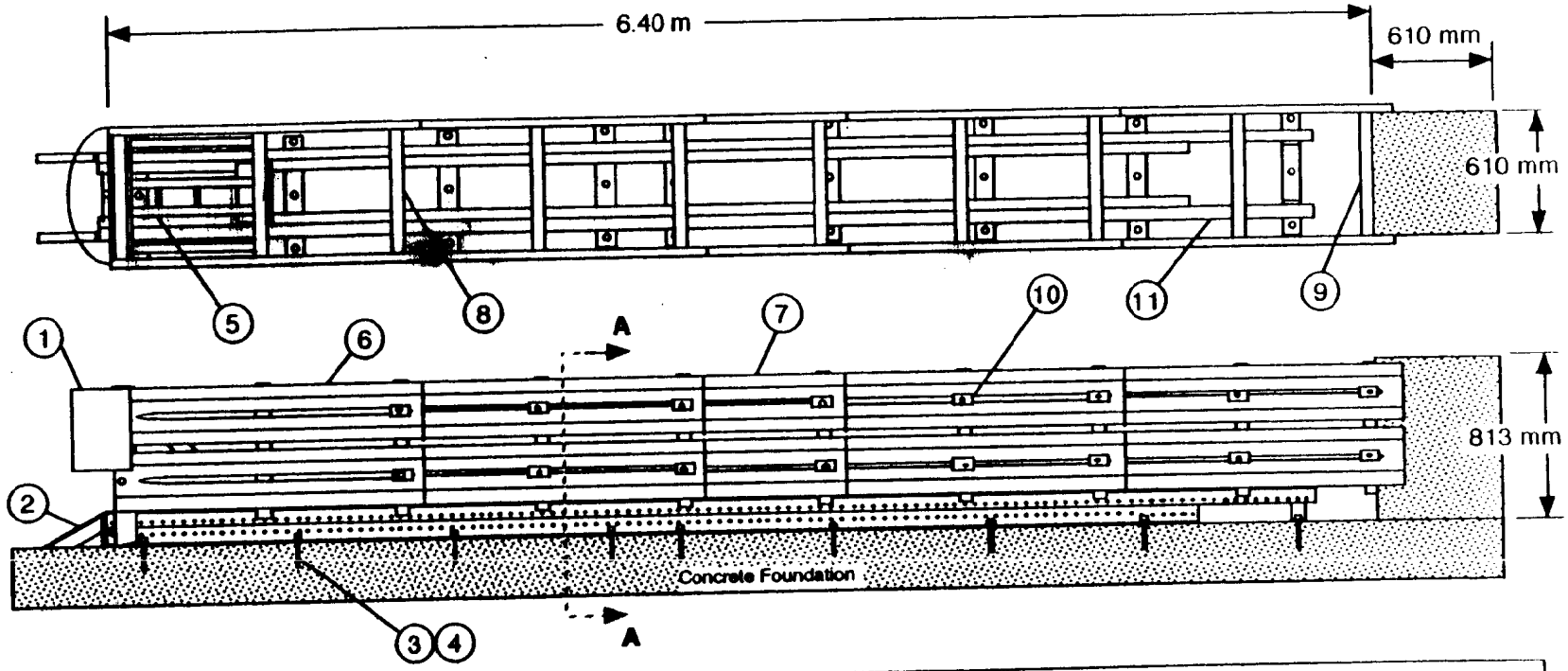
Based on our review, we conclude that the TRACC, as designed and tested, meets the evaluation criteria for an NCHRP Report 350 TL-3 attenuator and may be used on the National Highway System (NHS) as a permanent or temporary crash cushion. Since the TRACC is a proprietary product, its use on Federal-aid projects, except exempt non-NHS projects, is subject to the conditions noted in Title 23, Code of Federal Regulations,
Section 635.411.

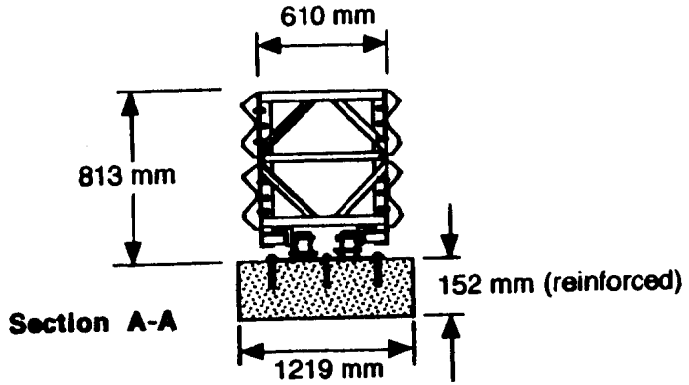
Sincerely yours,

(original signed by Dwight A. Horne)

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

3 Enclosures
Acceptance Letter CC-54



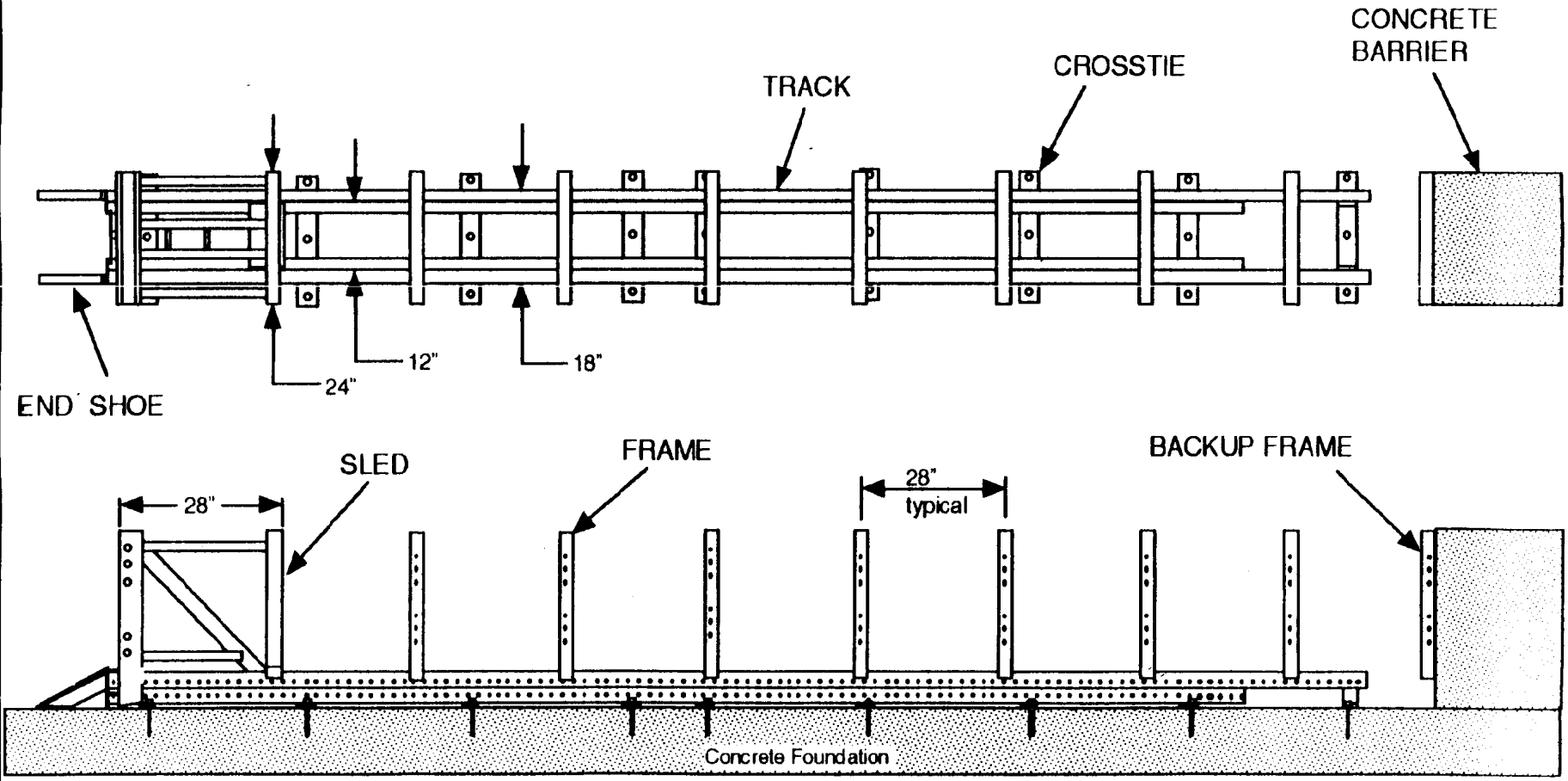


Trinity Industries, Inc., Narrow Crash Cushion	
Item	Description
1	Plastic Sheet w/ Reflective Delineator
2	Snag Eliminating Ramps
3	5/8" x 7.5" Anchor Stud
4	Chemical Grout
5	Sled
6	2-Bay Fender Panel
7	1-Bay Fender Panel
8	Intermediate Frame
9	Backup Frame
10	Slot Plate
11	Guide Angles

J.R. Albritton, P.E.
Exodyne Technologies, Inc.
817-560-1459
7-8-98

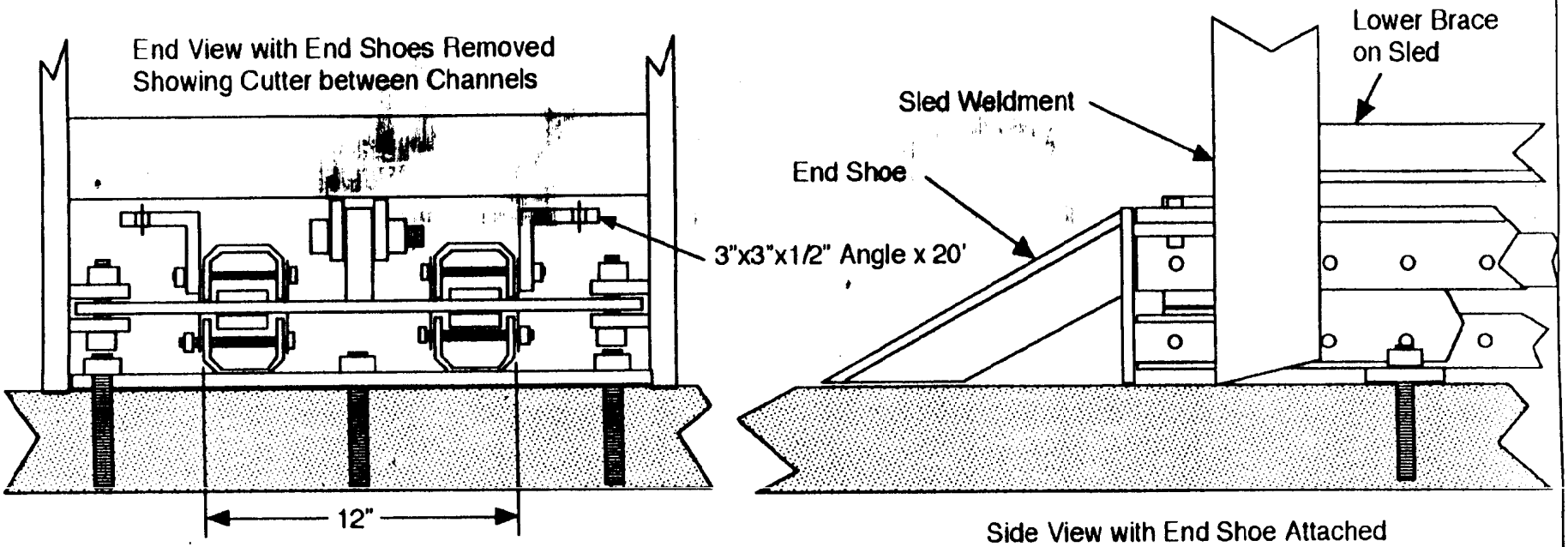
Figure 1. Details of the Syro/Trinity Crash Cushion.

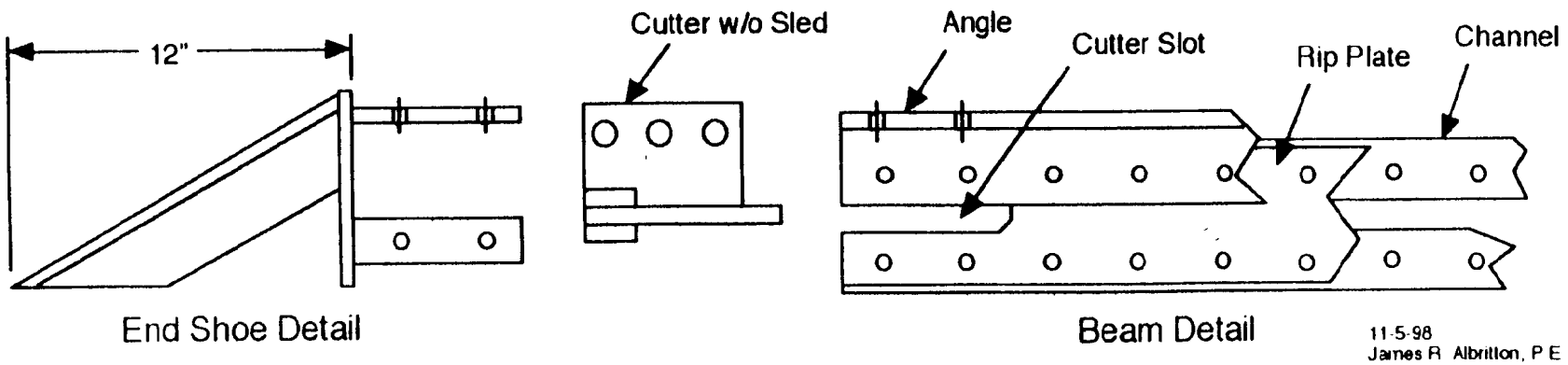
THE STRUCTURAL COMPONENTS



11-5-98
James R. Albritton, P.E.
Exodyne Technologies, Inc.
(817) 560-1459

Details of the Cutter Plate, Rip Plate, End Shoe Interface





End Shoe bolts to lower channel and angle after cutter slides into slot.

11-5-98
James R Albritton, P E
Exodyne Technologies, Inc
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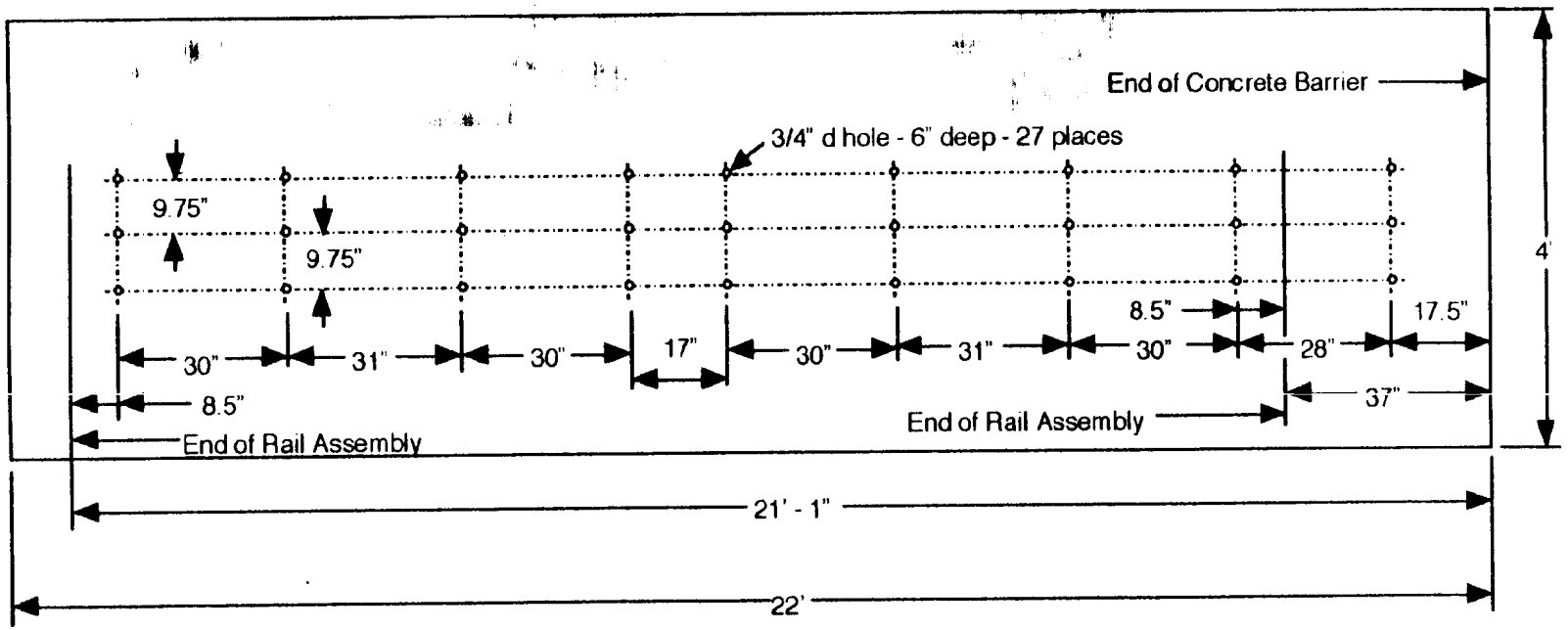
FOUNDATION PLAN

Top View



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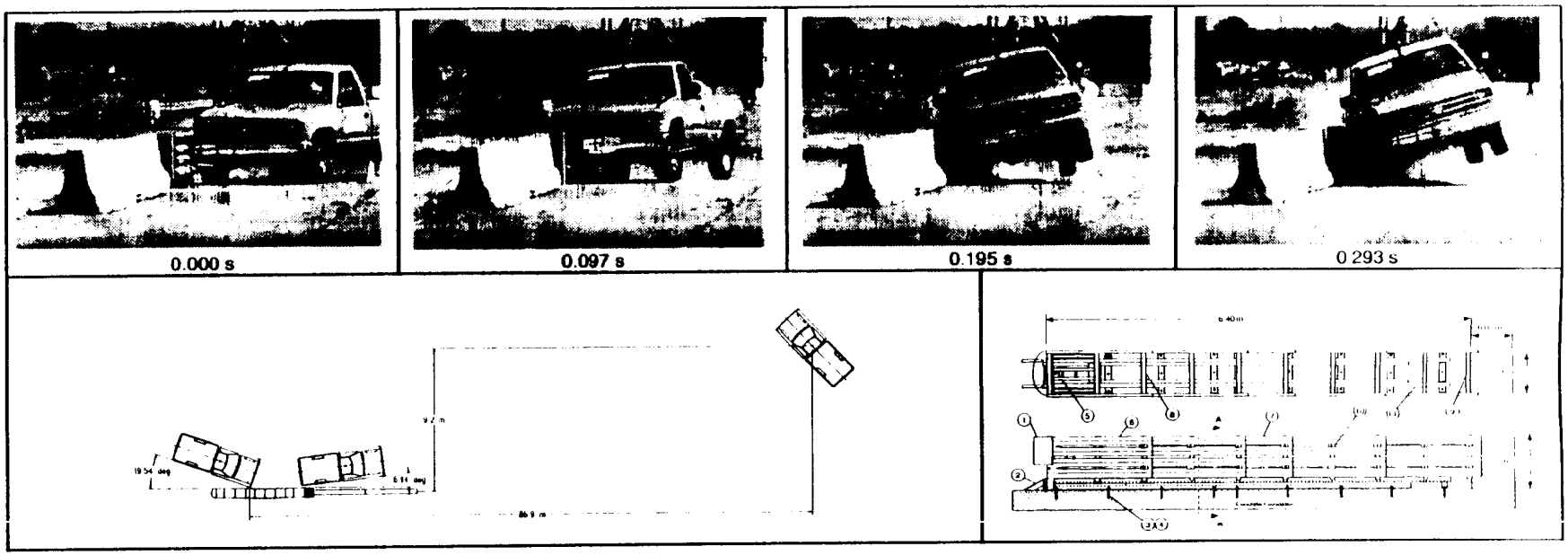
11-5-98



General Information
- Test Agency . . . . . Texas Transportation Institute
- Test No. 404091-2
- Date 07/1/97

Test Article
- Type . . . . . Crash Cushion
- Name or Manufacturer . . . . . Syro/Trinity Crash Cushion
- Installation Length (m) 6.40
- Material or Key Elements . . . Guidance Track, Impact Sled, Intermediate Frames, Fender Panels

Soil Type and Condition . . . . Concrete Pavement, Dry

Test Vehicle
- Type . . . . . Production
- Designation 2000P
- Model . . . . . 1993 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 1888
  - Test Inertial 2000
  - Dummy . . . . . No dummy
  - Gross Static 2000

Impact Conditions
- Speed (km/h) 101.2
- Angle (deg) 19.5

Exit Conditions
- Speed (km/h) 92.8
- Angle (deg) 6.9

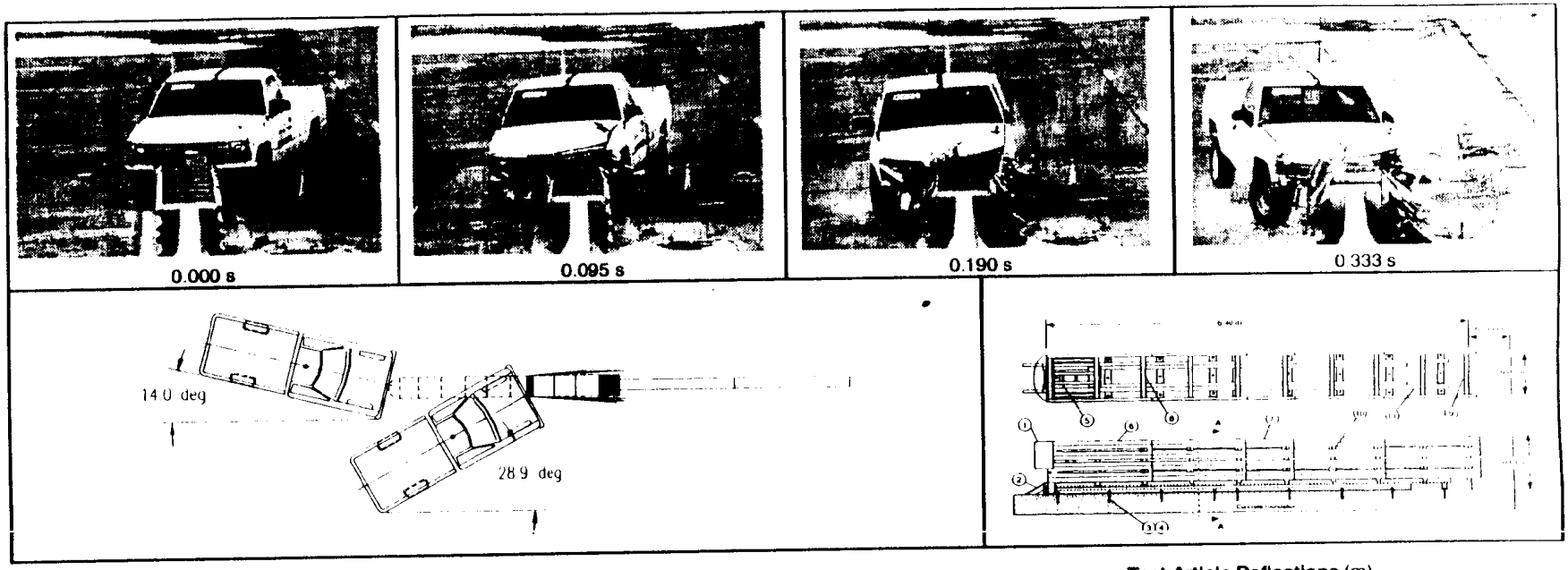
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 4.3
  - y-direction 6.5
- THIV (km/h) 24.7
- Ridedown Accelerations (g's)
  - x-direction . . . . . -7.4
  - y-direction . . . . . -12.8
- PHD (g's) 14.1
- ASI 1.13
- Max. 0.050-s Average (g's)
  - x-direction . . . . . -4.1
  - y-direction . . . . . -9.6
  - z-direction 3.6

Test Article Deflections (m)
- Dynamic 0.23
- Permanent 0.10

Vehicle Damage
- Exterior
  - VDS 01RFQ2
  - CDC 01FREW2
- Maximum Exterior
  - Vehicle Crush (mm) 380
- Interior
  - OCDI RS0000000
- Max. Occ. Compart
  - Deformation (mm) 0

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) 17
- Max. Pitch Angle (deg) . . . . -4
- Max. Roll Angle (deg) . . . . -30

Figure 10. Summary of results for test 404091-2, *NCHRP Report 350* test 3-38.



General Information
- Test Agency: Texas Transportation Institute
- Test No.: 404091-6
- Date: 11/13/97

Test Article
- Type: Crash Cushion
- Name or Manufacturer: Syro/Trinity Crash Cushion
- Installation Length (m): 6.40
- Material or Key Elements: Guidance Track, Impact Sled, Intermediate Frames, Fender Panels

Soil Type and Condition: Concrete Pavement, Dry

Test Vehicle
- Type: Production
- Designation: 2000P
- Model: 1992 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb: 2121
  - Test Inertial: 2000
  - Dummy: No dummy
  - Gross Static: 2000

Impact Conditions
- Speed (km/h): 98.1
- Angle (deg): 14.0

Exit Conditions
- Speed (km/h): Stopped
- Angle (deg): N/A

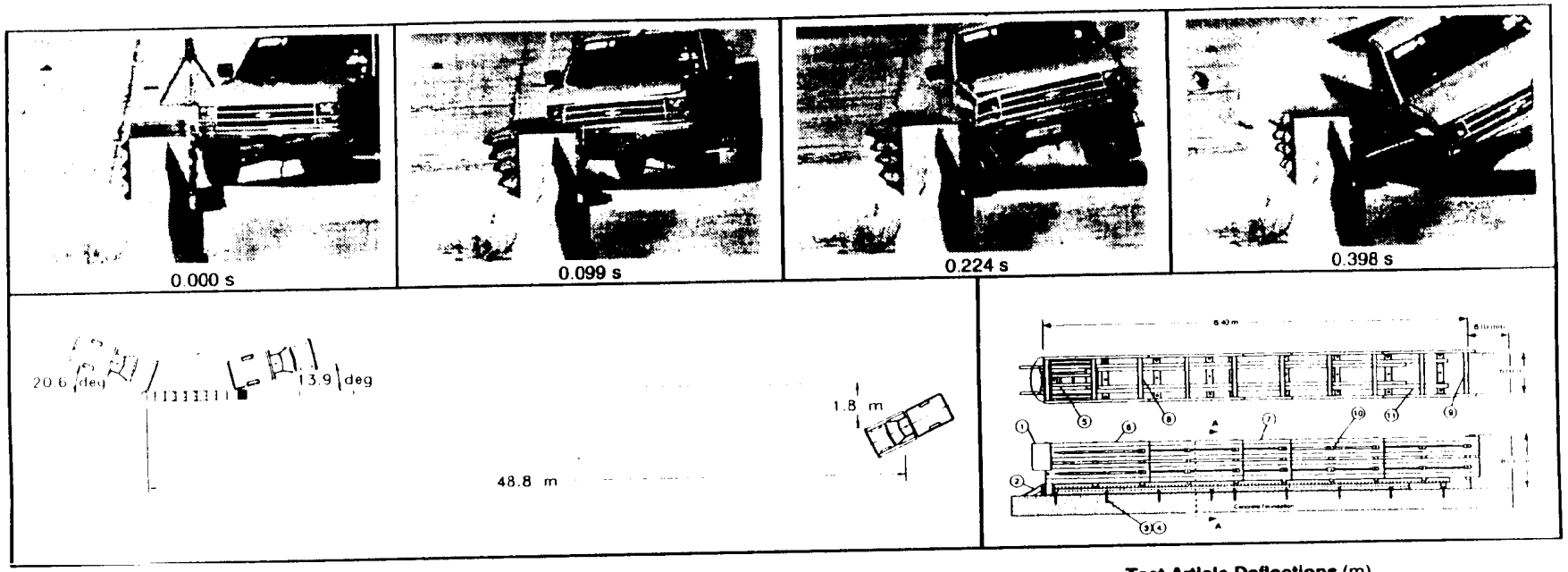
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction: 10.0
  - y-direction: 1.6
- THIV (km/h): 36.0
- Ridedown Accelerations (g's)
  - x-direction: -14.4
  - y-direction: -3.3
- PHD (g's): 14.6
- ASI: 1.06
- Max. 0.050-s Average (g's)
  - x-direction: -11.7
  - y-direction: -3.8
  - z-direction: 5.4

Test Article Deflections (m)
- Dynamic: 3.86
- Permanent: 3.64

Vehicle Damage
- Exterior
  - VDS: 12FD5
  - CDC: 12FDEW2
- Maximum Exterior Vehicle Crush (mm): 500
- Interior
  - OCDI: FS0000000
- Max. Occ. Compart Deformation (mm): 7

Post-Impact Behavior (during 1.0 s after impact)
- Max. Yaw Angle (deg): -45
- Max. Pitch Angle (deg): -4
- Max. Roll Angle (deg): 11

Figure 18. Summary of results for test 404091-6, *NCHRP Report 350* test 3-33.



General Information

Test Agency	Texas Transportation Institute
Test No.	404091-11
Date	03/05/98

Test Article

Type	Crash Cushion
Name or Manufacturer	Syro/Trinity Crash Cushion
Installation Length (m)	6.40
Material or Key Elements	Guidance Track, Impact Sled, Intermediate Frames, Fender Panels
Soil Type and Condition	Concrete Pavement, Dry

Test Vehicle

Type	Production
Designation	2000P
Model	1993 Chevrolet 2500 pickup truck
Mass (kg)	
Curb	2040
Test Inertial	2000
Dummy	No dummy
Gross Static	2000

Impact Conditions

Speed (km/h)	99.9
Angle (deg)	20.6

Exit Conditions

Speed (km/h)	81.0
Angle (deg)	13.9

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	5.3
y-direction	6.2
THIV (km/h)	25.3
Ridedown Accelerations (g's)	
x-direction	-3.9
y-direction	-9.3
PHD (g's)	10.6
ASI	0.92
Max. 0.050-s Average (g's)	
x-direction	-5.3
y-direction	-7.6
z-direction	2.6

Test Article Deflections (m)

Dynamic	0.38
Permanent	0.14

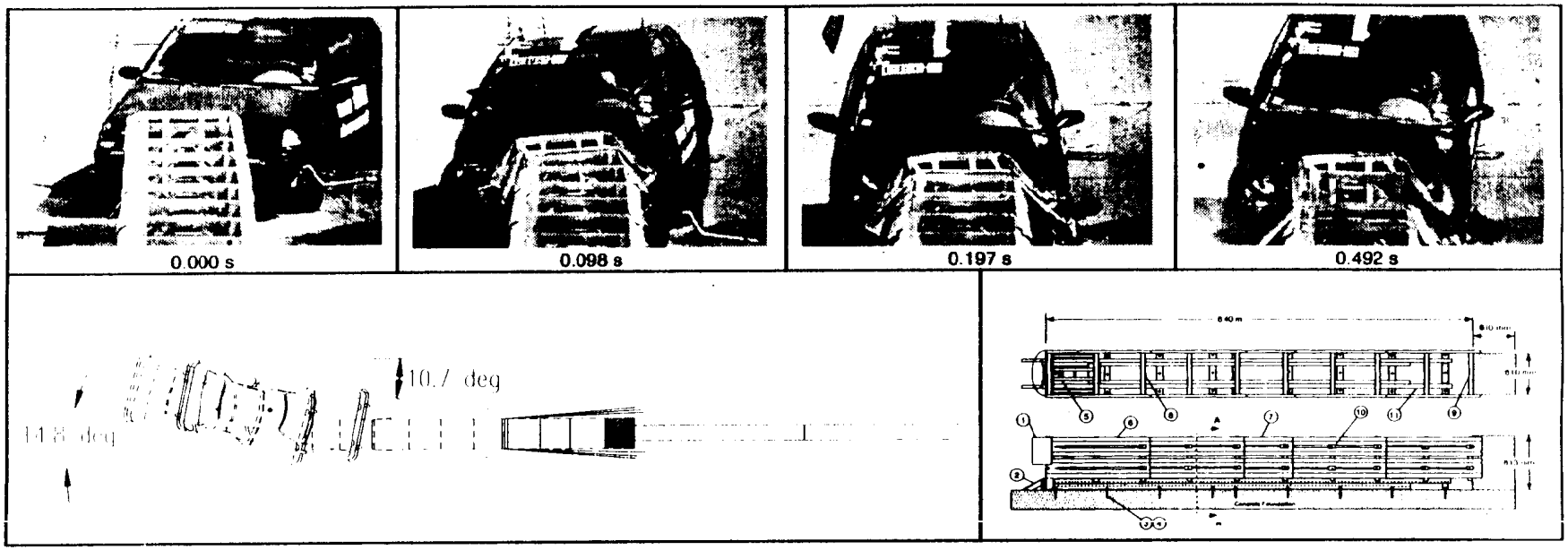
Vehicle Damage

Exterior	
VDS	01RFQ2
CDC	01FREW2
Maximum Exterior Vehicle Crush (mm)	330
Interior	
OCDI	RS0000000
Max. Occ. Compart. Deformation (mm)	0

Post-Impact Behavior
(during 1.0 s after impact)

Max. Yaw Angle (deg)	-34
Max. Pitch Angle (deg)	-12
Max. Roll Angle (deg)	35

Figure 26. Summary of results for test 404091-11, *NCHRP Report 350* test 3-37.



General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 404091-15
- Date 04/28/98

Test Article
- Type ..... Crash Cushion
- Name or Manufacturer ..... Syro/Trinity Crash Cushion
- Installation Length (m) 6.40
- Material or Key Elements ... Guidance Track, Impact Sled, Intermediate Frames, Fender Panels

Soil Type and Condition .... Concrete Pavement, Dry

Test Vehicle
- Type ..... Production
- Designation 820C
- Model ..... 1992 Geo Metro
- Mass (kg)
  - Curb 748
  - Test Inertial 820
  - Dummy 75
  - Gross Static 895

Impact Conditions
- Speed (km/h) 96.6
- Angle (deg) 14.8

Exit Conditions
- Speed (km/h) ..... Stopped
- Angle (deg) ..... N/A

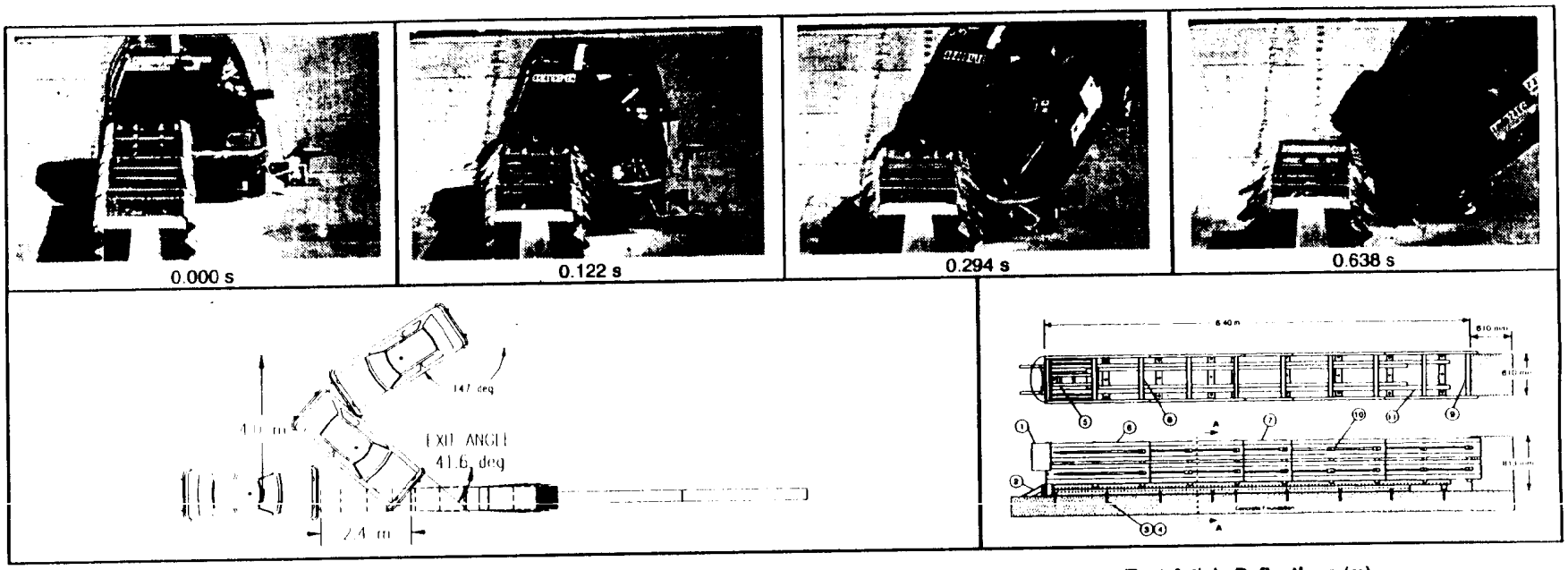
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 11.9
  - y-direction 3.6
- THIV (km/h) 44.8
- Ridedown Accelerations (g's)
  - x-direction ..... -14.3
  - y-direction ..... -8.8
- PHD (g's) 15.9
- ASI 1.73
- Max. 0.050-s Average (g's)
  - x-direction ..... -18.6
  - y-direction ..... -7.0
  - z-direction ..... -5.3

Test Article Deflections (m)
- Dynamic 2.52
- Permanent 2.47

Vehicle Damage
- Exterior
  - VDS 12FC5
  - CDC 12FCEW3
- Maximum Exterior
  - Vehicle Crush (mm) 440
- Interior
  - OCDI FS0020000
- Max. Occ. Compart.
  - Deformation (mm) 90

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) ..... -14
- Max. Pitch Angle (deg) ..... -12
- Max. Roll Angle (deg) ..... -4

Figure 34. Summary of results for test 404091-15, *NCHRP Report 350* test 3-32.



General Information

Test Agency	Texas Transportation Institute
Test No.	404091-16
Date	06/02/98

Test Article

Type	Crash Cushion
Name or Manufacturer	Syro/Trinity Crash Cushion
Installation Length (m)	6.40
Material or Key Elements	Guidance Track, Impact Sled, Intermediate Frames, Fender Panels
Soil Type and Condition	Concrete Pavement, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Ford Festiva
Mass (kg)	
Curb	800
Test Inertial	820
Dummy	76
Gross Static	896

Impact Conditions

Speed (km/h)	98.8
Angle (deg)	0

Exit Conditions

Speed (km/h)	6.7
Angle (deg)	41.6 toward cushion

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	10.2
y-direction	1.9
THIV (km/h)	36.1
Ridedown Accelerations (g's)	
x-direction	-15.5
y-direction	-5.3
PHD (g's)	15.8
ASI	1.28
Max. 0.050-s Average (g's)	
x-direction	-14.6
y-direction	-4.2
z-direction	2.7

Test Article Deflections (m)

Dynamic	2.94
Permanent	2.90

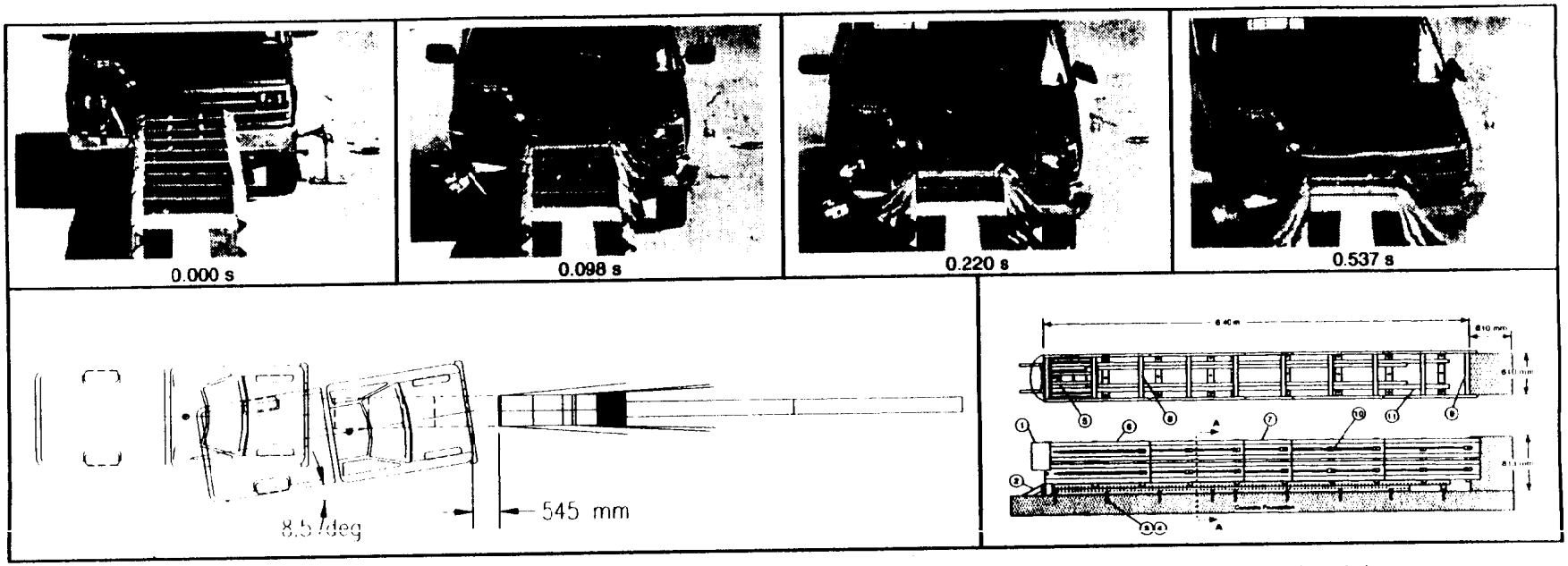
Vehicle Damage

Exterior	
VDS	12FR4
CDC	12FREW3
Maximum Exterior Vehicle Crush (mm)	350
Interior	
OCDI	RF0020000
Max. Occ. Compart. Deformation (mm)	85

Post-Impact Behavior (during 1.0 s after impact)

Max. Yaw Angle (deg)	102
Max. Pitch Angle (deg)	-33
Max. Roll Angle (deg)	-21

Figure 42. Summary of results for test 404091-16, *NCHRP Report 350* test 3-30.



General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 404091-17
- Date 06/16/98

Test Article
- Type ..... Crash Cushion
- Name or Manufacturer ..... Syro/Trinity Crash Cushion
- Installation Length (m) 6.40
- Material or Key Elements ... Guidance Track, Impact Sled, Intermediate Frames, Fender Panels

Soil Type and Condition .... Concrete Pavement, Dry

Test Vehicle
- Type ..... Production
- Designation 2000P
- Model ..... 1993 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 2106
  - Test Inertial 2000
  - Dummy ..... No dummy
  - Gross Static 2000

Impact Conditions
- Speed (km/h) 100.4
- Angle (deg) 0

Exit Conditions
- Speed (km/h) 4.8
- Angle (deg) 8.5

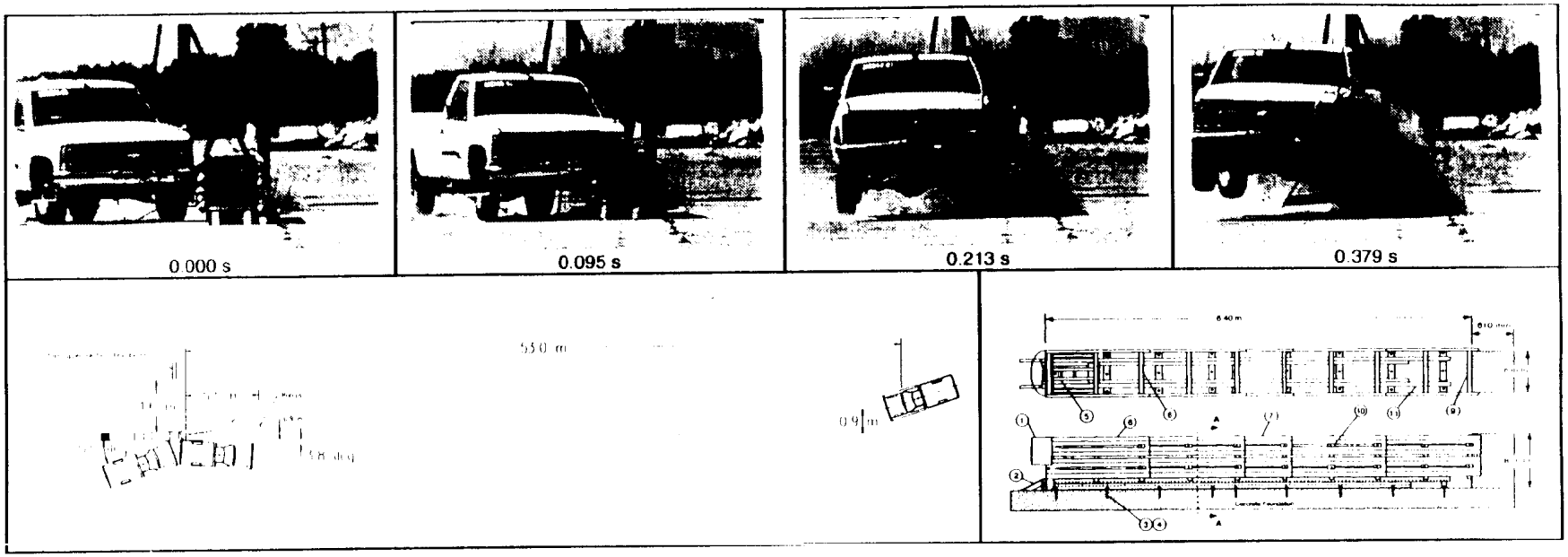
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 9.4
  - y-direction ..... No Contact
- THIV (km/h) 33.8
- Ridedown Accelerations (g's)
  - x-direction ..... -15.2
  - y-direction ..... No Contact
- PHD (g's) 15.8
- ASI 0.98
- Max. 0.050-s Average (g's)
  - x-direction ..... -11.7
  - y-direction 0.8
  - z-direction 4.3

Test Article Deflections (m)
- Dynamic 4.66
- Permanent 4.41

Vehicle Damage
- Exterior
  - VDS 12FC4
  - CDC 12FCEW3
- Maximum Exterior
  - Vehicle Crush (mm) 460
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) 7
- Max. Pitch Angle (deg) ..... -7
- Max. Roll Angle (deg) 3

Figure 50. Summary of results for test 404091-17, *NCHRP Report 350* test 3-31.



General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 404091-18
- Date 07/01/98

Test Article
- Type ..... Crash Cushion
- Name or Manufacturer .... Syro/Trinity Crash Cushion
- Installation Length (m) 6.40
- Material or Key Elements ... Guidance Track, Impact Sled, Intermediate Frames, Fender Panels

Soil Type and Condition .... Concrete Pavement, Dry

Test Vehicle
- Type ..... Production
- Designation 2000P
- Model ..... 1994 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 2091
  - Test Inertial 2000
  - Dummy ..... No dummy
  - Gross Static 2000

Impact Conditions
- Speed (km/h) 100.9
- Angle (deg) 20.0

Exit Conditions
- Speed (km/h) 72.2
- Angle (deg) 3.8

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.1
  - y-direction 6.4
- THIV (km/h) 28.0
- Ridedown Accelerations (g's)
  - x-direction ..... -16.4
  - y-direction 11.1
- PHD (g's) 23.2
- ASI 1.14
- Max. 0.050-s Average (g's)
  - x-direction ..... -7.6
  - y-direction 8.9
  - z-direction ..... -4.6

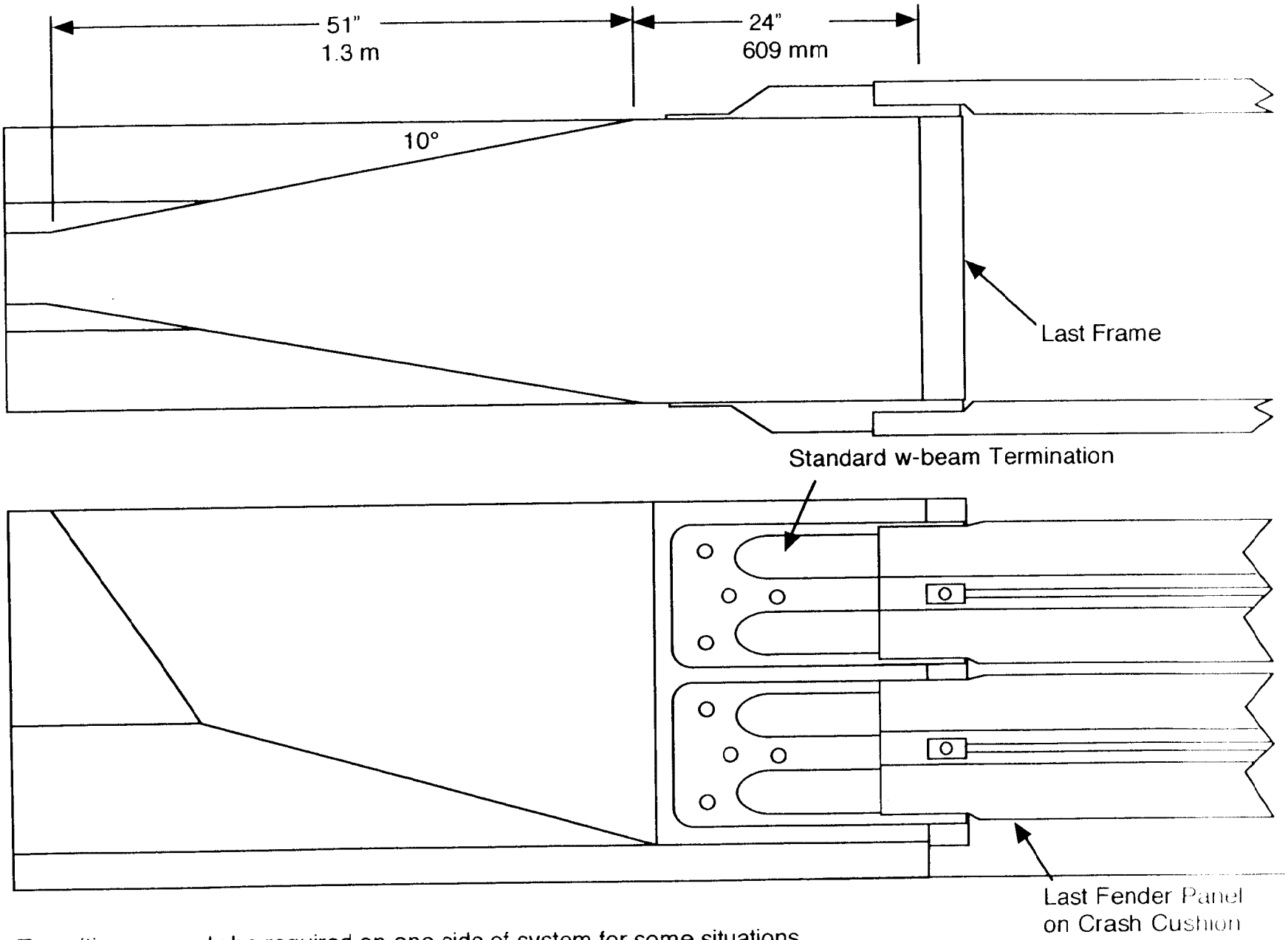
Test Article Deflections (m)
- Dynamic 0.28
- Permanent 0.24

Vehicle Damage
- Exterior
  - VDS 11LFQ3
  - CDC 11FLEK3
- Maximum Exterior & 11LYEW3
  - Vehicle Crush (mm) 340
- Interior
  - OCDI LF0001000
- Max. Occ. Compart.
  - Deformation (mm) 40

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) 24
- Max. Pitch Angle (deg) ..... -9
- Max. Roll Angle (deg) ..... -6

Figure 58. Summary of results for test 404091-18, *NCHRP Report 350* test 3-39.

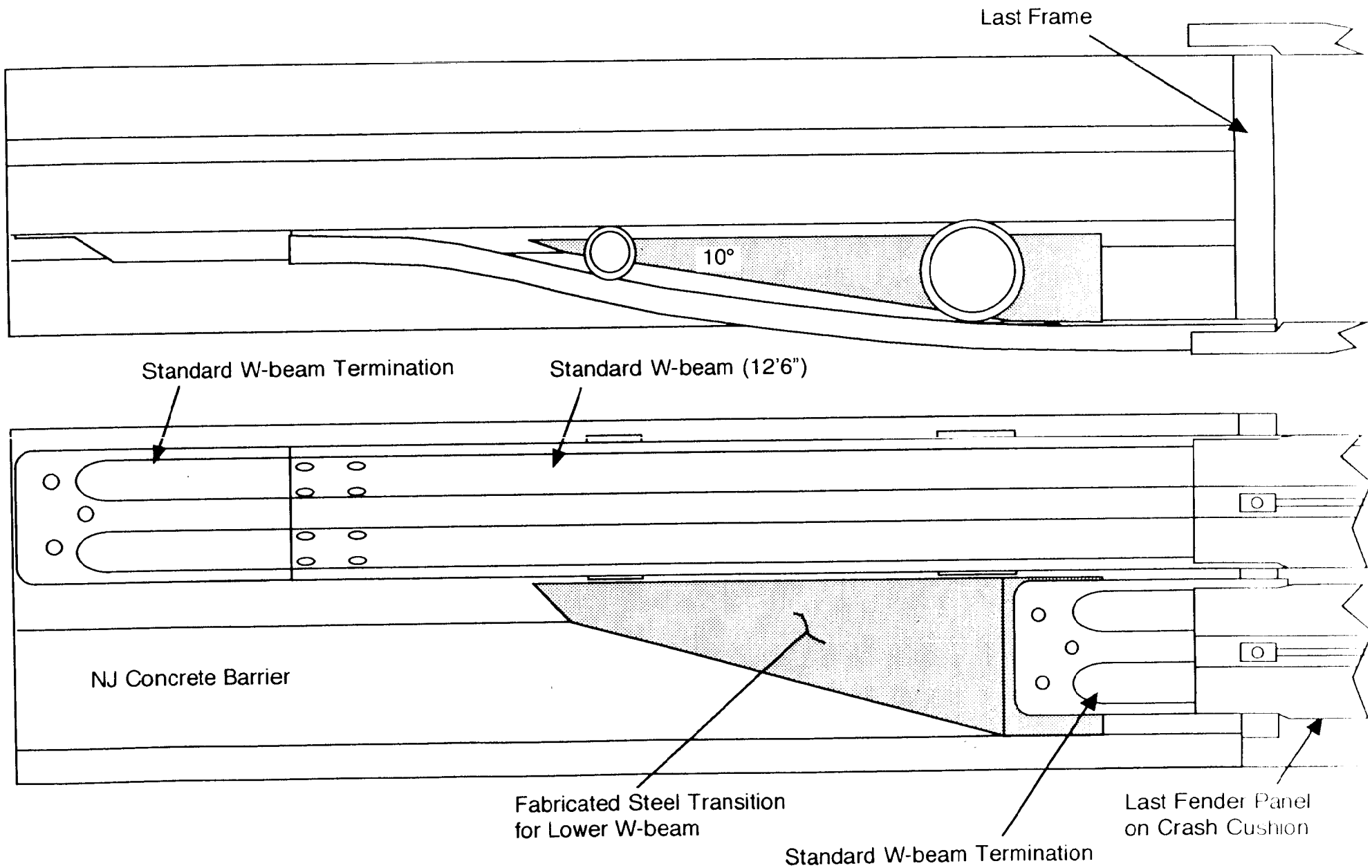
Figure 1. Concrete Transition for Bi-directional Traffic Application of Trinity / Exodyne Crash Cushion



Note: Transition may only be required on one side of system for some situations.

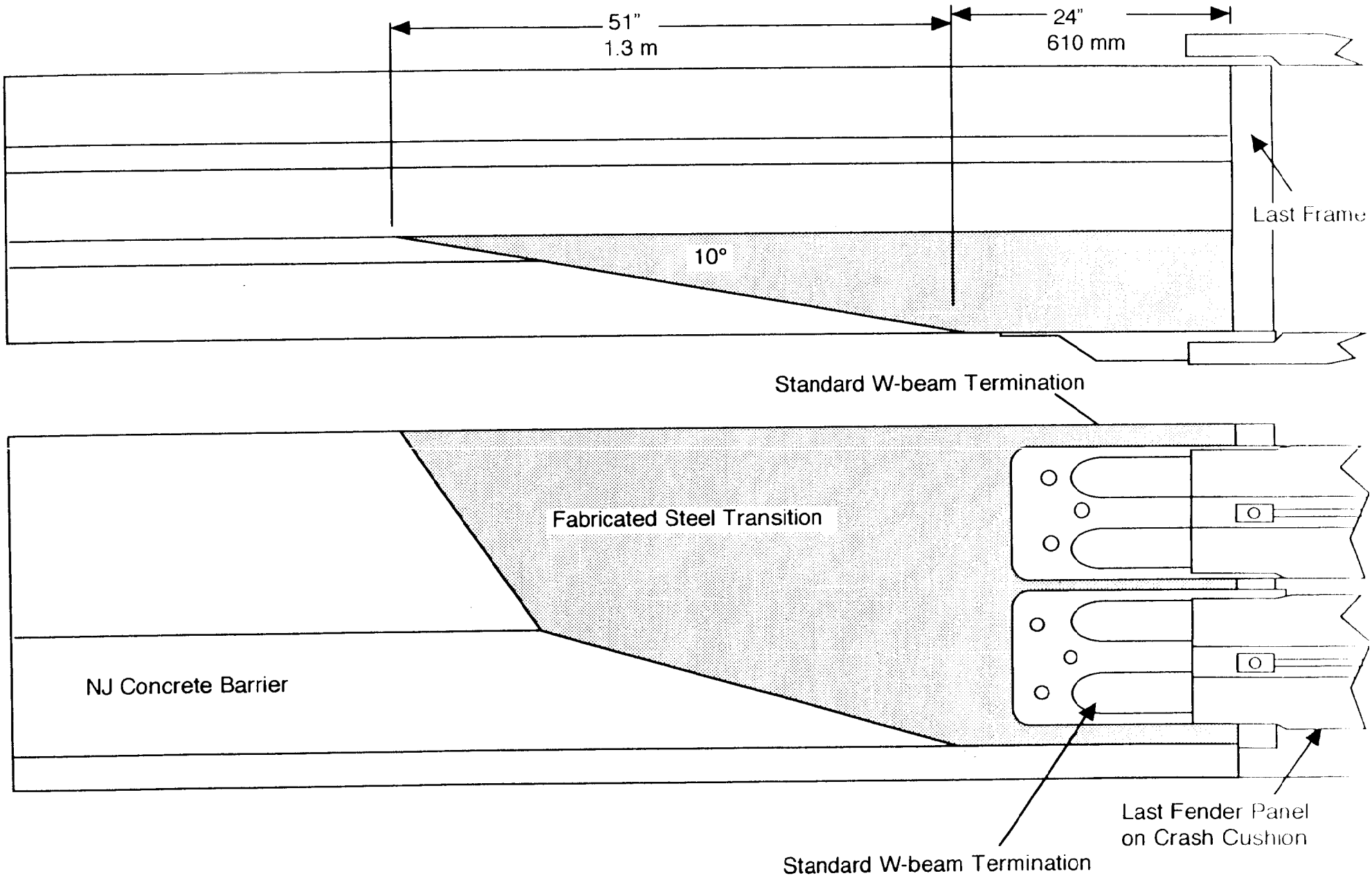
James H. [illegible], P.E.
Exodyne Technologies, Inc.
817-560-[illegible]
10-16-98

Figure 2. Transition for Bi-directional Traffic Application of Trinity / Exodyne Crash Cushion



James R. Albritton, P.E.
Exodyne Technologies, Inc.
817-560-1100
10-16-98

Figure 3. Transition for Bi-directional Traffic Application of Trinity / Exodyne Crash Cushion



James R. Albritton, P.E.
Exodyne Technologies, Inc.
817-560-1359
10-16-98