TTI: 9-1002

MASH TEST 3-11 ON THE TEXAS T101 BRIDGE RAIL

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Research/Test Report 9-1002-1

Cooperative Research Program

TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/document/9-1002-1.pdf

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-11/9-1002-1		

4. Title and Subtitle	5. Report Date
MASH TEST 3-11 ON THE TEXAS T101 BRIDGE RAIL	November 2010 Published: March 2011
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Roger P. Bligh and Wanda L. Menges	Report 9-1002-1
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute Proving Ground The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Project 9-1002
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	Test Report: September 2009–August 2010
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Roadside Safety Device Crash Testing Program
URL: http://tti.tamu.edu/document/9-1002-1.pdf

16. Abstract

The Texas T101 bridge rail is widely used in the state of Texas. Previous testing demonstrated its ability to contain and redirect passenger cars and a 20,000-lb school bus. Based on this testing, the Federal Highway Administration accepted the T101 bridge rail as an *NCHRP Report 350* TL-3 barrier. However, its impact performance with pickup trucks was never evaluated.

Under research project 0-5526, Impact Performance of roadside Safety Appurtenances, researchers conducted a performance assessment of Texas roadside safety devices to help evaluate the impact of adopting the new *MASH* guidelines on current hardware. Testing and evaluation of the T101 bridge rail was recommended as a high priority. This recommendation was based primarily on the absence of pickup truck testing on the system, and concerns that the 27-inch rail height may not be compatible with pickup trucks and SUVs under design impact conditions.

The T101 bridge rail did not meet *MASH* evaluation criteria for test 3-11. The vehicle overturned after losing contact with the barrier. If continued use of the T101 bridge rail is desired, it is recommended that an in-service performance evaluation be conducted. Alternatively, a new barrier system that satisfies the same key design criteria as the T101 bridge rail can be developed and tested under future research.

17. Key Words	18. Distribution Statement
Roadside Safety, Bridge Rail, Crash Test, MASH	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	88	

MASH TEST 3-11 ON THE T101 BRIDGE RAIL

by

Roger P. Bligh, P.E.
Research Engineer
Texas Transportation Institute

and

Wanda L. Menges
Associate Research Specialist
Texas Transportation Institute

Report 9-1002-1
Project 9-1002
Project Title: Roadside Safety Device Crash Testing Program

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

November 2010
Published: March 2011

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

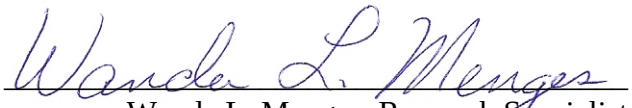
This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. The engineer in charge of the project was Roger P. Bligh, P.E. (Texas, #78550).

TTI PROVING GROUND DISCLAIMER

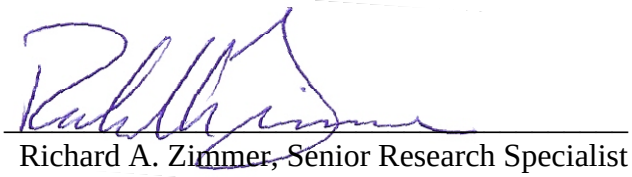
The results of the crash testing reported herein apply only to the article being tested.

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807



Wanda L. Menges, Research Specialist
Deputy Quality Manager



Richard A. Zimmer, Senior Research Specialist
Test Facility Manager
Quality Manager
Technical Manager

ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the Federal Highway Administration. The TxDOT project director for this research was Rory Meza, P.E., with the Design Division. John Holt, P.E., and Jon Reis with the Bridge Division served as project advisors and were also actively involved in this research. The TxDOT research engineer was Wade Odell, P.E., with the Research and Technologh Implementation Office. The authors acknowledge and appreciate their guidance and assistance.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

This project was set up to provide the Texas Department of Transportation (TxDOT) with a mechanism to quickly and effectively evaluate high priority issues related to roadside safety devices. Roadside safety devices shield motorists from roadside hazards such as non-traversable terrain and fixed objects. To maintain the desired level of safety for the motoring public, these safety devices must be designed to accommodate a variety of site conditions, placement locations, and a changing vehicle fleet. Periodically, there is a need to assess the compliance of existing safety devices with current vehicle testing criteria.

Under this project, roadside safety issues are identified and prioritized for investigation. Each roadside safety issue is addressed with a separate work plan, and the results are summarized in an individual test report.

1.2 BACKGROUND[*]

Bridge rails are longitudinal barriers designed to keep vehicles from encroaching off bridge structures and encountering underlying hazards. Bridge rails are typically rigid in nature due to the lack of space on bridge structures to accommodate barrier deflection. Common types of bridge rails include continuous concrete barriers, metal rails mounted on concrete parapets, and both concrete and metal beam and post systems.

TxDOT standards include various bridge rails that have been successfully tested or otherwise judged to meet the impact performance requirements of National Cooperative Highway Research Program (NCHRP) *Report 350* (*1*). These crashworthy rail systems meet *NCHRP Report 350* test levels ranging from TL-2 to TL-5. This variety of rail types provides the bridge design engineer the flexibility to select a railing for a specific bridge site that is safe, cost-effective, and aesthetic.

In order to meet impact performance requirements, a bridge rail must have sufficient structural capacity to contain and redirect a vehicle under prescribed impact conditions. Other issues that need to be addressed in addition to strength are vehicle stability and occupant compartment deformation. Adequate barrier height is required to prevent impacting vehicles from becoming unstable and rolling over. Poor rail geometrics can lead to severe vehicle-barrier snagging and result in excessive deformation of the occupant compartment.

Table 1.1 presents a summary of bridge rails currently in TxDOT standards. It can be seen that all but two bridge rails have a height of 32 inches or greater. The T101 and T6 bridge rails have a height of 27 inches. Crash testing indicates that 27 inches is at or near the minimum height required to contain and redirect the 3/4-ton, standard cab pickup under *NCHRP Report*

[*] *The opinions/interpretations expressed in this section are outside the scope of TTI Proving Ground's A2LA accreditation.*

350 test 3-11 impact conditions (*2,3*). The T6 tubular W-beam rail failed to meet TL-3 performance requirements due to rollover of the pickup truck in *NCHRP Report 350* test 3-11 (*4*) and was subsequently approved as a TL-2 barrier for use on lower-speed roadways.

Table 1.1. Summary of TxDOT Bridge Rails.

Std Name	Description	Height (inches)
T1F	Steel Post with Elliptical Aluminum Rails on Concrete Curb	33
T1W	Steel Post with Tubular Steel Rails on Concrete Curb	32
T101	Steel Post with W-Beam Backed by Steel Tubes	27
T223	Concrete Beam and Post Parapet with 6 ft Openings	32
T221	Vertical Concrete Parapet	32
T401	Concrete Parapet with Steel Post and Rail	33
T402	Concrete Parapet with Steel Post and Rail	42
T411	Concrete Traffic Rail with Windows (Texas Classic)	32
T551	Concrete Safety Shape Parapet with F-Shape Profile	32
T6	Steel Post with Tubular W-Beam*	27
T66	Concrete Beam and Post Parapet with 5 ft-3 inch Openings	32
T77	Steel Post with Two Elliptical Pipes on Concrete Parapet	33
SSTR	Single Slope Traffic Rail	36
T80HT	Concrete Safety Shape and Steel Heavy Truck Rail	50
T80SS	Concrete Single Slope Heavy Truck Rail	42

* Accepted as *NCHRP Report 350* Test Level 2 (TL-2) system for use on roadways with speeds less than 45 mph)

Figure 1.1 shows a cross-section of the T101 bridge rail. It is worthwhile noting that in addition to having demonstrated satisfactory impact performance with passenger cars of various sizes, the 27-inch tall T101 bridge rail has also successfully contained and redirected a 20,000-lb school bus impacting at a speed of 55 mph and an angle of 15 degrees (*5*). However, even though it has been accepted as an *NCHRP Report 350* TL-3 barrier by FHWA, the impact performance of the T101 with the 3/4-ton pickup truck has never been evaluated. Some concern exists that the rail height, aggravated by wheel snagging on the W6×20 posts, could lead to vehicle instability.

A recommended update to *NCHRP Report 350* was developed under NCHRP Project 22-14(02), "Improvement of Procedures for the Safety-Performance Evaluation of Roadside Features." The document was subsequently published by the American Association of State Highway and Transportation Officials (AASHTO) as the *Manual for Assessing Safety Hardware* (*MASH*) (*6*). *MASH* contains revised criteria for safety-performance evaluation of virtually all roadside safety features. Changes incorporated into the new manual include new design test vehicles, revised test matrices, and revised impact conditions.

Under research project 0-5526 (*7*), researchers conducted a performance assessment of Texas roadside safety devices to help evaluate the impact of adopting the new *MASH* guidelines on current hardware. Crash test results, engineering analyses, and engineering judgment were used to assist with the hardware evaluation.

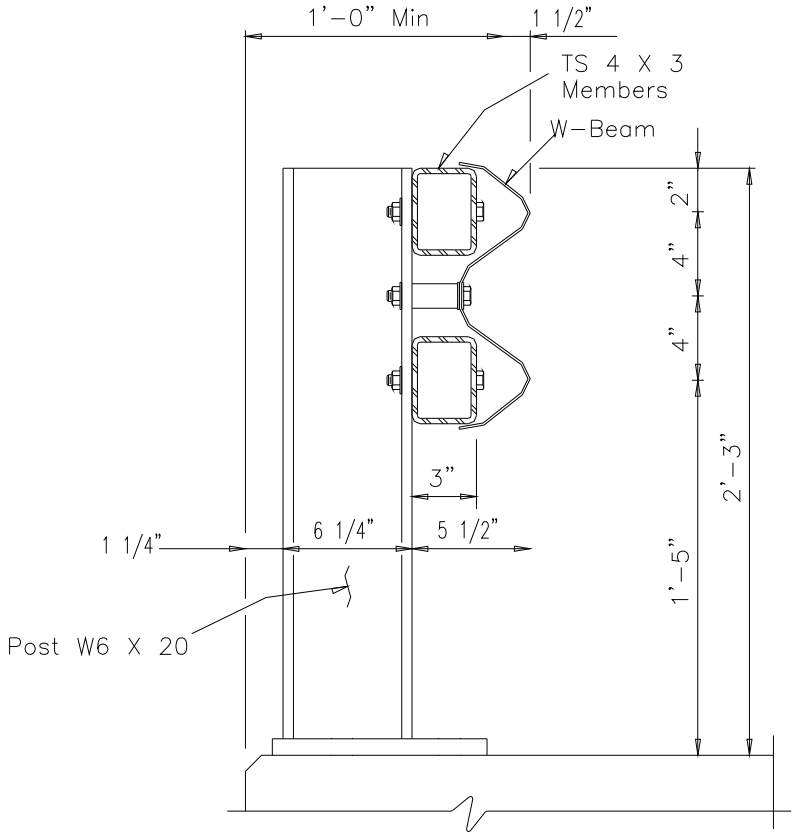


Figure 1.1. Cross Section of T101 Bridge Rail.

Results of the performance assessment were used to develop a prioritization scheme for further testing and evaluation deemed necessary to bring Texas roadside safety features into compliance with the new impact performance guidelines. Each device was assigned a priority rating of "High," "Medium," or "Low." The prioritization was based on the degree of testing to *MASH* (if any), the performance assessment, usage and/or perceived importance of the device to TxDOT operations, and other applicable factors.

Generally speaking, devices with higher risk of failure under the new guidelines were given higher priority in programming further crash testing and performance evaluation. Should the device ultimately fail to comply with *MASH* requirements, additional time and resources would be required to modify or upgrade the device to permit its continued use after adoption of *MASH*. Conversely, devices with low risk of failure (i.e., very high probability of complying with the update) are generally assigned a lower priority for further investigation. In these cases it is likely that the additional testing will merely confirm compliance of the device with the update, and not as much benefit will be derived from the expended resources.

The only device assigned a high priority for further testing and evaluation under *MASH* guidelines was the T101 bridge rail. This recommendation was based primarily on the absence of pickup truck testing on this system.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of this test was to evaluate the performance of the T101 bridge rail according to the *MASH* standards for Test Level 3 (TL-3) longitudinal barriers. The test performed was *MASH* test 3-11 involving a 2270P (5000 lb) vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This is a strength test to verify a barrier's performance for impacts involving light trucks and SUVs for all test levels. Reported herein are details of the T101 bridge rail, test conditions, description of the test performed, assessment of test results, and implementation recommendations.

CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE

The Texas T101 bridge rail consists of a 12 gauge, AASHTO M180 corrugated W-beam rail strengthened by two TS 4-inch × 3-inch × 3/16-inch A500 Grade C steel tubes. The tubes are placed behind the W-beam rail inside the upper and lower peaks. They are connected using 2-1/2-inch × 3-1/2-inch × 3/8-inch A500 Grade C steel splice tubes that are 24 inches in length. The W-beam and tubular steel rail elements are mounted to W6×20 steel posts spaced on 8 ft-4 inch centers using 5/8-inch diameter A307 hex head bolts. The bolt attaching the W-beam to the post runs through a 1-1/4-inch schedule 40 pipe sleeve. The height to the top of the W-beam rail is 27 inches.

The W6×20 posts are welded to 9 inch × 10 inch × 7/8-inch thick base plates that are anchored to the concrete bridge deck using four 3/4-inch diameter × 11 inches long A325 hex head through bolts. The deck cantilever to which the rail was attached was 30 inches wide and 8 inches thick and had a minimum specified concrete compressive strength of 3600 psi. The transverse reinforcement in the deck consisted of #5 bars at 6 inches in the top layer and #5 bars at 18 inches in the bottom layer. The longitudinal reinforcement was comprised of #4 bars at 9 inches in the top layer of steel and #5 bars at 12 inch spacing in the bottom layer. All reinforcement steel was Grade 60. A special bolt anchorage plate assembly fabricated from 1/4-inch A36 steel strap was embedded in the deck at each post location in the top layer of reinforcement. The transverse straps of the anchorage plate assembly were 39 inches long and incorporated semi-circular notches at 6-inch spacing.

The total length of the T101 bridge rail was 75 ft. Each end was terminated with a 12 ft-6 inch long ET-PLUS guardrail end treatment assembly, making the overall length of the test installation 100 ft. Details of the T101 bridge rail are shown in Figures 2.1 and 2.2 and Appendix A. Figure 2.3 shows photographs of the completed test installation.

2.2 MATERIAL SPECIFICATIONS

The rail element was 12 gauge AASHTO M180 grade corrugated W-beam backed by TS4×3×3/16 tubular steel elements of A500 Grade C steel. All reinforcement steel was Grade 60. The specified minimum compressive strength of the concrete for the T101 bridge deck was 3600 psi. On the day of the test, the compressive strength of the bridge deck measured 6344 psi. Appendix B contains mill certification sheets and other certification documents for the materials used in the T101 bridge rail installation, as well as concrete break tests.

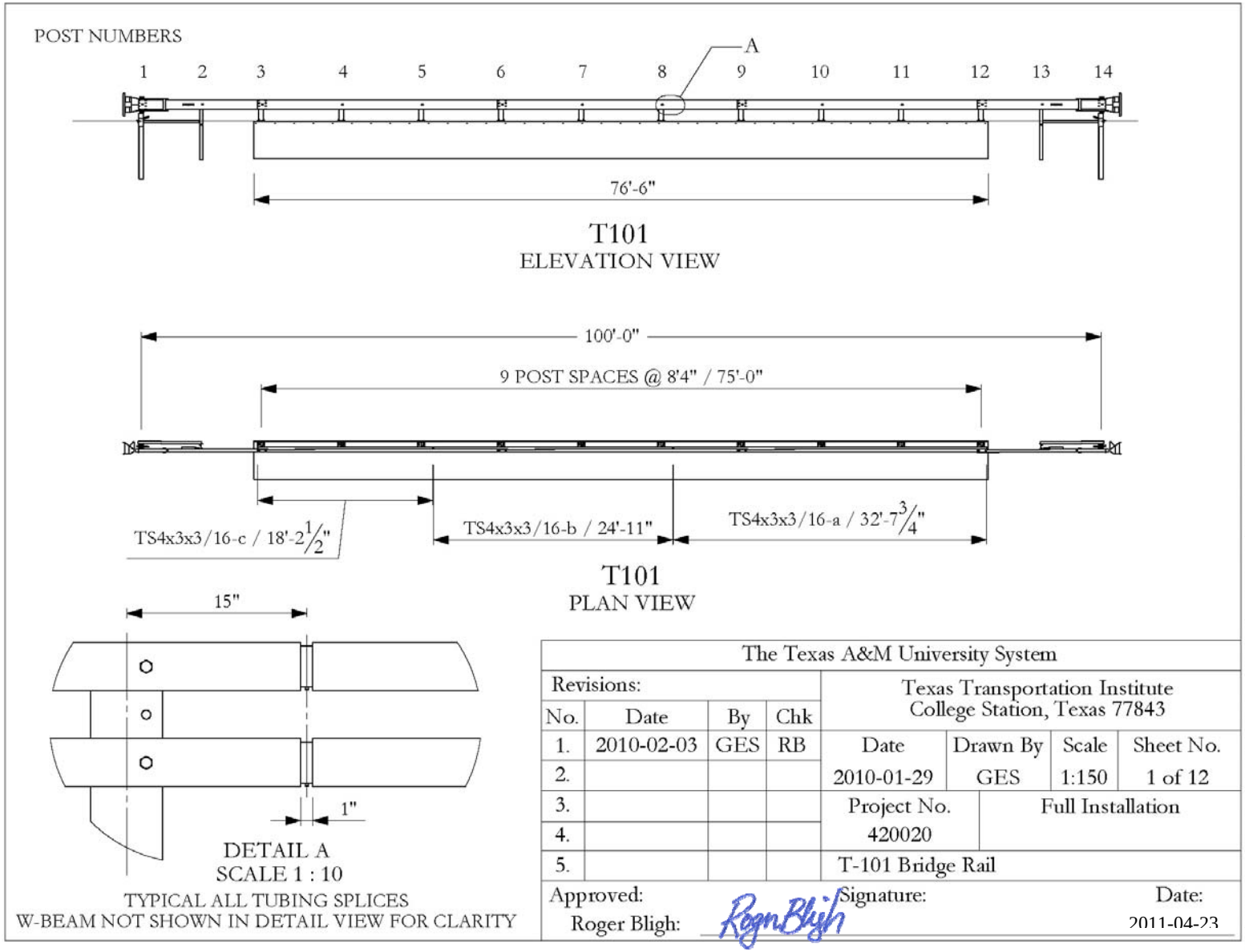


Figure 2.1. Details of the T101 Bridge Rail.

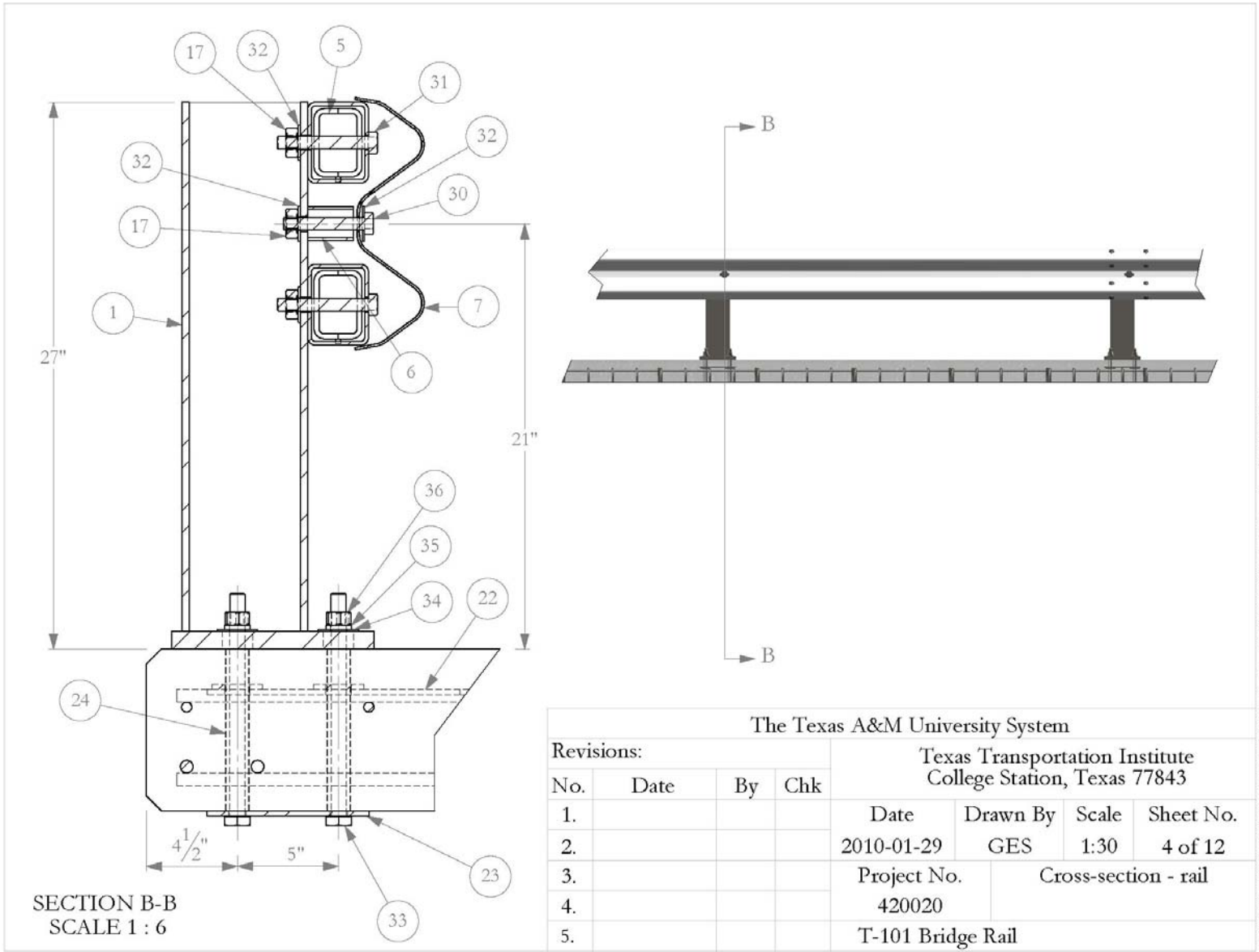


Figure 2.2. Cross Section of the T101 Bridge Rail.

Figure 2.3. T101 Bridge Rail before Test No. 420020-1a.

CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

According to *MASH*, two tests are recommended to evaluate longitudinal barriers to test level three (TL-3). Details of these tests are described below.

> ***MASH* test 3-10**: This test involves an 1100C (2425 lb/1100 kg) vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. It evaluates a barrier's ability to contain and redirect a small passenger vehicle.
>
> ***MASH* test 3-11**: This test involves a 2270P (5000 lb/2270 kg) vehicle impacting the CIP of the LON of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This is a strength test intended to evaluate a barrier's performance for impacts involving light trucks and SUVs.

The test reported herein corresponds to *MASH* test 3-11. Target impact point for this test on the T101 bridge rail was post 6.

All crash test, data analysis, and evaluation and reporting procedures followed under this project were in accordance with guidelines presented in *MASH*. Appendix C presents brief descriptions of these procedures.

3.2 EVALUATION CRITERIA

The crash test was evaluated in accordance with the criteria presented in *MASH*. The performance of the T101 bridge rail is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged upon the T101 bridge rail's ability to contain and redirect the vehicle. Occupant risk criteria are used to evaluate the potential risk or hazard to occupants in the impacting vehicle, and to some extent other traffic, pedestrians, or workers in construction zones, if applicable. Post impact vehicle trajectory is used to assess potential for secondary impacts with other vehicles or fixed objects that might create further risk of injury to occupants of the impacting vehicle and/or occupants in other vehicles. The appropriate safety evaluation criteria from table 5-1 of *MASH* were used to evaluate the crash test reported herein. These criteria are listed in further detail under the assessment of the crash test.

CHAPTER 4. CRASH TEST PROCEDURES

4.1 TEST FACILITY

The full-scale crash test reported herein was performed at Texas Transportation Institute (TTI) Proving Ground. TTI Proving Ground is an International Standards Organization (ISO) 17025 accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures and according to the *MASH* guidelines and standards.

The Texas Transportation Institute Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for construction and testing of the T101 bridge rail on pan-formed bridge deck evaluated under this project is along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5 ft by 15 ft blocks nominally 8 to 12 inches deep. The apron is over 50 years old, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE PROCEDURES

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A two-to-one speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, that measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra small size, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of

the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once recorded, the data are backed up inside the unit by internal batteries should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiating the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The raw data are then processed by the Test Risk Assessment Program (TRAP) software to produce detailed reports of the test results. Each of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2). Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact.

4.3.2 Anthropomorphic Dummy Instrumentation

Use of a dummy in the 2270P vehicle is optional according to *MASH*, and there was no dummy used in this test.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

CHAPTER 5. CRASH TEST RESULTS

5.1 TEST DESIGNATION AND ACTUAL TEST CONDITIONS

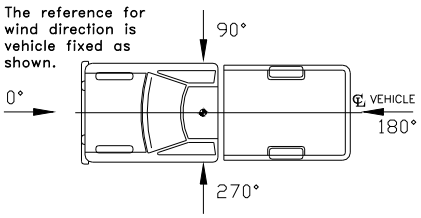
MASH test 3-11 involves a 2270P vehicle weighing 5000 lb ±100 lb impacting the bridge rail at a speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was post 6. The 2005 Dodge Ram 1500 Quad-Cab used in the test weighed 5023 lb and the actual impact speed and angle were 63.0 mi/h and 24.9 degrees, respectively. The actual impact point was at post 6. Impact severity equals 3801 kip-ft, or 3.0 percent above target.

5.2 TEST VEHICLE

A 2003 Dodge Ram 1500 Quad-Cab pickup, shown in Figures 5.1 and 5.2, was used for the crash test. Test inertia weight of the vehicle was 5023 lb, and its gross static weight was 5023 lb. The height to the lower edge of the vehicle bumper was 13.5 inches, and it was 26.0 inches to the upper edge of the bumper. The vertical height to the vehicle center of gravity was 28.0 inches. Figure C1 and Table C1 in Appendix C give additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

5.3 WEATHER CONDITIONS

The test was performed on the morning of April 23, 2010. At total of 0.5 inches of rainfall was recorded 4 days prior to the test. Weather conditions at the time of test were as follows: Wind speed: 7 mi/h; Wind direction: 184 degrees with respect to the vehicle (vehicle was traveling in a southwesterly direction); Temperature: 75°F; Relative humidity: 87 percent.



5.4 TEST DESCRIPTION

The 2003 Dodge Ram 1500 Quad-Cab pickup impacted the T101 bridge rail at post 6 at an impact speed of 63.0 mi/h and an impact angle of 24.9 degrees. At 0.029 s after impact, the right front wheel assembly and tire detached from the vehicle, and at 0.042 s, the forward edge of the front passenger door began to peel back. The vehicle began to redirect at 0.071 s, and the rear of the vehicle contacted the bridge rail at 0.176 s. At 0.200 s, the vehicle was traveling parallel with the bridge rail at a speed of 53.7 mi/h. At 0.310 s, the vehicle lost contact with the bridge rail traveling at an impact speed and angle of 51.2 mi/h and 6.0 degrees, respectively. The vehicle subsequently rolled onto the impact (passenger) side and slid to a stop. Brakes on the vehicle were not applied, and the vehicle subsequently came to rest 180 ft downstream of impact and 21 ft toward traffic lanes from the traffic face of the bridge rail. Figures D1 and D2 in Appendix D show sequential photographs of the test period.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 420020-1a.

Figure 5.2. Vehicle before Test No. 420020-1a.

5.4.1 Damage to Test Installation

Figures 5.3 and 5.4 show the damage to the T101 bridge rail. The soil around post 1 was disturbed. Post 6 was leaning toward the field side 10 degrees, the concrete deck was cracked around the post, the front upstream anchor bolt broke, and the lower half of the rail was torn. Post 7 was leaning toward the field side 11 degrees and the concrete deck around the post was cracked. Post 8 was leaning toward the field side 1 degree. Length of contact of the vehicle with the bridge rail was 18 ft. Working width was 2.9 ft. Dynamic deflection of the bridge rail during the test was 2.2 ft, and permanent deformation was 2.0 ft.

5.4.2 Vehicle Damage

Figure 5.5 shows damage to the vehicle. The right front upper and lower ball joint, right front upper and lower A-arms, front sway bar and right frame rail were deformed. Also damaged were the front bumper, right front fender, right front wheel rim and tire, right front door, right rear door, right rear exterior bed, right rear wheel rim, and rear bumper. Maximum exterior crush to the vehicle was 12.0 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 1.5 inches in the firewall to front seat area near the toe pan on the right side. Figure 5.6 shows photographs of the interior of the vehicle. Exterior vehicle crush and occupant compartment measurements are shown in Appendix C, Tables C2 and C3.

5.4.3 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 14.4 ft/s at 0.118 s, the highest 0.010-s occupant ridedown acceleration was −12.1 Gs from 0.133 to 0.143 s, and the maximum 0.050-s average acceleration was −6.5 Gs between 0.021 and 0.071 s. In the lateral direction, the occupant impact velocity was 20.3 ft/s at 0.118 s, the highest 0.010-s occupant ridedown acceleration was −12.0 Gs from 0.121 to 0.131 s, and the maximum 0.050-s average was −8.9 Gs between 0.044 and 0.094 s. Theoretical Head Impact Velocity (THIV) was 16.2 mi/h or 23.6 ft/s at 0.115 s; Post-Impact Head Decelerations (PHD) was 13.7 Gs between 0.133 and 0.143 s; and Acceleration Severity Index (ASI) was 1.07 between 0.044 and 0.094 s. These data and other pertinent information from the test are summarized in Figure 5.7. Vehicle angular displacements and accelerations versus time traces are presented in Appendix E, Figures E1 through E7.

Figure 5.3. After Impact Vehicle Position after Test No. 420020-1a.

Figure 5.4. Installation after Test No. 420020-1a.

Figure 5.5. Vehicle after Test No. 420020-1a.

Before Test

After Test

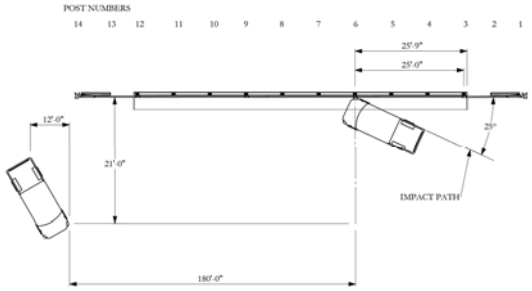
Figure 5.6. Interior of Vehicle for Test No. 420020-1a.

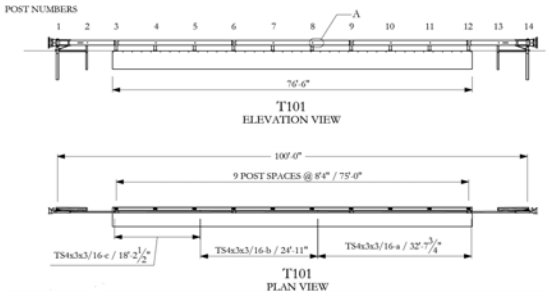
0.000 s

0.139 s

0.278 s

0.417 s





General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 420020-1a
- Test Standard Test No. ..... MASH 3-11
- Date 2010-04-23

Test Article
- Type ..... Bridge Rail
- Name ..... Texas T101 Bridge Rail
- Installation Length ..... 100 ft
- Material or Key Elements ..... 12 gauge W-beam backed by two TS 4-inch x 3-inch x 3/16-inch steel tubes mounted on W6x20 posts

Soil Type and Condition ..... Concrete deck

Test Vehicle
- Type ..... Production
- Designation 2270P
- Model ..... 2003 Dodge Ram 1500 Pickup
- Mass
  - Curb ..... 4742 lb
  - Test Inertial ..... 5023 lb
  - Gross Static ..... 5023 lb

Impact Conditions
- Speed ..... 63.0 mi/h
- Angle ..... 24.9 degrees

Exit Conditions
- Speed ..... 51.2 mi/h
- Angle ..... 6.0 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal ..... 14.4 ft/s
  - Lateral ..... 20.3 ft/s
- THIV ..... 16.2 mi/h
- Ridedown Accelerations
  - Longitudinal ..... 12.1 G
  - Lateral ..... 12.0 G
- PHD ..... 13.7 G
- ASI 1.07
- Max. 0.050-s Average
  - Longitudinal ..... 6.5 G
  - Lateral ..... 8.9 G
  - Vertical ..... 3.6 G

Post-Impact Trajectory
- Stopping Distance ..... 180 ft dwnstrm
  21 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle ..... 63 degrees
- Maximum Pitch Angle ..... 17 degrees
- Maximum Roll Angle ..... 97 degrees
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 2.2 ft
- Permanent ..... 2.0 ft
- Working Width ..... 2.9 ft

Vehicle Damage
- VDS 01RD5
- CDC 01RDEW4
- Max. Exterior Deformation ..... 12.0 inches
- OCDI RF0010000
- Max. Occupant Compartment Deformation ..... 1.5 inches

Impact Severity ..... 3801 kip-ft (+3%)

Figure 5.7. Summary of Results for *MASH* Test 3-11 on the T101 Bridge Rail.

CHAPTER 6. SUMMARY AND CONCLUSIONS

6.1 ASSESSMENT OF TEST RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria is provided below.

6.1.1 Structural Adequacy

A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.

Result: The T101 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection of the bridge rail during the test was 2.2 ft. (PASS)

6.1.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches)

Result: No detached elements, fragments, or other debris from the bridge rail were present to penetrate or to show potential for penetrating the 2270P vehicle, or to present hazard to others in the area. (PASS)
Maximum occupant compartment deformation was 1.5 inches in the firewall to passenger seat area near the toe pan on the right side. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Result: The vehicle rolled 97 degrees after loss of contact with the bridge rail, and then uprighted itself as it came to rest. (FAIL)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
30 ft/s	*40 ft/s*

Result: Longitudinal occupant impact velocity was 14.4 ft/s, and lateral occupant impact velocity was 20.3 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Result: Maximum longitudinal ridedown acceleration was −12.1 G, and maximum lateral ridedown acceleration was −12.0 G. (PASS)

6.1.3 Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box.

Result: The 2270P vehicle exited within the exit box. (PASS)

6.2 CONCLUSIONS

Impact performance of the T101 bridge rail was unsatisfactory for *MASH* test 3-11, as shown in Table 6.1. The vehicle overturned after losing contact with the barrier, which corresponds to failure of criterion F.

Table 6.1. Performance Evaluation Summary for *NCHRP Report 350* Test 3-11 on the T101 Bridge Rail.

Test Agency: Texas Transportation Institute | Test No.: 420020-1a | Test Date: 2010-04-23

***MASH* Test 3-11 Evaluation Criteria**	***Test Results***	***Assessment***
Structural Adequacy		
A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable	The T101 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection of the bridge rail during the test was 2.2 ft.	Pass
Occupant Risk		
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	No detached elements, fragments, or other debris from the bridge rail were present to penetrate or to show potential for penetrating the 2270P vehicle, or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 1.5 inches in the firewall to passenger seat area near the toe pan on the right side.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The vehicle rolled 97 degrees after loss of contact with the bridge rail, and then uprighted itself as it came to rest.	Fail
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 9.1 m/s (30 ft/s), or at least below the maximum allowable value of 12.2 m/s (40 ft/s).	Longitudinal occupant impact velocity was 14.4 ft/s, and lateral occupant impact velocity was 20.3 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.	Maximum longitudinal ridedown acceleration was −12.1 G, and maximum lateral ridedown acceleration was −12.0 G.	Pass
Vehicle Trajectory		
For redirective devices, the vehicle shall exit the barrier within the exit box.	The 2270P vehicle exited within the exit box.	Pass

CHAPTER 7. IMPLEMENTATION STATEMENT[†]

The Texas T101 bridge rail is widely used in the state of Texas. Previous testing demonstrated its ability to contain and redirect passenger cars and a 20,000-lb school bus (*5*). Based on this testing, FHWA accepted the T101 bridge rail as an *NCHRP Report 350* TL-3 barrier. However, its impact performance with pickup trucks was never evaluated.

Under research project 0-5526 (*7*), researchers conducted a performance assessment of Texas roadside safety devices to help evaluate the impact of adopting the new *MASH* (*6*) guidelines on current hardware. Testing and evaluation of the T101 bridge rail was recommended as a high priority. This was based on concerns that the 27-inch rail height may not be compatible with pickup trucks and SUVs under design impact conditions.

The T101 bridge rail did not meet *MASH* evaluation criteria for test 3-11. The vehicle overturned after losing contact with the barrier.

There currently is no implementation date for adopting *MASH*. If continued use of the T101 bridge rail is desired, it is recommended that an in-service performance evaluation be conducted to assess whether or not its field performance is satisfactory.

Alternatively, a new barrier system that satisfies the same key design criteria as the T101 bridge rail can be developed and tested under future research. Considerations should include efficient hydraulic characteristics, use of existing hardware components, and ability to retrofit existing T101 bridge rail installations as well as rails on older curbed bridge structures.

[†] *The opinions/interpretations expressed in this section are outside the scope of TTI Proving Ground's A2LA accreditation.*

REFERENCES

1. Ross, Jr., H.E., Sicking, D.L., Zimmer, R.A. and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Features," National Cooperative Highway Research Program *Report 350*, Transportation Research Board, National Research Council, Washington, D.C., 1993.

2. Buth, C. Eugene, Bligh, Roger P., and Menges, Wanda L., "NCHRP Report 350 Test 3-11 of the Texas Type T6 Bridge Rail," Report No. 1804-4, Texas Transportation Institute, College Station, TX, July 1998.

3. Buth, C.E., Williams, W.F., Bligh, R.P., Menges, W.L., and Butler, B.G., "NCHRP Report 350 Testing of the Texas Type T202 Bridge Rail," Report No. 1804-3, Texas Transportation Institute, College Station, TX, December 1998.

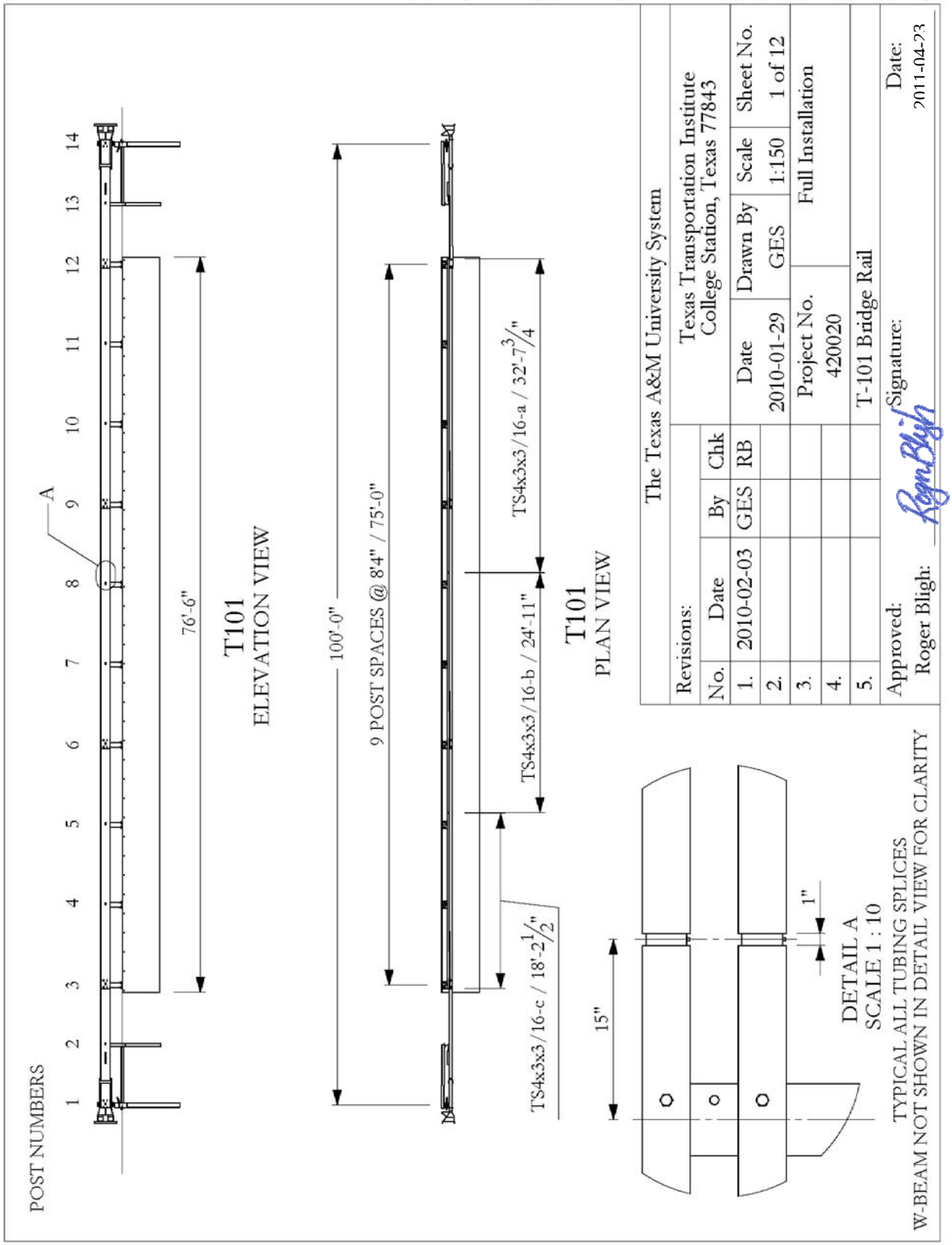
4. Buth, C.E., Williams, W.F., Bligh, R.P., Menges, W.L., and Haug, R.R., "Performance of the TxDOT T202 (MOD) Bridge Rail Reinforced with Fiber Reinforced Polymer Bars," Report No. 0-4138-3, Texas Transportation Institute, College Station, TX, November 2003.

5. Buth, C.E., Arnold, A.G., Campise, W.L., Hirsch, T.J., Ivey. D.L., and Noel, J.S., "Safer Bridge Railings, Volume 3: Appendix C, Part I," Report No. FHWA/RD-82/074.1, Texas Transportation Institute, College Station, TX, May 1983.

6. AASHTO, *Manual for Assessing Safety Hardware*, First Edition: American Association of State Highway and Transportation Officials, Washington, D.C., 2009.

7. Bligh, R.P. and Menges, W.L., "Initial Assessment of Compliance of Texas Roadside Safety Hardware with Proposed Update to NCHRP Report 350," Report No. 0-5526-1, Texas Transportation Institute, College Station, TX, September 2007.

APPENDIX A. DETAILS OF THE TXDOT T101 BRIDGE RAIL



RAIL PARTS

#	PART NAME	NOTE	QTY.
1	T-101 Post		10
2	TS4x3x3/16 - a	A500 Gr. C	2
3	TS4x3x3/16 - b	A500 Gr. C	2
4	TS4x3x3/16 - c	A500 Gr. C	2
5	Tube Splice	A500 Gr. C	4
6	Sleeve for Post Bolt	1-1/4" sch. 40	10
7	W-beam, 25' - 3 space, 12 ga.		3
8	Post, 27in. W6x8.5 SYTP		2
9	Post, CRP Bottom-W beam		2
10	CRP top-ET-27"		2
11	CRP bent plate washer		2
12	ET plus head		2

#	PART NAME	NOTE	QTY.
13	W-beam, ET		2
14	Anchor Cable		2
15	Anchor Bracket, ET Cable		2
16	Strut, CRP		2
17	Nut, Recessed Guardrail	5/8"	68
18	Bolt, 5/8" x 1-1/4"	Button-head	34
19	Rebar, transverse top	Gr. 60	153
20	Rebar, transverse bottom	Gr. 60	51
21	Rebar, wall tie	Gr. 60	39
22	Bolt Anchorage Plate	A36	10
23	Post Anchor Plate	A36	10
24	Sleeve for Anchor Bolts	1" EMT	40

The Texas A&M University System

Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.	2010-02-03	GES	RB	Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:500	2 of 12
3.				Project No.	Parts List		
4.				420020			
5.				T-101 Bridge Rail			

T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail

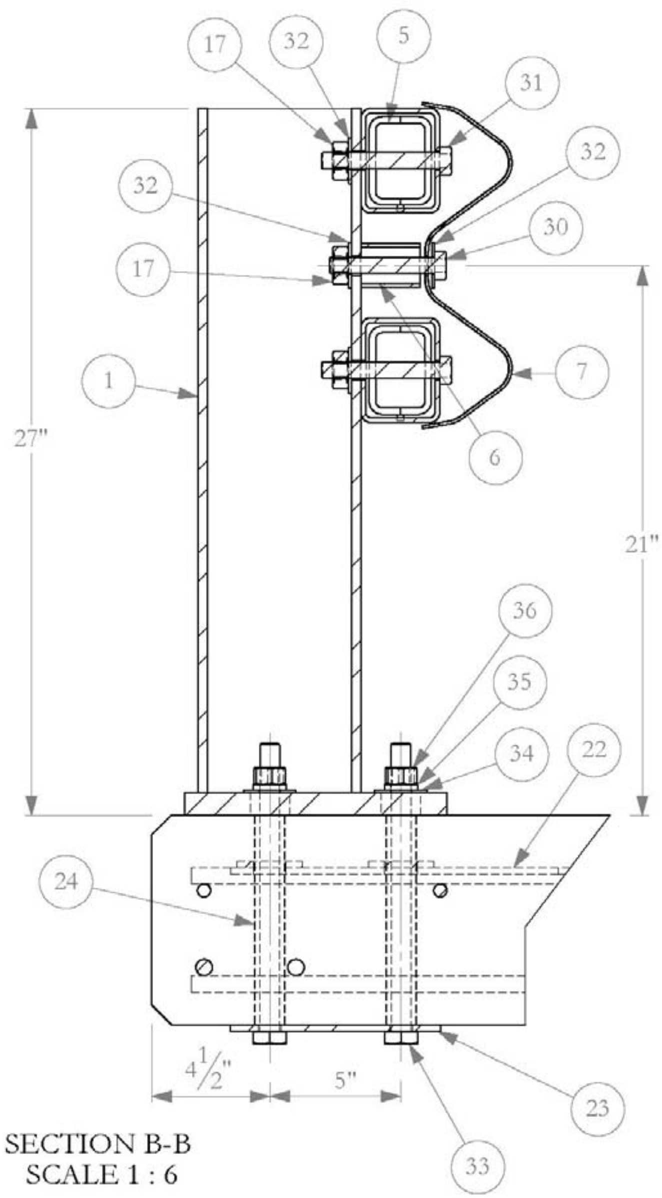
#	PART NAME	NOTE	QTY.
25	Nut, 5/16"		7
26	Bolt, 5/16" -18 x 1-1/2" hex		7
27	Bolt, 5/16" -18 x 2" hex		4
28	Washer, 5/16" flat		8
29	Bolt, 5/8" -11 x 2" hex	A307	4
30	Bolt, 5/8" -11 x 4" hex	A307	10
31	Bolt, 5/8" -11 x 4-1/2" hex	A307	20
32	Washer, 5/8" flat	FWC16a	44
33	Bolt, 3/4" -10 x 11" hex	A325	40
34	Washer, 3/4" flat galv.	2" O.D.	40
35	Washer, 3/4" flat	1-1/2" O.D. hardened	40
36	Nut, 3/4" -10 hex galv.		40
37	Washer, 1" flat	FWC24a	4
38	Nut, 1" -8 hex	FBX24a	4

RAIL HARDWARE

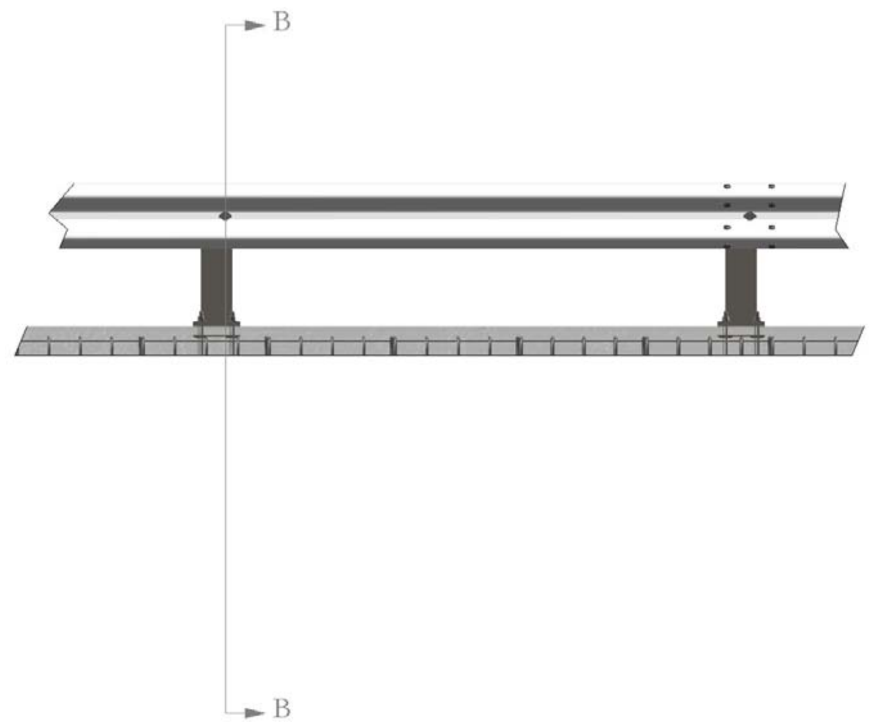
The Texas A&M University System

Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:500	3 of 12
3.				Project No.	Hardware		
4.				420020			
5.				T-101 Bridge Rail			

T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail

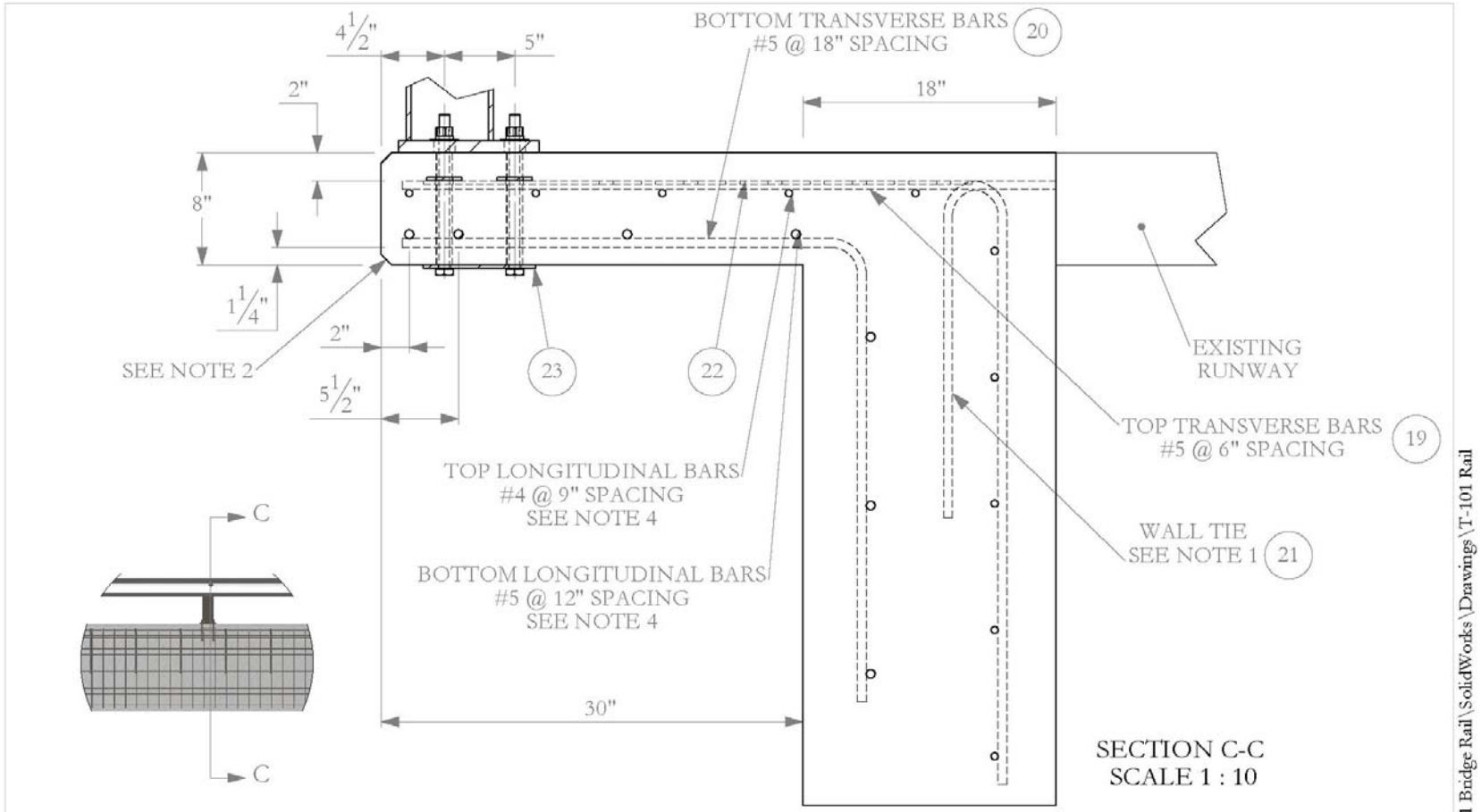


SECTION B-B
SCALE 1 : 6



The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:30	4 of 12
3.				Project No.	Cross-section - rail		
4.				420020			
5.				T-101 Bridge Rail			

T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail

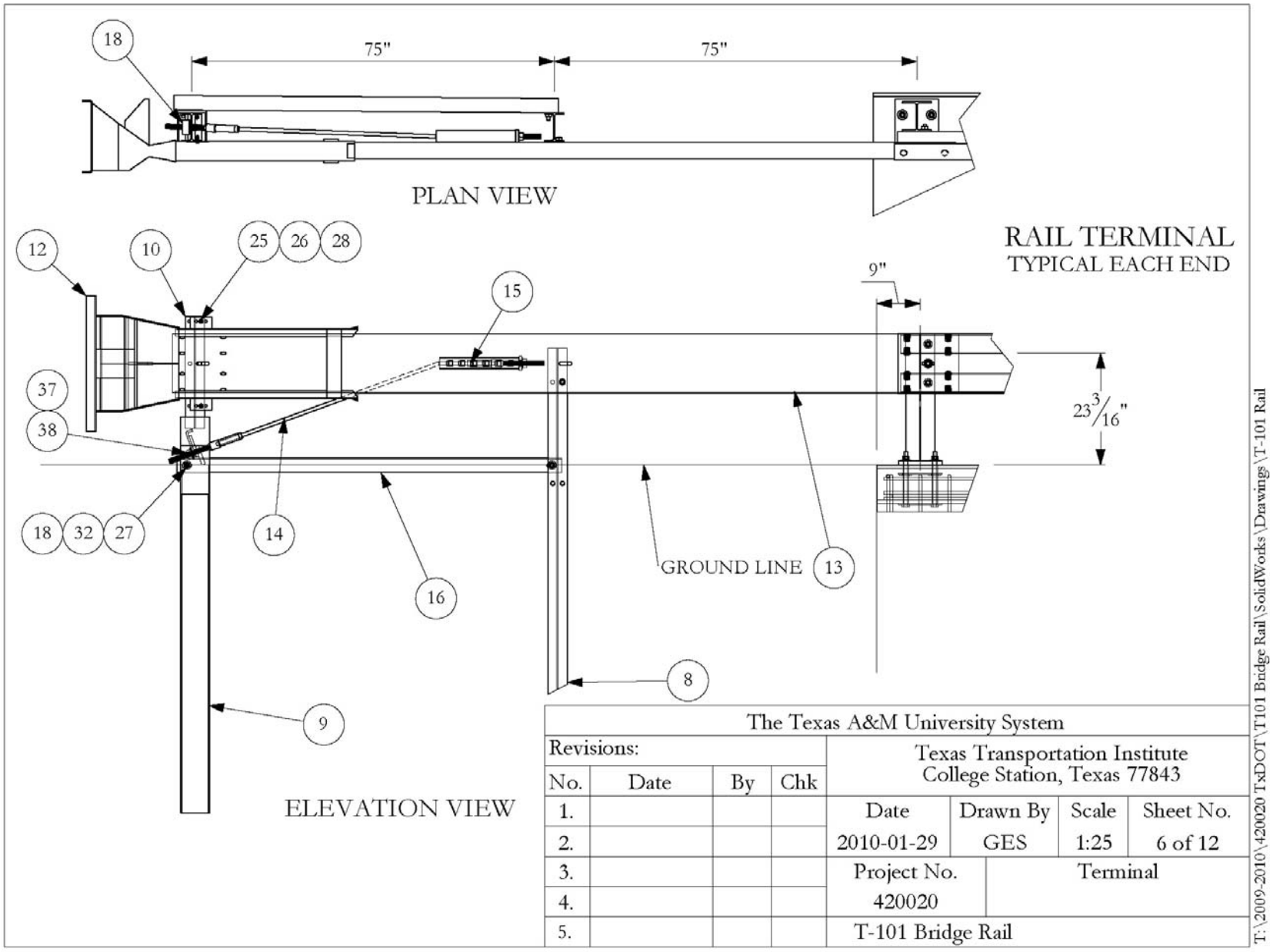


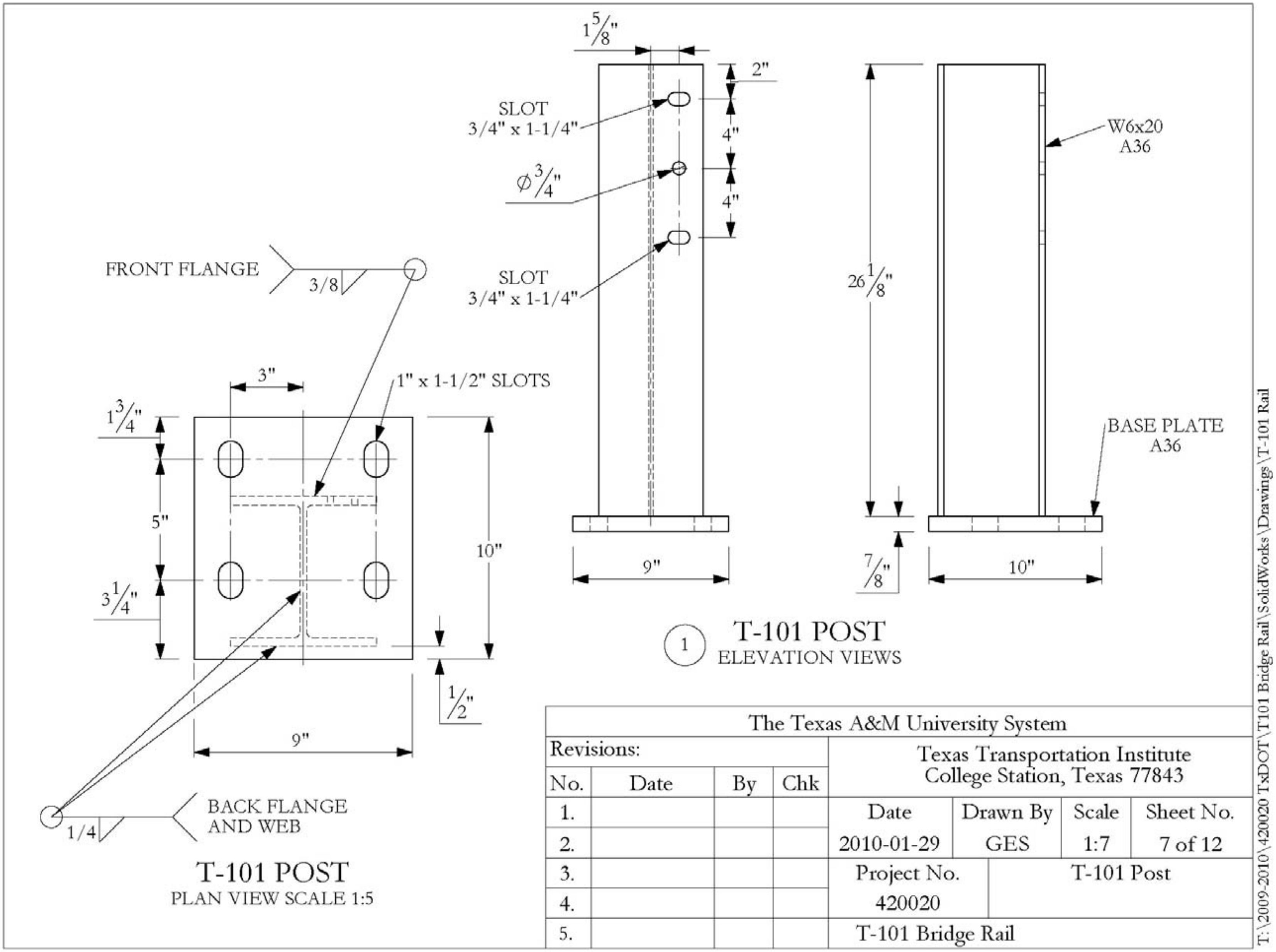
1. Wall tie rebar welded to existing rebar (not shown) at 24" spacing.
2. 3/4" chamfer top and bottom edges of deck.
3. Concrete - minimun 3600 p.s.i.
4. Rebar lap splices - #4 17"
   #5 21"

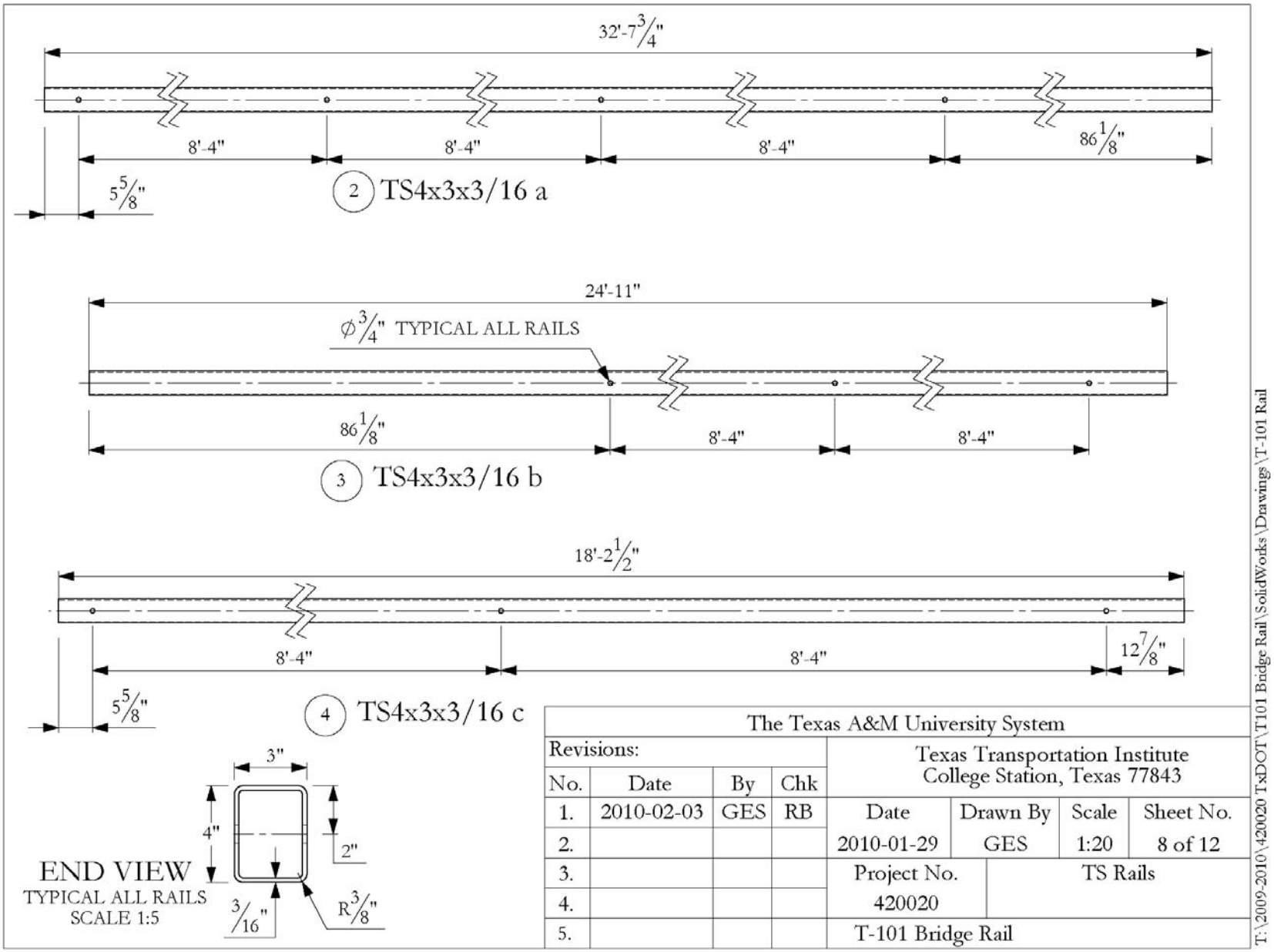
The Texas A&M University System

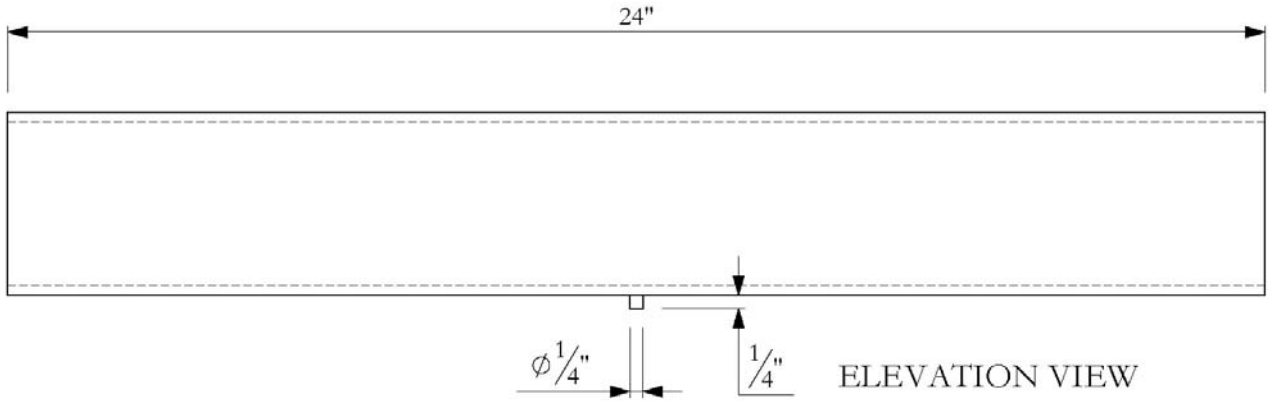
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:75	5 of 12
3.				Project No.	Cross-section Concrete		
4.				420020			
5.				T-101 Bridge Rail			

T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail


18
75"
75"
PLAN VIEW
RAIL TERMINAL
TYPICAL EACH END
12
10
25
26
28
15
9"
37
38
$23\frac{3}{16}$"
18
32
27
14
16
GROUND LINE
13
8
9
ELEVATION VIEW
The Texas A&M University System
Revisions:
No.
Date
By
Chk
1.
2.
3.
4.
5.
Texas Transportation Institute
College Station, Texas 77843
Date
2010-01-29
Drawn By
GES
Scale
1:25
Sheet No.
6 of 12
Project No.
420020
Terminal
T-101 Bridge Rail
T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail

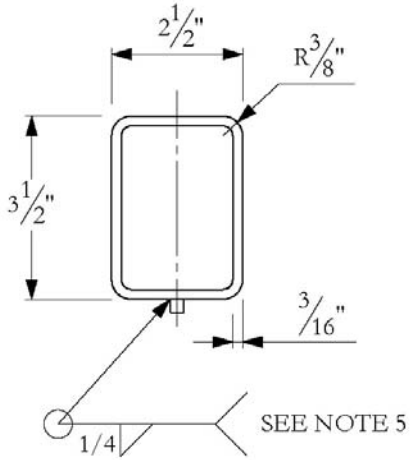

1 5/8"
2"
SLOT
3/4" x 1-1/4"
4"
Ø 3/4"
4"
SLOT
3/4" x 1-1/4"
W6x20
A36
26 1/8"
BASE PLATE
A36
9"
7/8"
10"
1
T-101 POST
ELEVATION VIEWS
FRONT FLANGE
3/8
3"
1" x 1-1/2" SLOTS
1 3/4"
5"
10"
3 1/4"
1/2"
9"
1/4
BACK FLANGE
AND WEB
T-101 POST
PLAN VIEW SCALE 1:5
The Texas A&M University System
Revisions:
No. Date By Chk
1.
2.
3.
4.
5.
Texas Transportation Institute
College Station, Texas 77843
Date Drawn By Scale Sheet No.
2010-01-29 GES 1:7 7 of 12
Project No. T-101 Post
420020
T-101 Bridge Rail
T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail


32'-7 3/4"
8'-4"
8'-4"
8'-4"
86 1/8"
5 5/8"
2 TS4x3x3/16 a
24'-11"
ϕ 3/4" TYPICAL ALL RAILS
86 1/8"
8'-4"
8'-4"
3 TS4x3x3/16 b
18'-2 1/2"
8'-4"
8'-4"
12 7/8"
5 5/8"
4 TS4x3x3/16 c
3"
4"
2"
3/16"
R 3/8"
END VIEW
TYPICAL ALL RAILS
SCALE 1:5
The Texas A&M University System
Revisions:
No. Date By Chk
1. 2010-02-03 GES RB
2.
3.
4.
5.
Texas Transportation Institute
College Station, Texas 77843
Date Drawn By Scale Sheet No.
2010-01-29 GES 1:20 8 of 12
Project No. TS Rails
420020
T-101 Bridge Rail
T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail



ELEVATION VIEW

5 TUBING SPLICE

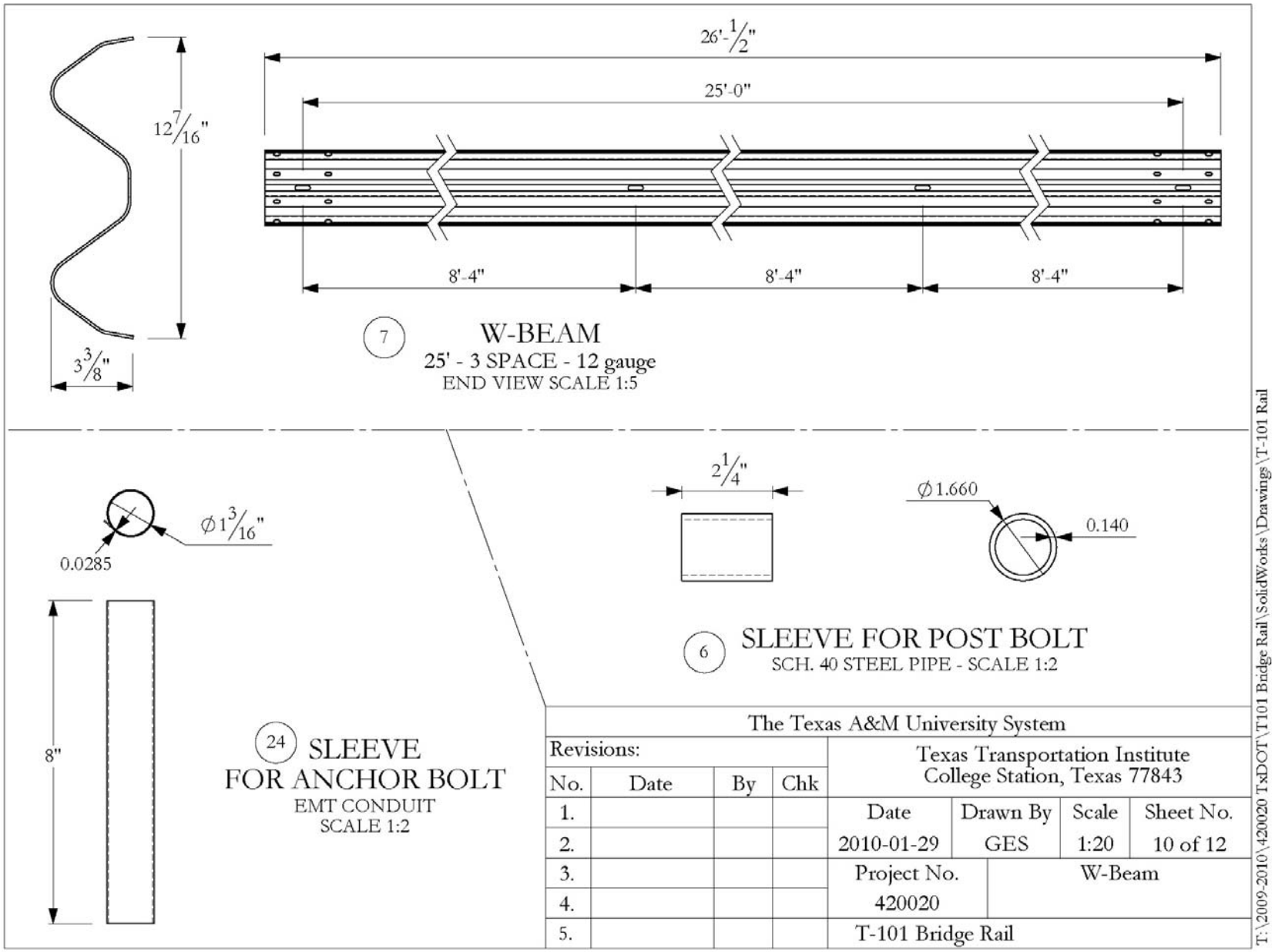


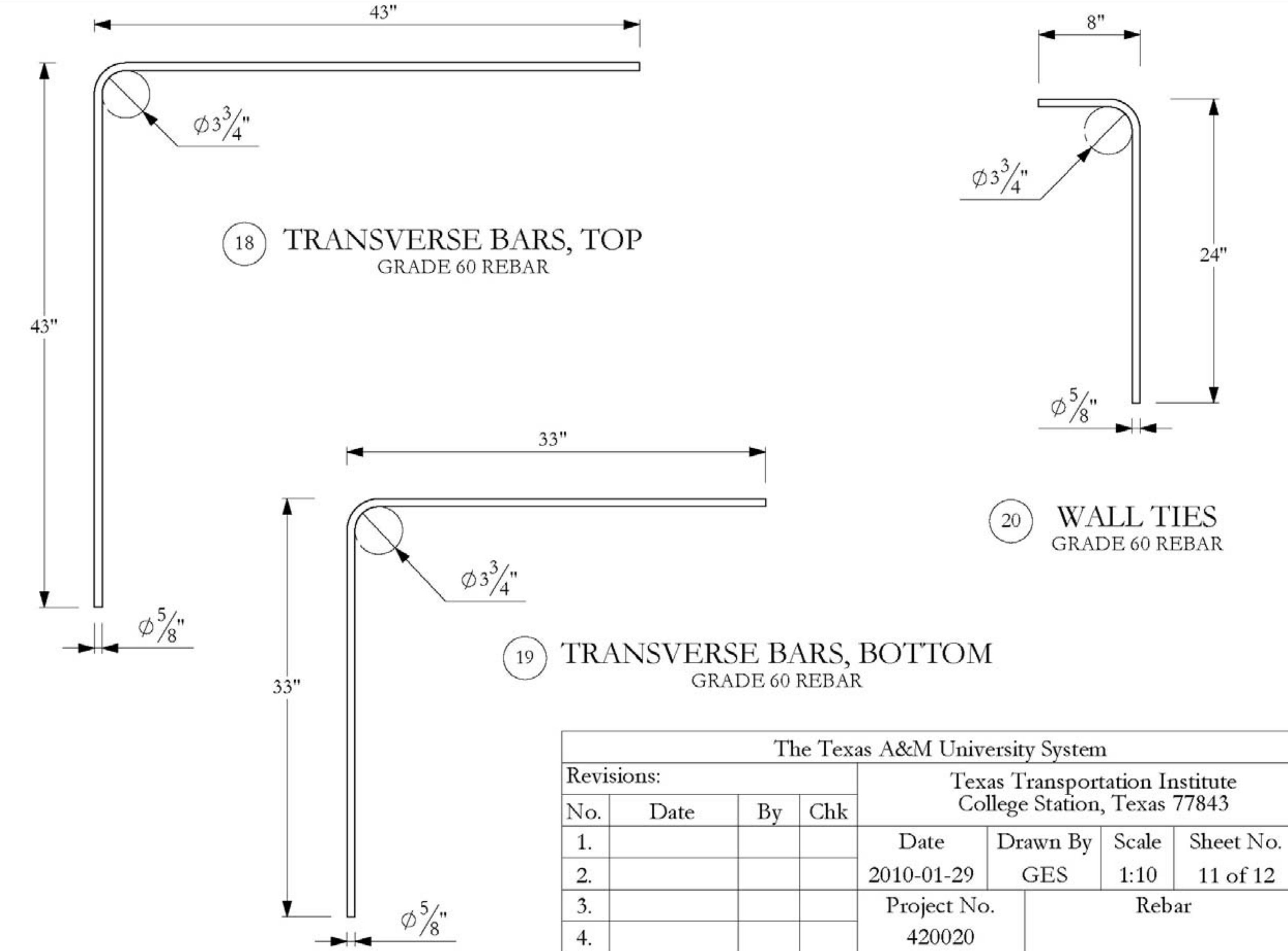
CROSS SECTION

5. Welded stud shown. Driving fit pin is acceptable alternative.
6. Stud is A36 rod. Tubing is A500 Gr. C.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.	2010-02-03	GES	RB	Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:3	9 of 12
3.				Project No.	Tube Splice		
4.				420020			
5.				T-101 Bridge Rail			

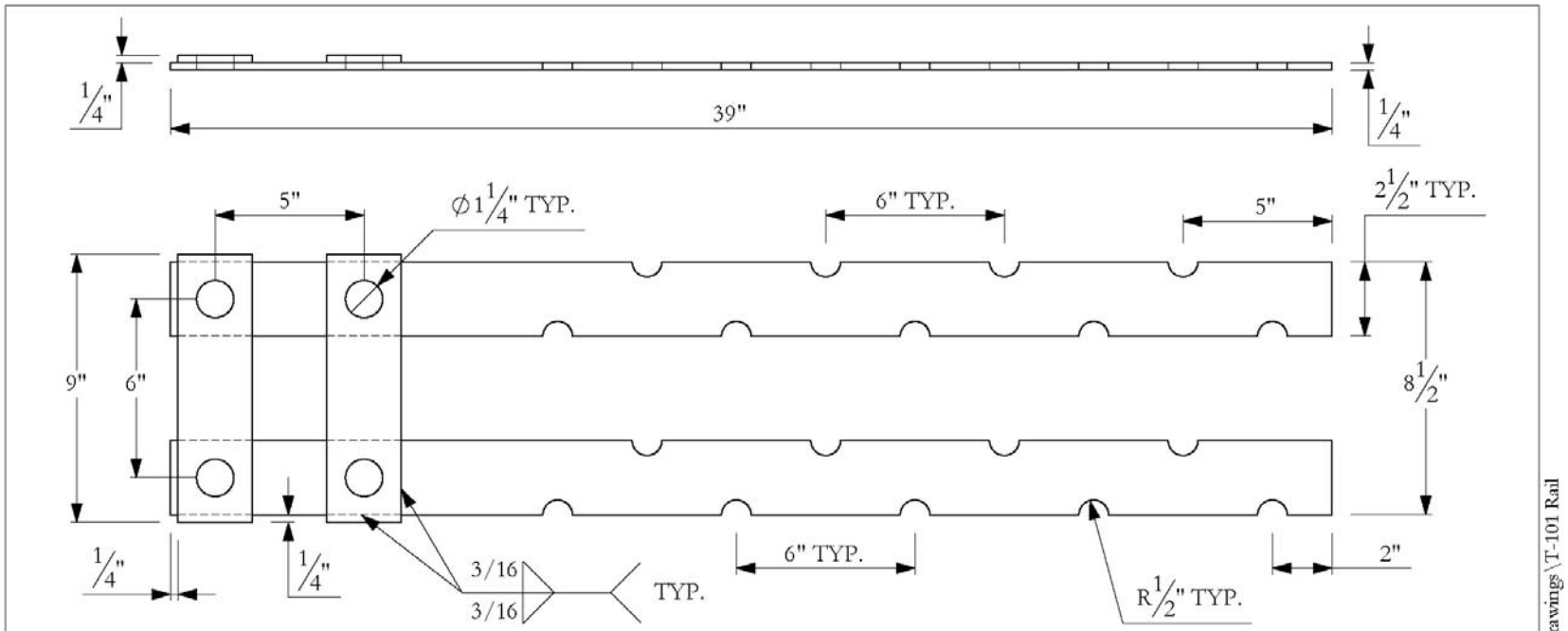
T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail


26'-1/2"
25'-0"
12 7/16"
8'-4"
8'-4"
8'-4"
3 3/8"
7
W-BEAM
25' - 3 SPACE - 12 gauge
END VIEW SCALE 1:5
2 1/4"
Ø1.660
0.140
Ø1 3/16"
0.0285
6
SLEEVE FOR POST BOLT
SCH. 40 STEEL PIPE - SCALE 1:2
8"
24
SLEEVE
FOR ANCHOR BOLT
EMT CONDUIT
SCALE 1:2
The Texas A&M University System
Revisions:
No. | Date | By | Chk
1.
2.
3.
4.
5.
Texas Transportation Institute
College Station, Texas 77843
Date: 2010-01-29
Drawn By: GES
Scale: 1:20
Sheet No.: 10 of 12
Project No.: 420020
W-Beam
T-101 Bridge Rail
T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail

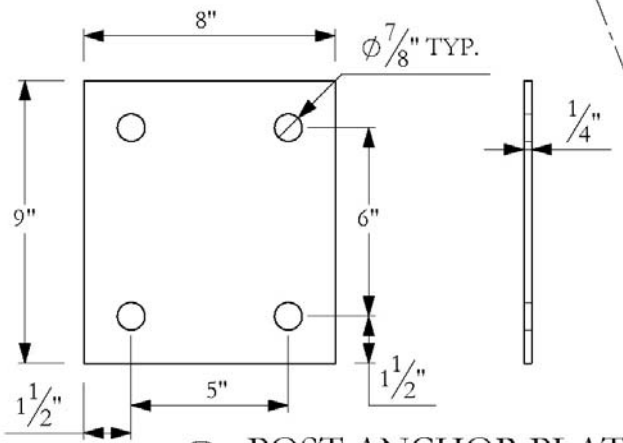


The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:10	11 of 12
3.				Project No.	Rebar		
4.				420020			
5.				T-101 Bridge Rail			

T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail



22 BOLT ANCHORAGE PLATE
A36



23 POST ANCHOR PLATE
A36

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk				
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-01-29	GES	1:5	12 of 12
3.				Project No.	Anchor Plates		
4.				420020			
5.				T-101 Bridge Rail			

T:\2009-2010\420020 TxDOT\T101 Bridge Rail\SolidWorks\Drawings\T-101 Rail

Texas Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. *5_7_2_Concrete_Break.doc*	Revision Date: 2010-02-12
Subject: **Quality Policy Form**	Revised by: W. L. Menges Approved by: C. E. Buth	Revision: 4	Page: 1 of 1

Project No.: 420020 **Casting Date:** 2010-02-19

Placement: DECK **Mix Design P.S.I.:** 4,000

Truck No.	Batch Ticket	Yards

Printed name of Technician taking sample: GLENN SCHROEDER

Signature of Technician taking sample: [signature]

Printed name of Technician breaking sample: EDDIE HAUG

Signature of Technician breaking sample: [signature]

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2010-02-26	7 DAYS	1	111,500	3944	
			111,000	3926	3979
			115,000	4067	
2010-03-25	34 DAYS		169,500		5995

Texas Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. *5_7_2_Concrete_Break.doc*	Revision Date: 2010-02-12
Subject: **Quality Policy Form**	Revised by: W. L. Menges Approved by: C. E. Buth	Revision: 4	Page: 1 of 1

Project No.: 420020 **Casting Date:** 2010-02-22

Placement: DECK **Mix Design P.S.I.:** 5,000

Truck No.	Batch Ticket	Yards

Printed name of Technician taking sample: EDDIE HAUG

Signature of Technician taking sample: Eddie Haug

Printed name of Technician breaking sample: EDDIE HAUG

Signature of Technician breaking sample: Eddie Haug

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2010-02-26	4 DAYS	1	79,000	2794	
			77,000	2723	
2010-03-25	31 DAYS		186,500	6597	6693
			192,000	6791	

MATERIAL USED

TEST NUMBER 420020-1A

DATE 2010-04-23

DATE RECEIVED	ITEM NUMBER	DESCRIPTION	SUPPLIER	HEAT #
2010-02-24	Parts 4	T101 parts	GSI	on file
2010-01-27	Rebar 04-13	1/2" x 20' gr 60	CMC-SHEPLERS	3013673
2010-01-27	Rebar 05-10	5/8" x 20' gr 60	CMC-SHEPLERS	3012466
2010-01-22	W-beam 6	12 ga. 3 sp. 25'	Trinity	generic Trinity
2010-04-20	Bolt 0.6250-3	5/8" x 4 1/2" A307	Mack Bolt & Steel	330805027
2010-04-20	Bolt 0.6250-4	5/8" x 4" A307	Mack Bolt & Steel	not given
2010-04-20	Bolt 0.7500-4	3/4-10 x 12" A325 (cut to 11")	Mack Bolt & Steel	09060322
2010-04-20	Nut 0.7500-5	3/4 A563 gr C (A325) heavy hex	Mack Bolt & Steel	07210497-1
2010-04-20	Washer 0.6250-4	5/8" flat zinc	Mack Bolt & Steel	not given
2010-04-20	Washer 0.7500-5	3/4" flat	Mack Bolt & Steel	not given
2010-04-20	Washer 0.7500-6	3/4" F436 flat	Mack Bolt & Steel	1Q058

ISO/TS 16949
BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2009/04/03

PURCHASER : PORTEOUS FASTENER COMPANY.
PO. NUMBER : 18100107
COMMODITY : HEX MACHINE BOLT GR-A
SIZE 5/8-11X4-1/2 NC
LOT NO B08101050
SHIP QUANTITY . 3,600 PCS
HEADMARKS : CYI & 307A

PACKING NO : GEM081127009
INVOICE NO : GEM/PFC-090403 HAY
PART NO : 00024-3042-021
SAMPLING PLAN : ASME B18.18.1
HEAT NO : 330805027
MATERIAL : ML08
FINISH : ZINC

PERCENTAGE COMPOSITION OF CHEMISTRY :

Chemistry	Al%	C%	Mn%	P%	S%	Si%
Spec. MIN.	0.0200	0.0500	0.3000			
MAX.		0.1000	0.6000	0.0350	0.0350	0.1000
Test Value	0.0540	0.0700	0.4200	0.0100	0.0070	0.0500

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307A-2007

TEST DATE : 2009/03/14 SAMPLED BY : ZHAO ZHENZHEN SAMPLING DATE : 2009/03/11

INSPECTIONS ITEM	SAMPLE	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	8 PCS	ASTM E18	69-100 HRB	79 HRB	8	0
TENSILE STRENGTH	4 PCS	ASTM F606/F606M	Min. 60 KSI	75 KSI	4	0

ALL TESTS ARE IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM/SAE/ASME/MIL-STD-120 SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

THIS CERTIFIED MATERIAL TEST REPORT APPLIES TO THE SAMPLES TESTED AND IT CANNOT BE REPRODUCED EXCEPT IN FULL.

SIGNATURE : Alison

Porteous Fastener Company

Product Information Sheet

Hex Bolts, Full Body, Inch Series

- PFC Product Categories: 00024, & 00026.
- Manufacturers test reports are typically available for this product.
- Typical Material: Low Carbon Steel
- Material and Mechanical Properties: Purchased to meet ASTM A307 Grade A
- Dimensions: ASME B18.2.1, Full Body, Rolled Threads
  - Standard thread length on bolt lengths up to 9 ¾ inches. 6 inches of threads on lengths 10 inches and longer.
- Zinc Plating: Purchased to meet ASTM F1941 FeZn3A
- Hot-Dip Galvanized: Purchased to meet ASTM A153.
- Typical Hardness: HRB 69-100
- Tensile Strength: 60,000 PSI Minimum

Tensile Strength					
Size	PSI	Pounds	Size	PSI	Pounds
1/4-20	60,000	1900	7/8-9	60,000	27,700
5/16-18	60,000	3100	1-8	60,000	36,350
3/8-16	60,000	4650	1 1/8-7	60,000	45,800
7/16-14	60,000	6350	1 1/4-7	60,000	58,150
1/2-13	60,000	8500	1 3/8-6	60,000	69,300
9/16-12	60,000	11,000	1 1/2-6	60,000	84,300
5/8-11	60,000	13,550	1 3/4-5	60,000	114,000
3/4-10	60,000	20,050	2-4 1/2	60,000	150,000

Length Tolerances for Hex Bolts						
	Nominal Size					
Nominal Length	1/4 to 3/8	7/16 & 1/2	9/16 to 3/4	7/8 to 1	1 1/8 to 1 1/2	Over 1 1/2
Up to & Incl 1"	+0.02/-0.03	+0.02/-0.03	+0.02/-0.03			
Over 1" to 2 1/2", incl.	+0.02/-0.04	+0.04/-0.06	+0.06/-0.08	+0.08/-0.10	+0.12/-0.12	+0.18/-0.18
Over 2 1/2" to 4", incl.	+0.04/-0.06	+0.06/-0.08	+0.08/-0.10	+0.10/-0.14	+0.16/-0.16	+0.20/-0.20
Over 4" to 6", incl.	+0.06/-0.10	+0.08/-0.10	+0.10/-0.10	+0.12/-0.16	+0.18/-0.18	+0.22/-0.22
Over 6"	+0.10/-0.18	+0.12/-0.18	+0.14/-0.20	+0.16/0.20	+0.22/-0.22	+0.24/-0.24

CERTIFICATE OF INSPECTION

Purchaser:	PFC	Date:	2009-8-10
P O NO:	PO 19062235	ISO NO:	0104Q17660R1M/3302
INV NO:	98017RB093154B REV1	Expire:	20-Sep-10
Manufacturer	Ningbo Zhenhai Xingy. Fasteners Co., Ltd.		
Address	Fangzhen Village(Ningbo Chemical Zone),Xiepu Town,Zhenhai District,Ningbo City 315204,Zhejiang Province,V.R.China		
	A325 STRUCTURAL BOLT, TYPE 1, W/"A325".		
Commodity	MFG'S I.D.ON HEAD	CUSTOMER PART NO.	00152-3272-020
Size	3/4-10 X 12	MANUFACTURING DATE:	2009.7.10
Lot NO	29E134-1	HEAT NO.	09060322
Ship quantity	0.595 MPCS	MATERIAL.	45# CARBON STEEL
Finish	PLN		

DIMENSIONAL INSPECTION: ACCORDING TO ASME B18.2.6-2003

TEST DATE: 2009-06-28 SAMPLED BY:MAOXIANQIN TITLE:QC MANAGER SAMPLING DATE: 2009-06-28

INSPECTION ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	ACCEPT	REJECT
APPEARANCE	100	ASME B18.2.6-2003	OK	100	0
Marking	100	A325&XYLX	OK	100	0
Body dia	8	0.768-0.729	0.729-0.73	8	0
Width across flats	32	1.250-1.212	1.236-1.238	32	0
Width across corners	8	1.443-1.383	1.422-1.425	8	0
Height	8	0.483-0.455	0.463-0.47	8	0
MAJOR DIAMETER	8	0.7482-0.7353	0.738-0.741	8	0
Length	32	12-11.75	11.928-11.948	32	0
Thread length	32	1.38 REF	1.403-1.449	32	0
Go-Gage	8	UNC-2A	OK	8	0
NO-GO gage	8	UNC-2A	OK	8	0

CHEMICAL COMPOSITION: ACCORDING TO ASTM A325-02

TEST DATE: 2009-06-19 SAMPLED BY:MAOXIANQIN TITLE:QC MANAGER SAMPLING DATE: 2009-06-19

CHEMICAL ELEMENT (%)	C	Mn	P	S	Si	Cr	Mo	Ni	Al	Ti	V
SPECIFIED	0.30-0.52	0.60 MIN	0.040 MAX	0.050 MAX	0.15-0.30						
TEST RESULT	0.44	0.6	0.012	0.01	0.22	0.04	0.006	0.08	0.027	0.002	0.001

MECHANICAL PROPERTIES: ACCORDING TO ASTM A325-02

TEST DATE: 2009-06-28 SAMPLED BY:MAOXIANQIN TITLE:QC MANAGER SAMPLING DATE: 2009-06-28

TEST ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	ACCEPT	REJECT
PROOF LOAD STRESS	1	85 KSI	85 KSI OK	1	0
TENSILE STRENGTH(KSI)	4	120 MIN	130-135	4	0
HARDNESS (HRC)	8	34 MAX	25-27	8	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY

SIGNATURE: MAOXIANQIN TITLE: QC MANAGER

CERTIFICATE OF INSPECTION

Purchaser:	PFC	Date:	2008-8-18
P.O.NO.	PO 18041739	ISO NO:	03407Q10012ROS
INV NO.	98017RB083126B	Expire:	2010-01-10
Manufacturer:	Lin'an Huaxing Fastening Piece Co.,Ltd.		
Address:	Tashan Village,Qianchuan Town,Lin'an City,Zhejiang Province,China		
	A563 GR.C HVY HEX NUT(A325), W/MFG'S		
Commodity	ID&3CIRCUMFERENTIAL LINES ON ONE FACE PLAIN	CUSTOMER PART NO.	00214-3200-300
Size:	3/4-10	MANUFACTURING DATE:	2008.7
Lot NO	28B1942-3	HEAT NO.	07210497-1
Lot quantity	153.000 MPCS	MATERIAL	35# Mediumn carbon steel
Finish	PLN		

DIMENSIONAL INSPECTION: ACCORDING TO ASME B18.2.2-1987

TEST DATE: 2008-07-18 SAMPLED BY: ZHUXIAOCHAO SAMPLING DATE: 2008-07-18

INSPECTION ITEM	SAMPLE SIZE	SPECIFICATION	ACTUAL RESULT	ACCEPT	REJECT
APPEARANCE	100	ASME B18.2.2-1987	OK	100	0
Marking	100	3 Circumferential Lines&01RC	OK	100	0
Width across flats	32	1.250-1.212	1.215-1.242	32	0
Width across corners	8	1.443-1.382	1.386-1.440	8	0
Thickness	8	0.758-0.710	0.715-0.750	8	0
Minor dia.	8	0.642-0.663	0.645-0.652	8	0
Runout of bearing face FIM	8	0.027 MAX	0.016-0.018	8	0
Go-Gage	8	UNC-2B	OK	8	0
NO-GO gage	8	UNC-2B	OK	8	0

CHEMICAL COMPOSITION: ACCORDING TO ASTM A563 GRADE C

TEST DATE: 2008-07-18 SAMPLED BY: ZHUXIAOCHAO SAMPLING DATE: 2008-07-18

CHEMICAL ELEMENT (%)	C	Mn	P	S	Si	Cr	Mo	Ni	Al	Ti	V
SPECIFICATION	0.55 MAX		0.12 MAX	0.15 MAX							
TEST RESULT	0.34	0.80	0.009	0.035	0.15						

MECHANICAL PROPERTIES: ACCORDING TO ASTM A563 GRADE C

TEST DATE: 2008-07-18 SAMPLED BY: ZHUXIAOCHAO SAMPLING DATE: 2008-07-18

TEST ITEM	SAMPLE SIZE	SPECIFICATION	ACTUAL RESULT	ACCEPT	REJECT
PROOF LOAD STRESS	4	144 KSI	144 KSI OK	4	0
HARDNESS	8	HRB78-HRC38	HRC28-32	8	0

THE MINIMUM TEMPERING TEMPERATURE: 800°F

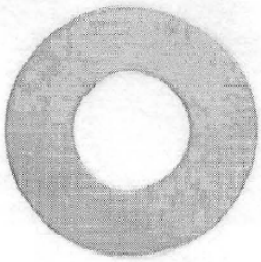
WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY

SIGNATURE: ZHUXIAOCHAO

Porteous Fastener Company

Product Information Sheet

Flat Washers, USS Pattern (Size W), Unhardened



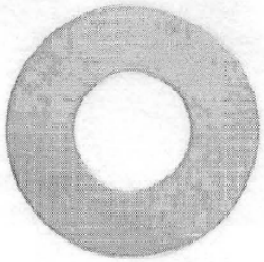
- PFC Product Category: 00370.
- Typical Material: Low Carbon Steel (made from scrap pieces of steel)
- Material and Mechanical Properties: No requirements
- Dimensions: ANSI B18.22.1, Table 1A, Size "W"
- Other specification: ASTM F844
- Zinc Plating: Purchased to meet ASTM F1941 FeZn3A
- Hot-Dip Galvanized: Purchased to meet ASTM A153.
- Hardness: No hardness requirements exist in the specifications

USS Flat Washer Dimensions							
Size	**I.D.**	**O.D.**	**Thickness**	**Size**	**I.D.**	**O.D.**	**Thickness**
3/16	0.245-0.265	0.557-0.577	0.036-0.065	1 1/8	1.243-1.280	2.743-2.780	0.136-0.192
1/4	0.307-0.327	0.727-0.749	0.051-0.080	1 1/4	1.368-1.405	2.993-3.030	0.136-0.192
5/16	0.370-0.390	0.868-0.905	0.064-0.104	1 3/8	1.490-1.545	2.743-2.780	0.153-0.213
3/8	0.433-0.453	0.993-1.030	0.064-0.104	1 1/2	1.615-1.670	3.240-3.295	0.153-0.213
7/16	0.495-0.515	1.243-1.280	0.064-0.104	1 5/8	1.740-1.795	3.490-3.545	0.153-0.213
1/2	0.557-0.577	1.368-1.405	0.086-0.132	1 3/4	1.865-1.920	3.900-4.045	0.153-0.213
9/16	0.620-0.640	1.462-1.499	0.086-0.132	2	2.115-2.170	4.490-4.545	0.153-0.213
5/8	0.681-0.718	1.743-1.780	0.108-0.160	2 1/4	2.365-2.420	4.740-4.795	0.193-0.248
3/4	0.805-0.842	1.993-2.030	0.122-0.177	2 1/2	2.615-2.670	4.990-5.045	0.210-0.280
7/8	0.931-0.968	2.243-2.280	0.136-0.192	2 3/4	2.865-2.945	5.240-5.315	0.228-0.310
1	1.055-1.092	2.493-2.530	0.136-0.192	3	3.115-3.190	5.490-5.565	0.249-0.327

Porteous Fastener Company

Product Information Sheet

Flat Washers, USS Pattern (Size W), Unhardened



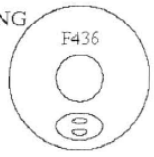
- PFC Product Category: 00370.
- Typical Material: Low Carbon Steel (made from scrap pieces of steel)
- Material and Mechanical Properties: No requirements
- Dimensions: ANSI B18.22.1, Table 1A, Size "W"
- Other specification: ASTM F844
- Zinc Plating: Purchased to meet ASTM F1941 FeZn3A
- Hot-Dip Galvanized: Purchased to meet ASTM A153.
- Hardness: No hardness requirements exist in the specifications

USS Flat Washer Dimensions							
Size	**I.D.**	**O.D.**	**Thickness**	**Size**	**I.D.**	**O.D.**	**Thickness**
3/16	0.245-0.265	0.557-0.577	0.036-0.065	1 1/8	1.243-1.280	2.743-2.780	0.136-0.192
1/4	0.307-0.327	0.727-0.749	0.051-0.080	1 1/4	1.368-1.405	2.993-3.030	0.136-0.192
5/16	0.370-0.390	0.868-0.905	0.064-0.104	1 3/8	1.490-1.545	2.743-2.780	0.153-0.213
3/8	0.433-0.453	0.993-1.030	0.064-0.104	1 1/2	1.615-1.670	3.240-3.295	0.153-0.213
7/16	0.495-0.515	1.243-1.280	0.064-0.104	1 5/8	1.740-1.795	3.490-3.545	0.153-0.213
1/2	0.557-0.577	1.368-1.405	0.086-0.132	1 3/4	1.865-1.920	3.900-4.045	0.153-0.213
9/16	0.620-0.640	1.462-1.499	0.086-0.132	2	2.115-2.170	4.490-4.545	0.153-0.213
5/8	0.681-0.718	1.743-1.780	0.108-0.160	2 1/4	2.365-2.420	4.740-4.795	0.193-0.248
3/4	0.805-0.842	1.993-2.030	0.122-0.177	2 1/2	2.615-2.670	4.990-5.045	0.210-0.280
7/8	0.931-0.968	2.243-2.280	0.136-0.192	2 3/4	2.865-2.945	5.240-5.315	0.228-0.310
1	1.055-1.092	2.493-2.530	0.136-0.192	3	3.115-3.190	5.490-5.565	0.249-0.327

HEXICO ENTERPRISE CO., LTD.

NO.355-3,SEC. 3,CHUNG SHAN ROAD,KAU-JEN,TAINAN,TAIWAN,R.O.C.
TEL : 886 - 6 - 2390616 FAX : 886 - 6 - 2308947

MARKING



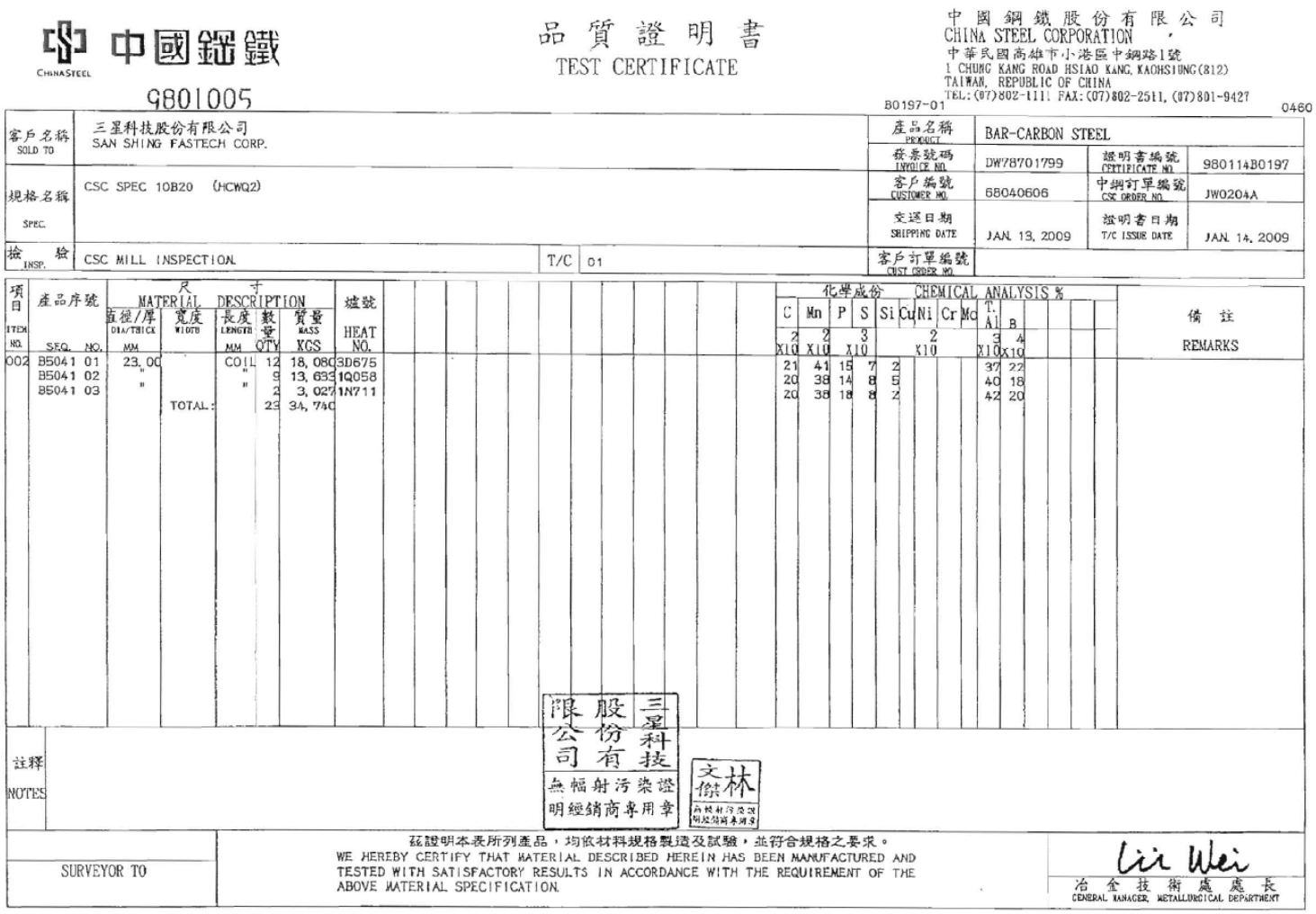
INSPECTION CERTIFICATE

CUSTOMER	PORTEOUS FASTENER CO.		
PART NAME	ASTM F436 - 07 TYPE 1 WASHERS		
SIZE	3/4"	DATE	November 20, 2009
PART NO	W2A6C6000S6H0	REPORT NO.	981120-01
CUST. PART NO.	00385-3200-020	SHIPPING NO.	
MATERIAL / DIA.	10B20 / 23 mm	ORDER NO.	19061512
HEAT(COIL) NO.	1Q058	LOT NO.	872C6PF22
LOT QTY	72,000 PCS	DOCUMENT NO.	9801005
STANDARD OF SAMPLING SCHEME	ANSI / ASME B18.18.2 M		

DIMENSIONS IN inch

	INSPECTION ITEM	SPEC. VALUE	INSPECTION RESULTS MIN.	INSPECTION RESULTS MAX.	REMARKS
1	OUTSIDE DIAMETER	1.4360 - 1.5000	1.4516	1.4776	
2	INSIDE DIAMETER	0.8130 - 0.8450	0.8374	0.8413	
3	THICKNESS	0.1220 - 0.1770	0.1256	0.1547	
4	HARDNESS	HRC 38 - 45	38.7	42.5	
5	COATING	--	--		
6	APPEARANCE	VISUAL	OK		

INSPECTED BY Yu Tain Lin CERTIFIED BY Jing Yeh Tsao



中鋼鋼鐵 CHINA STEEL

品質證明書
TEST CERTIFICATE

9801005

中國鋼鐵股份有限公司
CHINA STEEL CORPORATION
中華民國高雄市小港區中鋼路1號
1 CHUNG KANG ROAD HSIAO KANG, KAOHSIUNG(812)
TAIWAN, REPUBLIC OF CHINA
TEL:(07)802-1111 FAX:(07)802-2511, (07)801-9427

B0197-01 0460

客戶名稱 SOLD TO	三星科技股份有限公司 SAN SHING FASTECH CORP.		產品名稱 PRODUCT	BAR-CARBON STEEL	
			發票號碼 INVOICE NO.	DW78701799	證明書編號 CERTIFICATE NO. 980114B0197
規格名稱 SPEC.	CSC SPEC 10B20 (HCWQ2)		客戶編號 CUSTOMER NO.	68040606	中鋼訂單編號 CSC ORDER NO. JW0204A
			交送日期 SHIPPING DATE	JAN. 13, 2009	證明書日期 T/C ISSUE DATE JAN. 14, 2009
檢驗 INSP.	CSC MILL INSPECTION	T/C 01	客戶訂單編號 CUST ORDER NO.		

項目 ITEM NO.	產品序號 SEQ. NO.	尺寸 MATERIAL DESCRIPTION 直徑/厚 DIA/THICK MM	寬度 WIDTH	長度 LENGTH MM	數量 QTY	質量 MASS KGS	爐號 HEAT NO.	化學成份 CHEMICAL ANALYSIS % C X10	Mn X10	P X10	S X10	Si	Cu	Ni X10	Cr	Mo	Al X10	B X10	備註 REMARKS
002	B5041 01	23.00		COIL	12	18,080	3D675	21	41	15	7	2					37	22	
	B5041 02	"		"	9	13,633	1Q058	20	38	14	8	5					40	18	
	B5041 03	"		"	2	3,027	1N711	20	38	18	8	2					42	20	
			TOTAL:		23	34,740													

三星科技股份有限公司 無幅射污染證明經銷商專用章

林文傑

註釋 NOTES

SURVEYOR TO

茲證明本表所列產品，均依材料規格製造及試驗，並符合規格之要求。
WE HEREBY CERTIFY THAT MATERIAL DESCRIBED HEREIN HAS BEEN MANUFACTURED AND TESTED WITH SATISFACTORY RESULTS IN ACCORDANCE WITH THE REQUIREMENT OF THE ABOVE MATERIAL SPECIFICATION.

Lii Wei
冶金技術處處長
GENERAL MANAGER, METALLURGICAL DEPARTMENT

NUCOR STEEL - BERKELEY
P.O. Box 2259
Mt. Pleasant, S.C. 29464
Phone: (843) 336-6000

CERTIFIED MILL TEST REPORT

1/26/10 16:48:03

100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.

Sold To: NAMASCO CORPORATION
500 COLONIAL CENTER PKWY.
SUITE 500
ROSWELL, GA 30076

Ship To: NAMASCO-TAMPA
907 SOUTH 20TH STREET
TAMPA, FL 33675

Customer #.: 405 - 3
B.o.L. #...: 796029

SPECIFICATIONS: Tested in accordance with ASTM Specification A6/A6M and A370.
AASHTO : M270-50-05
ASTM : A992-06a:A36-08/A529-05-50/A572-07-50/A709-345M/A70909a0S

Description	Heat# Grade(s) Test	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr xxxxxx	Mn Mo xxxxxx	P Sn xxxxxx	S B xxxxxx	Si V N	Cu Nb xxxxxx	Ni xxxxxx CI	CE1 CE2 Pcm
W6X20	2911806	.79	53600	67500	24.48	.06	.80	.007	.034	.19	.17	.04	.22
050' 00.00"	A992-06a		370	465		.03	.00	.0075	.0004	.002	.024		.2661
W150X29.8		.79	53400	67400	24.40					.0049		4.05	.1304
015.2400m			368	465		9 Piece(s)		Customer PO: 6245230				Inv#:	0
W6X25	2000934	.78	55800	71900	23.76	.06	1.04	.010	.034	.23	.25	.06	.27
040' 00.00"	A992-06a		385	496		.04	.00	.0132	.0004	.002	.028		.3189
W150X37.1		.79	56300	71700	23.06					.0059		5.15	.1451
012.1920m			388	494		9 Piece(s)		Customer PO: 6245230				Inv#:	0

6 Heat(s) for this MIR.

Elongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.
CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29CuXNi)-(9.10NiXP)-33.39(CuXCu)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B

CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

I hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with material specifications, and when designated by the Purchaser, meet applicable specifications.

Bruce A. Work
Metallurgist

02-08-2010 23:35 Load - 780129 BL - 6585127 BLR466
Gordon's Specialties, Inc. GSI Highway Products Heat - 2911806
Cust. PO - 16849 CASEY Order-Line - 4776894 / 3

BLR466

BL - 6585127 Heat - 9100461

Load - 780129 Order-Line - 4776894 / 4

02-08-2010 23:35 Gordon's Specialties, Inc. GSI Highway Products

Cust. PO - 16849 CASEY

NUCOR
PLATE MILL

P.O.Box 279
Winton, NC 27986
(252) 356-3700

Mill Test Report

Page 1

NUCOR It's our Nature

Issuing Date : 01/26/2009 B/L No. : 223463 Load No. : 225050 Our Order No. : 69143/1 Cust. Order No. : 6179649

Vehicle No: WTI 3338

Specification : 0.8750" x 96.000" x 240.000"
ASTM A36-08/ASTM A709 Grade 36-08/ASME SA36-03a

Sold To : NAMASCO CORPORATION
500 COLONIAL CENTER PKWY
SUITE 500
ROSWELL,GA 30076

Ship To : NAMASCO - SHREVEPORT
4302 W 70TH STREET
SHREVEPORT,LA 71108

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Alz	V	Nb	Ti	N	Ca	B	Sn	CEQ	PCM
9100461	0.19	0.82	0.018	0.007	0.17	0.33	0.09	0.09	0.04	0.005	0.002	0.002	0.001		0.0010	0.0000	0.022	0.38	0.27

Tensile Test

Plate Serial No	Pieces	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % in 2"	Elongation % in 8"
9100461-03	7	20.01	T	46,900	70,400		18.3
			T	47,700	76,700		22.4

Charpy Impacts

Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.

Manufactured to fully killed practice by Electric Arc Furnace. Welding or weld repair was not performed on this material.
Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification.
Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
Melted and manufactured in the USA. ISO 9001-2000 certified (#006461) by SRI Quality System Registrar (#0985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant.
DIN 50049 3.1.B/EN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 06-MMPQA-383.

We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications, including customer specifications.

T. A. Depretis, Metallurgist

01/26/2009 2:40:22 PM

02-05-2010 23:21 Load - 779623 BL - 6585052 BLR466
Gordon's Specialties, Inc. GSI Highway Products Heat - A918501
Cust. PO - 16855 ASHLEY Order-Line - 4778880 / 2,4778880 / 1

02-03-'10 12:10 FROM-ITC 708-563-1950 T-601 P014/024 F-915

03Feb10 8:49 T E S T C E R T I F I C A T E No: DCR 657721

Sold By:
INDEPENDENCE TUBE CORPORATION
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 6248663
Rel
S/O No DCR 20253-003
B/L No DCR 13924-012 Shp 02Feb10
Inv No Inv

Sold To: (144)
NAMASCO-EAST
500 COLONIAL PARKWAY
SUITE 500
ROSWELL, GA 30076

Ship To: (8)
NAMASCO-SUWANEE
3775 INDUSTRIAL COURT
770-271-9948
SUWANEE, GA

Tel: 678-259-8845 Fax: 571 323-0613

CERTIFICATE of ANALYSIS and TESTS Cert. No: DCR 657721
02Feb10

Part No 003
TUBING A500 GRADE B(C)
4" X 3" X 3/16" X 40'

	Pcs	Wgt
	13	4,238

Heat Number	Tag No	Pcs	Wgt
A918501	640005	13	4,238

YLD=73200/TEN=84900/ELG=47.6

Heat Number *** Chemical Analysis ***
A918501 C=0.2100 Mn=0.4700 P=0.0090 S=0.0030 Si=0.0300 Al=0.0260
Cu=0.0900

T/R FAX

Test Report Clerk
MELTED IN U.S.A.

WE PROUDLY MANUFACTURE ALL OF OUR HSS IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED,
AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.
****
CURRENT STANDARDS:
..... A500/A500M-07
..... A513-07
..... A252-98 (2002)

Page: 1 .... Last

SSAB

Test Certificate

Form TC1: Revision 1: Date 31 Oct 2000

13609 Industrial Road, Houston, TX 77015

Customer:	Customer P.O. No.: 6247928	Mill Order No.: 41-262010-02	Shipping Manifest : HT060144
NAMASCO - ATTN ACCOUNTS PAYABL 500 COLONIAL CENTER PKWY SUITE 500 ROSWELL GA 30076	Product Description: ASTM A36(08)/A709(09A)36/ASME SA36(08A) AASHTO M270(01)36, 0.80-1.20 MN	Ship Date: 05 Feb 10 Cert Date: 05 Feb 10	Cert No: 031102364 (Page 1 of 1)
	Size: 0.250 X 96.00 X 240.0 (IN)		

Tested Pieces				Tensiles					Charpy Impact Tests										
Heat Id	Piece Id	Piece Dimensions	Tst Loc	YS (PSI)	UTS (PSI)	%RA	Elong % 2in	8in	Tst Dir	Average Hardness	Abs. Energy(FTLB) 1	2	3	Avg	% Shear 1	2	3	Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp	%Shr
E0A106	0098	0.250 X 96.00 (T.L.C)	L	53000	64000		30		T														
			C	54000	64000		32		T														
E0A106	0100	0.250 X 96.00 (T.L.C)	L	55000	63000		32		T														
			C	59000	64000		31		T														

Heat Id	Chemical Analysis C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	CEV	ORGN
E0A106	.05	1.09	.010	.002	.24	.030	.33	.18	.09	.06	.002	.005	.025	.0001	.0083	.30	USA

MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED
DURING THE MANUFACTURE OF THIS PRODUCT
CEV (IIW) = C + MN/6 + (CR+MO+V)/5 + (NI+CU)/15
MATERIAL MARKED WITH AN ASTERISK IS PRODUCED FROM COIL
100% MELTED AND MANUFACTURED IN THE U.S.A.
* E0A106 0100 PCES: 4, WGT: 6534 * E0A106 0101 PCES: 21, WGT: 34304

(F) Cust Part # :

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Jason Thomas
SENIOR METALLURGIST

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Daniel J. Schacht
Quality Assurance Manager

HEAT NO.:3013673 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-09 Gr 420/60 ROLL DATE: 12/12/2009 MELT DATE: 12/14/2009	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 80234296 BOL#: 70076586 CUST PO#: 3389-CC CUST P/N: DLVRY LBS / HEAT: 26292.000 LB DLVRY PCS / HEAT: 1968 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.42%				
Mn	0.68%				
P	0.015%				
S	0.036%				
Si	0.19%				
Cu	0.34%				
Cr	0.25%				
Ni	0.25%				
Mo	0.086%				
V	0.001%				
Cb	0.001%				
Sn	0.015%				
Al	0.002%				
Yield Strength test 1	69.1ksi				
Tensile Strength test 1	105.7ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.750IN				
Bend Test	Passed				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.
REMARKS :

12/16/2009 07:23:00
Page 1 OF 1

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Daniel J. Schacht
Quality Assurance Manager

HEAT NO.:3012466 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-08b Gr 420/60 ROLL DATE: 10/09/2009 MELT DATE: 10/09/2009	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 80227878 BOL#: 70073867 CUST PO#: 436501 CUST P/N: DLVRY LBS / HEAT: 2190.000 LB DLVRY PCS / HEAT: 105 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.40%				
Mn	0.86%				
P	0.015%				
S	0.024%				
Si	0.19%				
Cu	0.28%				
Cr	0.28%				
Ni	0.21%				
Mo	0.084%				
V	0.002%				
Cb	0.002%				
Sn	0.012%				
Al	0.002%				
Yield Strength test 1	74.9ksi				
Tensile Strength test 1	110.8ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	2.188IN				
Bend Test	Passed				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA. WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX

Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207

Sales Order: 1072852
Customer PO:
BOL # 29710
Document # 1

Print Date: 1/22/10
Project: SAMPLES-TESTING THIS ORDER FOR END TERMI
Shipped To: TX
Use State: TX

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** E.T. PLUS EXTRUDER TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
3	12/12'6/6'3 /S
5	12/12'6/6'3/S ET2000 ANC
6	12/25/8'4/S
6	6'0 POST/DB:DDR
5	CABLE ANCHOR BRKT ET-2000
1	ET-PLUS EXTRUDER HEAD
5	CBL 3/4X6'6/DBL SWG/NOHWD
7	5/8" RD WASHER 1 3/4 OD
110	5/8" GR HEX NUT
100	5/8"X1.25" GR BOLT
6	5/8"X10" GR BOLT A307
2	3/4" ROUND WASHER F436
2	3/4" HVY HEX NUT A563 DH
2	3/4"X2.5" HEX BOLT A325
10	1" ROUND WASHER F844
10	1" HEX NUT A563
6	WD BLK RTD 6X8X14
4	3/8" ROUND WASHER F436
2	3/8" FENDER WASHER F844
2	3/8" LOCK WASHER
2	3/8"X1.5" HEX BOLT GR-5
2	7/16" WASHER F844
2	7/16"X1.5" HEX BOLT GRD 5
2	7/16" LOCK WASHER
2	7/16" HEX NUT A563 DH
2	3/4" LOCK WASHER
1	REFL SHT 13X27.5 Y/B LT
2	3/8"X2" HEX BOLT GR-5 HDG
4	3/8" HVY HEX NUT A563GRDH
1	6'0 PST/8.5#/SYTP
1	HBA-BRG PL/WELDED TABS

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX

Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207

Sales Order: 1072852
Customer PO:
BOL # 29710
Document # 1

Print Date: 1/22/10
Project: SAMPLES-TESTING THIS ORDER FOR END TERMI
Shipped To: TX
Use State: TX

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** E.T. PLUS EXTRUDER TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
1	SYT-3"AN STRT 3-HL 6'6
1	ET HBA P1 TOP X 2-8 3/4
1	ET HBA P1-2 BTM X 6-1 1/2

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

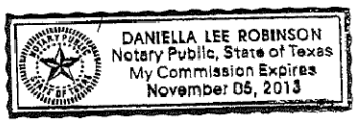
TL -3 or TL-4 COMPLIANT when installed according to manufactures specifications

61

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Texas, County of Tarrant. Sworn and Subscribed before me this 22nd day of January, 2010

Notary Public:
Commission Expires:



Trinity Highway Products, LLC
Certified By:
Quality Assurance

APPENDIX C. TEST VEHICLE PROPERTIES AND INFORMATION

Date: 2010-04-23 Test No.: 420020-1a VIN No.: 1D7HA18NV3J505635

Year: 2003 Make: Dodge Model: Ram 1500

Tire Size: 245/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 129186

Note any damage to the vehicle prior to test:

• Denotes accelerometer location.

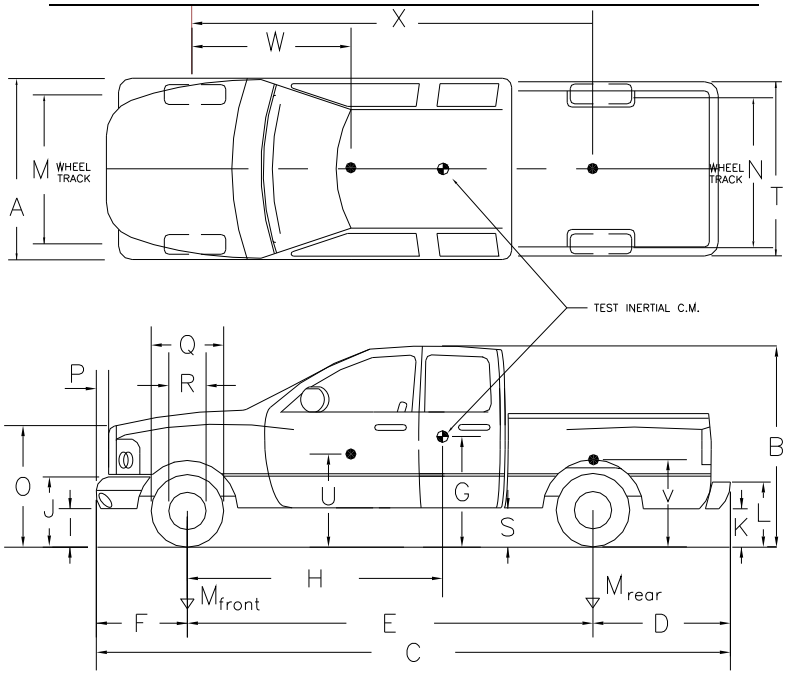
NOTES:

Engine Type: V-8
Engine CID: 4.7 liter

Transmission Type:
x Auto or ___ Manual
___ FWD x RWD ___ 4WD

Optional Equipment:

Dummy Data:
Type: No dummy
Mass:
Seat Position:



Geometry: inches

A	77.00	F	39.00	K	20.50	P	3.00	U	27.50
B	73.85	G	28.00	L	28.75	Q	29.50	V	33.00
C	227.00	H	63.10	M	68.25	R	18.50	W	59.50
D	47.50	I	13.50	N	67.25	S	14.25	X	140.50
E	140.50	J	26.0	O	44.75	T	75.50		

Wheel Center Ht Front	14.125	Wheel Well Clearance (FR)	6.125	Frame Ht (FR)	16.625
Wheel Center Ht Rear	14.125	Wheel Well Clearance (RR)	11.250	Frame Ht (RR)	24.250

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; M+N/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial		Gross Static	
Front	3650	M_{front}	2775	2767	Allowable		Allowable
Back	3900	M_{rear}	1967	2256	Range		Range
Total	6650	M_{Total}	4742	5023	5000 ±110 lb		5000 ±110 lb

Mass Distribution:
lb LF: 1425 RF: 1342 LR: 1118 RR: 1138

Figure C1. Vehicle Properties for Test No. 420020-1a.

Table C1. Vehicle Center-of-Gravity Measurements for Test No. 420020-1a.

Date: 2010-04-22 Test No.: 420020-1a VIN: 1D7HA18NV3J505635

Year: 2003 Make: Dodge Model: Ram 1500

Body Style: Quad Cab Mileage: 129186

Engine: 4.7 liter Transmission: Automatic

Fuel Level: Empty Ballast: 235 lb at front of bed (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 245/70R17

Measured Vehicle Weights: (lb)								
LF:	1390	RF:	1373	Front Axle:	2763			
LR:	1114	RR:	1135	Rear Axle:	2249			
Left:	2504	Right:	2508	Total:	5012			
				5000 ±110 lb allowed				
Wheel Base:	140.5 inches	Track: F:	68.25 inches	R:	67.25 inches			
148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed					
Center of Gravity, SAE J874 Suspension Method								
X:	63.05 in	Rear of Front Axle	(63 ±4 inches allowed)					
Y:	0.03 in	Left -	Right +	of Vehicle Centerline				
Z:	28.00 in	Above Ground	(minumum 28.0 inches allowed)					

Hood Height: 44.75 inches
43 ±4 inches allowed

Front Bumper Height: 26.00 inches

Front Overhang: 39.00 inches
39 ±3 inches allowed

Rear Bumper Height: 28.75 inches

Overall Length: 227.00 inches
237 ±13 inches allowed

Table C2. Exterior Crush Measurements for Test No. 420020-1a.

Date: 2010-04-23 Test No.: 420020-1a VIN No.: 1D7HA18NV3J505635

Year: 2003 Make: Dodge Model: Ram 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width _____	Bowing: B1 _____ X1 _____
Corner shift: A1 _____	B2 _____ X2 _____
A2 _____	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1 + X2}{2}$ = _____
< 4 inches _____	
≥ 4 inches _____	

Note: Measure C_1 to C_6 from driver to passenger side in front or rear impacts – rear to front in side impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bumper ht	12	10	24	1	3	5.5	6	7	10	+12
2	Side plane above bumper ht	12	12	56	2	3.5	6	8	9.5	12	+74

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

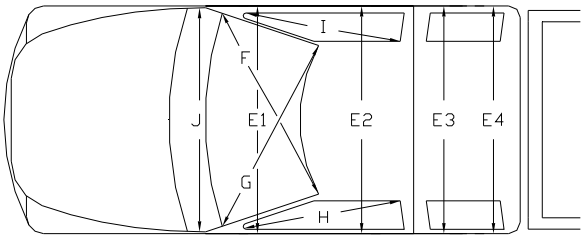
***Measure and document on the vehicle diagram the location of the maximum crush.

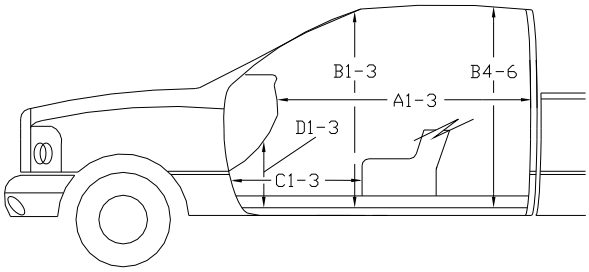
Note: Use as many lines/columns as necessary to describe each damage profile.

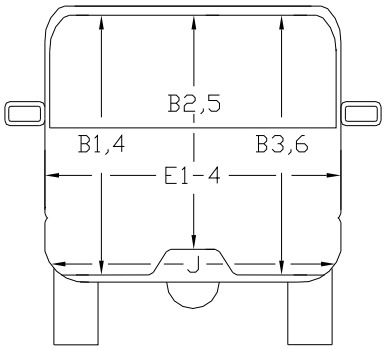
Table C3. Occupant Compartment Measurements for Test No. 420020-1a.

Date: 2010-04-23 Test No.: 420020-1a VIN No.: 1D7HA18NV3J505635

Year: 2003 Make: Dodge Model: Ram 1500







*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT	Before (inches)	After (inches)
A1	64.50	64.50
A2	64.50	64.25
A3	65.00	64.50
B1	45.50	45.50
B2	39.38	39.38
B3	45.25	46.00
B4	42.25	42.25
B5	42.62	42.62
B6	42.25	42.25
C1	28.50	28.50
C2	-----	-----
C3	27.00	25.50
D1	12.75	12.75
D2	2.50	2.50
D3	11.75	12.25
E1	62.62	63.00
E2	64.50	64.75
E3	64.00	64.00
E4	64.00	64.00
F	60.00	60.00
G	60.00	60.00
H	39.50	39.50
I	39.50	39.50
J*	62.25	61.00

APPENDIX D. SEQUENTIAL PHOTOGRAPHS

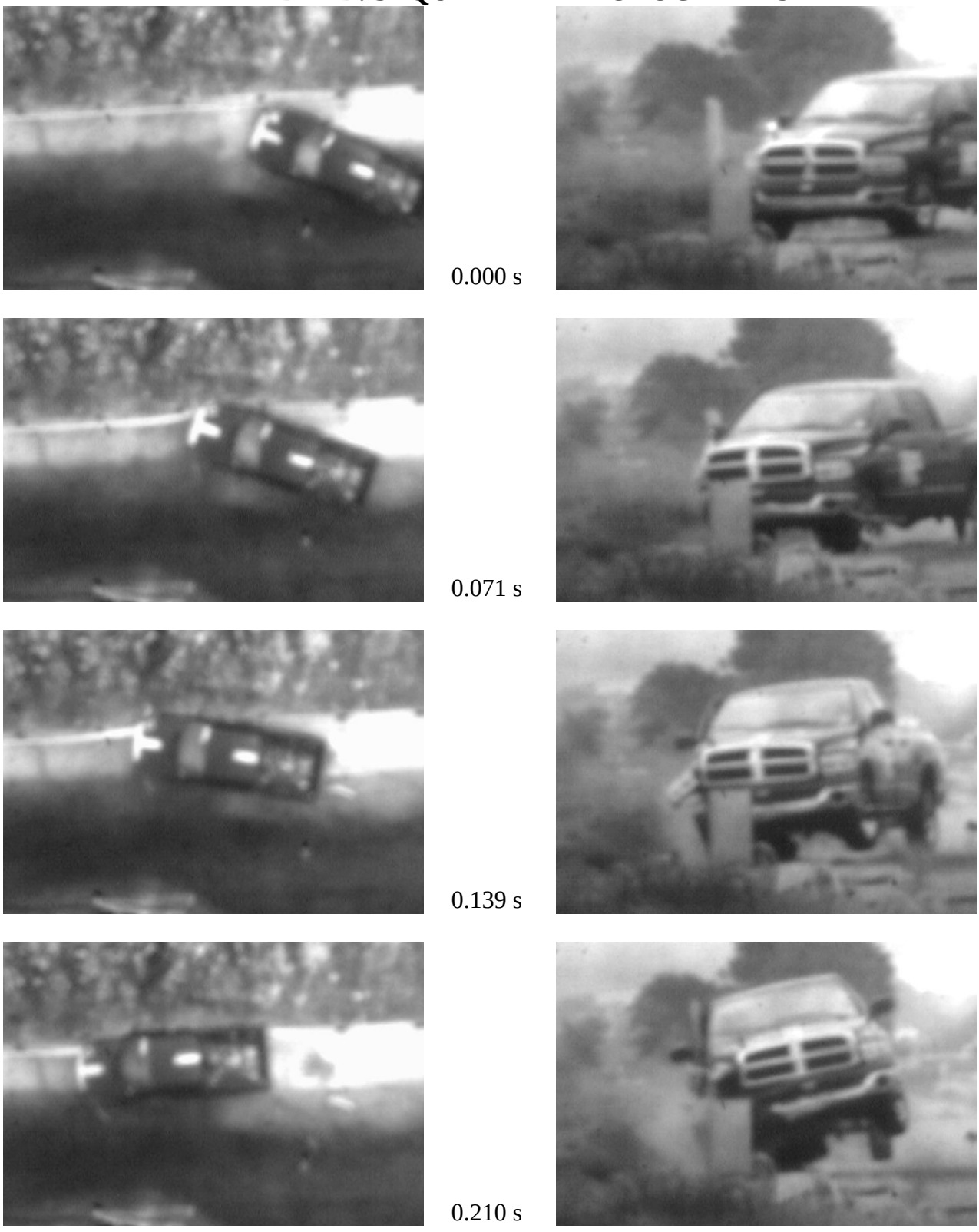


Figure D1. Sequential Photographs for Test No. 420020-1a (Overhead and Frontal Views).

Figure D1. Sequential Photographs for Test No. 420020-1a (Overhead and Frontal Views) (Continued).

0.000 s

0.278 s

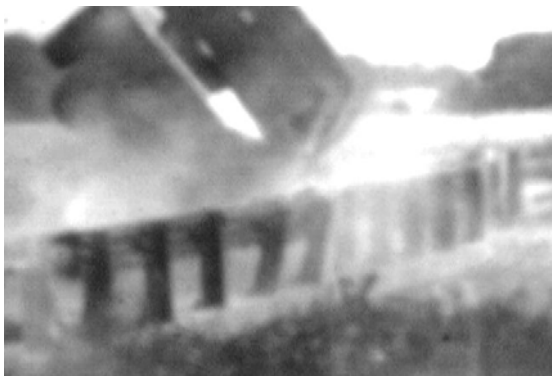
0.071 s

0.349 s

0.139 s

0.417 s

0.210 s



0.488 s

Figure D2. Sequential Photographs for Test No. 420020-1a (Rear View).

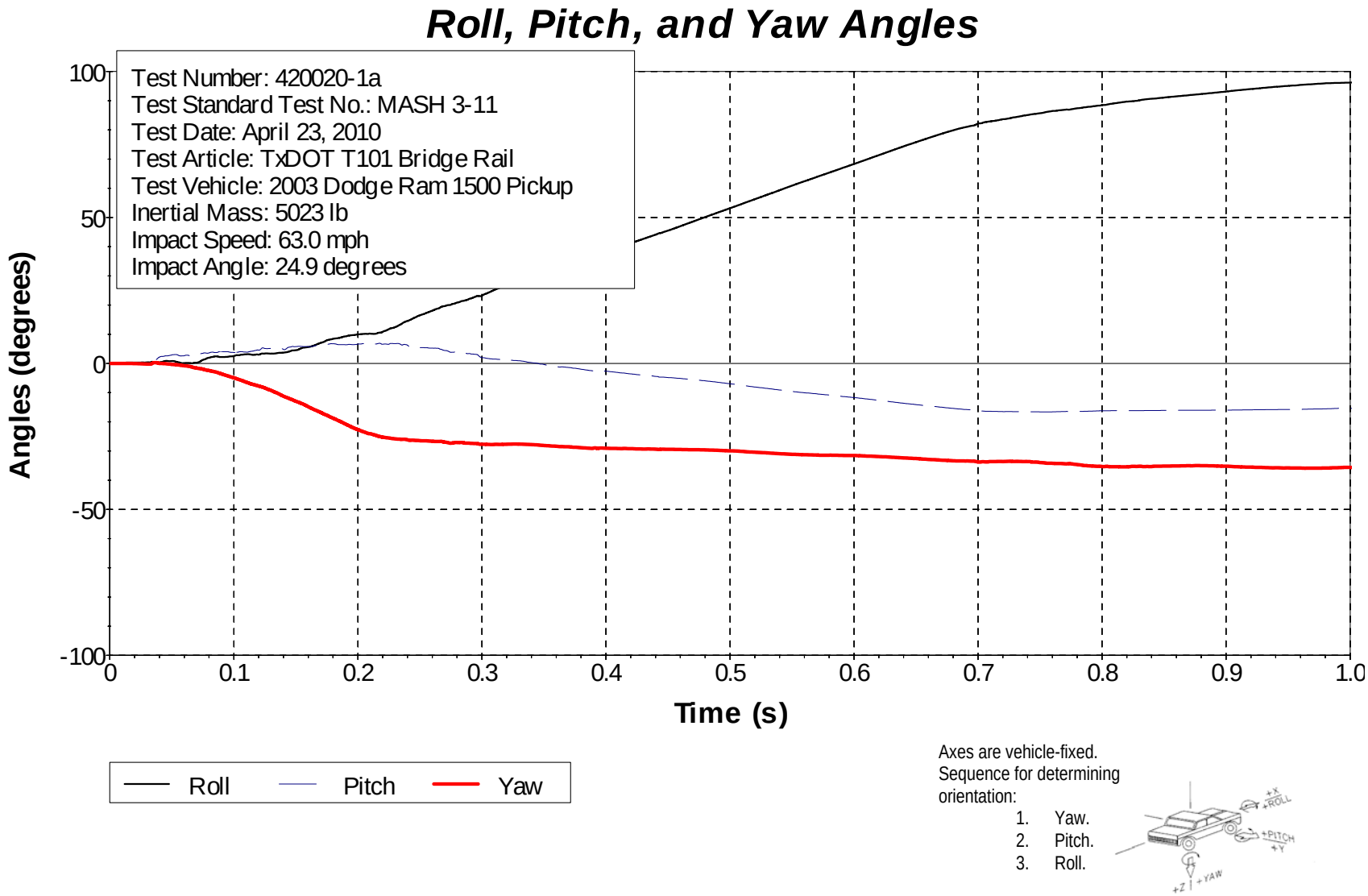


Figure E1. Vehicle Angular Displacements for Test No. 420020-1a.

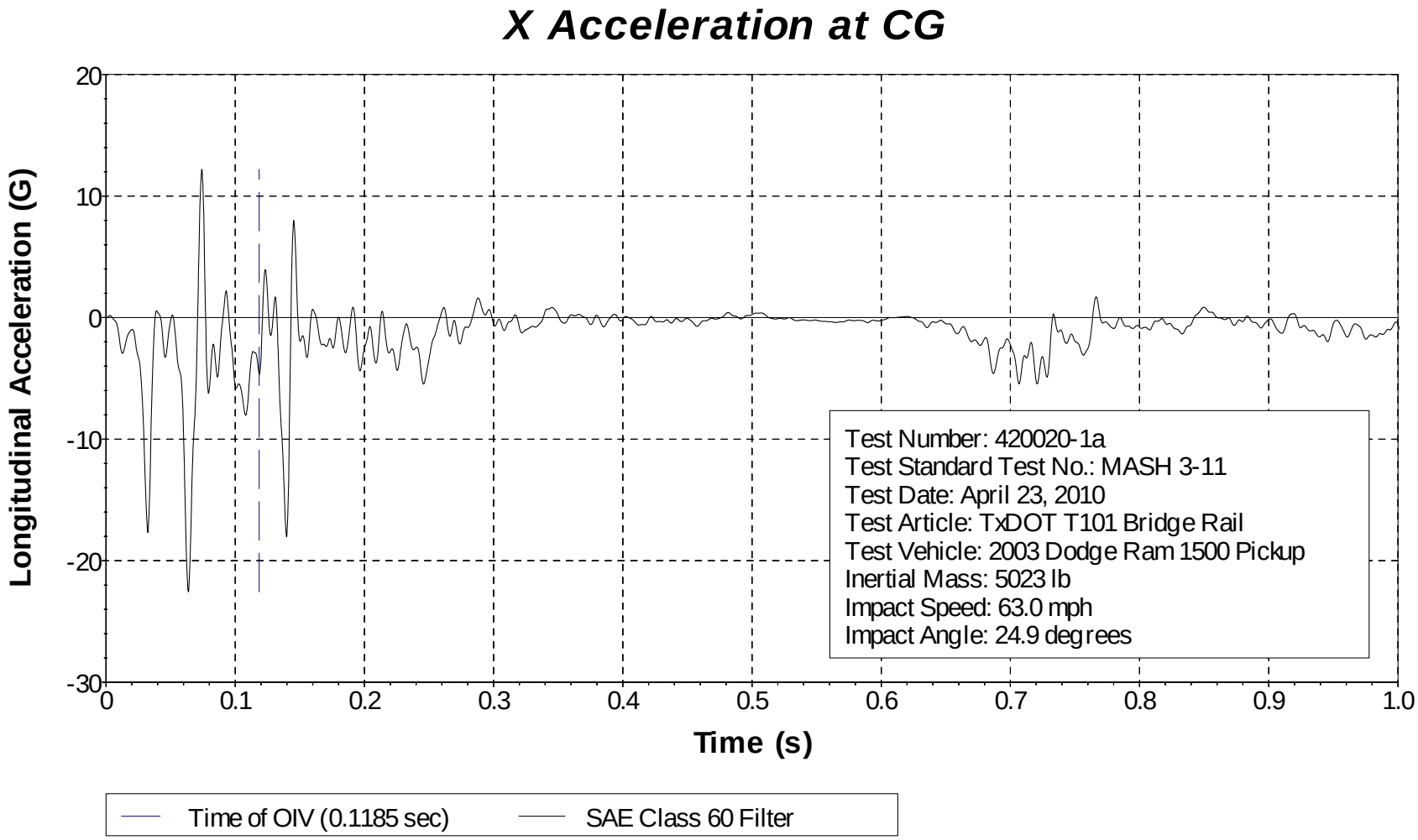


Figure E2. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-1a (Accelerometer Located at Center of Gravity).

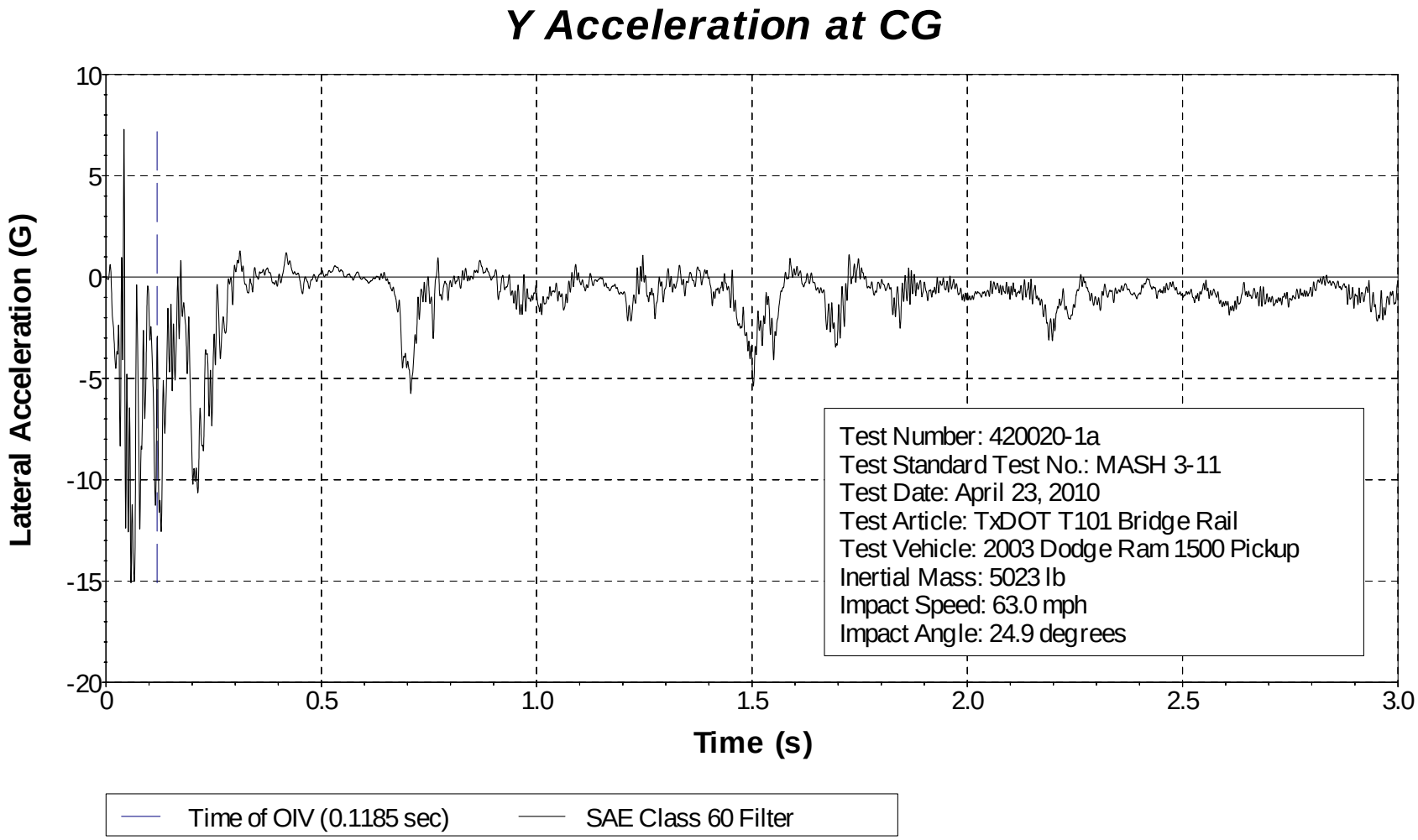


Figure E3. Vehicle Lateral Accelerometer Trace for Test No. 420020-1a (Accelerometer Located at Center of Gravity).

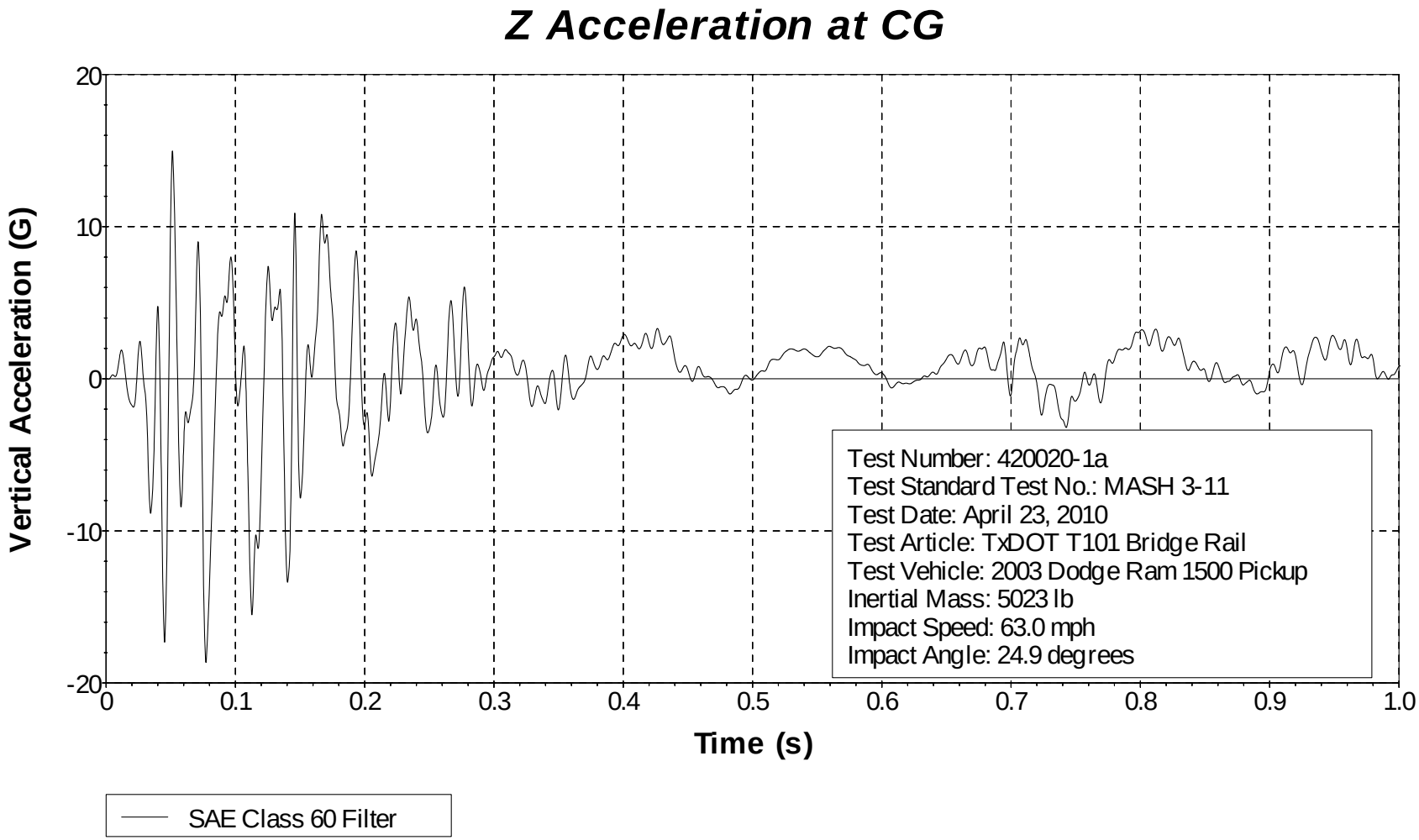


Figure E4. Vehicle Vertical Accelerometer Trace for Test No. 420020-1a (Accelerometer Located at Center of Gravity).

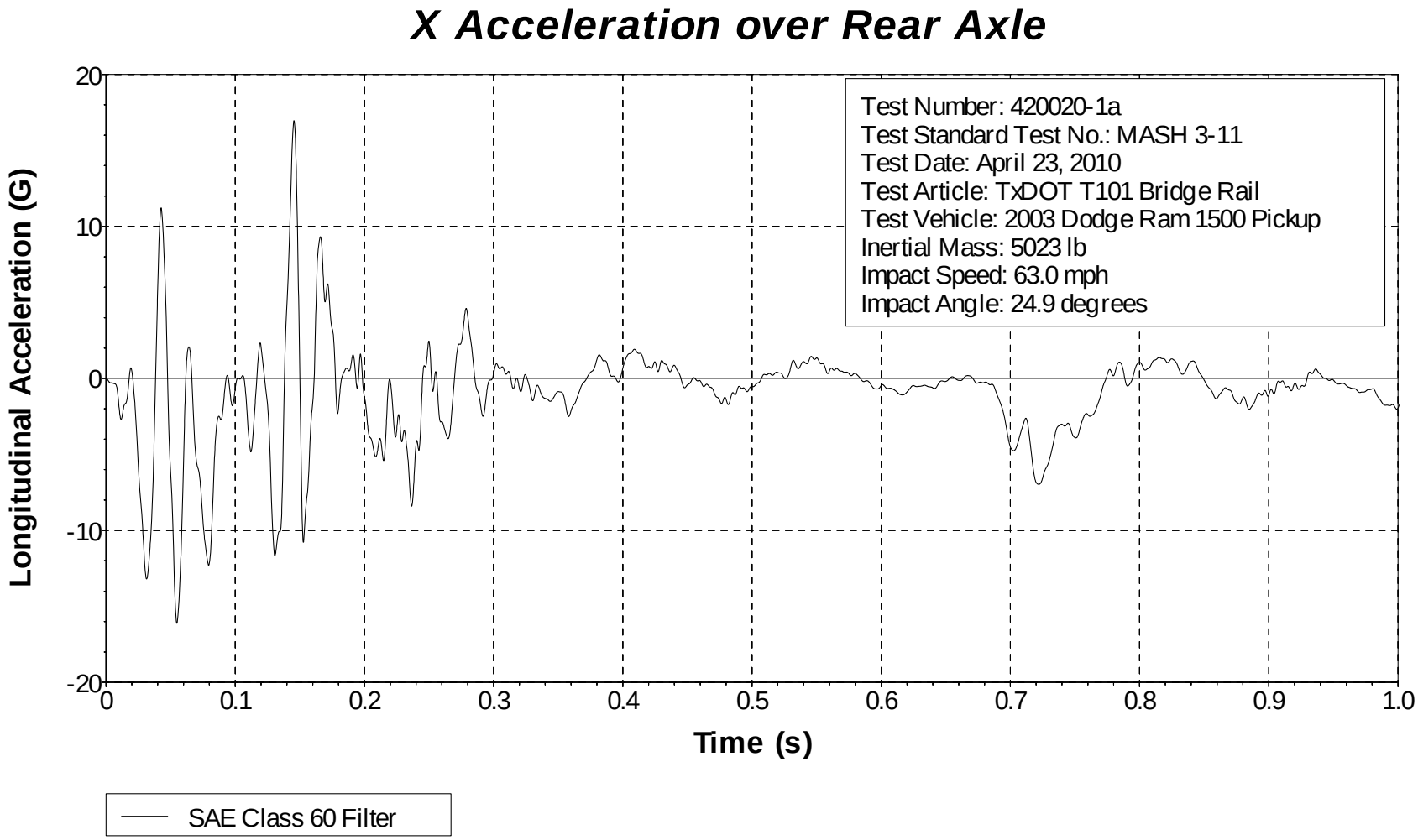


Figure E5. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-1a (Accelerometer Located over Rear Axle).

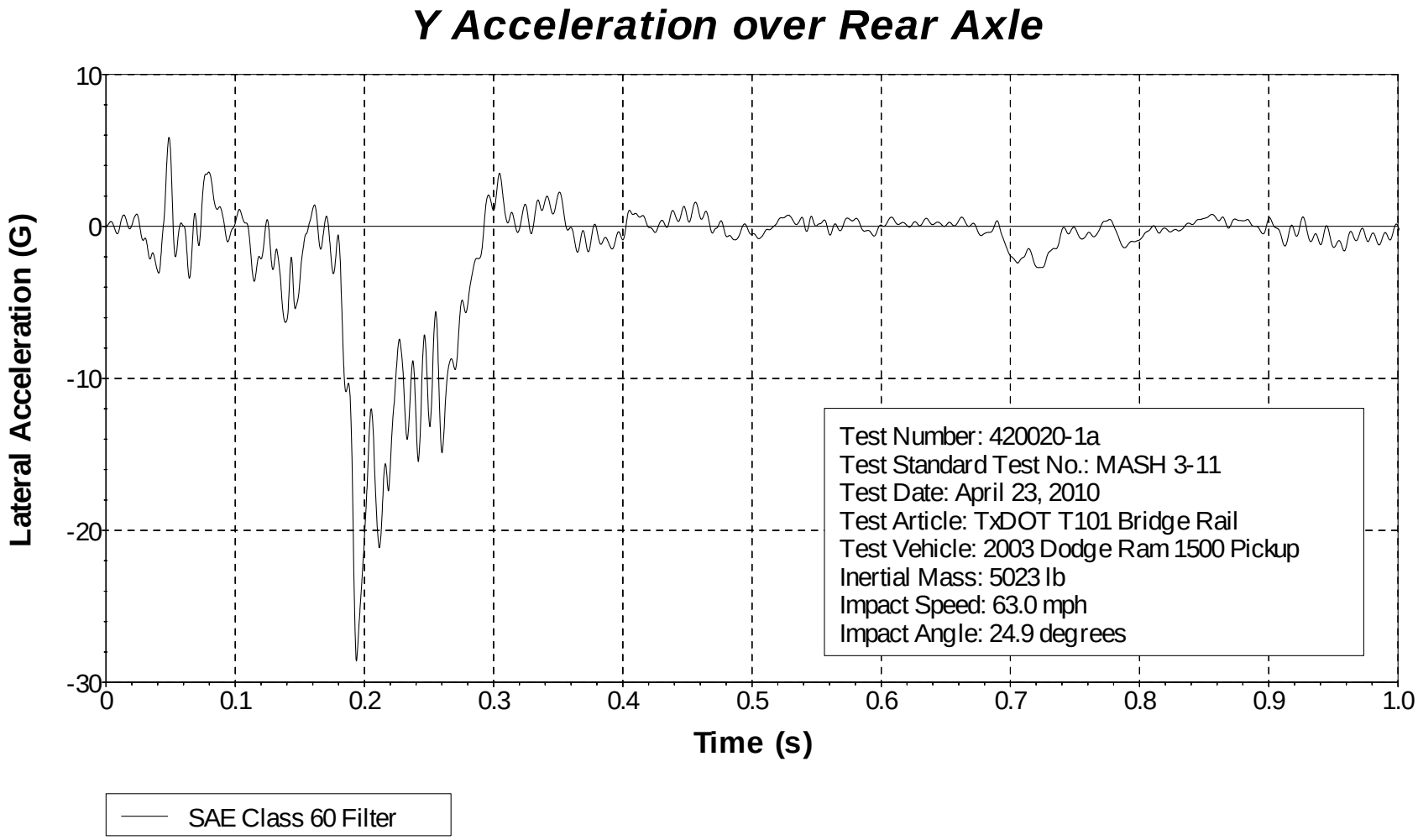


Figure E6. Vehicle Lateral Accelerometer Trace for Test No. 420020-1a (Accelerometer Located over Rear Axle).

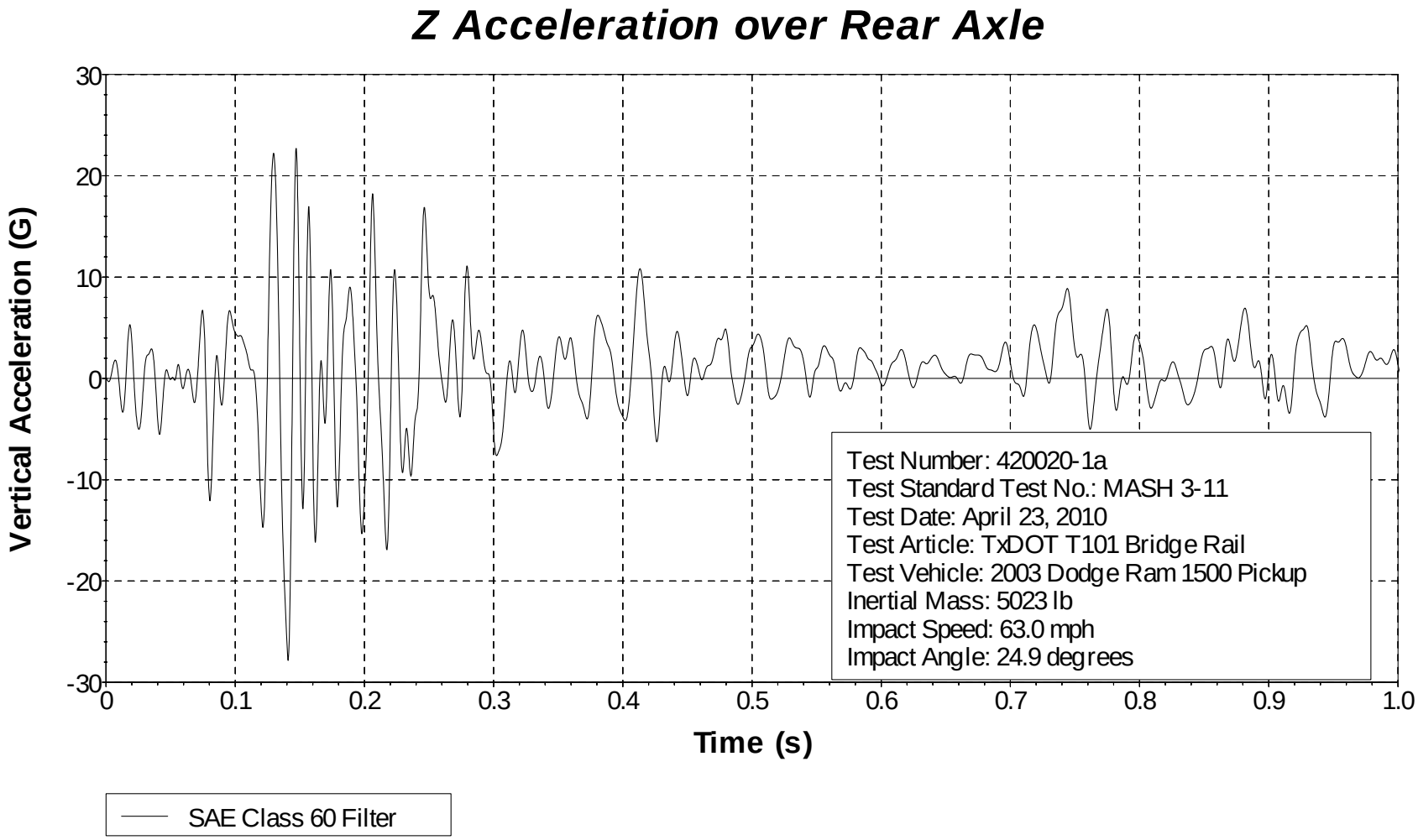


Figure E7. Vehicle Vertical Accelerometer Trace for Test No. 420020-1a (Accelerometer Located over Rear Axle).