Texas A&M Transportation Institute

MASH TL-3 TESTING AND EVALUATION OF A STEEL BRIDGE RAIL WITH PICKETS

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01
Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Test Report 9-1002-12-2

Cooperative Research Program

TEXAS A&M 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
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16. Abstract

TxDOT has a need for a steel bridge rail that anchors to a concrete curb with an aesthetic appearance using steel pickets. Bridge railings that use pickets (concrete and steel) have exhibited undesirable safety performance characteristics. The purpose of this portion of the project was to design and evaluate a steel bridge rail with pickets that would meet the strength and safety performance criteria for Test Level 3 (TL-3) of *MASH*. The bridge rail tested for this project was similar to the Wyoming 2-tube bridge rail that was successfully crash tested under *NCHRP Report 350* criteria (Texas Transportation Institute [TTI] Project No. 472610-4, dated May 1996). Details from the Wyoming 2-Tube design were incorporated and used in the design of the new TxDOT Picket Rail.

The TxDOT Picket Rail evaluated and presented herein met all the safety performance criteria for *MASH* TL-3 and is suitable for implementation on new bridge construction.

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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.

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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

This project was set up to provide 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 and develop new devices that address identified needs.

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

The American Association of State Highway Transportation Officials (AASHTO) published the *Manual for Assessing Safety Hardware (MASH)* in October 2009 (*1*). *MASH* supersedes *National Cooperative Highway Research Program (NCHRP) Report 350* (*2*) as the recommended guidance for the safety performance evaluation of roadside safety features.

1.3 OBJECTIVES/SCOPE OF RESEARCH

TxDOT has a need for an aesthetic steel bridge rail that incorporates steel pickets and anchors to a concrete curb. The purpose of this portion of the project was to design and evaluate a steel bridge rail with pickets that would meet the strength and safety performance criteria for Test Level 3 (TL-3) of *MASH*. The bridge rail tested for this project was similar to the Wyoming 2-tube bridge rail that was successfully crash tested under *NCHRP Report 350* criteria (Texas Transportation Institute [TTI] Project No. 472610-4, dated May 1996) (*3*). Details from the Wyoming 2-tube design were incorporated and used in the design of the new TxDOT Picket Rail.

The testing reported here assesses the performance of the TxDOT Picket Rail according to the safety-performance evaluation guidelines included in *MASH* for TL-3. Two tests are required to evaluate the bridge rail: one test with a 2425 lb vehicle and a second test with a 5000 lb pickup truck, both impacting the critical impact point of the length of need of the bridge rail at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. The report includes details of the TxDOT Picket Rail, details of the crash tests performed, and evaluation of the tests according to *MASH*.

CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The TxDOT Picket Rail consists of three tubular steel rail elements supported by fabricated steel plate posts. The overall length of the test installation was 92 ft and consisted of 12 posts spaced 8 ft on centers. The total height of the bridge rail is 36 inches above the pavement surface. The steel bridge rail was anchored to a 14-inch wide by 9-inch high cast-in-place concrete curb. The concrete curb was anchored to a cast-in-place 8-inch thick concrete deck cantilever. The width of the cantilever was 30 inches. Mr. John Holt with TxDOT provided detailed design information on the bridge rail.

The top rail element was an A500 Grade B 4-inch diameter pipe (0.174-inch wall thickness). The lower two rail elements were A500 Grade B HSS6×2×¼ steel tubes. The heights from the pavement surface to the top of the rail elements were 18 inches, 28 inches, and 36 inches for the lower, middle, and top rail elements, respectively. Each rail element was attached to each post using a ½-inch diameter A36 bent U-Bolt. The steel posts consisted of two ¾-inch thick plates welded to a ¾-inch thick base plate. The steel plates used to fabricate the steel posts were 9 inches wide at the base, 3¾ inches wide at the top, and 26 inches high (including the width of the ¾-inch thick baseplate). The post plates were notched 3¼ inches for the lower two rail elements and 2¼ inches for the top rail element. The post base plates consisted of 12-inch × 14-inch × ¾-inch thick A572 Grade 50 material. The posts were anchored to the concrete curb using four ⅞-inch diameter × 10½ inches long A325 bolts with a ¼-inch thick anchor plate. These anchor bolts were cast in the curb, with the top of the concrete deck supporting the hex heads. Steel pickets were located on the field side face of the bridge rail. These pickets consisted of ⅝-inch square × 22¾-inch long A36 steel bars that were located on 6-inch centers and were bolted to the rail in panel sections measuring approximately 73 inches long.

For this project, a concrete bridge deck cantilever and curb was constructed immediately adjacent to an existing concrete runway located at the TTI Proving Ground test facility. The total length of the installation was 92 ft long. The bridge deck cantilever was 30 inches wide and 8 inches thick. Reinforcement in the deck consisted of two layers of reinforcing steel placed in the transverse and longitudinal directions. The top transverse reinforcement consisted of #5 bars located on 6-inch centers. Longitudinal reinforcement in the top layer consisted of three #4 bars on 9-inch centers. The bottom transverse reinforcement consisted of #5 bars located on 18-inch centers. Longitudinal reinforcement in the bottom layer consisted of four #5 bars, three of which were spaced on 12-inch centers, with the two bars closest to the field side edge of the deck spaced approximately 3½ inches on centers. Vertical reinforcement in the curb consisted of #5 stirrups located on 6-inch centers. Two longitudinal #5 bars were located within the top corners of the curb stirrups. For additional information on the bridge railing test installation, please refer to Figures 2.1 and 2.2, and Appendix A. Figure 2.3 shows photographs of the installation before testing.

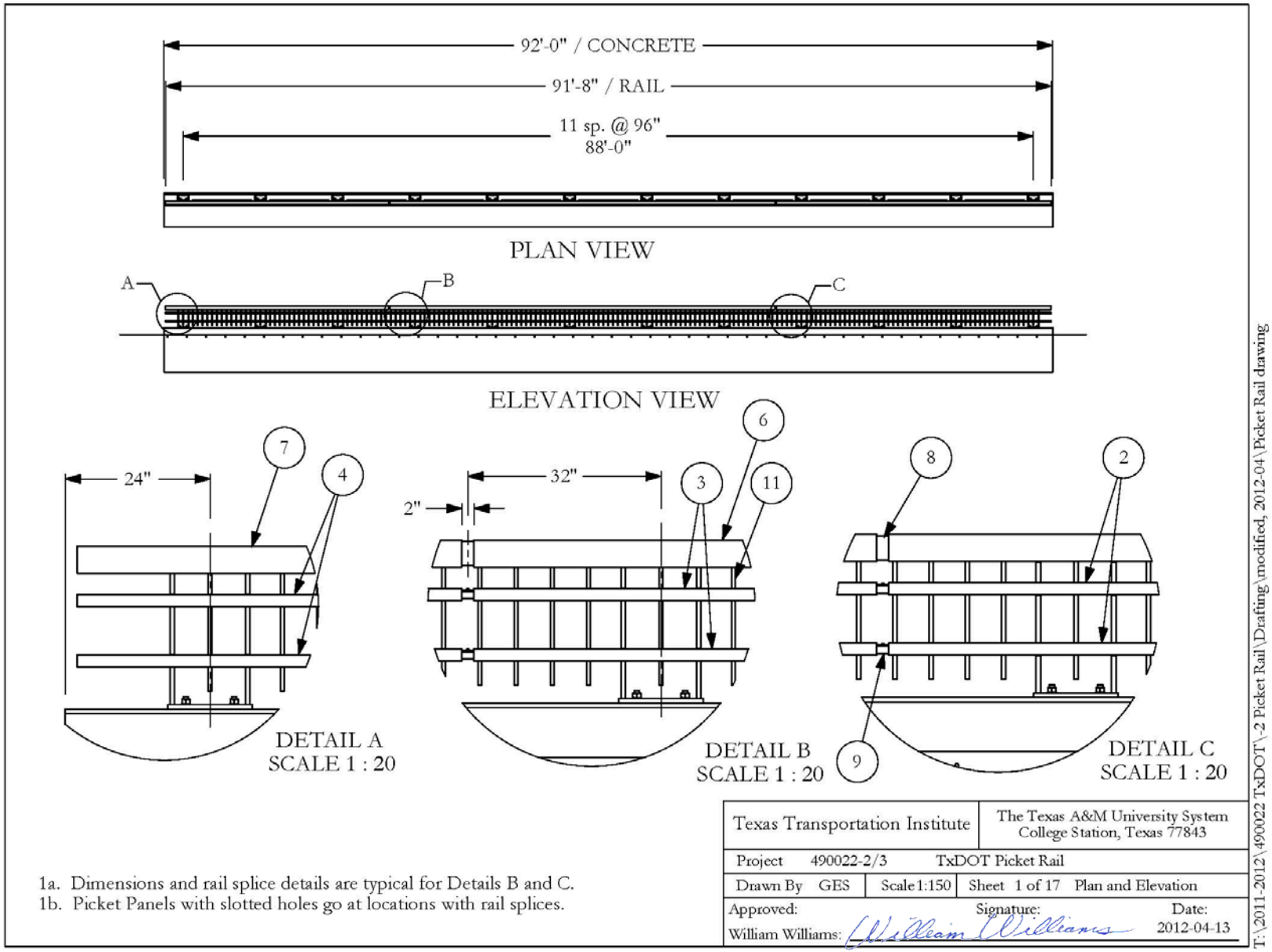


Figure 2.1. Details of the TxDOT Picket Rail Installation.

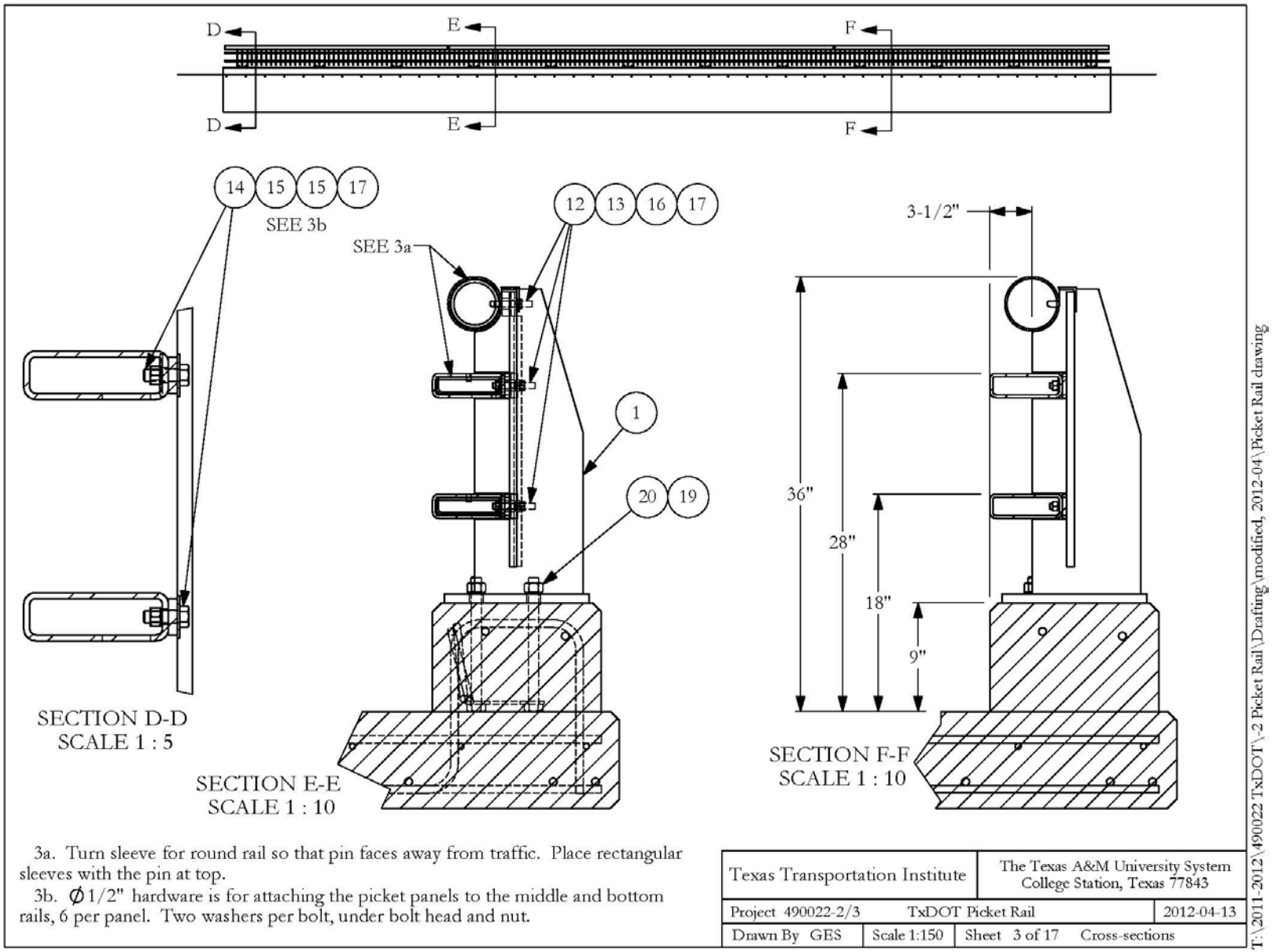


Figure 2.2. Cross Section of the TxDOT Picket Rail Installation.

Figure 2.3. TxDOT Picket Rail before Testing.

2.2 MATERIAL SPECIFICATIONS

All reinforcement used in the concrete deck had a specified yield strength of 60 ksi. The concrete deck and curb has a specified concrete strength of 4000 psi. Concrete compressive strength tests were performed on the day of the first crash test. The tests performed at 19 days of age on the concrete deck, resulted in an average compressive strength of 5506 psi. The tests performed at 11 days of age on the concrete curb resulted in an average compressive strength of 3837 psi.

CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

According to *MASH*, two tests are recommended for evaluation of longitudinal barriers to test level three (TL-3).

- ***MASH* Test 3-10:** A 2425 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 test investigates a barrier's ability to successfully contain and redirect a small passenger vehicle.

- ***MASH* Test 3-11:** A 5000 lb pickup truck 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 test investigates a barrier's ability to successfully contain and redirect light trucks and sport utility vehicles.

Both of these tests were performed on the Picket Rail. The critical impact points for each test were determined using *MASH* guidelines. Target impact point for *MASH* test 3-10 was 3.6 ft upstream of post 9; for *MASH* Test 3-11, it was 4.3 ft upstream of post 4.

The crash test and data analysis procedures followed the guidelines presented in *MASH*. Chapter 4 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 TxDOT Picket Rail is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged on the ability of the TxDOT Picket Rail to contain and redirect the vehicle. Occupant risk criteria evaluate the potential risk of 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 assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate the crash tests reported here, and are listed in further detail under the assessment of each crash test.

CHAPTER 4. CRASH TEST PROCEDURES

4.1 TEST FACILITY

The full-scale crash test reported here was performed at Texas A&M Transportation Institute (TTI) Proving Ground, 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 TTI 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 TxDOT Picket Rail evaluated under this project was 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 6 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 vehicles were towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicles 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 vehicles were 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 that Diversified Technical Systems, Inc. produced. The accelerometers, measuring the x, y, and z axis of vehicle acceleration, are a strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra small, solid state units designs 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 the data are recorded, internal batteries will back these up inside the unit 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 Test Risk Assessment Program (TRAP) software then processes the raw data 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.

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

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of the 1100C vehicle. The dummy was uninstrumented. Use of a dummy in the 2270P vehicle is optional according to *MASH*, and there was no dummy used in the test with the 2270P vehicle.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of each 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 each test.

CHAPTER 5. *MASH* TEST 3-10 CRASH TEST RESULTS

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

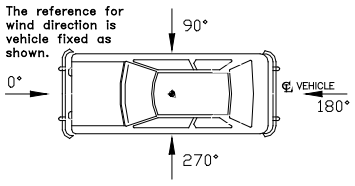
MASH Test 3-10 involves an 1100C vehicle weighing 2425 lb ±55 lb impacting the bridge rail at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 3.6 ft upstream of post 9. The 2005 Kia Rio used in the test had a test inertial mass of 2431 lb and gross static mass of 2597 lb. The actual impact speed and angle were 62.0 mi/h and 24.9 degrees, respectively. The actual impact point was 3.7 ft upstream of post 9. Target impact severity (IS) was 56.0 kip-ft, and actual IS was 59.2 kip-ft, which was 5.7 percent greater than the target IS.

5.2 TEST VEHICLE

A 2005 Kia Rio, shown in Figures 5.1 and 5.2, was used for the crash test. Test inertia weight of the vehicle was 2431 lb, and its gross static weight was 2597 lb. The height to the lower edge of the vehicle bumper was 8.50 inches, and it was 22.75 inches to the upper edge of the bumper. Table C1 in Appendix C gives 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 9, 2012. Weather conditions at the time of testing were as follows: wind speed: 2 mi/h; wind direction: 82 degrees with respect to the vehicle (vehicle was traveling in a southwesterly direction); temperature: 74°F, relative humidity: 72 percent.



5.4 TEST DESCRIPTION

The 2005 Kia Rio, traveling at an impact speed of 62.0 mi/h, impacted the TxDOT Picket Rail 3.7 ft upstream of post 9 at an impact angle of 24.9 degrees. At approximately 0.019 s, the vehicle began to redirect, and at 0.029 s, the right front tire blew out. Maximum deflection of 0.9 inch on the top rail occurred at 0.051 s. At 0.067 s, the front passenger window shattered, and at 0.167 s, the vehicle was traveling parallel with the bridge rail at a speed of 52.2 mi/h. The rear of the vehicle contacted the bridge rail at 0.168 s. At 0.256 s, the vehicle lost contact with the bridge rail and was traveling at an exit speed and angle of 51.1 mi/h and 6.5 degrees, respectively. Brakes on the vehicle were applied 1.16 s after impact, and the vehicle subsequently came to rest 195 ft downstream of impact and 21 ft toward traffic lanes. Figures C1 and C2 in Appendix C show sequential photographs of the test period.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 490022-2.

Figure 5.2. Vehicle before Test No. 490022-2.

5.5 DAMAGE TO TEST INSTALLATION

Figures 5.3 and 5.4 show damage to the TxDOT Picket Rail. Cracks in the curb radiated from the front and rear anchor bolts toward the field side at post 9, and from the rear anchor bolt on the upstream side of post 10. Tire marks were evident on the traffic face of all the horizontal metal rail elements from 3.7 ft upstream of post 9 for a length of 10.0 ft. There was no evidence of contact on the vertical pickets. Working width was 10.7 inches, and maximum dynamic deflection of the horizontal metal rail element was 0.9 inch. Residual permanent deformation was minimal and not measureable.

5.6 VEHICLE DAMAGE

Figure 5.5 shows damage to the vehicle. The right front strut and strut tower were deformed. The front bumper, hood, right front tire and wheel rim, right front fender, right front door and door glass, right rear door, right rear wheel rim, right rear quarter panel, and rear bumper were also damaged. Maximum exterior crush to the vehicle was 11.0 inches in the side plane at the right front corner at bumper height. The right side floor pan was also deformed, with a maximum occupant compartment deformation of 3.0 inches. Figure 5.6 shows the interior of the vehicle. Exterior vehicle crush and occupant compartment measurements are shown in Appendix C, Tables C2 and C3.

5.7 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 22.0 ft/s at 0.074 s, the highest 0.010-s occupant ridedown acceleration was 5.7 Gs from 0.178 to 0.188 s, and the maximum 0.050-s average acceleration was −12.8 Gs between 0.023 and 0.073 s. In the lateral direction, the occupant impact velocity was 33.5 ft/s at 0.074 s, the highest 0.010-s occupant ridedown acceleration was 12.2 Gs from 0.181 to 0.191 s, and the maximum 0.050-s average was −19.4 Gs between 0.017 and 0.067 s. Theoretical Head Impact Velocity (THIV) was 43.7 km/h or 12.1 m/s at 0.073 s; Post-Impact Head Decelerations (PHD) was 13.2 Gs between 0.181 and 0.191 s; and Acceleration Severity Index (ASI) was 2.39 between 0.017 and 0.067 s. Figure 5.7 summarizes these data and other pertinent information from the test. In Appendix C, Figures C3 through C9 present Vehicle angular displacements and accelerations versus time traces.

Figure 5.3. Vehicle/Installation after Impact for Test No. 490022-2.

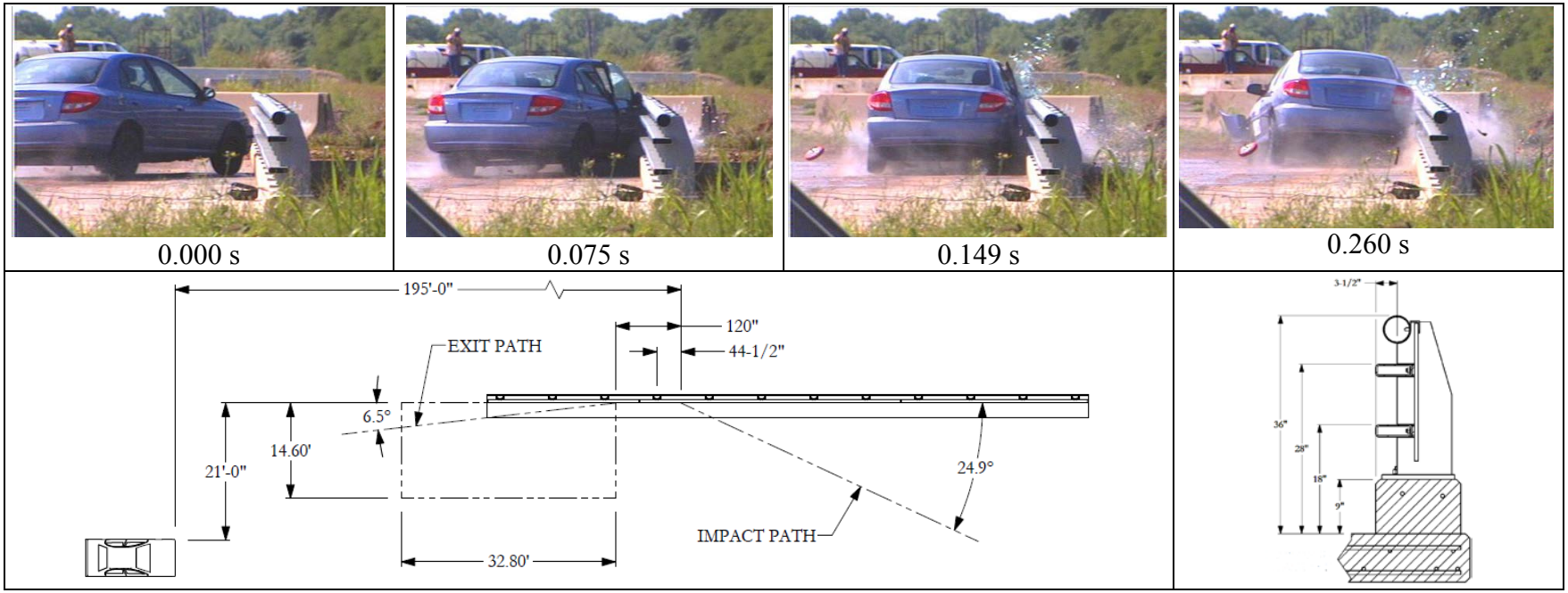
Figure 5.4. Installation after Test No. 490022-2.

Figure 5.5. Vehicle after Test No. 490022-2.

Before Test

After Test

Figure 5.6. Interior of Vehicle for Test No. 490022-2.



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-10
- TTI Test No. 490022-2
- Test Date 2012-04-09

Test Article
- Type ..... Bridge Rail
- Name ..... TxDOT Picket Rail
- Installation Length ..... 92.0 ft
- Material or Key Elements ..... Three tubular steel rail elements with vertical pickets mounted on steel plate posts anchored on concrete deck and curb

Soil Type and Condition ..... Concrete bridge deck and curb, dry

Test Vehicle
- Type/Designation 1100C
- Make and Model ..... 2005 Kia Rio
- Curb ..... 2373 lb
- Test Inertial ..... 2431 lb
- Dummy ..... 166 lb
- Gross Static ..... 2597 lb

Impact Conditions
- Speed ..... 62.0 mi/h
- Angle ..... 24.9 degrees
- Location/Orientation ..... 3.7 ft upstream of post 9

Exit Conditions
- Speed ..... 51.1 mi/h
- Angle ..... 6.5 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal ..... 22.0 ft/s
  - Lateral ..... 33.5 ft/s
- Ridedown Accelerations
  - Longitudinal ..... 5.7 G
  - Lateral ..... 12.2 G
- THIV ..... 43.7 km/h
- PHD ..... 13.2 G
- ASI 2.39
- Max. 0.050-s Average
  - Longitudinal ..... −12.8 G
  - Lateral ..... −19.4 G
  - Vertical ..... −2.5 G

Post-Impact Trajectory
- Stopping Distance ..... 195 ft dnstrm 21 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle ..... 60 degrees
- Maximum Pitch Angle ..... 8 degrees
- Maximum Roll Angle ..... 25 degrees
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 0.9 inch
- Permanent ..... Nil
- Working Width ..... 10.7 inches

Vehicle Damage
- VDS 01RFQ4
- CDC 01FREW3
- Max. Exterior Deformation ..... 11.0 inches
- OCDI RF0030000
- Max. Occupant Compartment Deformation ..... 3.0 inches

Figure 5.7. Summary of Results for *MASH* Test 3-10 on the TxDOT Picket Rail.

5.8 ASSESSMENT OF TEST RESULTS

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

5.8.1 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.

Results: The TxDOT Picket Rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the horizontal metal rail elements was 0.9 inch. (PASS)

5.8.2 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).

Results: No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others. (PASS)
Maximum occupant compartment deformation was 3.0 inches in the right floor pan area. (PASS)

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

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 25 degrees and 8 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

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

Results: Longitudinal occupant impact velocity was 22.0 ft/s, and lateral occupant impact velocity was 33.5 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*

Results: Maximum longitudinal ridedown acceleration was 5.7 Gs, and maximum lateral ridedown acceleration was 12.2 Gs. (PASS)

5.8.3 Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).

Result: The 1100C vehicle crossed the exit box 60 ft downstream of loss of contact with the bridge rail. (PASS)

CHAPTER 6. *MASH* TEST 3-11 CRASH TEST RESULTS

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

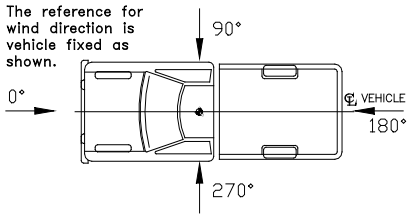
MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the test article at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 4.3 ft upstream of post 4. The 2006 Dodge Ram 1500 pickup truck used in the test weighed 5018 lb and the actual impact speed and angle were 61.6 mi/h and 24.2 degrees, respectively. The actual impact point was 5.0 ft upstream of post 4. Target impact severity (IS) was 115.6 kip-ft, and actual IS was 107.0 kip-ft, which was 7.4 percent less than the target IS.

6.2 TEST VEHICLE

A 2006 Dodge Ram 1500 pickup truck, shown in Figures 6.1 and 6.2, was used for the crash test. Test inertia weight of the vehicle was 5018 lb, and its gross static weight was 2018 lb. The height to the lower edge of the vehicle bumper was 13.75 inches, and it was 25.38 inches to the upper edge of the bumper. The height to the center of gravity was 28.25 inches. Tables D1 and D2 in Appendix D 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.

6.3 WEATHER CONDITIONS

The test was performed on the morning of April 10, 2012. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 195 degrees with respect to the vehicle (vehicle was traveling in a southwesterly direction); temperature: 77°F, relative humidity: 62 percent.



6.4 TEST DESCRIPTION

The test vehicle, traveling at an impact speed of 61.6 mi/h, impacted the Picket Rail 5.0 ft upstream of post 4 at an impact angle of 24.2 degrees. At approximately 0.024 s after impact, the right front tire blew out, and at 0.039 s, the vehicle began to redirect. The top of the front passenger door and rear passenger door separated from the frame of the cab at 0.046 s and 0.061 s, respectively. Stress cracks in the windshield appeared at 0.074 s, and the rear of the vehicle impacted the bridge rail at 0.155 s. The vehicle began traveling parallel with the bridge rail at 0.166 s. At 0.295 s, the vehicle lost contact with the bridge rail while traveling at an exit speed and angle of 57.6 mi/h and 19.6 degrees. Brakes on the vehicle were applied at 1.308 s, and the vehicle subsequently came to rest 240 ft downstream of impact and 35 ft toward traffic lanes. Figures D1 and D2 in Appendix D show sequential photographs of the test period.

Figure 6.1. Vehicle/Installation Geometrics for Test No. 490022-3.

Figure 6.2. Vehicle before Test No. 490022-3.

6.5 DAMAGE TO TEST INSTALLATION

Figures 6.3 and 6.4 show damage to the TxDOT picket rail. A crack in the concrete curb radiated toward the field side from the rear anchor bolt on the impact side of post 3. Cracks in the concrete curb radiated toward the field side from the front and rear anchor bolts on both sides of post 4, and extended into the concrete deck where each radiated downward and outward on each side of the post. Working width was 10.4 inches. Maximum dynamic deflection of the top rail was 2.8 inches. Maximum permanent deformation of the rail elements was 0.8 inch on the top rail, 0.7 inch on the middle rail, and 0.9 inch on the bottom rail.

6.6 VEHICLE DAMAGE

Figure 6.5 shows damage to the 2270P vehicle. The right front frame rail and right front upper and lower A-arms were deformed. Also damaged were the front bumper, hood, right front tire and wheel rim, right front fender, right front and rear doors, right exterior bed, right rear tire and wheel rim and the rear bumper. The windshield sustained stress cracks in each lower corner near the hood. Maximum exterior crush to the vehicle was 11.0 inches in both the front and side planes at the right front corner at bumper height. Maximum occupant compartment deformation was 2.75 inches in the lateral area across the cab at the passenger side kickpanel. Figure 6.6 shows the interior of the vehicle, while Tables D3 and D4 in Appendix D show the exterior vehicle crush and occupant compartment measurements.

6.7 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 10.8 ft/s at 0.091 s, the highest 0.010-s occupant ridedown acceleration was 4.6 Gs from 0.182 to 0.192 s, and the maximum 0.050-s average acceleration was −6.5 Gs between 0.028 and 0.078 s. In the lateral direction, the occupant impact velocity was 28.5 ft/s at 0.091 s, the highest 0.010-s occupant ridedown acceleration was 15.2 Gs from 0.201 to 0.211 s, and the maximum 0.050-s average was −15.7 Gs between 0.035 and 0.085 s. Theoretical Head Impact Velocity (THIV) was 34.1 km/h or 9.5 m/s at 0.090 s; Post-Impact Head Decelerations (PHD) was 15.5 Gs between 0.201 and 0.211 s; and Acceleration Severity Index (ASI) was 1.83 between 0.029 and 0.079 s. Figure 5.7 summarizes these data and other pertinent information from the test. In Appendix D, Figures D3 through D9 present the Vehicle angular displacements and accelerations versus time traces.

Figure 6.3. Installation/Vehicle after Impact for Test No. 490022-3.

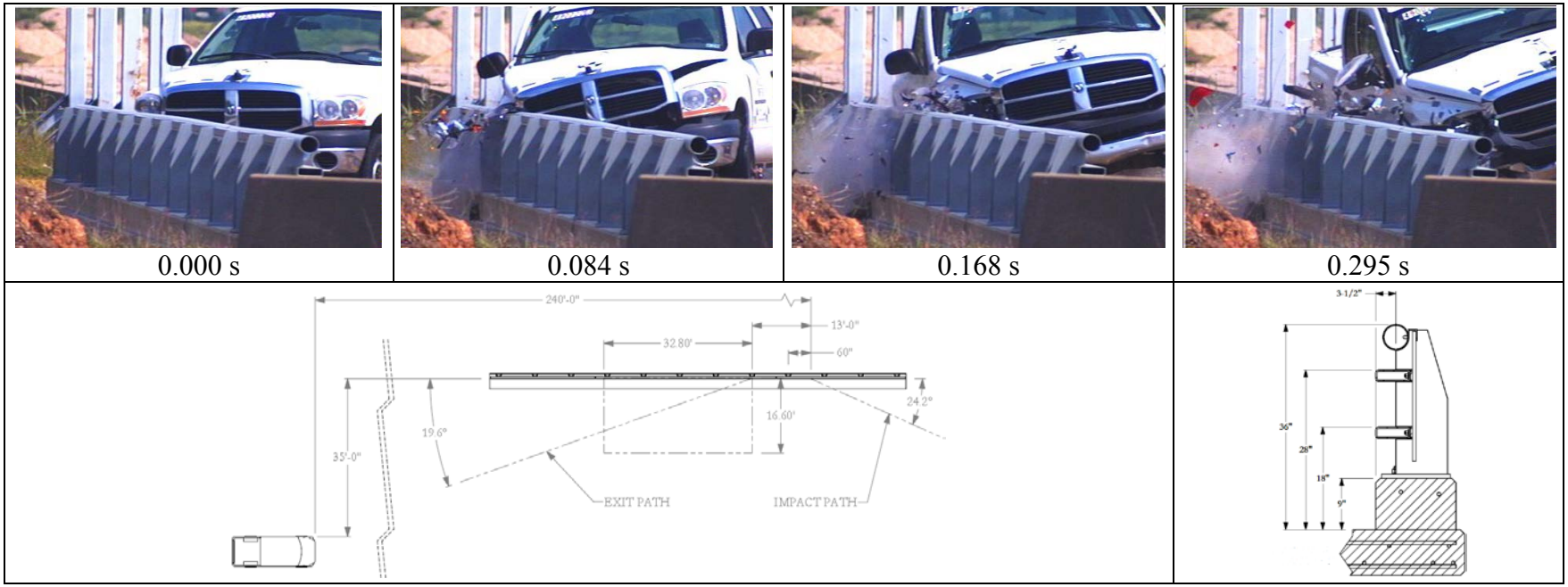
Figure 6.4. Installation after Test No. 490022-3.

Figure 6.5. Vehicle after Test No. 490022-3.

Before Test

After Test

Figure 6.6. Interior of Vehicle for Test No. 490022-3.



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-11
- TTI Test No. 490022-3
- Test Date 2012-04-10

Test Article
- Type ..... Bridge Rail
- Name ..... TxDOT Picket Rail
- Installation Length ..... 92.0 ft
- Material or Key Elements .... Three tubular steel rail elements with vertical pickets mounted on steel plate posts anchored on concrete deck and curb

Soil Type and Condition..... Concrete bridge deck and curb, dry

Test Vehicle
- Type/Designation 2270P
- Make and Model..... 2006 Dodge Ram 1500 Pickup
- Curb ..... 5018 lb
- Test Inertial ..... 5018 lb
- Dummy..... No dummy
- Gross Static..... 5018 lb

Impact Conditions
- Speed.....61.6 mi/h
- Angle.....24.2 degrees
- Location/Orientation .....5.0 ft upstream of post 4

Exit Conditions
- Speed.....57.6 mi/h
- Angle.....19.6 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal.....10.8 ft/s
  - Lateral.....28.5 ft/s
- Ridedown Accelerations
  - Longitudinal.....4.6 g
  - Lateral.....15.2 G
- THIV.....34.1 km/h
- PHD .....15.5 G
- ASI 1.83
- Max. 0.050-s Average
  - Longitudinal.....−6.5 G
  - Lateral.....−15.7 G
  - Vertical.....−2.7 G

Post-Impact Trajectory
- Stopping Distance ..... 240 ft dwnstrm
  35 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle..... 35 degrees
- Maximum Pitch Angle..... 5 degrees
- Maximum Roll Angle..... 23 degrees
- Vehicle Snagging..... No
- Vehicle Pocketing..... No

Test Article Deflections
- Dynamic ..... 2.8 inches
- Permanent..... 0.9 inch
- Working Width ..... 10.4 inches

Vehicle Damage
- VDS..... 01RFQ5
- CDC 01FREW4
- Max. Exterior Deformation ..... 11.0 inches
- OCDI RF0000000
- Max. Occupant Compartment Deformation..... 2.75 inches

Figure 6.7. Summary of Results for *MASH* Test 3-11 on the TxDOT Picket Rail.

6.8 ASSESSMENT OF TEST RESULTS

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

6.8.1 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.

Results: The TxDOT Picket Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.8 inches. (PASS)

6.8.2 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).

Results: No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others. (PASS)
Maximum occupant compartment deformation was 2.75 inches in the lateral area across the cab at the front passenger kick panel. (PASS)

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

Results: The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 23 degrees and 5 degrees, respectively. (PASS)

I. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
9.0 m/s (30 ft/s)	*12.2 m/s (40 ft/s)*

Results: Longitudinal occupant impact velocity was 10.8 ft/s, and lateral occupant impact velocity was 28.5 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*

Results: Maximum longitudinal ridedown acceleration was 4.6 G, and maximum lateral ridedown acceleration was 15.2 G. (PASS)

6.8.3 Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).

Result: The 2270P vehicle crossed the exit box 105 ft downstream of loss of contact with the bridge rail. (PASS)

CHAPTER 7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY OF RESULTS

7.1.1 *MASH* Test 3-10 (Test No. 490022-2)

The TxDOT Picket Rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the horizontal metal rail elements was 0.9 inch. No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others. Maximum occupant compartment deformation was 3.0 inches in the right floor pan area. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 25 degrees and 8 degrees, respectively. Occupant compartment risk factors were within the limits specified in *MASH*. The 1100C vehicle crossed the exit box 60 ft downstream of loss of contact with the bridge rail.

7.1.2 *MASH* Test 3-11 (Test No. 490022-3)

The TxDOT Picket Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.8 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others. Maximum occupant compartment deformation was 2.75 inches in the lateral area across the cab at the front passenger kick panel. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 23 degrees and 5 degrees, respectively. Occupant compartment risk factors were within the limits specified in *MASH*. The 2270P vehicle crossed the exit box 105 ft downstream of loss of contact with the bridge rail.

7.2 CONCLUSIONS

The TxDOT Picket Rail performed acceptably for *MASH* TL-3 (see Tables 7.1 and 7.2).

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-10 on the TxDOT Picket Rail.

Test Agency: Texas A&M Transportation Institute Test No.: 490022-2 Test Date: 2012-04-09

MASH Test 3-10 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 TxDOT Picket Rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the horizontal metal rail elements was 0.9 inch.	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 was present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others.	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 3.0 inches in the right floor pan area.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 25 degrees and 8 degrees, respectively.	Pass
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).	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 25 degrees and 8 degrees, respectively.	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 5.7 Gs, and maximum lateral ridedown acceleration was 12.2 Gs.	Pass
Vehicle Trajectory		
For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).	The 1100C vehicle crossed the exit box 60 ft downstream of loss of contact with the bridge rail.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-11 on the TxDOT Picket Rail.

Test Agency: Texas A&M Transportation Institute Test No.: 490022-3 Test Date: 2012-04-10

***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 TxDOT Picket Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.8 inches.	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 were present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others.	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 2.75 inches in the lateral area across the cab at the front passenger kick panel.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 23 degrees and 5 degrees, respectively.	Pass
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 10.8 ft/s, and lateral occupant impact velocity was 28.5 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 4.6 G, and maximum lateral ridedown acceleration was 15.2 G.	Pass
Vehicle Trajectory		
For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).	The 2270P vehicle crossed the exit box 105 ft downstream of loss of contact with the bridge rail.	Pass

CHAPTER 8. IMPLEMENTATION STATEMENT

The purpose of this project was to develop and evaluate a new aesthetic bridge rail with steel pickets that meets the current *MASH* safety performance criteria for TL-3. The TxDOT Picket Rail tested under this project met all the safety performance criteria for *MASH* TL-3 and is suitable for implementation on new bridge construction.

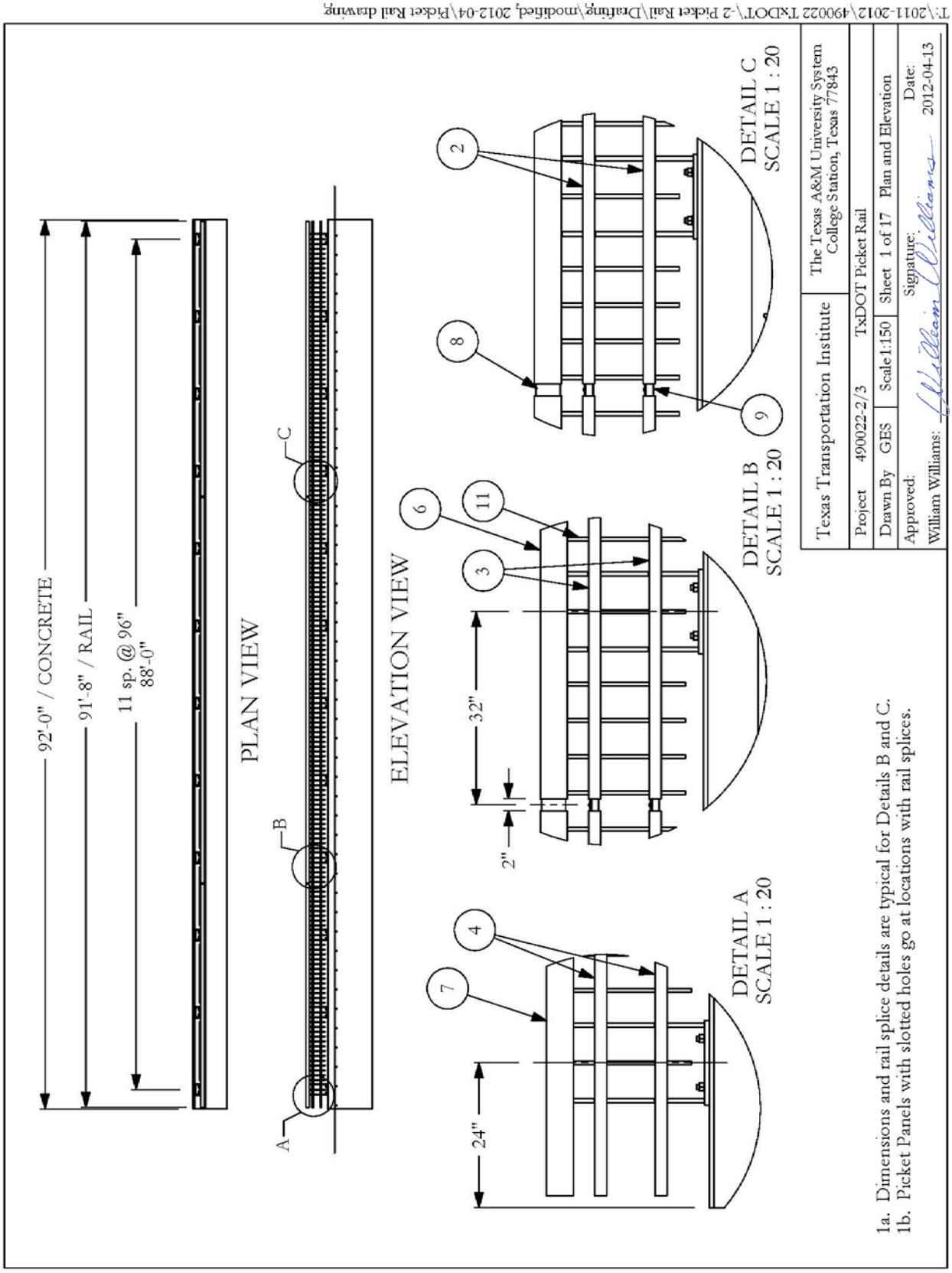
REFERENCES

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

2. H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie. *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.

3. K. K. Mak, D. L. Bullard, Jr., and W. L. Menges. Testing and Evaluation of the Wyoming 740WYBRAIL Bridge Railing System, TTI Project No. 472610-4, Texas Transportation Institute, The Texas A&M University System, May 1996.

APPENDIX A. DETAILS OF THE TXDOT PICKET RAIL BRIDGE RAIL



RAIL PARTS			
#	PART NAME	QTY.	SHT/GRD
1	Post for Picket Rail	12	sheet 4 - 5
2	HSS6x2x1/4 Left	2	sheet 6 - 7
3	HSS6x2x1/4 Center	2	sheet 8 - 9
4	HSS6x2x1/4 Right	2	sheet 10
5	HSS Round 4-1/2 x 3/16 Left	1	sheet 11
6	HSS Round 4-1/2 x 3/16 Center	1	sheet 11
7	HSS Round 4-1/2 x 3/16 Right	1	sheet 12
8	Splice Sleeve for HSS Round Rail	2	sheet 12
9	Splice Sleeve for HSS Rect. Rail	4	sheet 14
10	Picket Panel	9	sheet 13
11	Picket Panel at Rail Splice	2	sheet 13
12	U-bolt for Picket Rail	36	sheet 14
13	Plate Washer for Picket Rail	72	sheet 14

RAIL PARTS			
#	PART NAME	QTY.	SHT/GRD
14	Bolt, 1/2 x 1-1/2 hex	66	A325
15	Washer, 1" flat hardened	132	
16	Washer, 1/2 lock	72	
17	Nut, 1/2 hex	138	A563
18	Bolt, 7/8 x 10-1/2 hex	48	see 2b
19	Washer, 7/8 hardened	48	
20	Nut, 7/8 hex	48	Heavy Hex
21	Anchor Plate for Picket Rail	12	sheet 14
22	Rebar, Z	24	sheet 17
23	Rebar, transverse bottom	62	sheet 17
24	Rebar, transverse top	184	sheet 17
25	Rebar, wall tie	46	sheet 17
26	Rebar, curb stirrup	184	sheet 17

2a. All HSS Rails and HSS Round Splice Sleeve for this test are ASTM - A500 grade B. Do not substitute grade C.

2b. Ø7/8 bolts are A325. Ø7/8 Threaded Rod (ASTM A193 or B7) 11" long may be substituted, with additional 7/8 Heavy Hex nut tack-welded flush at bottom.

2c. A449 or A325T hardware is acceptable alternative to A325.

2d. Tolerances on steel parts is ±1/8" unless otherwise indicated.

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Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:150	Sheet 2 of 17 BOM

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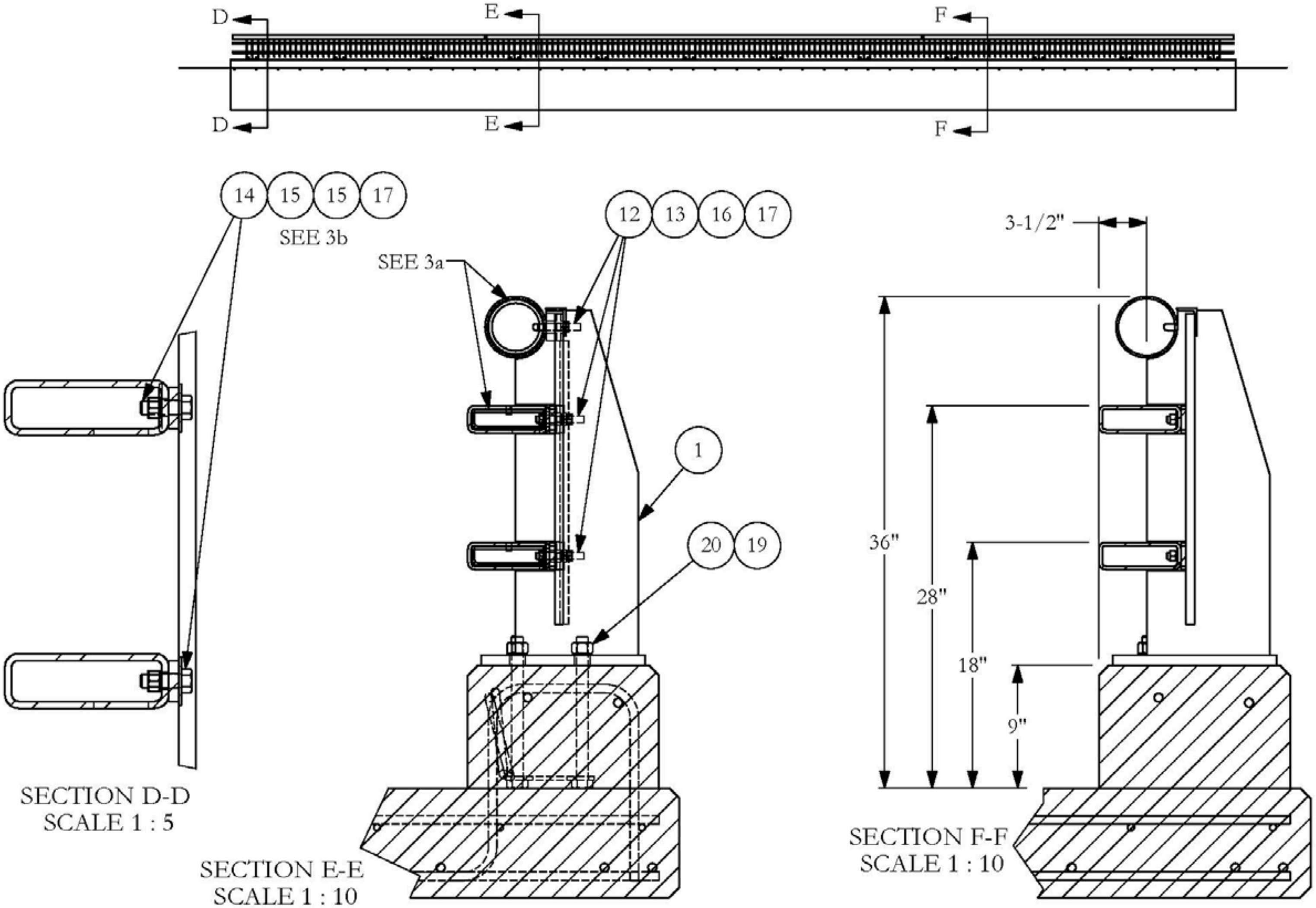

3a. Turn sleeve for round rail so that pin faces away from traffic. Place rectangular sleeves with the pin at top.

3b. ∅1/2" hardware is for attaching the picket panels to the middle and bottom rails, 6 per panel. Two washers per bolt, under bolt head and nut.

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Drawn By GES	Scale 1:150	Sheet 3 of 17	Cross-sections

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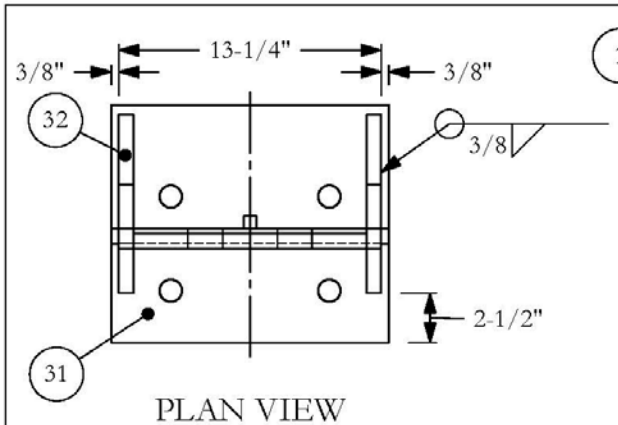
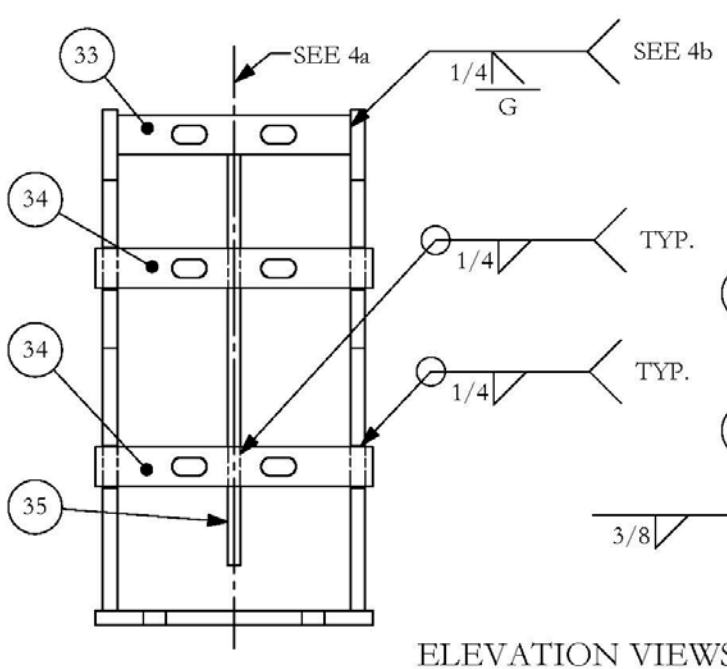
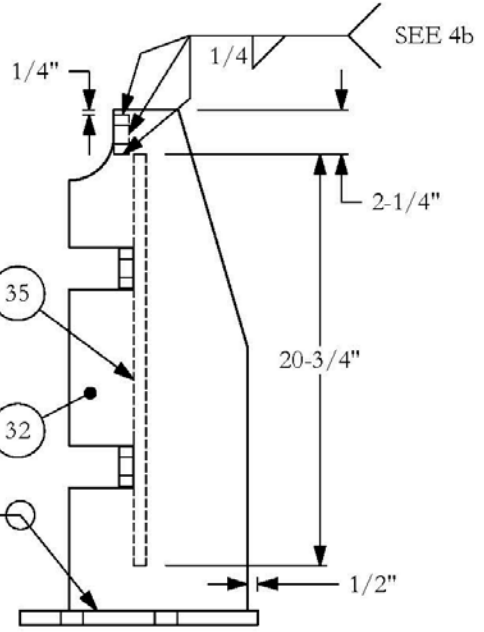


PLAN VIEW

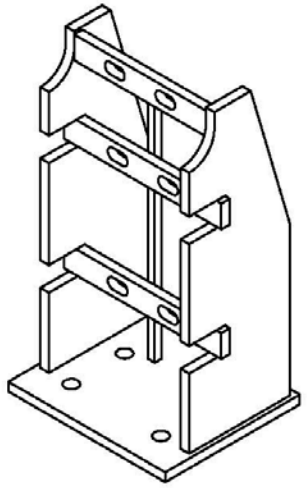
1 POST FOR PICKET RAIL

POST PARTS			
#	DESCRIPTION	QTY.	SIZE / GRADE
31	Base Plate	1	3/4" - A572 gr. 50
32	Side Plate	2	3/4" - A572 gr. 50
33	Top Strap	1	3/4" x 2" A36
34	Middle / Bottom Strap	2	3/4" x 2" A36
35	Post Picket	1	5/8" sq. A36





ELEVATION VIEWS



ISOMETRIC VIEW
SCALE 1:10

4a. Post is symmetric about ℄.
4b. Top Strap to Side Plates, bevel weld front side and fillet weld other 3 sides.
4c. All Post parts, except Picket, are detailed on next sheet.

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Drawn By GES	Scale 1:8	Sheet 4 of 17 Post Details

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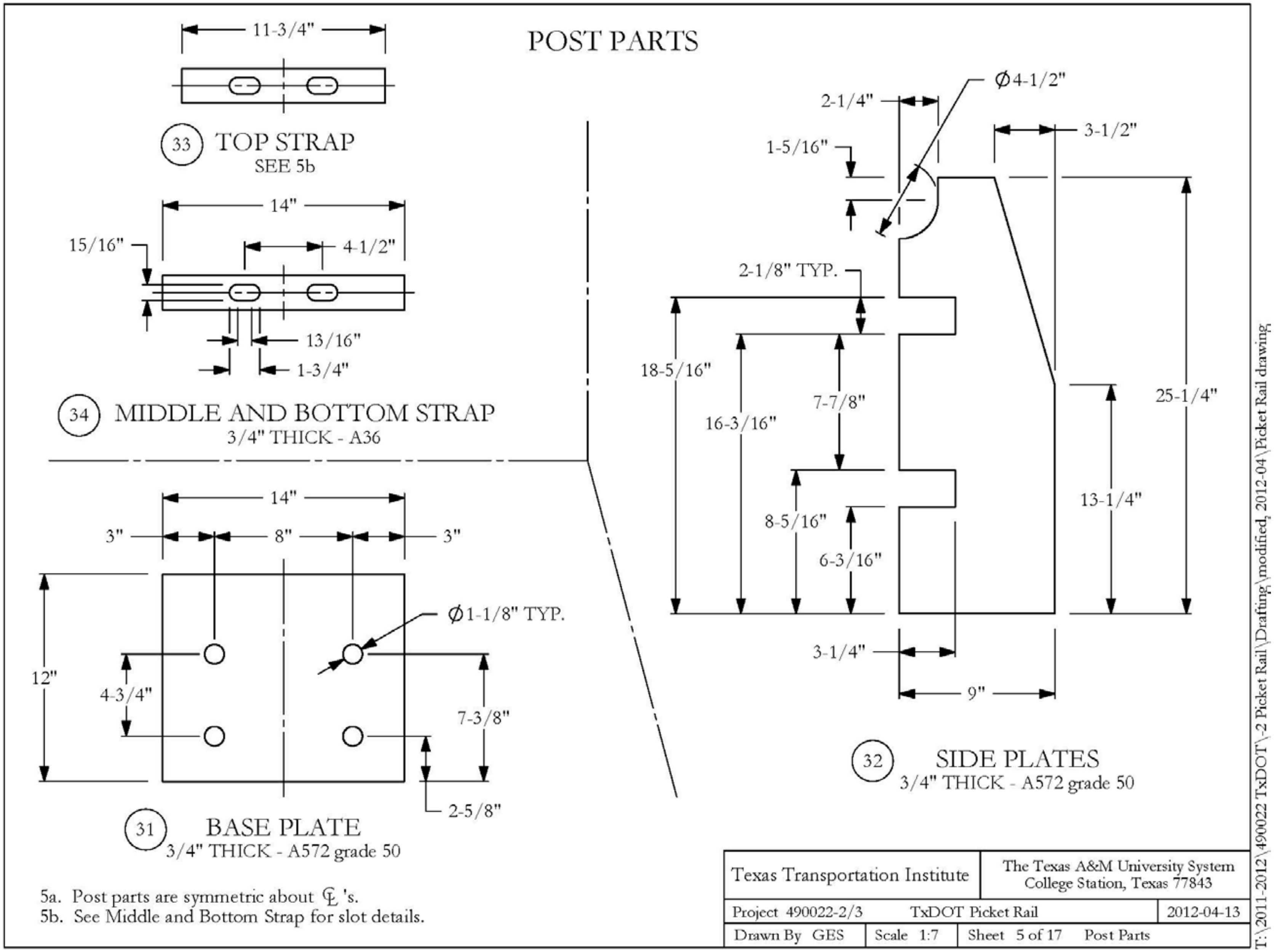
POST PARTS
11-3/4"
33 TOP STRAP
SEE 5b
14"
15/16"
4-1/2"
13/16"
1-3/4"
34 MIDDLE AND BOTTOM STRAP
3/4" THICK - A36
14"
3" 8" 3"
Ø1-1/8" TYP.
12"
4-3/4"
7-3/8"
2-5/8"
31 BASE PLATE
3/4" THICK - A572 grade 50
5a. Post parts are symmetric about ℄'s.
5b. See Middle and Bottom Strap for slot details.
Ø4-1/2"
2-1/4"
3-1/2"
1-5/16"
2-1/8" TYP.
18-5/16"
16-3/16"
7-7/8"
25-1/4"
13-1/4"
8-5/16"
6-3/16"
3-1/4"
9"
32 SIDE PLATES
3/4" THICK - A572 grade 50
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Project 490022-2/3
TxDOT Picket Rail
2012-04-13
Drawn By GES
Scale 1:7
Sheet 5 of 17
Post Parts
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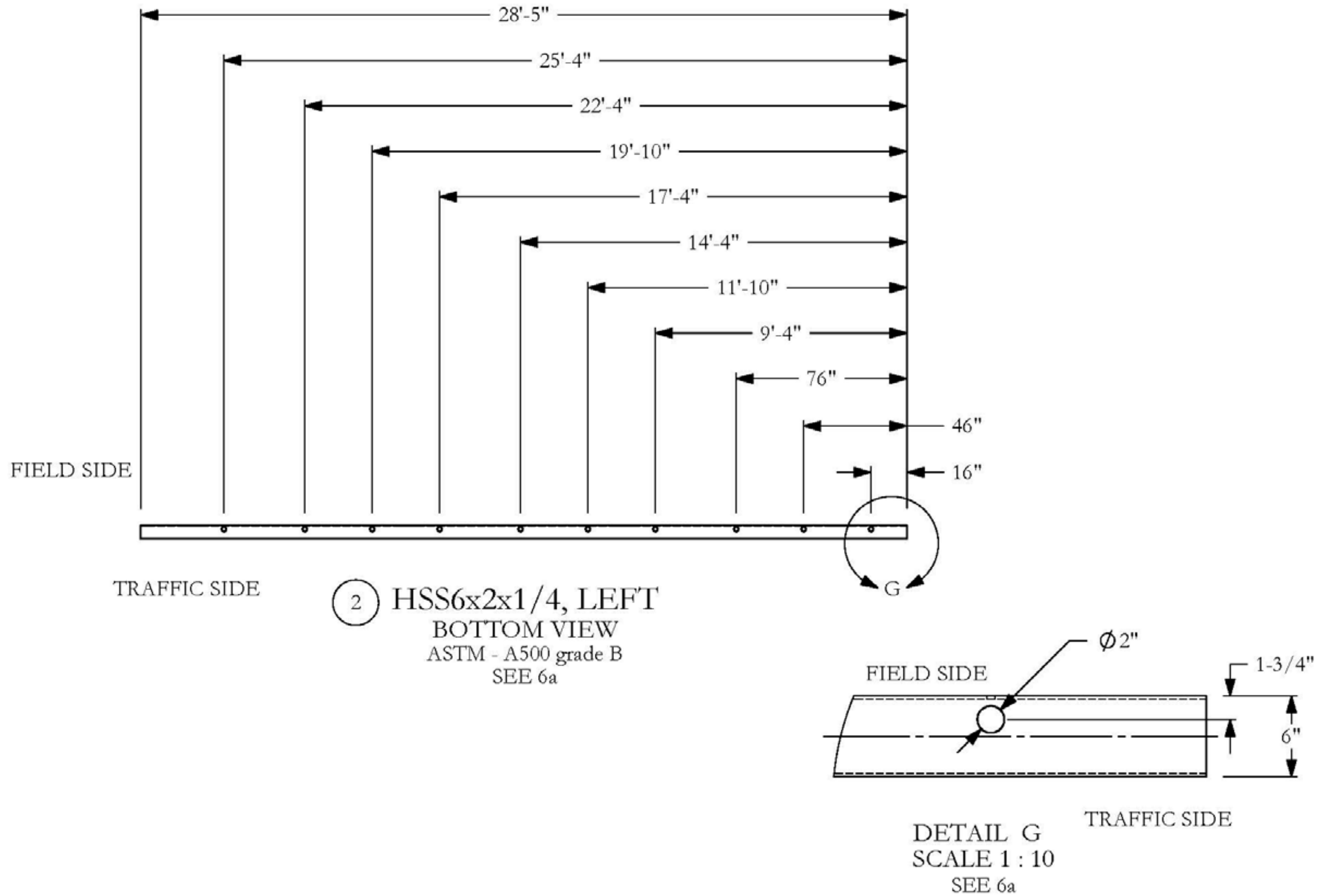

6a. Ø2" holes in Plan View are for access to nuts and washers for picket panel attachment, on bottom side only, 10 times.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843
Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:60	Sheet 6 of 17 Rail 2 - Bottom

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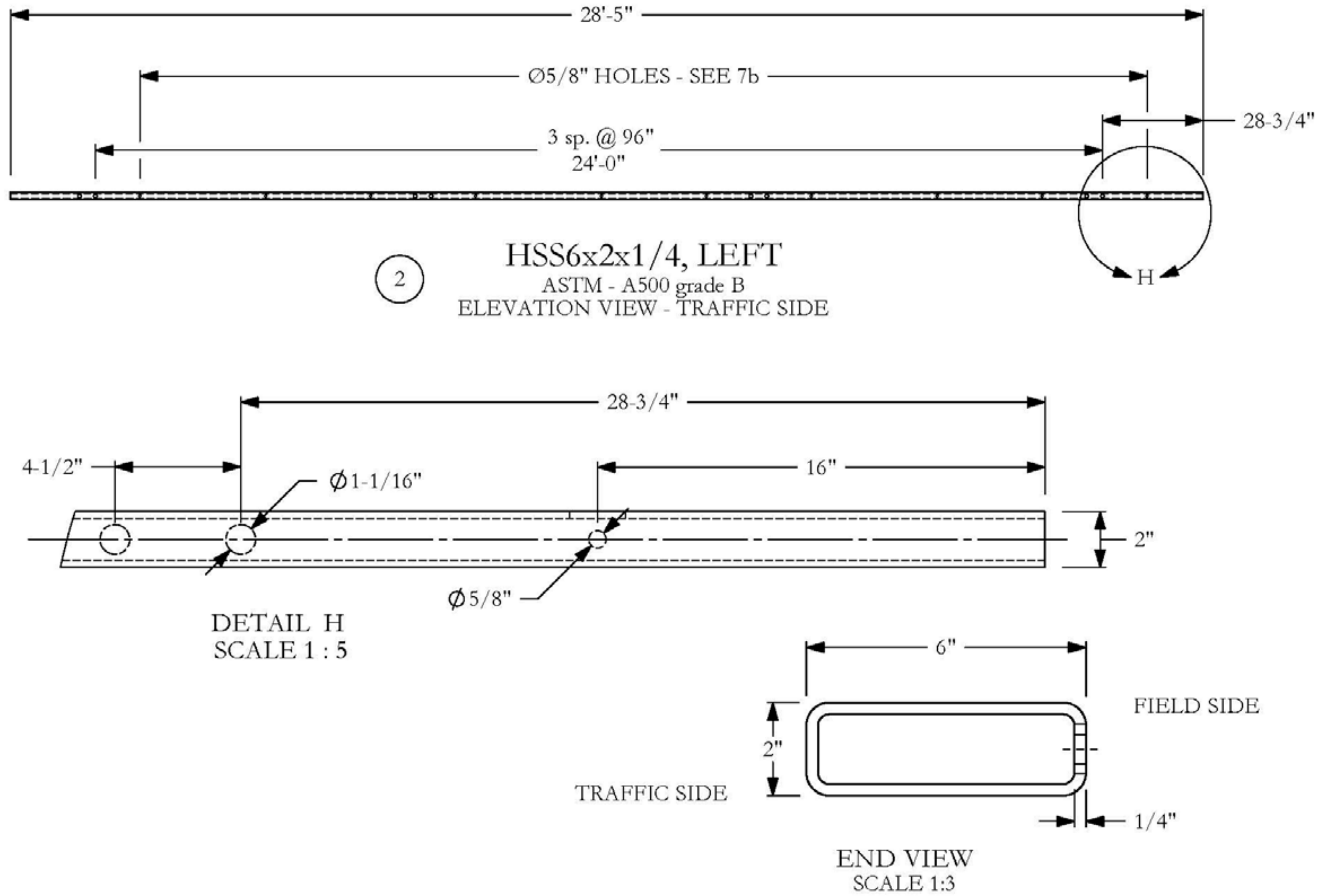

7a. Pairs of Ø1-1/16" holes at 4-1/2" apart are for attaching rail to posts with U-bolts, field side only, 4 times. Ø5/8" holes are for attaching picket panels to rails, field side only, 10 times.

7b. See Bottom View, previous sheet, for Ø5/8" hole spacing.

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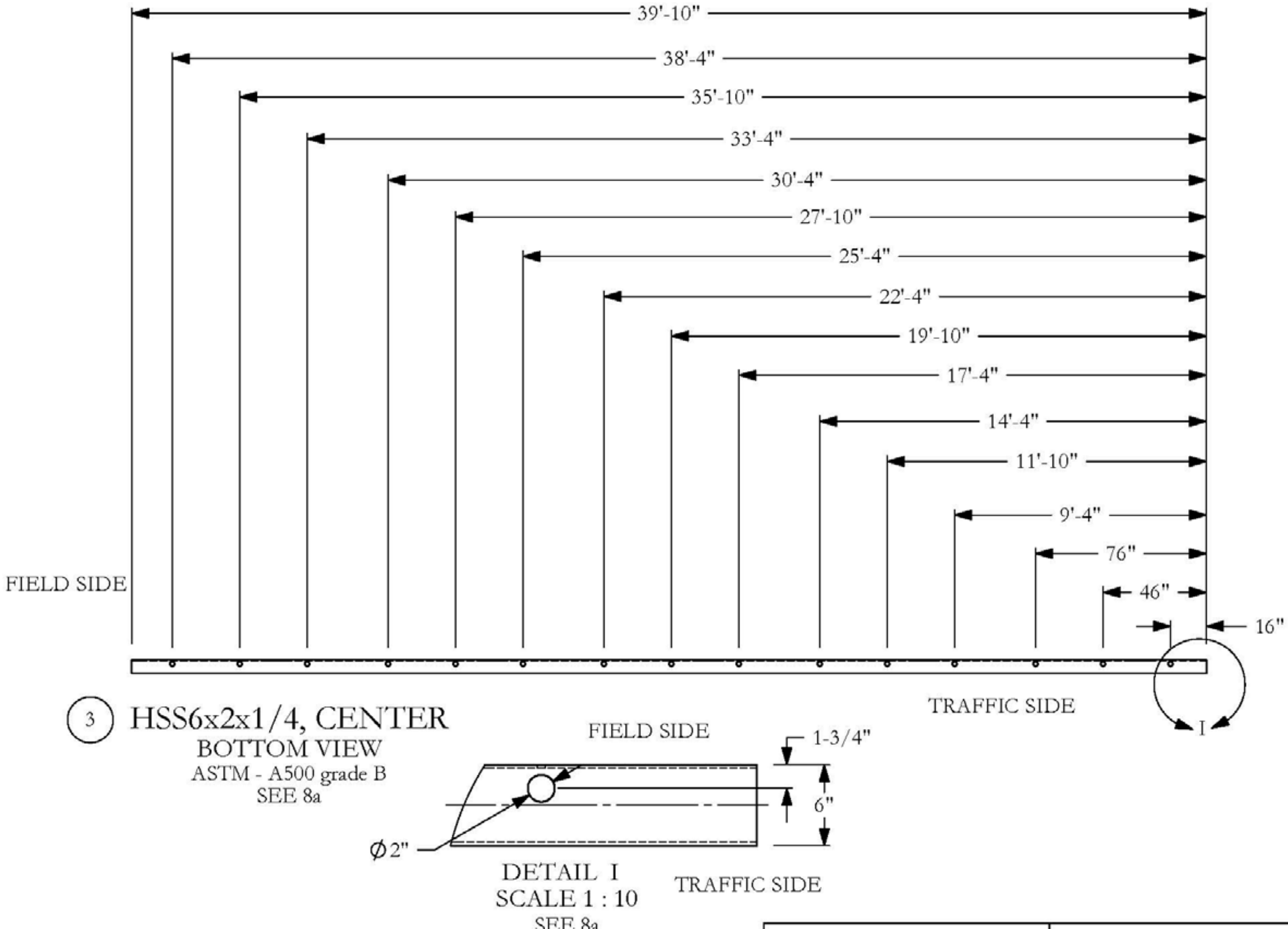
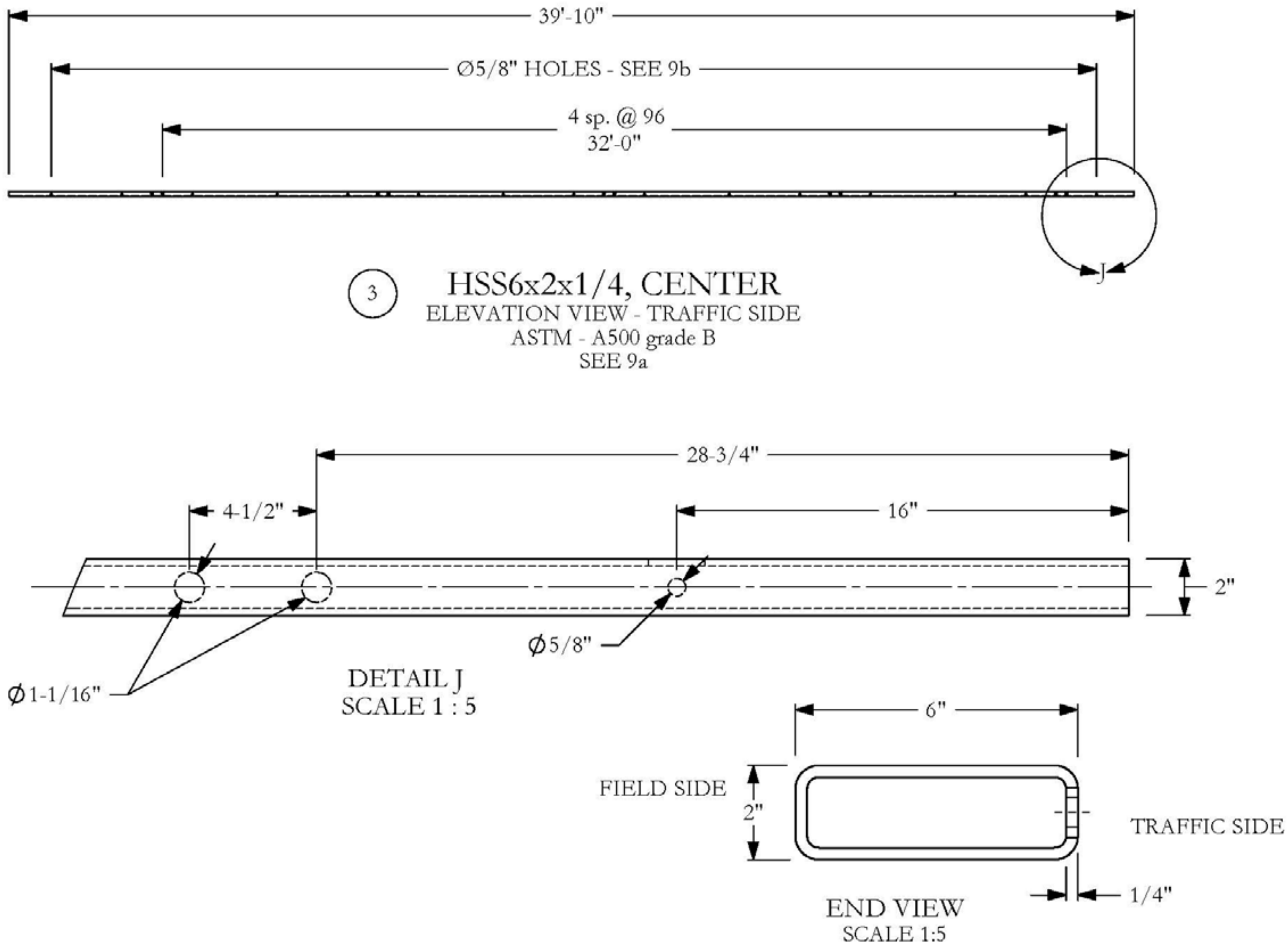
Project 490022-2/3		TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:40	Sheet 7 of 17	Rail 2 - Elevation



8a. Ø2" holes in Plan View are for access to nuts and washers for picket panel attachment, on bottom side only, 15 times.

Texas Transportation Institute	The Texas A&M University System College Station, Texas 77843	
Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:60	Sheet 8 of 17 Rail 3 - Bottom

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing

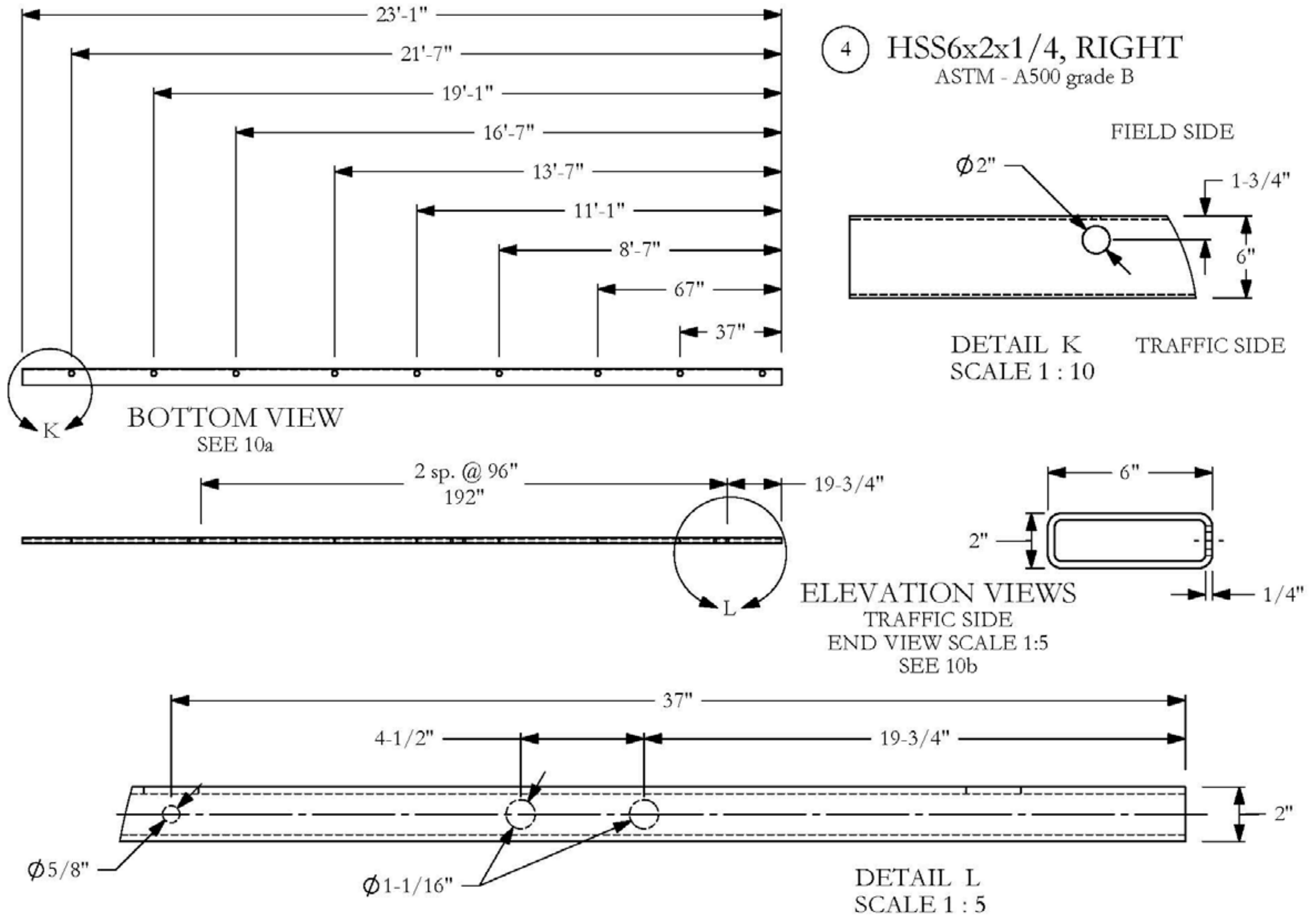


9a. Pairs of Ø1-1/16" holes at 4-1/2" apart are for attaching rail to posts with U-bolts, back side only. Ø5/8" holes are for attaching picket panels to rails, back side only, 15 times.

9b. See Bottom View, previous sheet, for Ø5/8" hole spacing.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-2/3	TxDOT Picket Rail		2012-04-13
Drawn By GES	Scale 1:60	Sheet 9 of 17	Rail 3 - Elevation

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing

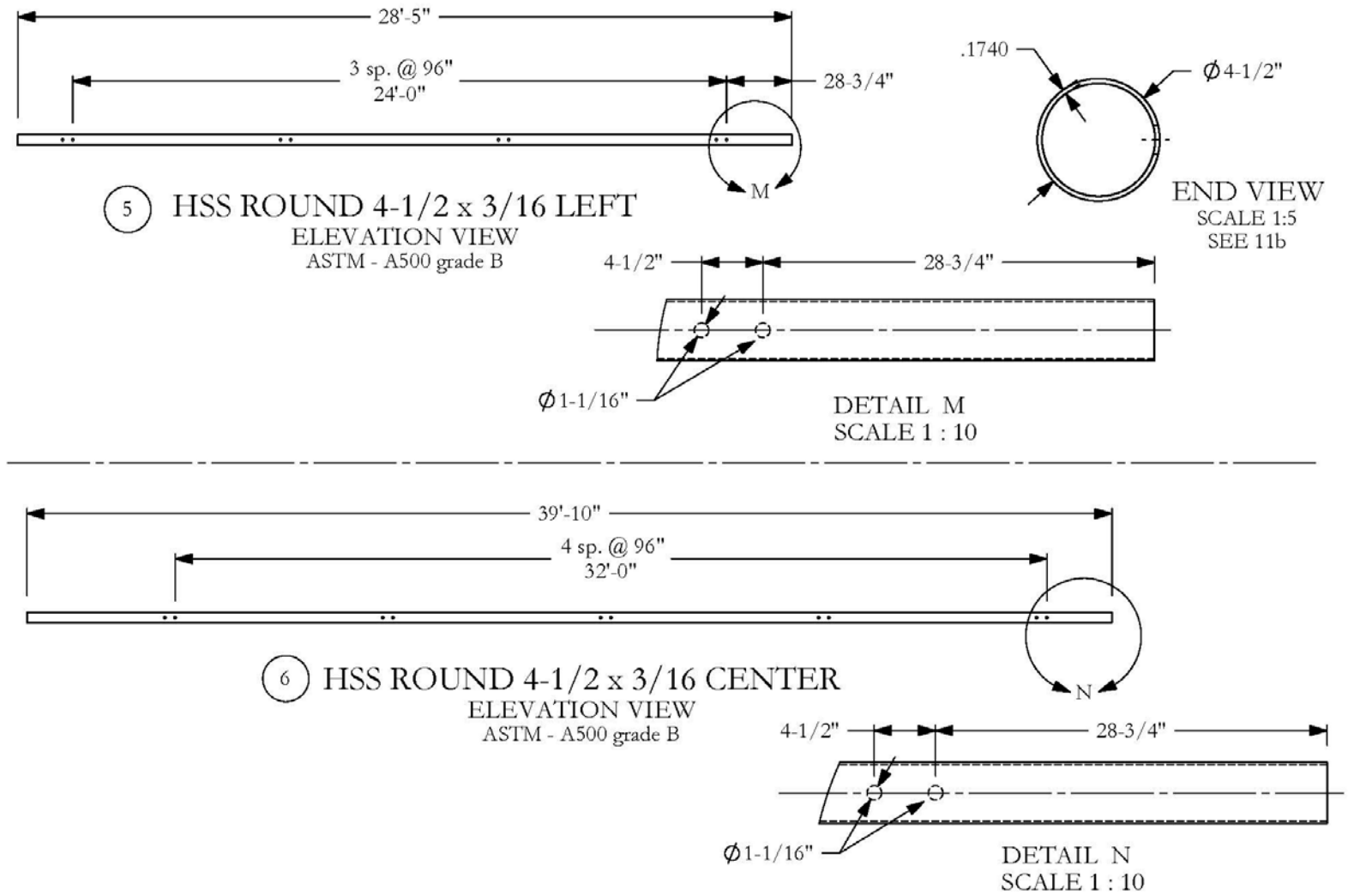


10a. Ø2" holes in Plan View are for access to nuts for picket panel attachment, on bottom side only, 8 times.

10b. Pairs of Ø1-1/16" holes at 4-1/2" apart are for attaching rail to posts with U-bolts, back side only, 3 times. Ø5/8" holes are for securing picket panels to rails, back side only, 8 times. See Plan View for spacing.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-2/3	TxDOT Picket Rail		2012-04-13
Drawn By GES	Scale 1:50	Sheet 10 of 17 Rail 4	

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing

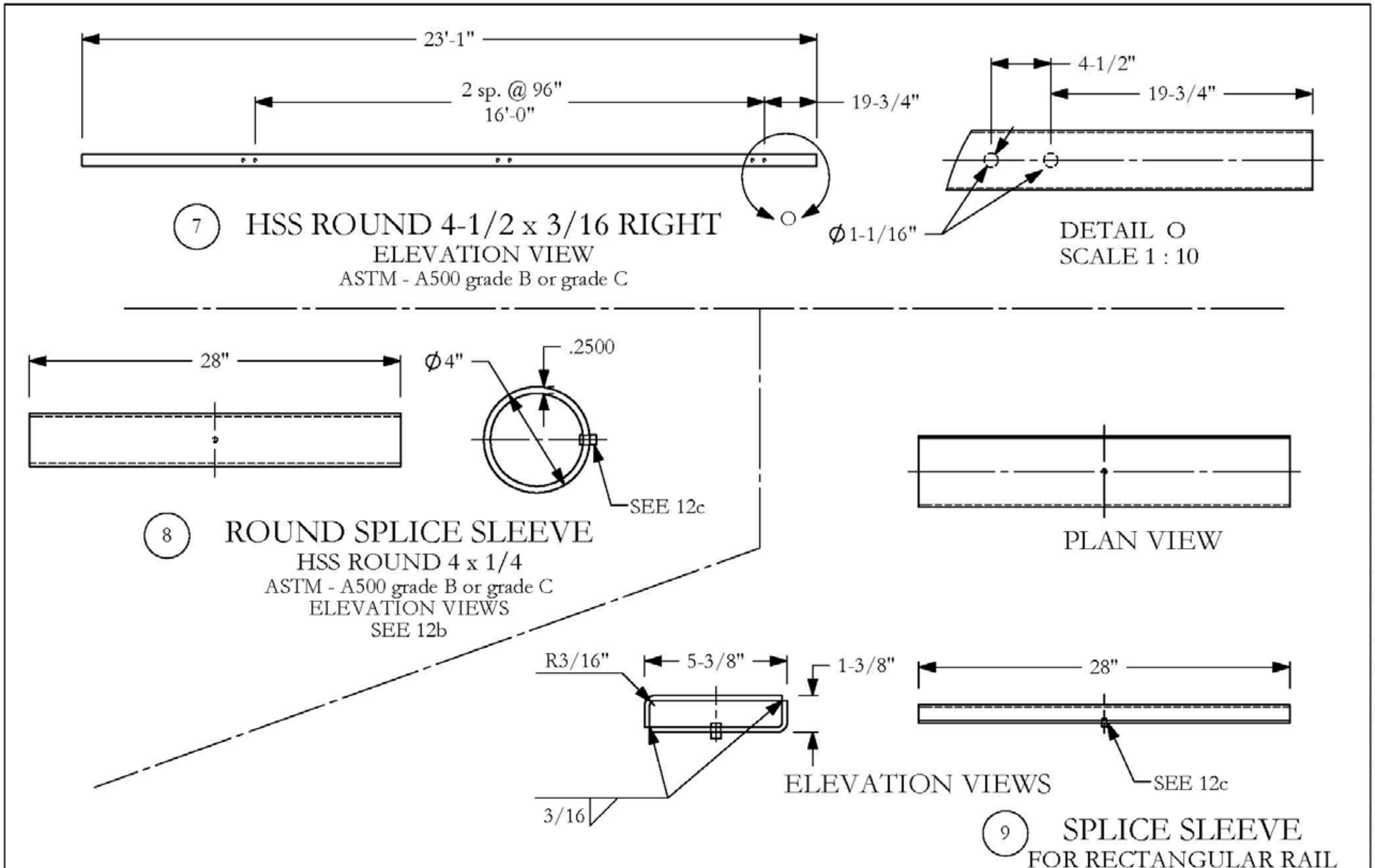


11a. Pairs of Ø1-1/16" holes at 4-1/2" apart are for attaching rail to posts with U-bolts, back side only, 4 times.

11b. End View is typical for all three round rails.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843
Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:60	Sheet 11 of 17 Rails 5 and 6

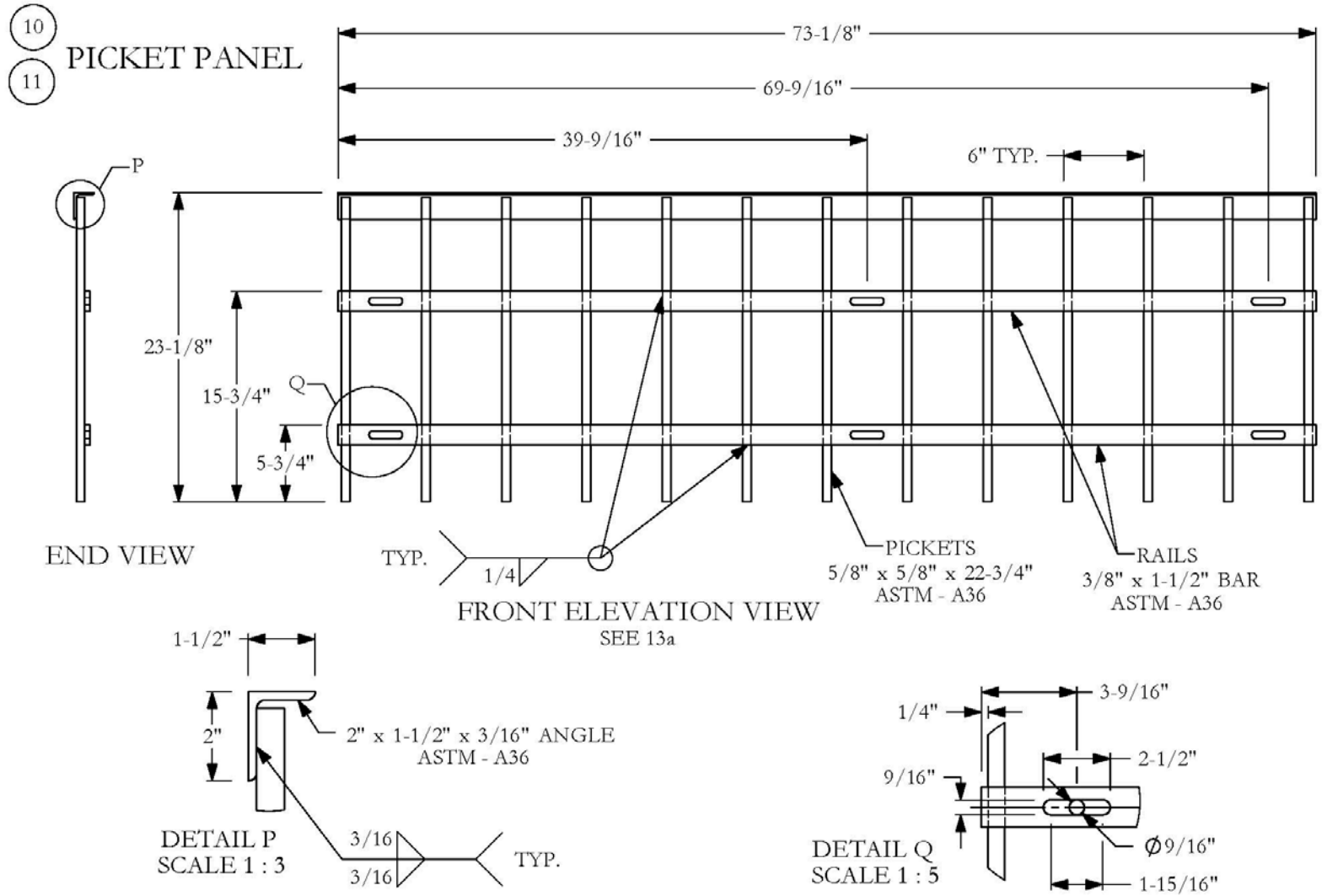
T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing



12a. Pairs of Ø1-1/16" holes are for attaching rail to posts with U-bolts, back side only, 3 times.
12b. Front View scale 1:10, End View scale 1:5.
12c. Ø3/8" driving fit Pin, 1/4" protruding past sleeve..
12d. Tolerance on thickness and width for this part is ±1/16". Grind weld smooth and verify that Sleeve will fit easily into Rail. Plan and Front Elevation Views scale 1:10, End View scale 1:5.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843
Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:50	Sheet 12 of 17 Rail 7 and Splice Sleeves

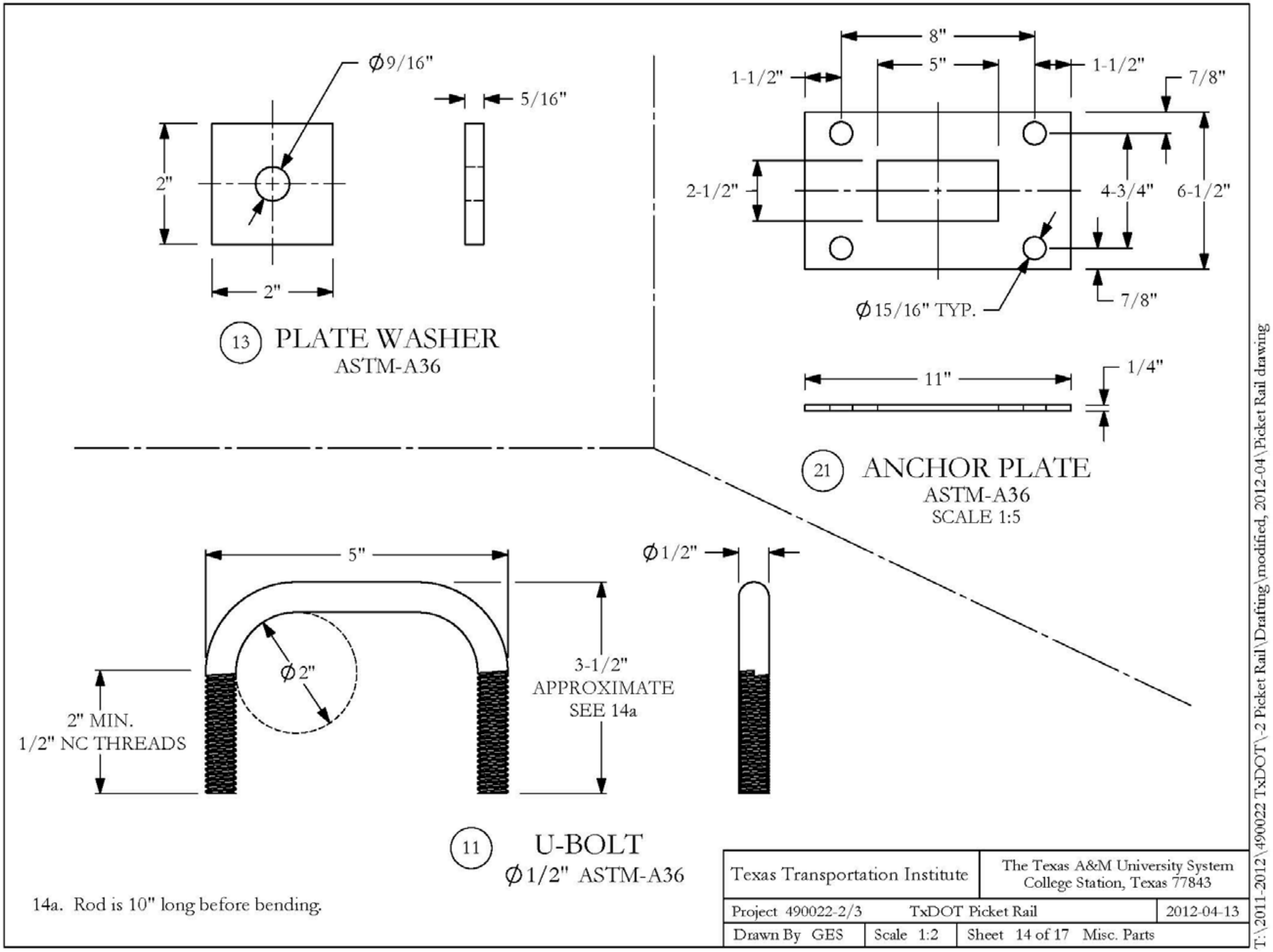
T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing

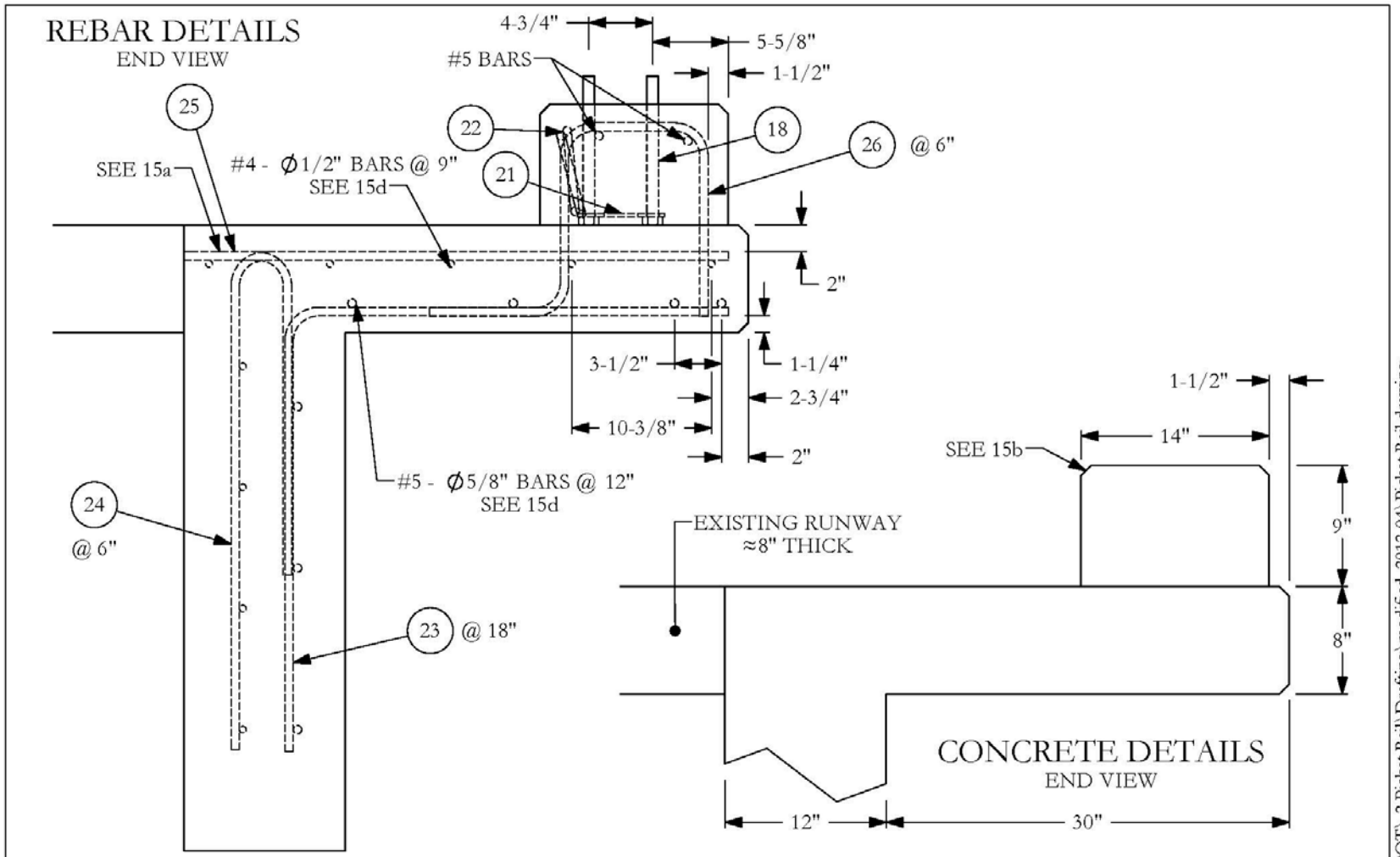


13a. Picket Panel at Rail Splice is shown in Front Elevation View. Standard Picket Panels have Ø9/16" round holes instead of slots at same locations (See Detail Q). Panels are otherwise identical.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843
Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:10	Sheet 13 of 17 Picket Panel

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing


Ø9/16"
5/16"
2"
2"
13 PLATE WASHER
ASTM-A36
8"
1-1/2"
5"
1-1/2"
7/8"
2-1/2"
4-3/4"
6-1/2"
7/8"
Ø15/16" TYP.
11"
1/4"
21 ANCHOR PLATE
ASTM-A36
SCALE 1:5
5"
Ø1/2"
Ø2"
3-1/2"
APPROXIMATE
SEE 14a
2" MIN.
1/2" NC THREADS
11 U-BOLT
Ø1/2" ASTM-A36
14a. Rod is 10" long before bending.
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843
Project 490022-2/3
TxDOT Picket Rail
2012-04-13
Drawn By GES
Scale 1:2
Sheet 14 of 17 Misc. Parts
T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing



15a. Wall tie rebar (25) is at ≈24" spacing and welded to existing rebar (not shown).

15b. 3/4" chamfer exposed edges of deck and curb.

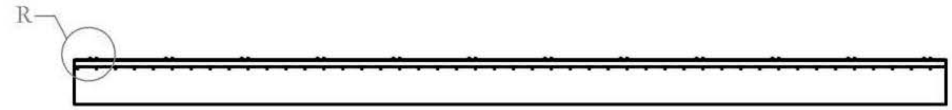
15c. Concrete is Class S - 4000 psi for deck and curb.

15d. Rebar is grade 60. Longitudinal bars in top mat are Ø1/2" at 9", unless otherwise shown, with 17" laps. Longitudinal bars in bottom mat are Ø5/8" at 12", unless otherwise shown, with 21" laps on all Ø5/8" bars.

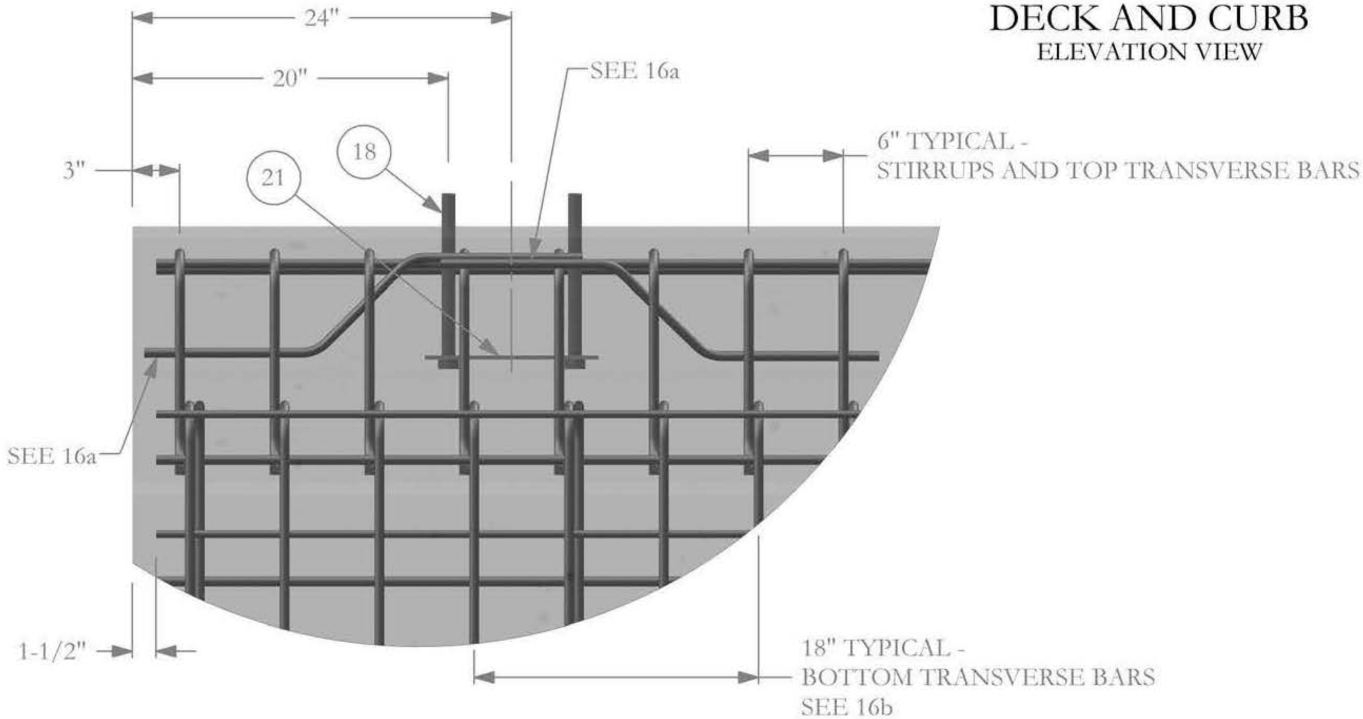
15e. Tolerance on concrete dimensions and rebar spacing is ±1/4".

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843
Project 490022-2/3	TxDOT Picket Rail	2012-04-13
Drawn By GES	Scale 1:10	Sheet 15 of 17 Concrete Cross-sections

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing



DECK AND CURB
ELEVATION VIEW



DETAIL R
SCALE 1 : 10

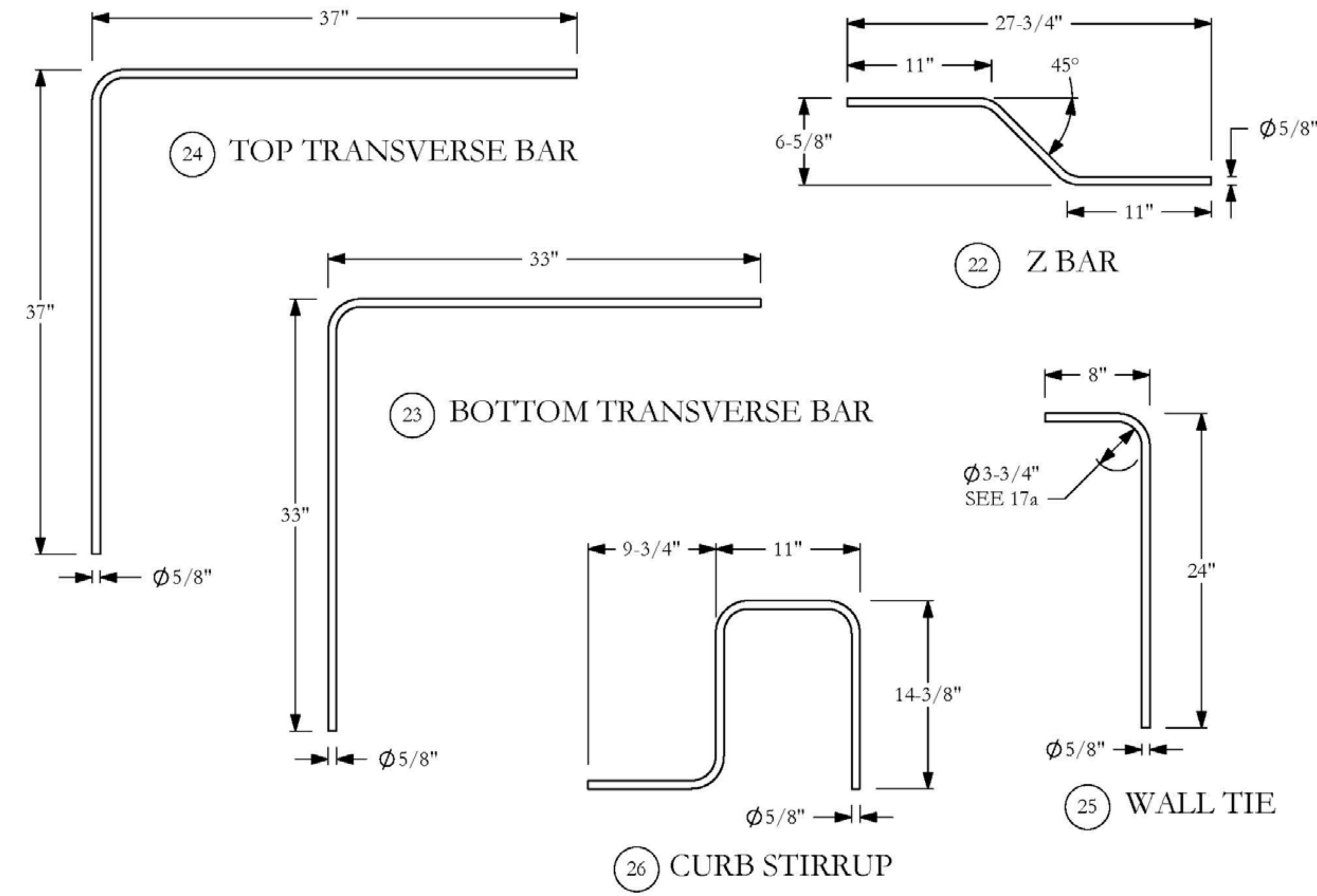
16a. Lap Z- bars minimum 9", with lap centered on post. Increase lap at end posts to keep 1-1/2" clearance from curb end. Place Z- bars with upper end outside of stirrups at the bend and with the lower end inside the stirrups.

16b. Bottom Transverse Bars are in line with Top Transverse Bars, so are not visible in this view.

16c. Anchor Bolt heads rest on deck.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-2/3	TxDOT Picket Rail		2012-04-13
Drawn By GES	Scale 1:200	Sheet 16 of 17	Concrete Elevation

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing



17a. All rebar this sheet is Ø5/8" grade 60 and bend diameter dimension shown for Wall Tie is typical.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-2/3	TxDOT Picket Rail		2012-04-13
Drawn By GES	Scale 1:10	Sheet 17 of 17 Rebar Details	

T:\2011-2012\490022 TxDOT\-2 Picket Rail\Drafting\modified, 2012-04\Picket Rail drawing

APPENDIX B. CERTIFICATION DOCUMENTATION

MATERIAL USED

TEST NUMBER 490022-2/3

TEST NAME TxDOT Picket Rail

DATE 2012-04-09/10

DATE RECEIVED	ITEM NUMBER	DESCRIPTION	SUPPLIER	HEAT #
2012-03-19	Parts-18	Picket Rail Parts	Brazos Industries	see file
2012-02-23	Rebar 04-26	1/2" x 20' gr 60	CMC-Sheplers	3029770
2012-02-23	Rebar 05-15	5/8" x 20' grd 60	CMC-Sheplers	3028494

Independence Tube
6226 W. 74th St
Chicago, IL 60638
708-496-0380
Fax: 708-563-1950
independencetube.com
itctube.com
Certificate Number: CHI 816292

Sold By:
INDEPENDENCE TUBE CORPORATION
6226 W. 74th St.
Chicago, IL 60638
Tel: 708-496-0380
Fax: 708-563-1950

Purchase Order No: po-023591
Sales Order No: CHI 191963 - 1
Bill of Lading No: CHI 112447 - 1
Invoice No:

Shipped: 9/22/2011
Invoiced:

Sold To:
2025 - TUBULAR STEEL
1031 EXECUTIVE PKWY DRIVE
ST. LOUIS, MO 63141-6351

Ship To:
84 - TUBULAR STEEL
1700 TUBULAR STEEL ROAD
STAUNTON, IL 62088

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

ROUND A500 GRADE B(C)
4.000"OD X .250"

Certificate No: CHI 816292
Test Date: 9/15/2011

Total Pieces	Total Weight
30	7,215

Heat Number: C56944

Bundle Tag	Yield, Tensile Strength, Elongation, Measurements	Y/T Ratio	Pieces	Weight
557474	YLD=64158/TEN=79907/ELG=27.46	0.8029	10	2,405
557475	YLD=64158/TEN=79907/ELG=27.46	0.8029	10	2,405
557478	YLD=64158/TEN=79907/ELG=27.46	0.8029	10	2,405

Heat Number
C56944

*** Chemical Analysis ***
C=0.2000 Mn=0.7000 P=0.0070 S=0.0040 Si=0.0300 Al=0.0310 Cu=0.0800
Carbon Eq.=0.3167 Carbon Eq. = C + (Mn/6)

MEETS ASTM A500/A500M-10a GRADE B AND GRADE C
MELTED & MANUFACTURED IN THE USA

Certification:

I certify that the above results are a true and correct copy of records prepared and maintained by Independence Tube Corporation. Sworn this day, 9/15/2011

Annette Gorz, Test Report Clerk

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-10a
.....A513-07
.....A262-98 (2002)

CN FASTENER MANUFACTURING, CO.

QUALITY CERTIFICATE

Date: Dec. 03, 2010
Product: B7 STUDDING
Size: 7/8 x 12'
(48 Pcs. 7/8-9 x 10-1/2)

Production No: 00241364
Lot#: 315010042
Surface Coating: PLN
QTY: 12015 pcs.

CHEMICAL COMPOSITION

	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	
MILL HEAT #:	0.40	0.27	0.83	0.015	0.007	0.04	0.02	0.97	0.18		
0103002											

MECHANICAL PROPERTIES

LTR: Tempering Temperature

CHARACTERISTICS	REQUIRED	<< OBSERVATIONS >>
HARDNESS [HR]	HRC Max 35 C	HRC 30.0 ~ 33.0
Tensile Strength [N/mm²]	860 min	966 ~ 967 N/mm²
Yield Strength [N/mm²]	725 min	889 – 890 N/mm²
Elongation [%]	16 min	21.4 – 21.5
Reduction pf Area [%]	50 min	60.3 – 60.4
Thickness [UM]		
Surface Coating: PLN		
Dimmnl. Inspn: SATISFACTORY		

The information on chemical composition is based on the test certificated received from the steel mill or material supplier described in this document has been inspected under the parameters setforth and found to be in conformance with the physical requirement we certify the above product meets specified requirement of.

Quality Control Manager: G.P.

#1822 P.001/001

03/12/2012 07:22 1

MILL TEST REPORT **BRIGHTON-BEST INTERNATIONAL INC.** www.BrightonBest.com This MTR contains 1 pages (Page: 1)

Lot#: LM11032804 Part#: 314250

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A194/A194M-10a GRADE 2H HVY HEX NUTS

FACTORY: NINGBO HAIXIN HARDWARE CO.,LTD. DATE: OCT.12.2011
ADDRESS: XIJINGTANG,LUOTUO NINGBO ZHEJIANG 315205 CHINA
MFG LOT NUMBER: LM11032804
CUSTOMER: BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC PO NUMBER: U04299
QNTY SHIPPED: 64,800MPCS PART NO: 314250
SAMPLE SIZE : ACC. TO ASME B18 . 18 . 1 - 02
SIZE & DESCRIPTION: 7/8-9(BLK)

STEEL PROPERTIES:
STEEL GRADE: SWRCH45K SIZE: 34mm HEAT NO: 331105356
CHEMISTRY COMPOSITION:

CHEMIST	C %	Mn %	P %	S %	Si %	Cr %	Ni %	Cu %	Mo %	OTHERS
SPE:	MIN	MAX	MAX	MAX	MAX					
	0.40	1.00	0.04	0.05	0.40					
TEST:	0.45	0.76	0.011	0.003	0.21					

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME/ANSI B18 . 2 . 2 - 87(R1999)

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F812-02		PASSED	100	0
WIDTH A/F	1.394"-1.438"		1.409"-1.424"	32	0
WIDTH A/C	1.589"-1.660"		1.608"-1.638"	32	0
THREAD	ASME B1.1-02		PASSED	8	0
HEIGHT	0.833"-0.885"		0.843"-0.860"	32	0
MARK	2H LM		PASSED	100	0

MECHANICAL PROPERTIES: TO 1-1/2" in SPECIFICATION: ASTM A194-10a

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HARDNESS	ASTM E18-05	24-35HRC	HRC29-30	5	0
PROOF LOAD	ASTM F606-07	80850lbf	80850lbf	5	0
DECARBURIZATION	SAE J121		PASSED	1	0
HARDNESS AFTER 24H AT 540°C ASTM A194 MIN 89 HRB			HRB 92-94	5	0
TEMPERING TEMPERATURE Min455°C			PASSED(520°C)		
MACROETCH	ASTM E381	S1/R1/C1~S4/R4/C4	S2/R2/C2	5	0

PARTS ARE MANUFACTURED AND TESTED IN ACCORDANCE WITH ASTM A194/A194M-10a
ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
All parts meet the requirements of FQA and records of compliance are on file.
Maker's ISO#00109Q10593R0M/3302

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

STAMPING THE FUTURE

WROUGHT WASHER MFG., INC.

January 16, 2009

Certification of Compliance

012476
ALBRITTON & GROVES - HOUSTON
3605 WILLOWBEND BLVD. #550
HOUSTON, TX 77054

Wrought Washer Ord#/Lot Number
230425
HT 228734

Chemical Analysis

Heat Number	C	Mn	P	S	Si
284276	0.350	0.640	0.008	0.001	0.213

Purchase Order Number	Part Description	Date Shipped	Quantity Shipped
HARDENED	7/8 S MARK HT	01/15/2009	30,000

We hereby certify that the subject parts conform to the requirements of the applicable specification indicated for the subject parts and are in complete conformance to F436-04. We hereby certify that the subject parts were hardened to RC 38-45.

We hereby certify that all statutory requirements as to American Production and Labor Standards and all conditions of purchase applicable to the transaction have been complied with and that the subject parts were melted and manufactured in the U.S.A.

Truly yours,
Wrought Washer Mfg., Inc.

Paul Schaefer
Q.C. Manager

Sworn and subscribed before me on January 16, 2009
My commission expires June 21, 2009

.030 SMARK HT F436
WW INTERNAL USE: 5362S-001Q16Q17308, 5321

1901 CHICORY RD. • MOUNT PLEASANT, WI 53403 • PHONE (262) 554-9550 • FAX (262) 554-9584
VISIT OUR WEBSITE: www.wroughtwasher.com

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.:3011321 SECTION: ROUND 1/2 x 20'0" A36/52950 GRADE: ASTM A36-08/A529-05 Gr 50 ROLL DATE: 08/15/2009 MELT DATE: 08/14/2009	S O L D T O	Madden Bolt Corp 13420 Hempstead Rd Houston TX US 77040-5813 7139399999 7139397200	S H I P T O	Madden Bolt Corp 13420 Hempstead Rd Houston TX US 77040-5813 7139399999 7139397200	Delivery#: 80199515 BOL#: 70063367 CUST PO#: PE33988 CUST P/N: DLVRY LBS / HEAT: 4562.000 LB DLVRY PCS / HEAT: 341 EA	

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.13%				
Mn	0.81%				
P	0.008%				
S	0.039%				
Si	0.19%				
Cu	0.15%				
Cr	0.16%				
Ni	0.09%				
Mo	0.033%				
V	0.008%				
Cb	0.001%				
Sn	0.007%				
Al	0.002%				
Carbon Eq A529	0.36%				
Yield Strength test 1	51.6ksi				
Tensile Strength test 1	77.5ksi				
Elongation test 1	29%				
Elongation Gage Lgth test 1	8IN				

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

REMARKS :

10/02/2009 20:07:59
Page 1 OF 1

SOLD TO: NAMASCO CORP
500 COLONIAL CENTER PKWY
STE 500
ROSWELL, GA 30076-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

Page: 2

SHIP TO: NAMASCO
SOUTH LOOP 4
BUDA, TX 78610-

Ship from:
Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 14-Oct-2011
B.L. Number: 585706
Load Number: 196747

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

NBMG-08 March 8 2011

HEAT NUM. *	DESCRIPTION	PHYSICAL TESTS YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	CHEMICAL TESTS C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	6381281												
JW1110866601	Nucor Steel - Texas	58,900	76,500	21.0%			.11	1.06	.018	.039	.20	.38	
	3/4x10" Flat	406MPa	527MPa				.12	.17	.034	.003	.032		
	20' A529 Gr55	58,200	76,000	19.0%			CBV	CEA529	MN/C				
	ASTM A529/A529M-05 GR 55	401MPa	524MPa				0.040	0.40	09.64				
	COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1												
PO# =>	6369968												
JW1110866601	Nucor Steel - Texas	58,900	76,500	21.0%			.11	1.06	.018	.039	.20	.38	
	3/4x10" Flat	406MPa	527MPa				.12	.17	.034	.003	.032		
	20' A529 Gr55	58,200	76,000	19.0%			CBV	CEA529	MN/C				
	ASTM A529/A529M-05 GR 55	401MPa	524MPa				0.040	0.40	09.64				
	COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1												

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
1.) Weld repair was not performed on this material.
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form have not been used in the production of this material.

QUALITY ASSURANCE: Nathan Stewart

02-14-2012 12:03 Load - 1168331 BL - 3681309 BLR466
Brazos Industries Inc Heat - C017163
Cust. PO - Order-Line - 7140964 / 5

GERDAU
CHARLOTTE STEEL MILL
6601 LAKEVIEW ROAD
CHARLOTTE NC 28269 USA
(704) 596-0361

Chemical and Physical Test Report
MADE IN UNITED STATES

C-563056

SHIP TO	INVOICE TO	SHIP DATE
NAMASCO CORP SOUTH LOOP 4, EXIT 217 512-472-5533 BUDA, TX 78610	NAMASCO CORP ***ACCTS PAYABLE** 500 COLONIAL CENTER PKWY S-500 ROSWELL, GA 30076	01/12/12 **CUST. ACCOUNT NO** 33119363

PRODUCED IN: CHARLOTTE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
S5/8	A36	ASTM A36-08 AASME SA36-08A & ASTM A709-07	2700133-06	6414227-06

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	Sn	C Eqv
C017163	.16	.70	.012	.088	.19	.42	.12	.06	.020	.002	<.008	.011	.37

Mechanical Test: Yield 50277 PSI, 346.65 MPA Tensile: 72506 PSI, 499.9 MPA %El: 23.8/8in, 23.8/200MM Red B 64
Customer Requirements CASTING: STRAND CAST
CUST ITEM NUMBER: MB58SQ20A36

Customer Notes

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

This material, including the billets, was melted and manufactured in the United States of America

THE ABOVE FIGURES ARE CERTIFIED CHEMICAL AND PHYSICAL TEST RECORDS AS CONTAINED IN THE PERMANENT RECORDS OF COMPANY.

Bhaskar Yalamanchili
Quality Director
Gerdau

Metallurgical Services Manager
CHARLOTTE STEEL MILL

Seller warrants that all material furnished shall comply with specifications subject to standard published manufacturing variations. NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, ARE MADE BY THE SELLER, AND SPECIFICALLY EXCLUDED ARE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.
In no event shall seller be liable for indirect, consequential or punitive damages arising out of or related to the materials furnished by seller.
Any claim for damages for materials that do not conform to specifications must be made from buyer to seller immediately after delivery of same in order to allow the seller the opportunity to inspect the material in question.

Namasco

02-14-2012 12:03 Load - 1168331 BL - 3681309 BLR466
Brazos Industries Inc Heat - A60808
Cust. PO - Order-Line - 7140964 / 3

JAN-18-2012(WED) 16:39 ATLAS TUBE P.004/005

Atlas Tube Inc.
5039N County Road 1015
Blytheville, Arkansas, USA
72315
Tel: 870-838-2000
Fax: 870-762-6630

Atlas Tube
JMC STEEL GROUP

Ref.B/L: 80460814
Date: 01.18.2012
Customer: 980

MATERIAL TEST REPORT

Sold to

NAMASCO CORPORATION
Steel Warehousing Corporati
500 COLONIAL CENTER PR
ROSWELL GA 30076
USA

Shipped to

NAMASCO SOUTH WEST
SOUTH LOOP 4, P.O. BOX
BUDA TX 78715-0387
USA

Material: 5.0x3.0x250x40'0"0(4x3). Material No: 500302504000 Made in: USA
Melted in: USA
Sales order: 676809 Purchase Order: 6392958 Cust Material #: T5314RECTA5000480

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
35461D	0.210	0.790	0.009	0.009	0.009	0.041	0.030	0.000	0.000	0.010	0.040	0.000	0.001	0.000	0.000

Bundle No	PCs	Yield	Tensile	Elm.2in	Certification	CE: 0.35
M400040721	12	061160 Psi	071150 Psi	31 %	ASTM A500-10A GRADE B&C	

Material Note:
Sales Or.Note:

Material: 6.0x2.0x250x40'0"0(3x4). Material No: 600202504000 Made in: USA
Melted in: USA
Sales order: 676809 Purchase Order: 6392958 Cust Material #: T6214RECTA6000480

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
A60808	0.220	0.810	0.012	0.003	0.030	0.023	0.100	0.000	0.020	0.050	0.060	0.001	0.001	0.000	0.000

Bundle No	PCs	Yield	Tensile	Elm.2in	Certification	CE: 0.39
M400040785	12	066300 Psi	078930 Psi	29 %	ASTM A500-10A GRADE B&C	

Material Note:
Sales Or.Note:

Material: 6.0x2.0x250x40'0"0(3x4). Material No: 600202504000 Made in: USA
Melted in: USA
Sales order: 676809 Purchase Order: 6392958 Cust Material #: T6214RECTA6000480

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
A60808	0.220	0.810	0.012	0.003	0.030	0.023	0.100	0.000	0.020	0.050	0.060	0.001	0.001	0.000	0.000

Bundle No	PCs	Yield	Tensile	Elm.2in	Certification	CE: 0.39
M400040785	12	066300 Psi	078930 Psi	29 %	ASTM A500-10A GRADE B&C	

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Namasco

02-14-2012 12:03 Load - 1168331 BL - 3681309 BLR466
Brazos Industries Inc Heat - 515678
Cust. PO - Order-Line - 7140964 / 2

SOUTHLAND TUBE INCORPORATED

3525 Richard Arrington, Jr., Blvd. N.
Birmingham, AL 35234
Phone (205) 251-1884
Lab Fax (205) 421-4561
Lab@SouthlandTube.com

TEST REPORT

Customer Name: NAMASCO CORPORATION LTD
Customer PO No: 6426668

Heat No.:	515678	Spec/Grade:	A500-10/B/C
Description:	CARBON STEEL TUBING	Print Date:	2/9/2012
Size/Length:	2" X 6" 1/4" Wall 40'	Wall Thickness:	0.2500

Carbon (C):	0.2000	Tin (Sn):	0.0020	Vanadium (V):	0.0010
Manganese (Mn):	0.4300	Nickel (Ni):	0.0150	Columbium (Cb):	0.0000
Phosphorus (P):	0.0100	Chromium (Cr):	0.0430	Titanium (Ti):	0.0010
Sulphur (S):	0.0110	Molybdenum (Mo):	0.0060	Boron (B):	0.0001
Silicon (Si):	0.0120	Aluminum (Al):	0.0360	Calcium (Ca):	0.0000
Copper (Cu):	0.0380	Nitrogen (N):	0.0037	Carbon Equiv. (CE):	0.2852

Sample Number	Sample Date	Tensile (psi)	Yield (psi)	Elongation (%)
SL31866	2/6/2012	68,400	56,200	26.00

We hereby certify that the above figures are correct as contained in the records of this company. Tensile testing (if applicable) is performed according to ASTM A370 and ASTM E8 (Yield Strength determined using 0.2% offset method).

Computer Generated Document
Quality Assurance

Melted & Manufactured in the U.S.A.

STI Pickup No: 021J3081 STI Order No: 264127 STI Item No: 2.0X6.025040

Page: 3

SOLD TO: NAMASCO CORP
500 COLONIAL CENTER PKWY
STE 500
ROSWELL, GA 30076-

SHIP TO: NAMASCO
SOUTH LOOP 4
BUDA, TX 78610-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

Ship from:

Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 3-Feb-2012
B.L. Number: 596310
Load Number: 206091

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

NBMG-08 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS: YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	CHEMICAL TESTS: C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	6425459												
JW1210056101	Nucor Steel - Texas	42,700	64,100	25.0%			.11	.69	.012	.050	.20	.32	.30
JW12100561	3/4x2" Flat	294MPa	442MPa				.15	.17	.044	.003	.001		
	20' A36	42,800	64,100	25.0%									
	ASTM A36/A36M-08, A709/A709M-11	295MPa	442MPa										
	GR36, ASME SA36-07 Ed 11 Ad												

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
1) Weld repair was not performed on this material
2) Melted and Manufactured in the United States
3) Mercury, Radium, or Alpha source materials in any form have not been used in the production of this material

QUALITY ASSURANCE: ______________________

SOLD TO: NAMASCO CORP
500 COLONIAL CENTER PKWY
STE 500
ROSWELL, GA 30076-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

Page: 1

SHIP TO: NAMASCO
SOUTH LOOP 4
BUDA, TX 78610-

Ship from:
Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 7-Feb-2012
B.L. Number: 596570
Load Number: 206093

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

RBMS-08 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS: YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	CHEMICAL TESTS: C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	6425459												
JW1111038701	Nucor Steel - Texas	48,300	68,000	25.0%			.15	.70	.017	.030	.21	.32	.35
JW11110387	3/8x1-1/2" Flat	333MPa	469MPa				.15	.22	.050	.004	.002		
	20' A36	48,500	68,000	26.0%									
	ASTM A36/A36M-08, A709/A709M-11	334MPa	469MPa										
	GR36, ASME SA36-07 Ed 11 Ad												
PO# =>	6425459												
JW1210041501	Nucor Steel - Texas	48,400	65,200	26.0%			.12	.63	.016	.030	.20	.36	.29
JW12100415	1/4x2-1/2" Flat	334MPa	450MPa				.11	.14	.036	.002	.002		
	20' A36	49,400	66,300	27.0%									
	ASTM A36/A36M-08, A709/A709M-11	341MPa	457MPa										
	GR36, ASME SA36-07 Ed 11 Ad												
PO# =>	6425459												
JW1210060501	Nucor Steel - Texas	50,100	68,300	25.0%			.11	.70	.008	.030	.21	.33	.31
JW12100605	1/4x1" Flat	345MPa	471MPa				.19	.17	.054	.002	.003		
	20' A36	50,600	68,400	25.0%									
	ASTM A36/A36M-08, A709/A709M-11	349MPa	472MPa										
	GR36, ASME SA36-07 Ed 11 Ad												
PO# =>	6425459												
JW1210075601	Nucor Steel - Texas	53,500	71,300	24.0%			.11	.86	.007	.035	.22	.32	
JW12100756	1-1/2x1-1/2x3/16 Angle	369MPa	492MPa				.17	.13	.044			.012	
	20' A36/A529 Gr50	54,700	72,400	27.0%			AL	CE4020	CEA529	PB			
	ASTM A36-08, A529-05, A709-09a G	377MPa	499MPa				0.000	0.32	0.36	0.001			
	R 36, ASME SA36-07 Ed 11 Ad												

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
1.) Weld repair was not performed on this material.
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form have not been used in the production of this material.

QUALITY ASSURANCE: Nathan Stewart

Atlas Tube Canada ULC
200 Clark St.
Harrow, Ontario, Canada
N0R 1G0
Tel: 519-738-3541
Fax: 519-738-3537

Atlas Tube
JMC STEEL GROUP

Ref.B/L: 80426715
Date: 04.18.2011
Customer: 193

MATERIAL TEST REPORT

Sold to

:KWAY

USA

Shipped to

[illegible]oad

USA

Material: 4.500x188x42'0"0(19x1).-CSA **Material No:** R045001884200-CSA **Made in:** Canada **Melted in:** Canada

Sales order: 629471 **Purchase Order:** PO-022403

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
758508	0.190	0.790	0.017	0.008	0.010	0.000	0.044	0.005	0.005	0.016	0.055	0.002	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.34
M100997855	19	058520 Psi	066240 Psi	30.0 %	CSA G40.21-04 50W CLASS C	

Material Note:
Sales Or.Note: Meets ASTM A500-07 Grade B&C

Material: 4.500x188x42'0"0(19x1).-CSA **Material No:** R045001884200-CSA **Made in:** Canada **Melted in:** Canada

Sales order: 629471 **Purchase Order:** PO-022403

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
758508	0.190	0.790	0.017	0.008	0.010	0.000	0.044	0.005	0.005	0.016	0.055	0.002	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.34
M100997853	19	058520 Psi	066240 Psi	30.0 %	CSA G40.21-04 50W CLASS C	

Material Note:
Sales Or.Note: Meets ASTM A500-07 Grade B&C

Material: 10.000x250x48'0"0(2x1). **Material No:** R160002504800 **Made in:** Canada **Melted in:** Canada

Sales order: 630305 **Purchase Order:** PO-022558

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
759207	0.180	0.770	0.009	0.008	0.015	0.038	0.047	0.006	0.004	0.013	0.046	0.002	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.33
M200738165	2	050900 Psi	071220 Psi	35.0 %	ASTM A500-07 GRADE B&C	

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
[illegible] D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

TR No. 9-1002-12-2

76

2012-10-25

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
Daniel J. Schacht
Quality Assurance Manager

HEAT NO.:3028494 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-09b Gr 420/60 ROLL DATE: 11/18/2011 MELT DATE: 11/14/2011	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#: 80669347 BOL#: 70236513 CUST PO#: 5434V CUST P/N: DLVRY LBS / HEAT: 45990.000 LB DLVRY PCS / HEAT: 2205 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.38%				
Mn	1.00%				
P	0.015%				
S	0.030%				
Si	0.22%				
Cu	0.33%				
Cr	0.21%				
Ni	0.19%				
Mo	0.088%				
V	0.003%				
Cb	0.001%				
Sn	0.013%				
Al	0.002%				
Yield Strength test 1	68.3ksi				
Tensile Strength test 1	108.1ksi				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	2.188IN				
Bend Test 1	Passed				

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

REMARKS :

TR No. 9-1002-12-2

77

2012-10-25

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

Daniel J. Schacht

Quality Assurance Manager

HEAT NO.:3029770 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-09b Gr 420/60 ROLL DATE: 01/22/2012 MELT DATE: 01/15/2012	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#: 80681077 BOL#: 70240462 CUST PO#: 53534v CUST P/N: DLVRY LBS / HEAT: 43820.000 LB DLVRY PCS / HEAT: 3280 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.45%				
Mn	0.83%				
P	0.009%				
S	0.034%				
Si	0.18%				
Cu	0.41%				
Cr	0.15%				
Ni	0.22%				
Mo	0.070%				
V	0.002%				
Cb	0.002%				
Sn	0.014%				
Al	0.002%				
Yield Strength test 1	65.7ksi				
Tensile Strength test 1	102.8ksi				
Elongation test 1	12%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.750IN				
Bend Test 1	Passed				

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

REMARKS :

APPENDIX C. RESULTS FOR *MASH* TEST 3-10 (TEST NO. 490022-2).

C1. TEST VEHICLE PROPERTIES AND INFORMATION

Table C1. Vehicle Properties for Test No. 490022-2.

Date: 2012-04-09 Test No.: 490022-2 VIN No.: KNADC125856364918

Year: 2005 Make: Kia Model: Rio

Tire Inflation Pressure: 30 psi Odometer: 133137 Tire Size: 175/65R14

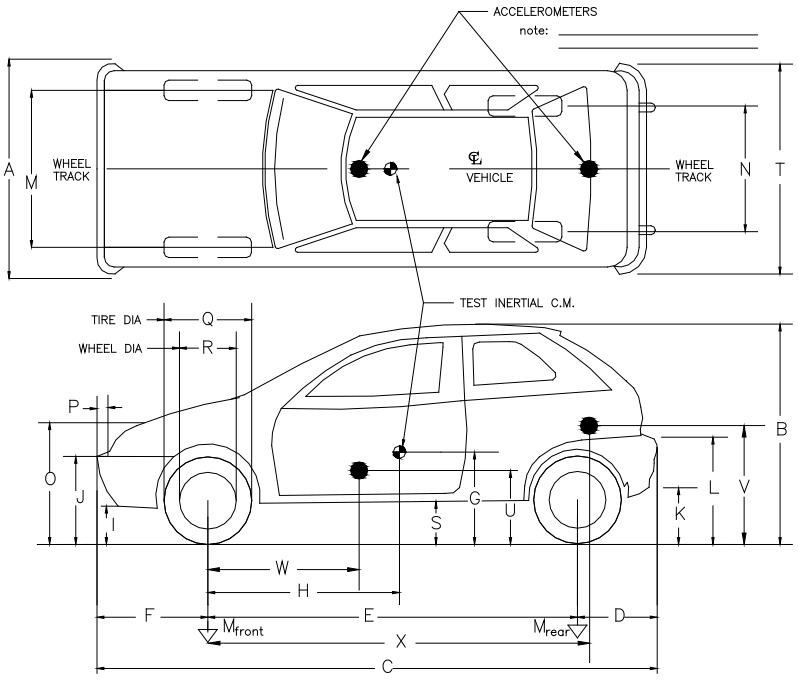
Describe any damage to the vehicle prior to test:

• Denotes accelerometer location.

NOTES:

Engine Type: 4 cylinder
Engine CID:
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:

Dummy Data:
Type: 50th percentile male
Mass: 166 lb
Seat Position: Front passenger



Geometry: inches

A	62.50	F	32.00	K	12.00	P	3.25	U	15.50
B	56.12	G		L	24.25	Q	22.50	V	21.50
C	164.25	H	35.38	M	56.50	R	15.50	W	35.00
D	37.00	I	8.50	N	57.00	S	8.62	X	104.50
E	95.25	J	22.75	O	28.00	T	63.00		

Wheel Center Ht Front 10.75 Wheel Center Ht Rear 11.125

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1691	M_{front}	1521	1528	1610
Back	1559	M_{rear}	852	903	987
Total	3250	M_{Total}	2373	2431	2597

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:

lb LF: 790 RF: 738 LR: 458 RR: 445

Table C2. Exterior Crush Measurements for Test No. 490022-2.

Date: 2012-04-09 Test No.: 490022-2 VIN No.: KNADC125856364918

Year: 2005 Make: Kia Model: Rio

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	19.0	10.0	24	0	4.0	5.5	6.5	7.5	10.0	-14
2	Side plane at bumper ht	19.0	11.0	36	0	1.25	4.0	6.0	8.0	11.0	
	Measurements recorded										
	in inches										

[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).

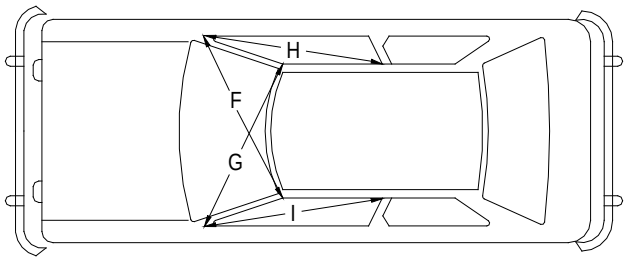
***Measure and document on the vehicle diagram the location of the maximum crush.

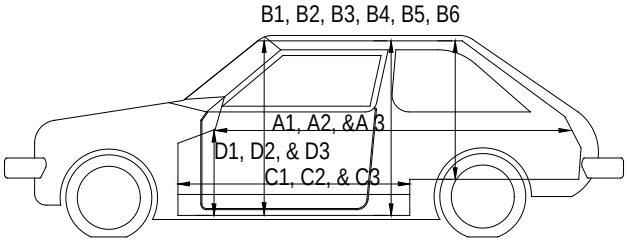
Note: Use as many lines/columns as necessary to describe each damage profile.

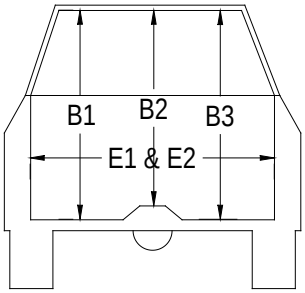
Table C3. Occupant Compartment Measurements for Test No. 490022-2.

Date: 2012-04-09 Test No.: 490022-2 VIN No.: KNADC125856364918

Year: 2005 Make: Kia Model: Rio







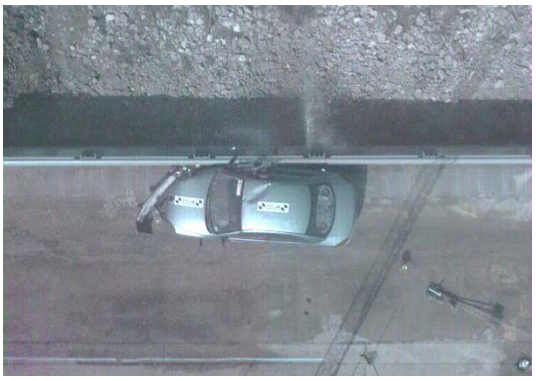
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.25	67.25
A2	65.00	65.00
A3	37.25	66.75
B1	39.25	39.25
B2	35.50	35.50
B3	39.25	40.25
B4	34.75	34.75
B5	35.00	35.00
B6	34.75	34.75
C1	26.75	26.75
C2	-----	-----
C3	26.50	23.50
D1	10.75	10.75
D2	-----	-----
D3	8.75	8.25
E1	49.00	49.25
E2	50.50	53.50
F	49.25	49.50
G	49.25	47.75
H	36.50	36.50
I	36.50	36.50
J*	50.25	49.00

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

C2. SEQUENTIAL PHOTOGRAPHS

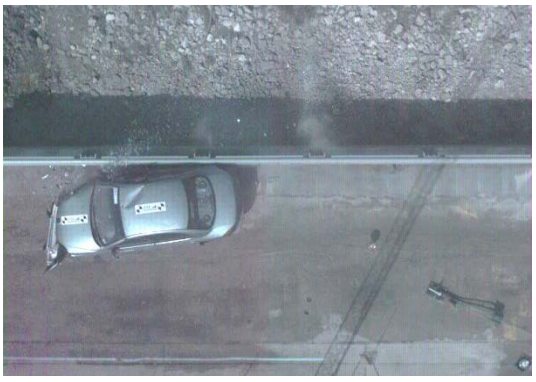
Figure C1. Sequential Photographs for Test No. 490022-2 (Overhead and Rear Views).




0.149s


0.186 s


0.223 s




0.260 s

Figure C1. Sequential Photographs for Test No. 490022-2 (Overhead and Rear Views) (continued).

0.000 s

0.149 s

0.038 s

0.186 s

0.076 s

0.223 s

0.112 s

0.260 s

Figure C2. Sequential Photographs for Test No. 490022-2 (Rear of Bridge Rail View).

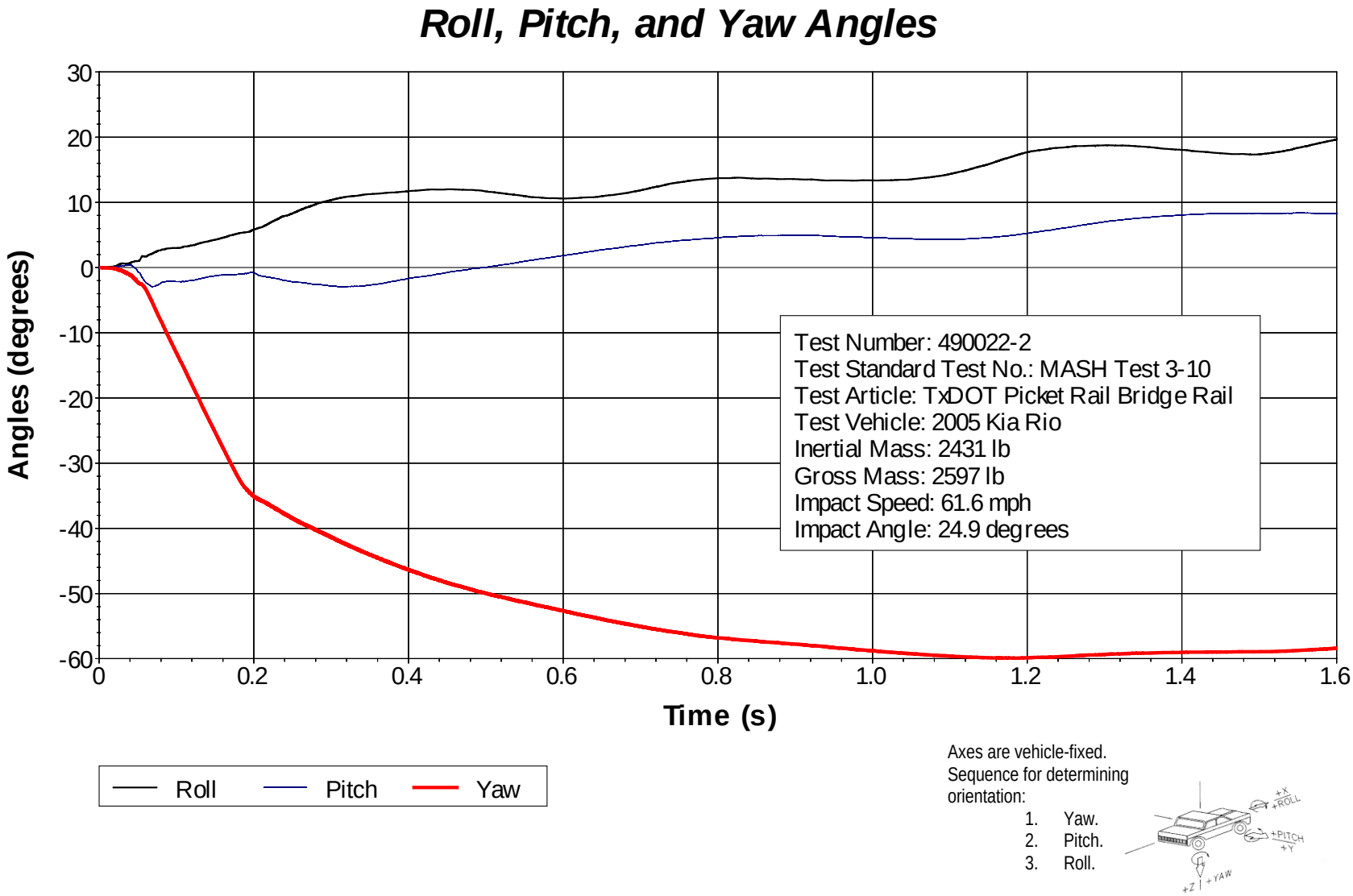


Figure C3. Vehicle Angular Displacements for Test No. 490022-2.

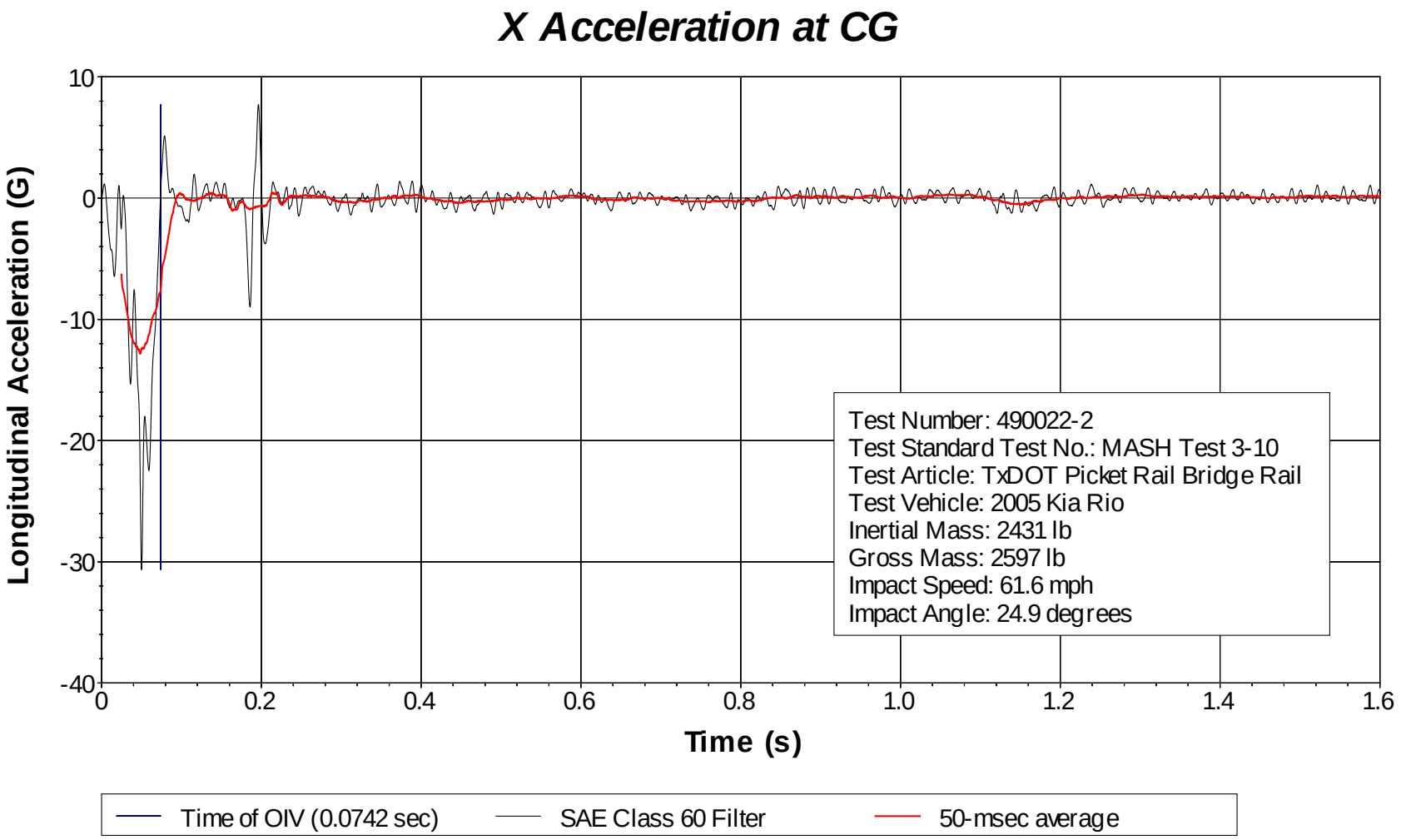


Figure C4. Vehicle Longitudinal Accelerometer Trace for Test No. 490022-2 (Accelerometer Located at Center of Gravity).

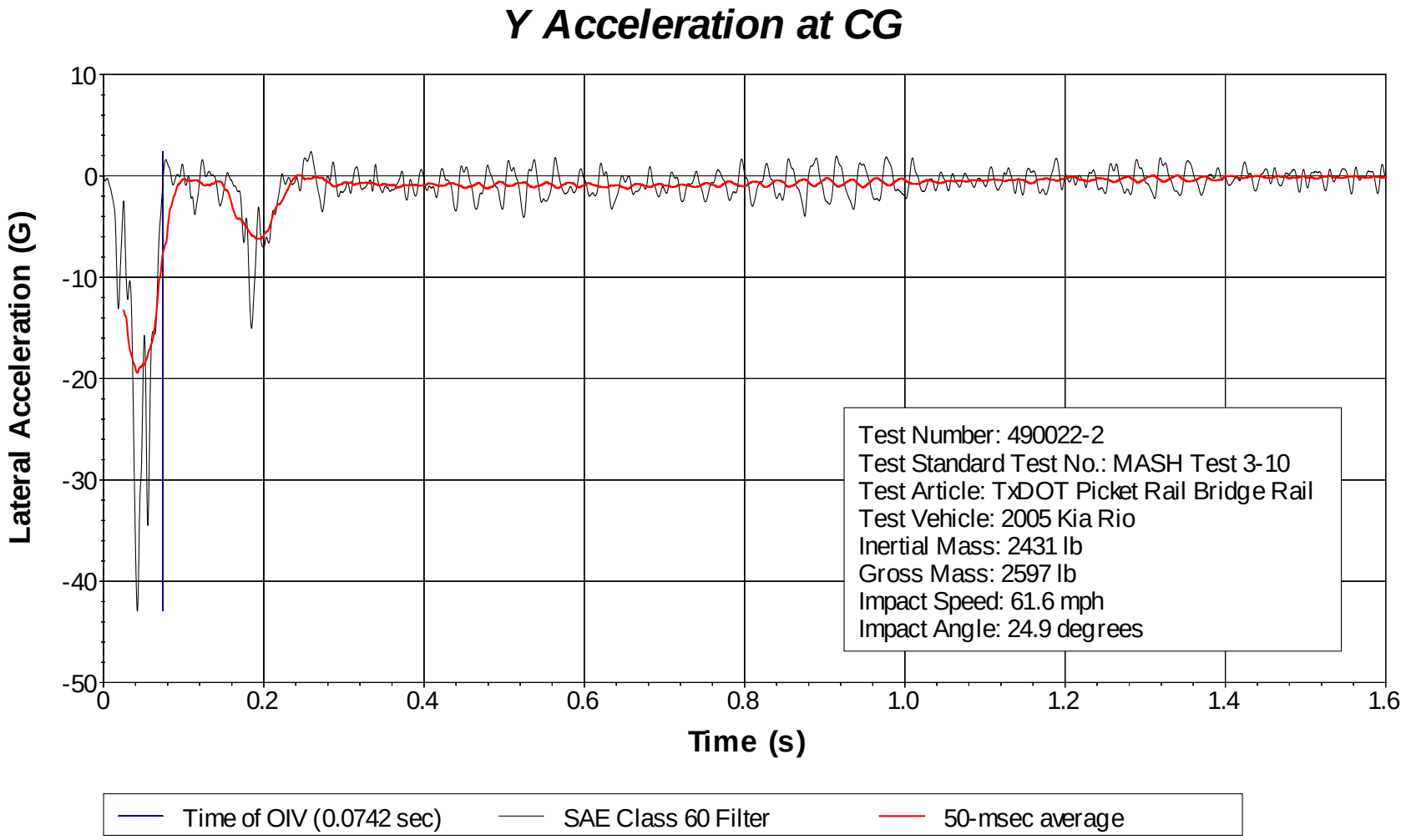


Figure C5. Vehicle Lateral Accelerometer Trace for Test No. 490022-2 (Accelerometer Located at Center of Gravity).

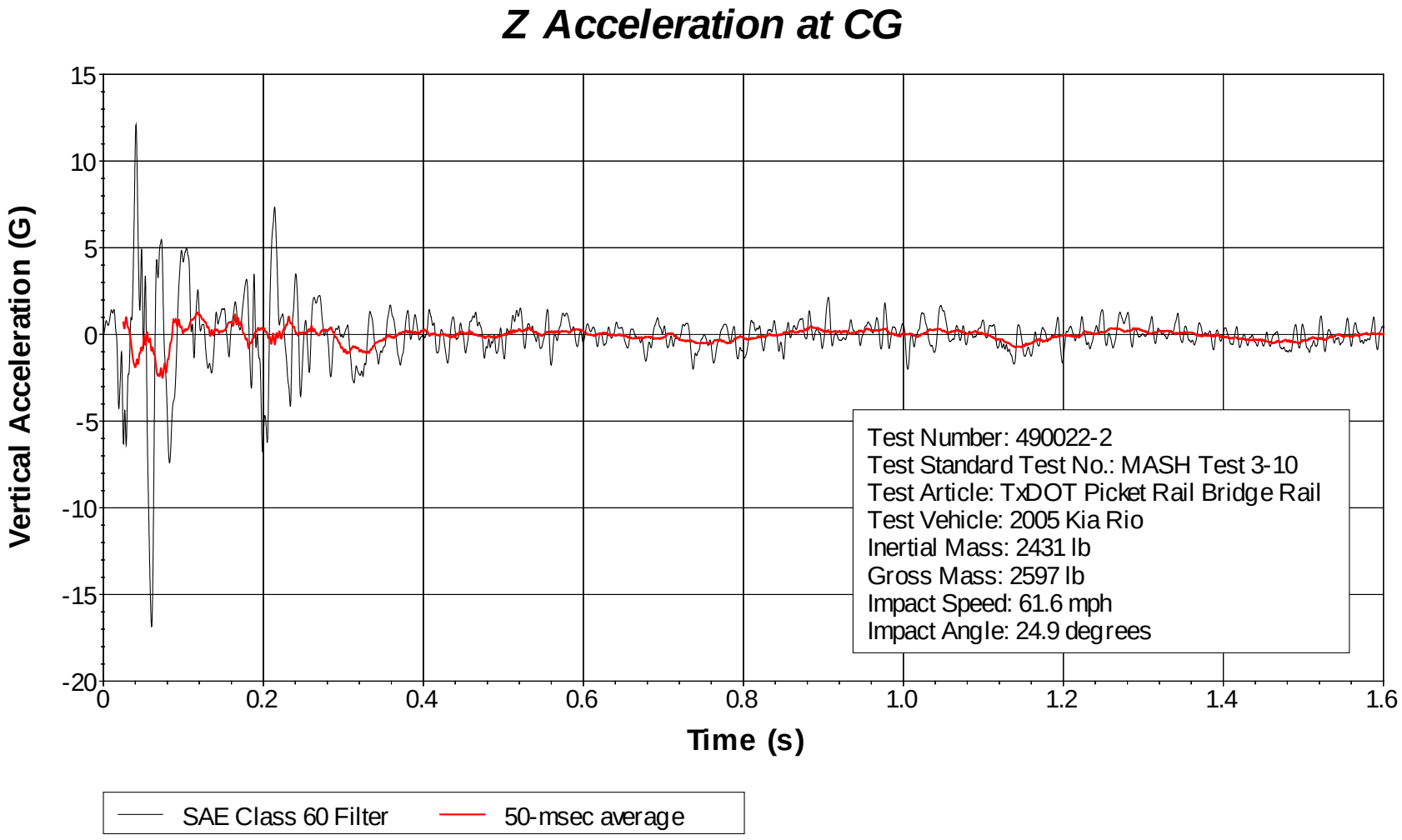


Figure C6. Vehicle Vertical Accelerometer Trace for Test No. 490022-2 (Accelerometer Located at Center of Gravity).

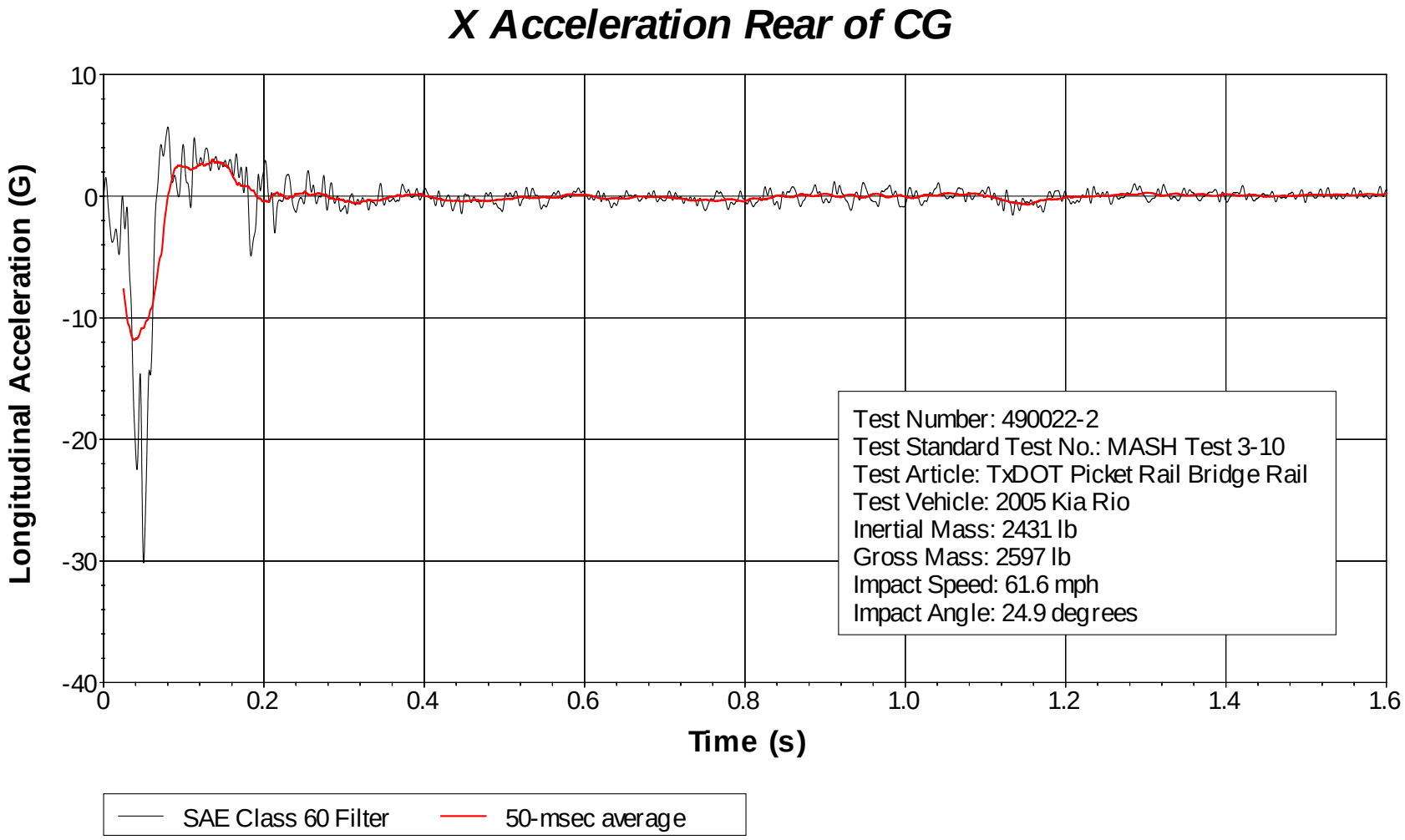


Figure C7. Vehicle Longitudinal Accelerometer Trace for Test No. 490022-2 (Accelerometer Located Rear of Center of Gravity).

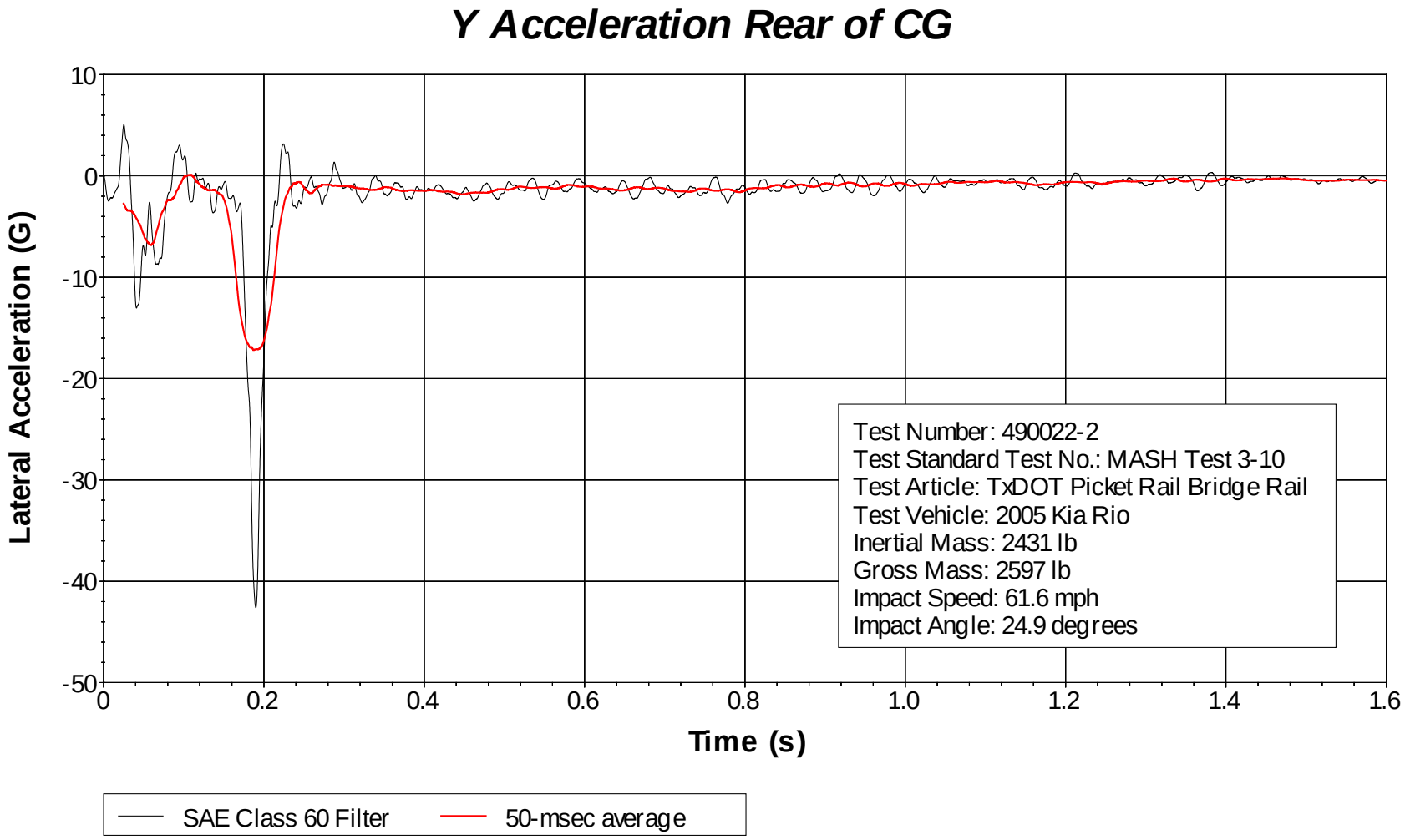


Figure C8. Vehicle Lateral Accelerometer Trace for Test No. 490022-2 (Accelerometer Located Rear of Center of Gravity).

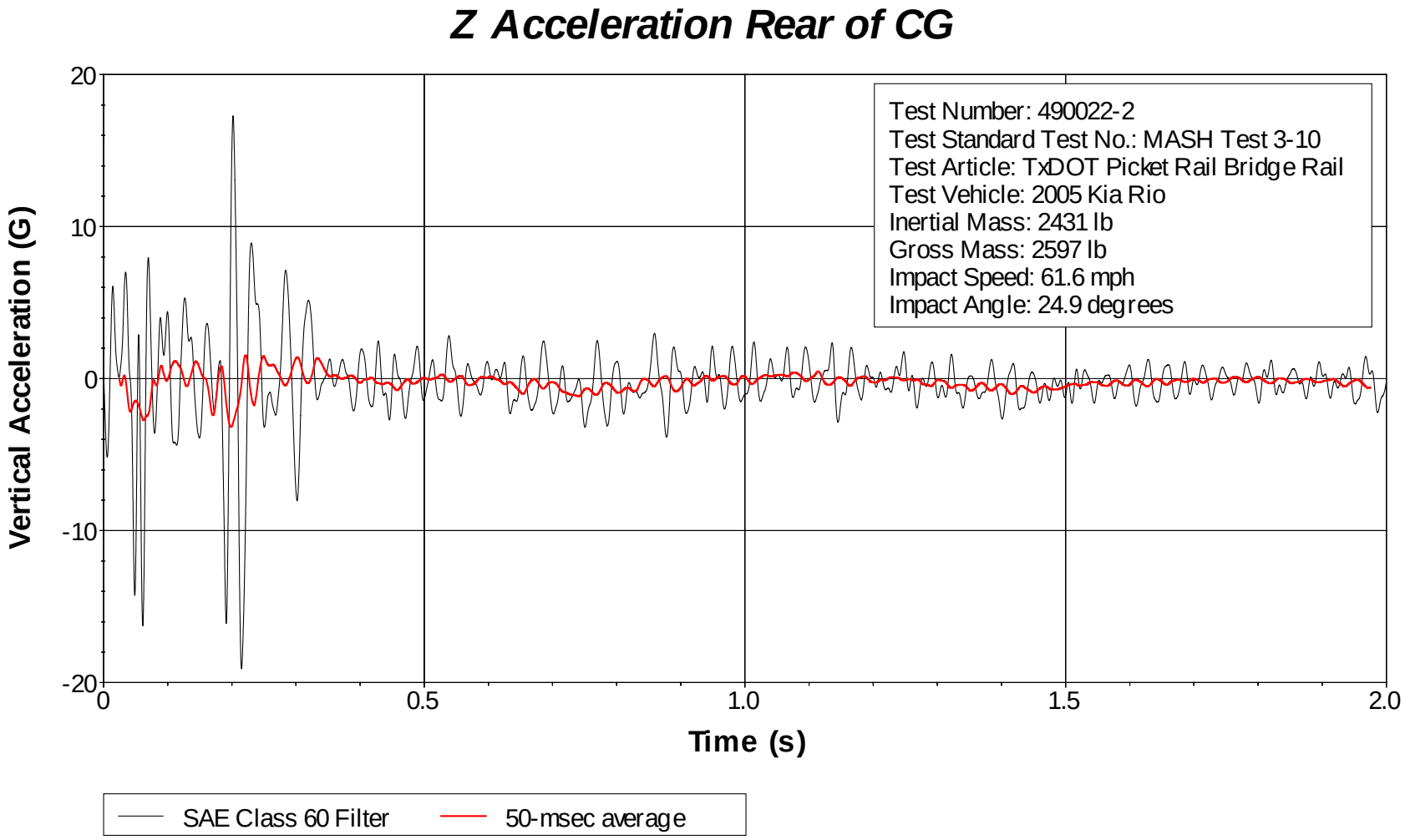


Figure C9. Vehicle Vertical Accelerometer Trace for Test No. 490022-2 (Accelerometer Located Rear of Center of Gravity).

APPENDIX D. RESULTS FOR *MASH* TEST 3-11 (TEST NO. 490022-3).

D1. TEST VEHICLE PROPERTIES AND INFORMATION

Table D1. Vehicle Properties for Test No. 490022-3.

Date: 2012-04-10 Test No.: 490022-3 VIN No.: 1D7HA18X65708197

Year: 2006 Make: Dodge Model: Ram 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 129282

Note any damage to the vehicle prior to test:

• Denotes accelerometer location.

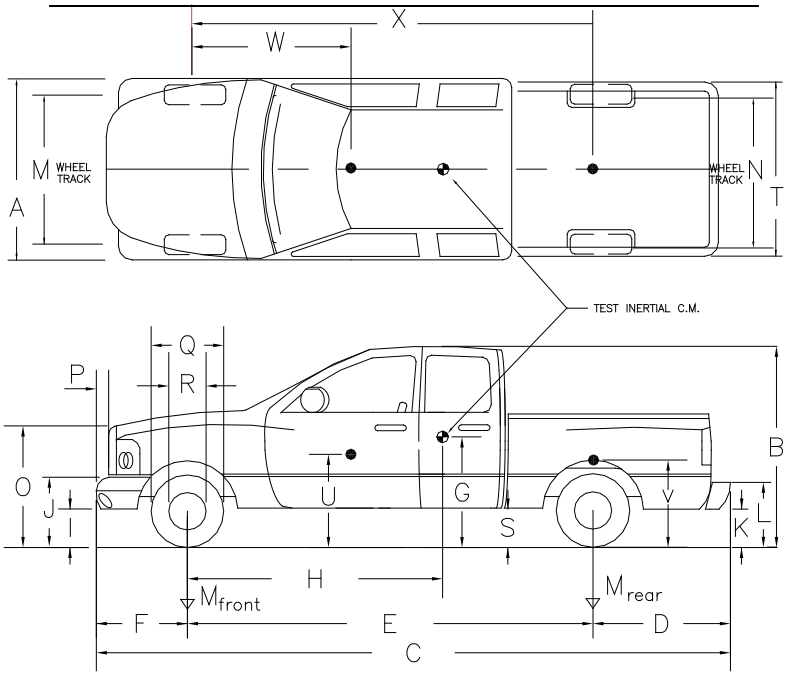
NOTES:

Engine Type:
Engine CID:

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

Optional Equipment:

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



Geometry: inches

A	78.25	F	36.00	K	20.50	P	2.88	U	28.50
B	75.00	G	28.25	L	29.12	Q	31.25	V	29.50
C	223.75	H	61.51	M	68.50	R	18.38	W	60.50
D	47.25	I	13.75	N	68.00	S	12.00	X	78.00
E	140.50	J	25.38	O	44.50	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	5.00	Bottom Frame Height - Front	17.12
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	10.25	Bottom Frame Height - Rear	24.75

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2852	2821	
Back	3900	M_{rear}	2166	2197	
Total	6700	M_{Total}	5018	5018	

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1430 RF: 1391 LR: 1058 RR: 1139

Table D2. Vehicle Parameters for Test No. 490022-3.

Date: 2012-04-10 Test No.: 490022-3 VIN: 1D7HA18X65708197

Year: 2006 Make: Dodge Model: Ram 1500

Body Style: Quad-Cab Mileage: 129282

Engine: Transmission: Automatic

Fuel Level: Empty Ballast: 100 lb at front of bed (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)								
LF:	1430	RF:	1391	Front Axle:	2821			
LR:	1058	RR:	1139	Rear Axle:	2197			
Left:	2488	Right:	2530	Total:	5018			
				5000 ±110 lb allowed				
Wheel Base:	140.5 inches	Track: F:	68.5 inches	R:	68 inches			
148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed					
Center of Gravity, SAE J874 Suspension Method								
X:	61.51 in	Rear of Front Axle	(63 ±4 inches allowed)					
Y:	0.29 in	Left -	Right +	of Vehicle Centerline				
Z:	28.25 in	Above Ground	(minumum 28.0 inches allowed)					

Hood Height: 44.50 inches
43 ±4 inches allowed

Front Bumper Height: 25.375 inches

Front Overhang: 36.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.125 inches

Overall Length: 223.78 inches
237 ±13 inches allowed

Table D3. Exterior Crush Measurements for Test No. 490022-3.

Date: 2012-04-10 Test No.: 490022-3 VIN No.: 1D7HA18X65708197

Year: 2006 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	17.0	11.0	30	0	1	2.5	11	9	11	+15
2	Side plane at bumper ht	17.0	11.0	10	1	---	---	---	---	11	+68
	Measurements recorded										
	in inches										

[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).

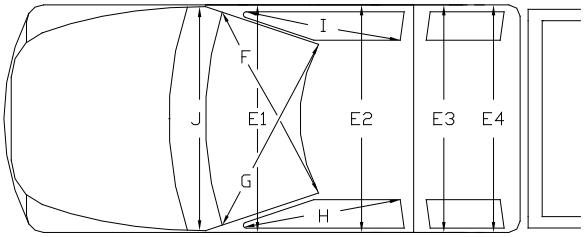
***Measure and document on the vehicle diagram the location of the maximum crush.

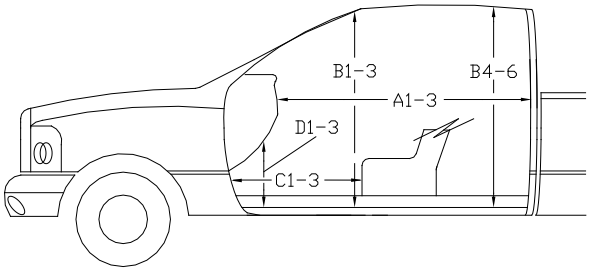
Note: Use as many lines/columns as necessary to describe each damage profile.

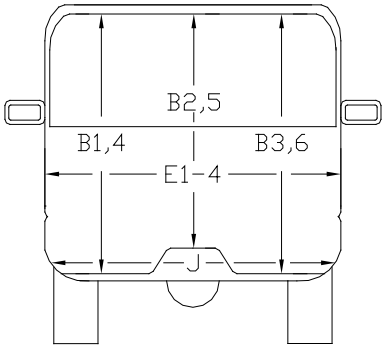
Table D4. Occupant Compartment Measurements for Test No. 490022-3.

Date: 2012-04-10 Test No.: 490022-3 VIN No.: 1D7HA18X65708197

Year: 2006 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	64.50
A3	65.00	65.00
B1	45.25	45.25
B2	39.25	39.25
B3	45.25	45.25
B4	42.00	42.00
B5	4.25	4.25
B6	42.00	42.00
C1	27.25	27.25
C2	----	----
C3	29.25	29.25
D1	12.75	12.75
D2	----	----
D3	11.25	11.25
E1	63.00	62.50
E2	64.50	64.75
E3	64.00	63.50
E4	64.50	93.75
F	60.00	60.00
G	60.00	60.00
H	39.00	39.00
I	39.00	39.00
J*	63.25	60.50

D2. SEQUENTIAL PHOTOGRAPHS

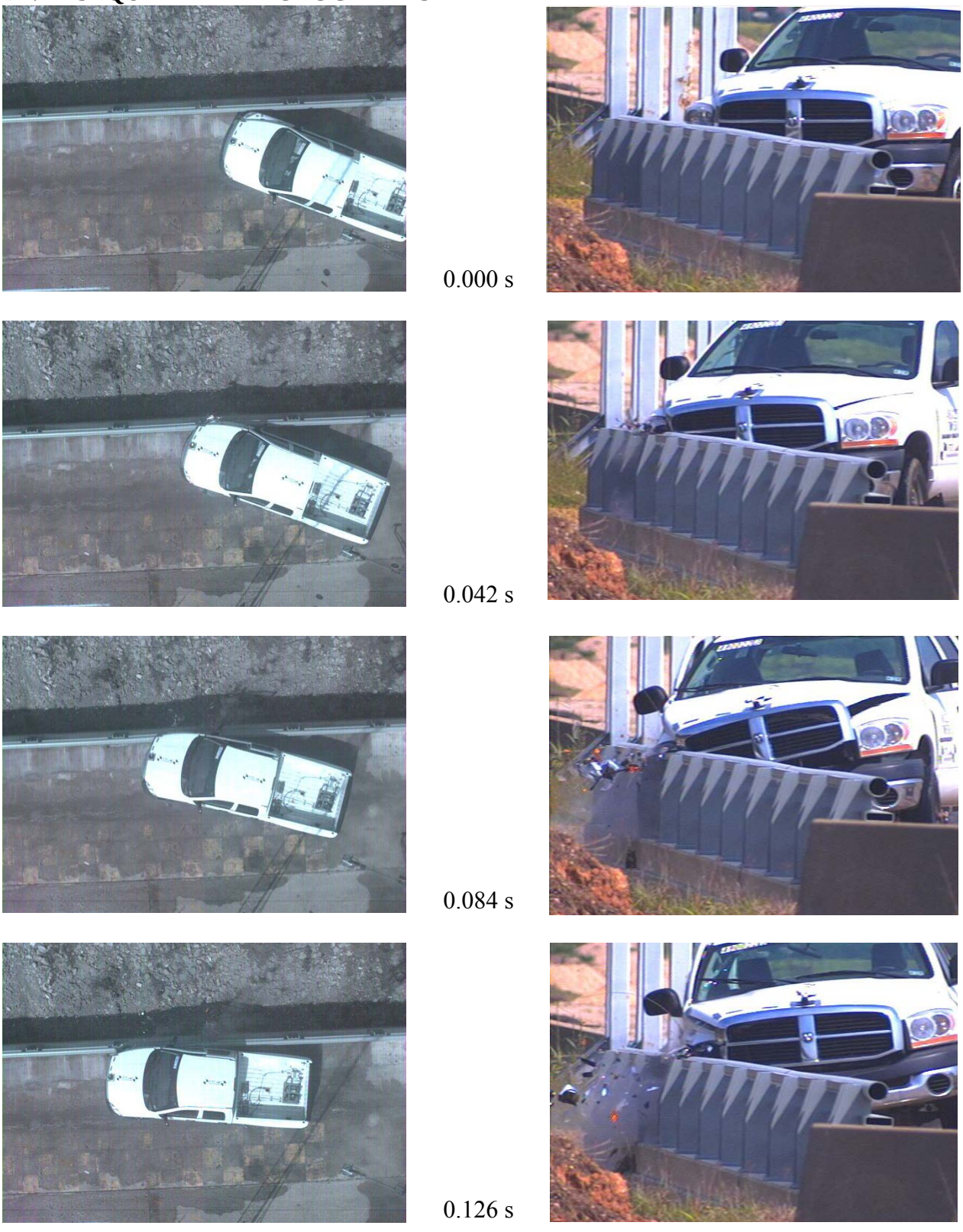


Figure D1. Sequential Photographs for Test No. 490022-3 (Overhead and Frontal Views).


0.168 s


0.210 s


0.252 s


0.295 s

Figure D1. Sequential Photographs for Test No. 490022-3 (Overhead and Frontal Views) (continued).


0.000 s


0.168 s


0.042 s


0.210 s


0.084 s


0.252 s


0.126 s


0.295 s

Figure D2. Sequential Photographs for Test No. 490022-3 (Rear of Bridge Rail View).

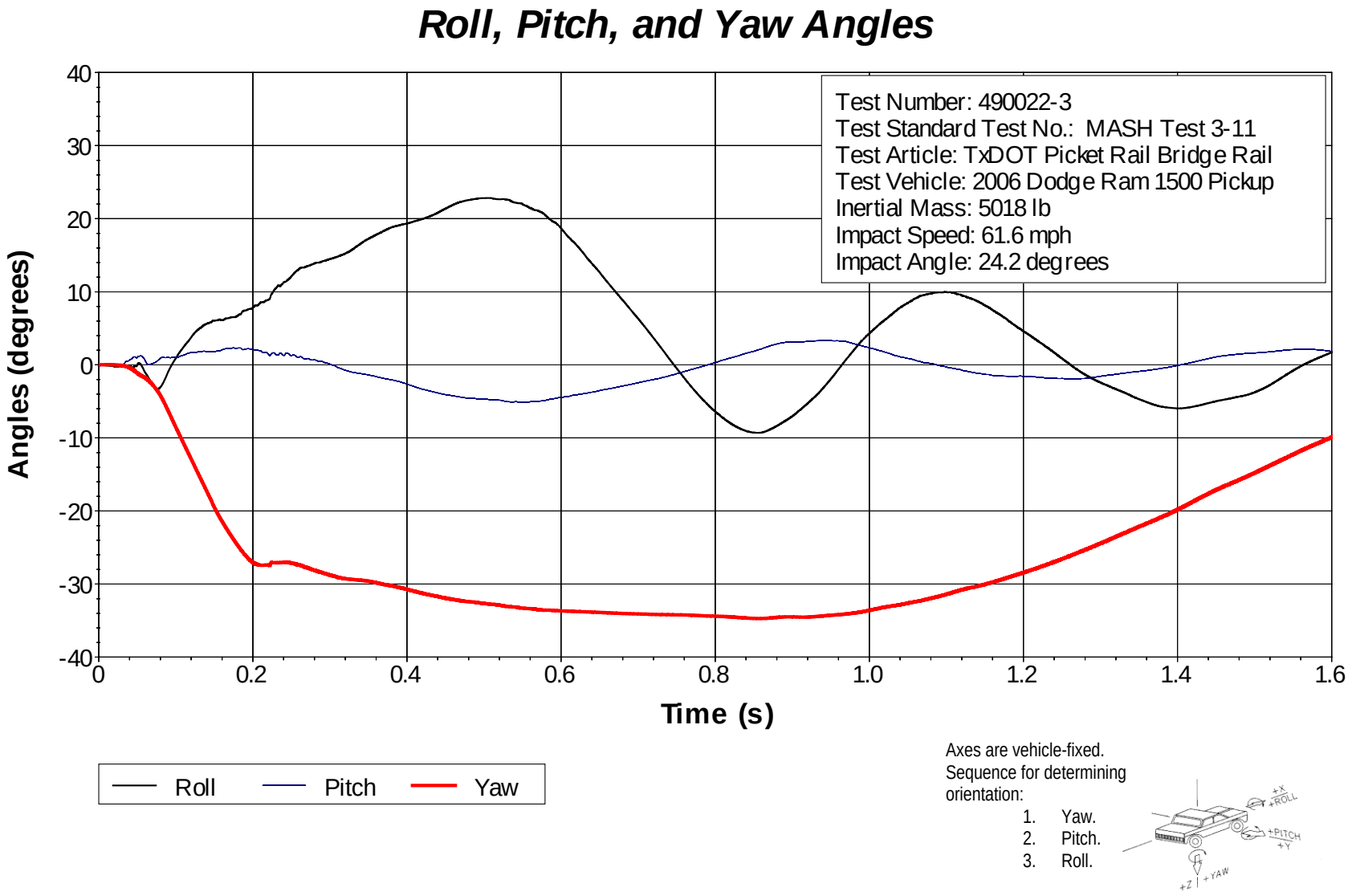


Figure D3. Vehicle Angular Displacements for Test No. 490022-3.

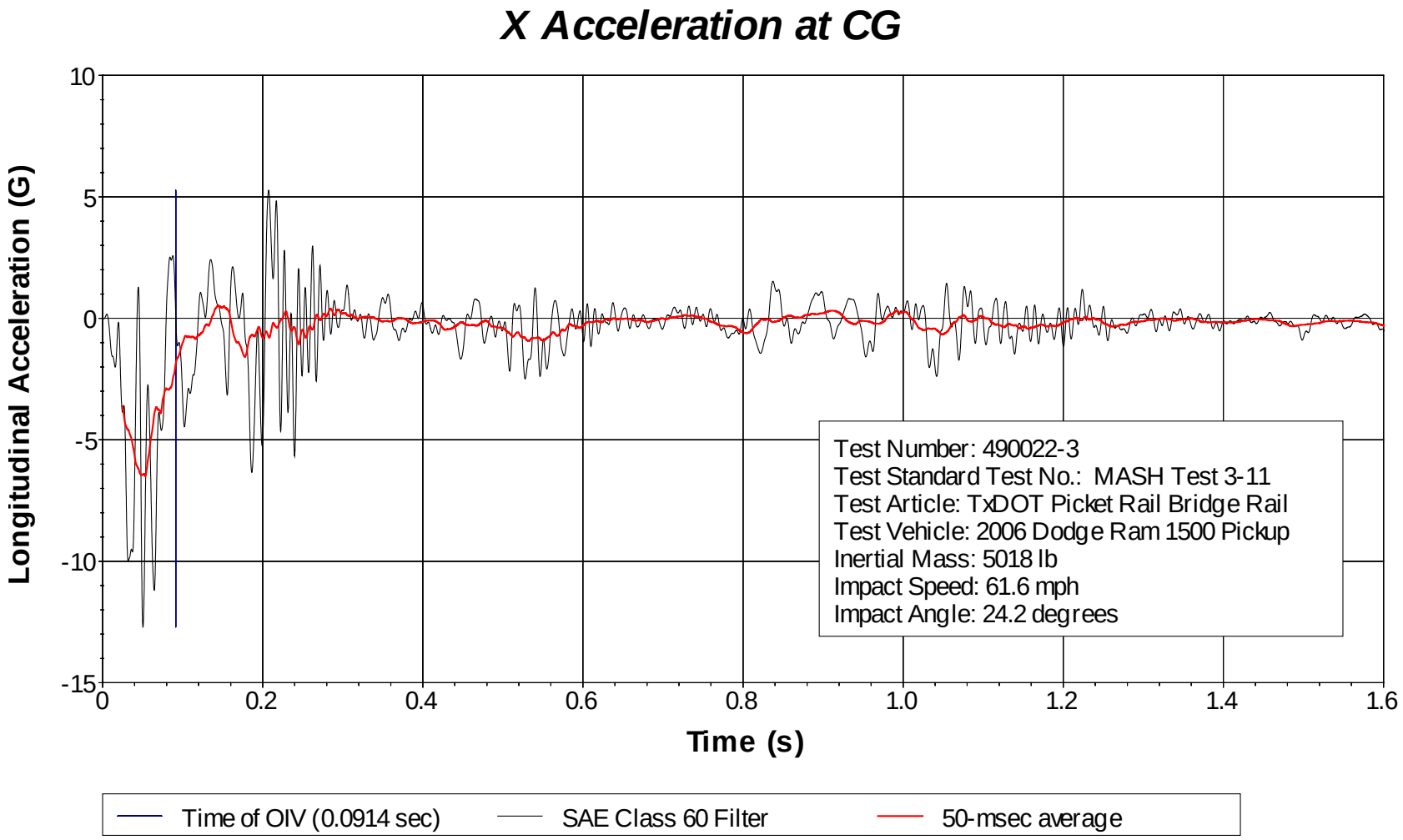


Figure D4. Vehicle Longitudinal Accelerometer Trace for Test No. 490022-3 (Accelerometer Located at Center of Gravity).

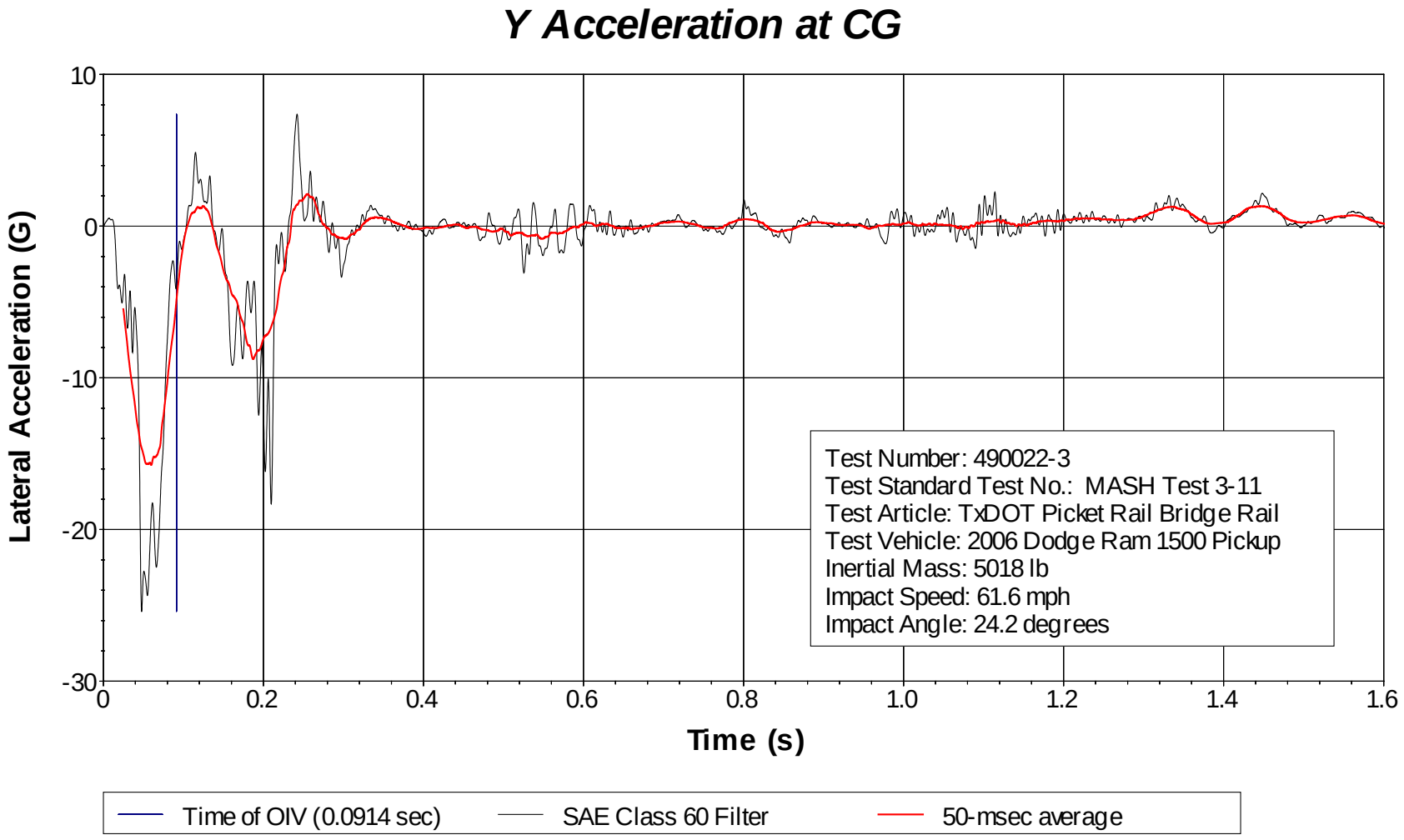


Figure D5. Vehicle Lateral Accelerometer Trace for Test No. 490022-3 (Accelerometer Located at Center of Gravity).

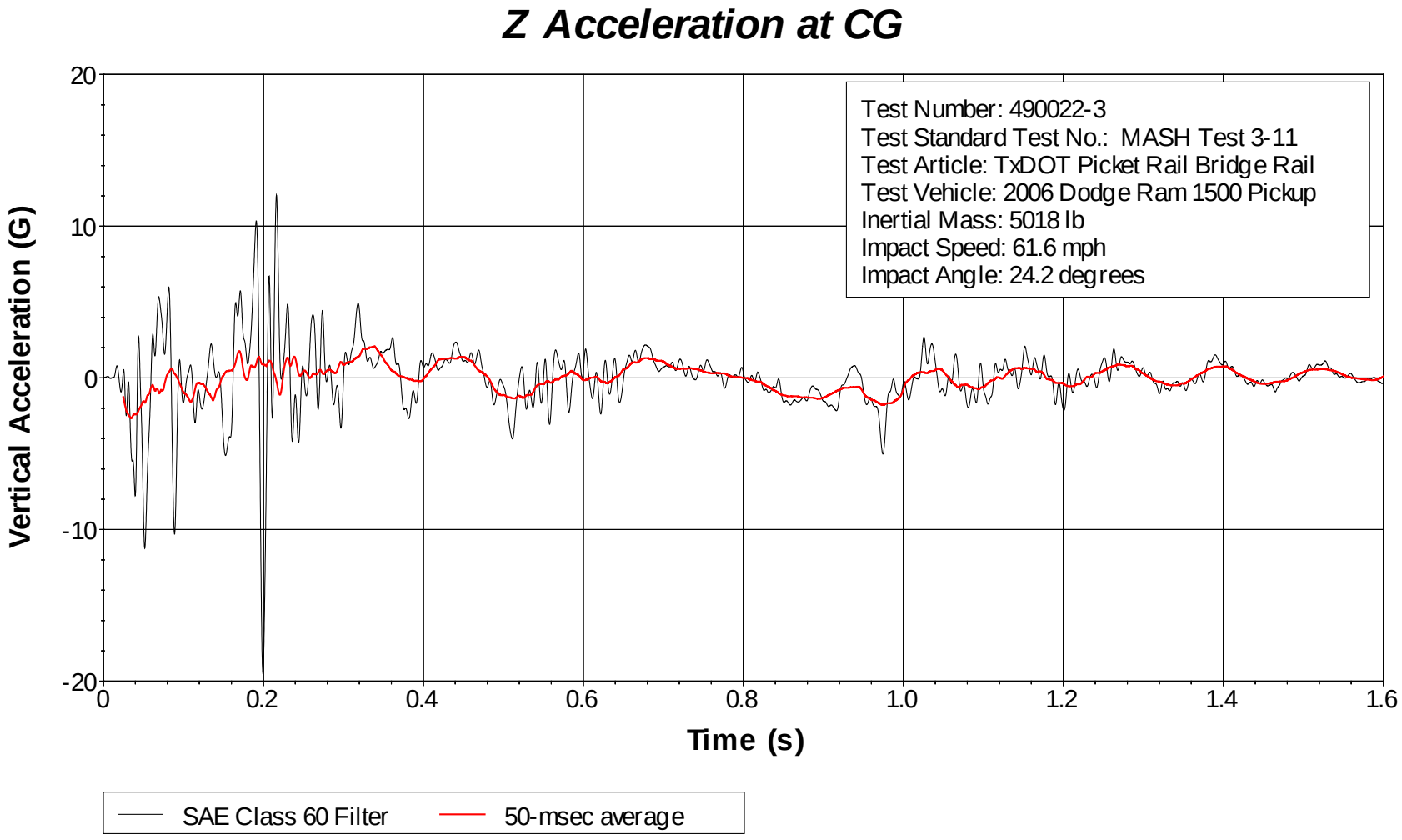


Figure D6. Vehicle Vertical Accelerometer Trace for Test No. 490022-3 (Accelerometer Located at Center of Gravity).

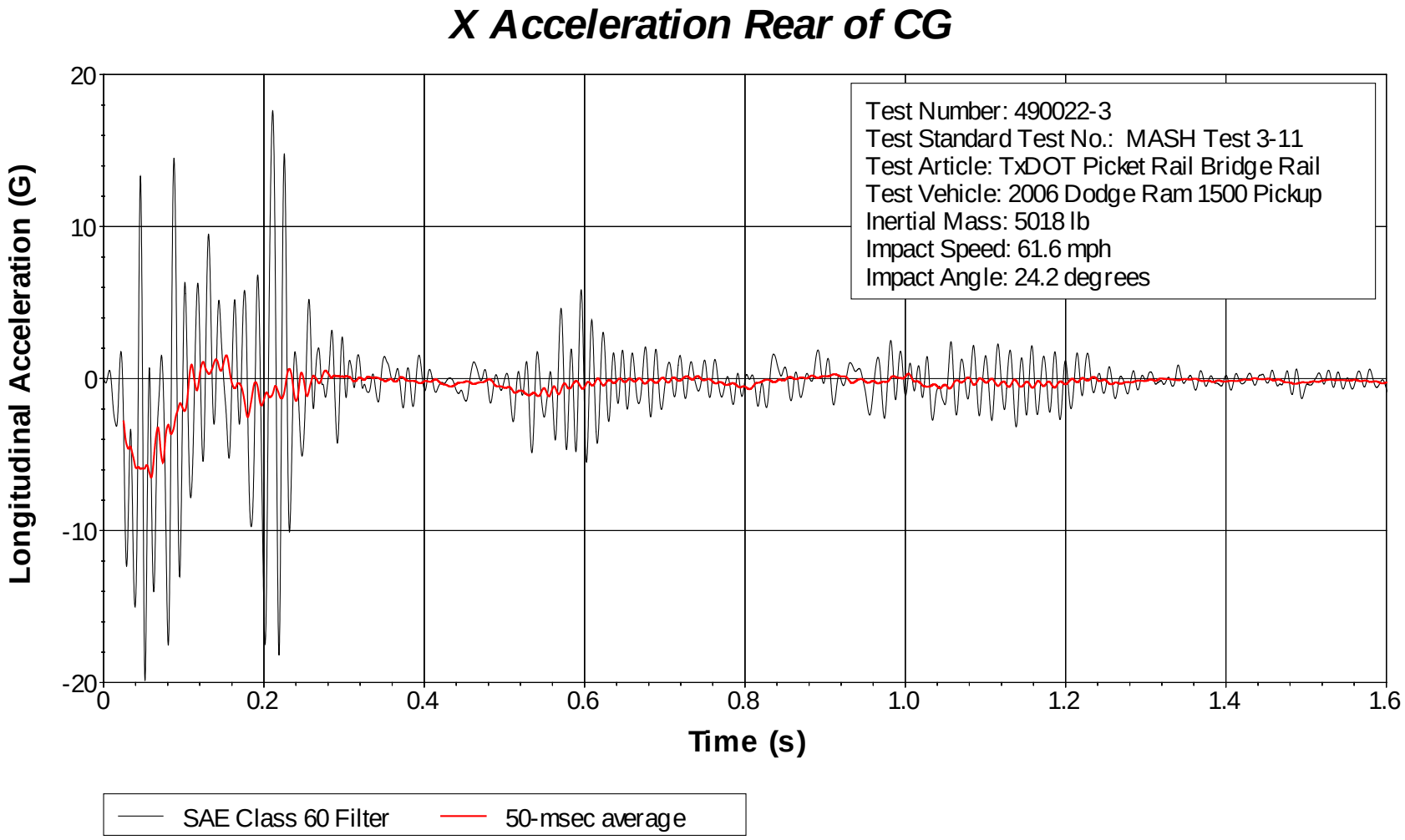


Figure D7. Vehicle Longitudinal Accelerometer Trace for Test No. 490022-3 (Accelerometer Located Rear of Center of Gravity).

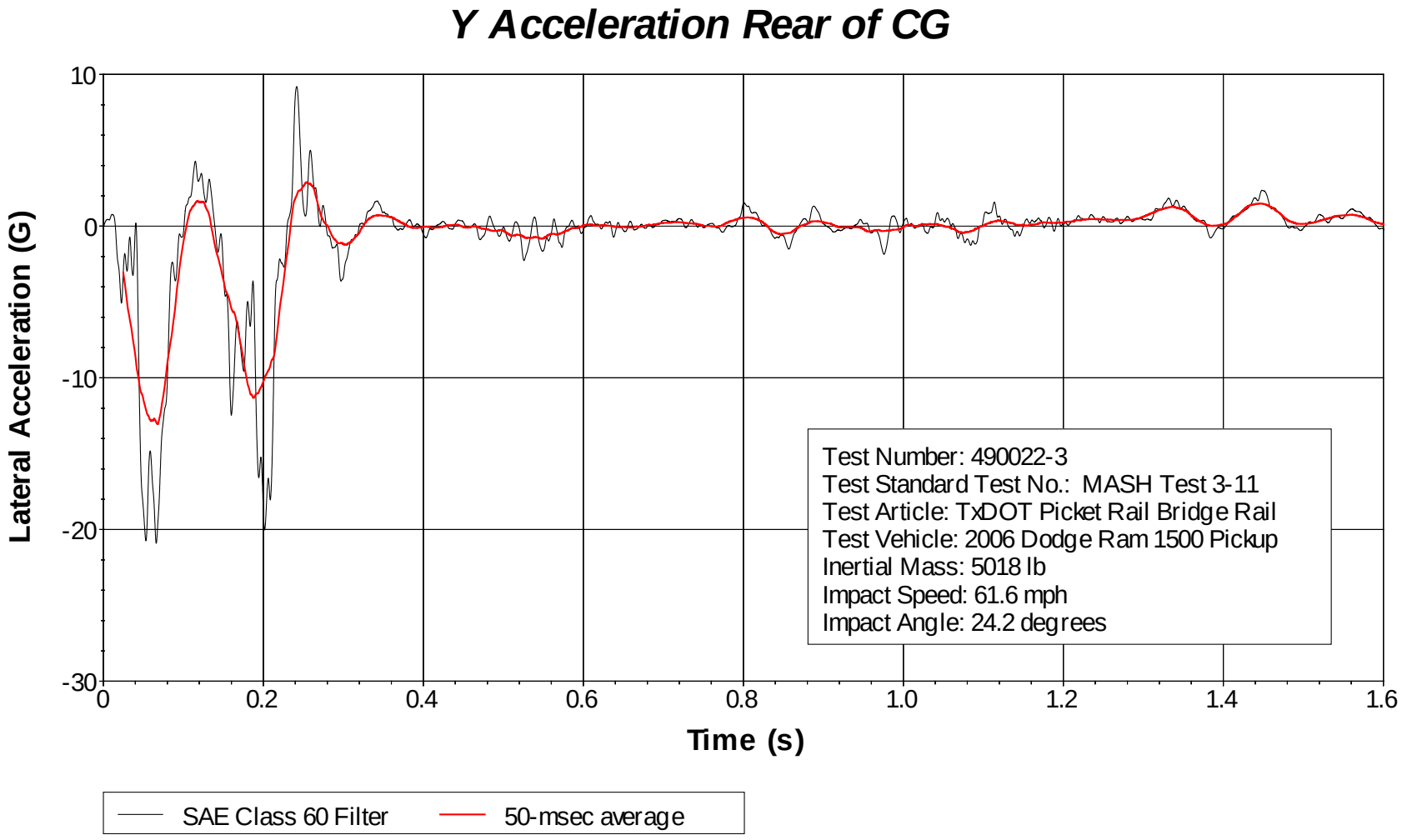


Figure D8. Vehicle Lateral Accelerometer Trace for Test No. 490022-3 (Accelerometer Located Rear of Center of Gravity).

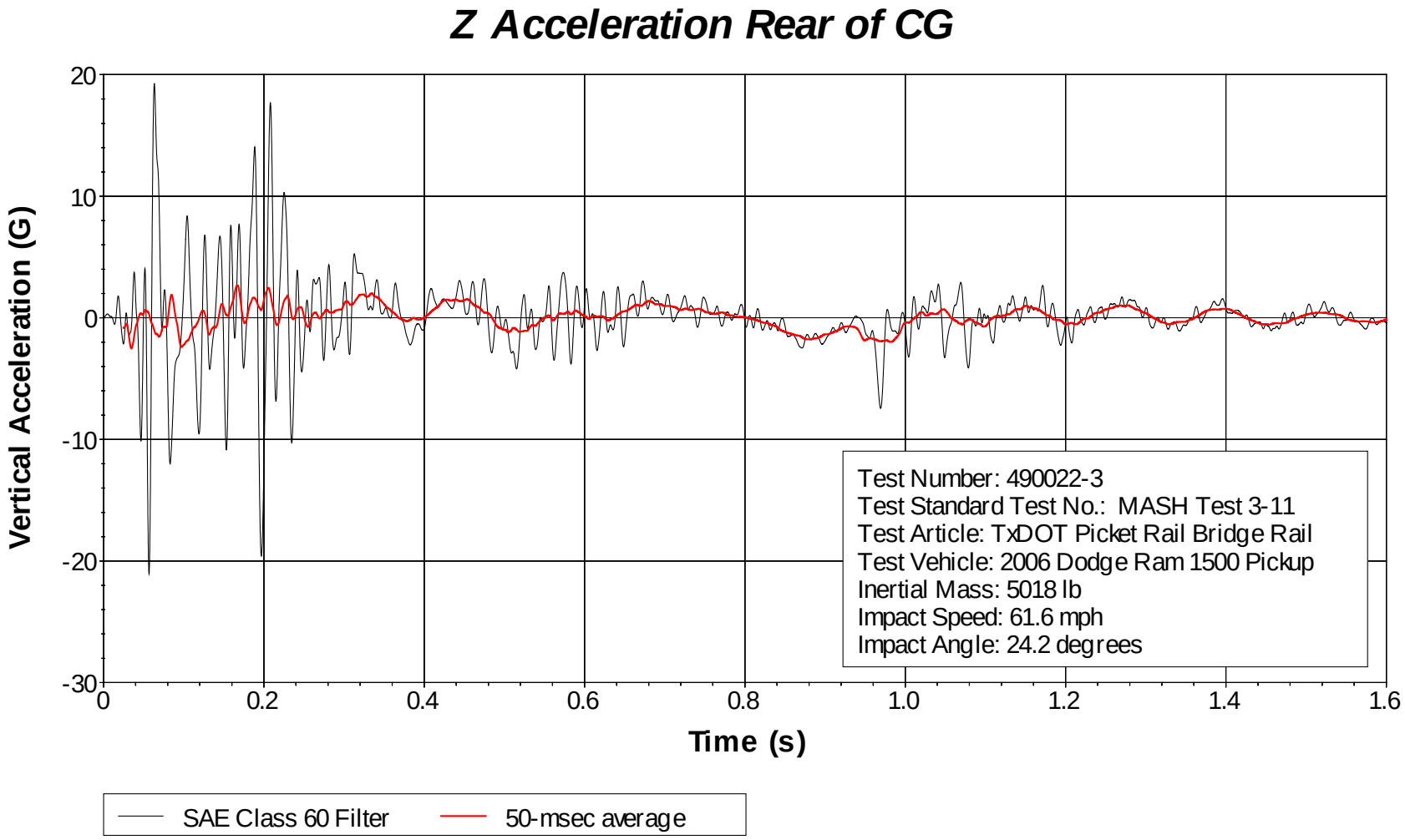


Figure D9. Vehicle Vertical Accelerometer Trace for Test No. 490022-3 (Accelerometer Located Rear of Center of Gravity).